Fiscal Year:	FY 2016	**Task Last Updated:**	FY 05/09/2017
PI Name:	Wood, Scott J. Ph.D.		
Project Title:	Effect of Sensorimotor Adaptation Following Long-Duration Spaceflight on Perception and Control of Vehicular Motion		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Biomedical countermeasures		
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 (Revised as of IRP Rev M)		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Comments:	NOTE: PI returned to NASA JSC in January 2017. PI was at Azusa Pacific University from August 2013 – January 2017; prior to August 2013, PI was at NASA JSC.		
Project Type:	FLIGHT	**Solicitation / Funding Source:**	2008 Crew Health NNJ08ZSA002N
Start Date:	10/01/2009	**End Date:**	08/15/2016
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	1	**Monitoring Center:**	NASA JSC
Contact Monitor:	Loerch, Linda	**Contact Phone:**	
Contact Email:	linda.loerch-1@nasa.gov		
Flight Program:	ISS		
Flight Assignment:	ISS Expeditions 32S, 33S, 35S, 37S, 38S, 39S, and 41S (per PI) (Ed., 8/7/14) ISS Increments 33-34, 35-36, and 37-38 (pending in September 2012)--per PI (Ed., 8/7/2012) NOTE: End date is 8/15/2016 per L. Taylor/JSC HRP (Ed., 5/10/2017) NOTE: End date is now 2/29/2016 per HRP Master Task List dated 7/12/2011 (Ed., 8/4/2011)		
Key Personnel Changes/Previous PI:	None		
COI Name (Institution):			
Grant/Contract No.:	Internal Project		
Performance Goal No.:			
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Task Description:	The central nervous system must resolve new patterns of sensory cues during movement in a novel gravitoinertial environment in order to maintain accurate spatial orientation awareness. We hypothesize that adaptive change in how inertial cues from the vestibular system are integrated with other sensory information leads to perceptual disturbances and impaired manual control during transition to a new gravity environment. The primary goals of this investigation are to quantify post-flight decrements in manual control performance during a rover simulation (both acute and recovery), and to examine the relationship between manual control errors and adaptive changes in sensorimotor function and motion perception. Eight crewmembers returning from 6 month stays onboard the International Space Station (ISS) will be tested on a six degree-of-freedom motion simulator during four pre-flight and three post-flight sessions on R+0/1, 4, and 8 days following landing. Ground control studies on non-astronauts will assess effects associated with learning across multiple sessions, changes in proficiency as a function of time between pre- and post-flight sessions and two factors of influence studies involving changes in performance with galvanic vestibular stimulation and acute sleep loss. This rover simulation study has been incorporated within the manual control study titled “Assessment of operator proficiency following long-duration spaceflight” under the direction of principal investigator Dr. Steven Moore. Dr. Moore’s project includes a test battery to assess sensorimotor and cognitive function, including vestibular (pitch/roll tilt motion perception), visual acuity, manual dexterity, manual tracking with and without dual tasking, reaction time, sleepiness scale, perspective taking, and spatial memory (match-to-sample). Dr. Moore’s experiment also includes driving and flying simulations. According to our hypothesis, we predict that decrements in sensorimotor and cognitive function will correlate with performance metrics during the operator simulations. The simulator utilizes a Stewart-type motion base (CKAS, Australia), single-seat cabin with triple scene projection covering 150° horizontal by 50° vertical, and joystick controller. The rover simulation consists of a serial presentation of four discrete docking tasks that the crewmember attempts to complete within each session. Each task consists of 1) perspective-taking, using a map that defines the rover orientation and location relative to the docking target, 2) navigation toward the target around a Martian outpost as efficiently as possible, and 3) docking a side hatch of the rover to another rover or habitat hatch using a visually guided targeting system. The primary dependent variables obtained from each component include time to completion and accuracy. At the completion of each task, a new perspective map will appear to initiate the next task in the series. The total time the crewmember can complete four docking tasks will determine the overall operator proficiency for the rover simulation.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Sensorimotor function is critical for spatial orientation, gaze stabilization, and postural stability. This project examines how adaptive changes in sensorimotor and cognitive function may increase the risk of impaired ability to maintain control of vehicles and other complex systems. The goal is to map changes in physiological function with functional measures of manual control. Establishing these relationships will be relevant to how pathophysiological impairments in sensorimotor processing may affect other vehicular control tasks, such as driving with vestibular patients. Vehicle driving is one of the most complex tasks required of humans. A majority of vestibular-impaired patients report that driving is difficult or dangerous. Successful completion of this project will contribute to the development of assessment techniques for determining fitness for driving duty. Specifically, the rover simulation utilizes a multiple degree-of-freedom motion base simulator to address aspects of vehicular control performance, including perspective taking, navigating a course safely, and fine positioning control. This approach can be easily adapted to a wide variety of simulated vehicle designs to provide similar assessments in other operational and civilian populations.
	FINAL REPORTING--MAY 2017 During the final period of reporting, we completed a ground study on the effects of sleepiness on our rover simulation measures. The Stanford Sleepiness Scale was incorporated in our pre- and post-flight astronaut study as a subjective report from each crewmember on their level of sleepiness at the time of testing. There was a significant increase in sleepiness level reported during our first post-flight session (4.0 ± 1.6 on R+0 versus 2.0 ± 0.5 on the final preflight session, mean ± SD). The purpose of this factors-of-influence study was to characterize the sensitivity of specific measures to sleepiness independent of post-flight neurosensory adaptation. In order to accomplish this, nine subjects participated in a 30-hour sleep restriction period. Due to an equipment malfunction following the sleep restriction period, data from 8 subjects are included in this report. A limited set of our experimental measures from the integrated protocol were compared before and immediately after this sleep restriction. These included the driving simulation, rover simulation, dual tracking task, reaction time, and the Stanford Sleepiness Scale. Each subject participated in three baseline laboratory sessions (separated by at least one week), the 30 hr sleep restriction period, and a post-sleep restriction laboratory session. In order to acquire task proficiency in the three baseline sessions, each subject performed eight rover trials during the first two sessions. The effects of sleep restriction were then assessed by comparing the change between the last baseline session and the post-sleep restriction session, which were conducted with 4 rover trials identical to the flight protocol. Throughout the sleep restriction period, subjects also participated in a 3-min psychomotor vigilance test (PVT) to monitor changes in behavioral alertness (Basner et al. 2011). This test was administered on an iPad (Joggle Research, Seattle, WA). At each test administration, subjects recorded their score on the Stanford Sleepiness Scale and described their activities since the previous test. Based on these self-reports, all subjects were able to complete the entire 30 hr period without sleep. Subjects maintained a normal amount of caffeine consumption during the final 10 hours of the sleep restriction period. The PVT and questionnaire were repeated at 5 hr intervals during the first 10 hr block, 2 hr intervals during the second 10 hr block, and 1 hr intervals during the final 10 hr block for a total of 18 times. The final PVT was conducted in the lab just prior to conducting the manual control test measures. There was a highly significant increase in the Stanford Sleepiness Scale during the sleep deprivation period (p No significant changes were found in any of the Mars rover simulation parameters between the last baseline session and the post-acute sleep restriction session. These results suggest that the subjects may have been able to remain as vigilant during rover simulation following 30-hour sleep deprivation period as they were during the final baseline session despite being subjectively more tired. We conclude it is important to control for functional alertness, or vigilance, rather than just sleepiness when testing for the neurosensory consequences of sleep loss. During this final year, we also made progress on a peer-reviewed manuscript to summarize our results. The main conclusions and recommendations from our study are summarized below:

In conclusion, the results from our study appear consistent with our hypothesis that adaptive changes in how inertial cues from the vestibular system are integrated with other sensory information can lead to impaired manual control during transition to a new gravity environment. However, these impairments are highly variable across crewmembers. In tasks like the rover simulation, some amount of neurosensory disruption can be compensated by greater reliance on effective visual cues. Based on our results, future design reference missions can assume that most crewmembers should be able to perform seated rover type tasks within the first few days following landing.

There are a number of countermeasures that should be explored while access is available to returning crews from the International Space Station (ISS). Similar to the "PILOT" project during the Shuttle era, 'just-in-time' refresher training for landing and post-flight manual control tasks would be especially important to develop. This will be true for novel operational tasks such as the rover that will be more affected by learning effects. The value of this countermeasure approach will depend of course on level of fidelity that can be incorporated. Fidelity of the training simulations could be heightened by utilizing vestibular perturbations such as Galvanic vestibular stimulation, which will promote development of compensatory strategies that reduce reliance on vestibular input.

Similar to the heads-up display in the Shuttle cockpit, improved displays will provide an important countermeasure. The docking alignment guides included in our rover simulation minimized the alignment errors we would have otherwise captured if the alignment was performed with the side cameras alone. It is important to note that the display aids can by non-visual, such as vibrotactile feedback that has proven successful in improving pilot performance in rotatory wing aircraft (Rupert 2004).

An improved awareness of sensorimotor-cognitive status will help performance in crewmembers during autonomous operations. This awareness may result from improvements in both adaptability training paradigms (Bloomberg et al. 2015) as well as self-administered testing that relies on established standards. These tests should include functional tests for sensorimotor function and spatial awareness, and also include tests for vigilance and cognitive reserve during dual tasking. For post-landing tasks such as operating rovers, the level of head movements and general activity following landing is an extremely important component in promoting adaptation to the new g state. Either restricting head movements and activity too much or allowing too much amplitude can exacerbate symptoms and impede adaptation to the new state. The earlier introduction of head movements and other motor activity after landing, as long as self-paced within one's threshold for motion tolerance ("Goldilock's" approach), is recommended to facilitate the transition to minimize sensorimotor related manual control risks (Wood et al. 2011).

Task Progress:

References

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Rupert AH (2004) The future of tactile systems for military applications. Aviat Space Environ Med 75:B97

Bloomberg JJ, Peters BT, Cohen HS, Mulavara AP (2015) Enhancing astronaut performance using sensorimotor adaptability training. Front Syst Neurosci 9:129

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ANNUAL REPORTING--JULY 2015

ISS Flight Study: Our flight study utilized a repeated measures pre- versus post-flight design on eight ISS astronauts, where each subject served as their own control. During this reporting period, the final data collection was completed for the flight study with the 41S landing in June 2015. The duration of these ISS missions was 5.6 ± 0.7 months (mean ± standard deviation, SD) with a range from 4.7 to 6.6 months. The time separating the last preflight session with the first postflight session was 8.1 ± 0.5 months (mean ± SD) with a range from 7.2 to 8.8 months. Seven of the eight crewmembers were tested within the "R+0" schedule following the direct return to Houston prior to the first sleep period at crew quarters.

Perspective taking: At the beginning of each trial, the subject was presented a map detailing the current location of the rover along with the docking location to which they were to navigate. Subjects used a joystick to point in the relative direction of the docking target from their starting position, without receiving any visual feedback of their pointing accuracy. Both time to complete and accuracy (absolute error in deg) were the primary dependent measures.

Path navigation: After completing the perspective taking task, the subject drove the rover to the desired location as fast as possible while avoiding obstacles. The time to arrive within a set radius of the docking target, and total path length were the main dependent measures. The navigation phase had a 120 sec time limit, after which the subjects would be forwarded to the docking area. Further analysis of this data will also focus on characterizing the linear accelerations that the crewmembers exposed themselves to during the path navigation phase.

Docking task: Once the subjects arrived at the final docking area (either a habitat module or another rover), visual references provided the precise location and alignment angles to guide the subject in completing a docking task. The subject was required to use side camera views to precisely position one of the rover's side hatches at the docking target. Time to complete the docking and misalignment angle were the primary dependent measures. The docking task had a 90 sec time limit to completion.

Overall proficiency: The four rover trials were conducted in a consistent order across all subjects and sessions. The cumulative time to complete all four trials each session (including perspective taking, navigation, and docking phases) was used as a measure of overall operator proficiency for the rover simulation.

Ground control studies

Changes as a function of session recency (shadow control study): For the flight study, changes in proficiency were expected as a function of time lapsed independent of the effects of microgravity. As described above, there were ~8 months between the last preflight and first postflight sessions. One of our ground control studies completed this past year examined the changes in operator proficiency following an 8-month gap between the 4th and 5th sessions as a control for this recency effect (referred to as a shadow control study). Since this control study included Dr. Moore's T38 simulation, age and gender matched non-astronaut pilots were recruited to participate.

Changes as a function of acute sleep loss: The Stanford Sleepiness Scale was incorporated in our pre- and post-flight astronaut study as a subjective report from each crewmember on their level of sleepiness at the time of each session. This scale (based on Hoddes et al., Pschophysiol, 1973) is a seven point scale ranging from 1 feeling wide awake to 7 sleep onset soon. The last preflight session mean score was 1.9 (± 0.4 SD) representing “functioning at a high level.” There was a significant increase in sleepiness reported during our first post-flight session (4.1 ± 1.7 SD representing "a little foggy"). This suggests that sleepiness could have potentially contributed to the impairments observed for some of our post-flight measures. Therefore, during our final year we have initiated a factors-of-influence study to examine the effect of acute sleep loss to characterize the sensitivity of our measures to sleepiness independent of post-flight neurosensory adaptation. In order to accomplish this, twelve subjects will be recruited to participate in a 30-hour sleep restriction period.

Each subject will participate in three baseline laboratory sessions (separated by at least one week), the 30 hr sleep restriction period, and a post-sleep restriction laboratory session. The three baseline sessions are required to acquire task proficiency to minimize learning effects. Throughout the sleep restriction period, subjects will also participate in an additional short test battery conducted on a tablet or laptop computer, including the psychomotor vigilance test (PVT), to monitor fatigue-related changes in cognitive performance. This cognition battery will be administered on an iPad or laptop (Basner et al., 2011). In addition to a baseline test at the beginning of the sleep restriction period, this cognition test battery will be performed at 5 hr intervals during the first 10 hr block, 2 hr intervals during the second 10 hr block, and 1 hr intervals during the final 10 hr block for a total of 18 times. The final test battery will be completed in the lab just prior to conducting the manual control test measures (driving simulation, rover simulation, dual tracking task, and reaction time test).

Bibliography Type:	Description: (Last Updated: 08/02/2022)
Abstracts for Journals and Proceedings	Lopez B, Pereira MA, Wood SJ. "Visual feedback compensates for vestibular impairment during roll tilt." Presented at the 27th Annual Convention of the Association for Psychological Science, New York, NY, May 21-24, 2015. 27th Annual Convention of the Association for Psychological Science, New York, NY, May 21-24, 2015. , May-2015
Abstracts for Journals and Proceedings	Beltran EJ, Wood SJ, Moore ST. "Assessment of proficiency during simulated rover operations following long-duration spaceflight." Presented at the 2015 NASA Human Research Program Investigators’ Workshop, Galveston, TX, January 13-15, 2015. Workshop: Integrated Pathways to Mars. 2015 NASA Human Research Program Investigators’ Workshop, Galveston, TX, January 13-15, 2015. , Jan-2015
Abstracts for Journals and Proceedings	Beltran EJ, Wood SJ, Moore ST. "Assessment of proficiency during simulated rover operations following long-duration spaceflight." Presented at the 2016 NASA Human Research Program Investigators’ Workshop, Galveston, TX, February 8-11, 2016. 2016 NASA Human Research Program Investigators’ Workshop, Galveston, TX, February 8-11, 2016. , Feb-2016