Fiscal Year:	FY 2006	**Task Last Updated:**	FY 01/08/2007
PI Name:	Wood, Scott J. Ph.D.		
Project Title:	Sensorimotor adaptation following exposure to ambiguous inertial motion cues		
Division Name:	Human Research		
Program/Discipline:	NSBRI Teams		
Program/Discipline--Element/Subdiscipline:	NSBRI Teams--Sensorimotor Adaptation Team		
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		
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:	Ground	**Solicitation / Funding Source:**	2003 Biomedical Research & Countermeasures 03-OBPR-04
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No. of PhD Candidates:	0	**No. of Master' Degrees:**	1
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	3
No. of Bachelor's Candidates:	1	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
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Key Personnel Changes/Previous PI:			
COI Name (Institution):	Harm, Deborah (NASA JSC) Clement, Gilles (Centre National de la Recherche Scientifique) Rupert, Angus (Naval Aerospace Medical Research Laboratory)		
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Task Description:

The central nervous system must resolve the ambiguity of inertial motion sensory cues in order to derive accurate spatial orientation awareness. Our general hypothesis is that the central nervous system utilizes both multi-sensory integration and frequency segregation as neural strategies to resolve the ambiguity of tilt and translation stimuli. Movement in an altered gravity environment, such as weightlessness without a stable gravity reference, results in new patterns of sensory cues. For example, the semicircular canals, vision and neck proprioception provide information about head tilt on orbit without the normal otolith head-tilt position that is omnipresent on Earth. Adaptive changes in how inertial cues from the otolith system are integrated with other sensory information lead to perceptual and postural disturbances upon return to Earth's gravity. The primary goals of this ground-based research investigation are to explore physiological mechanisms and operational implications of disorientation and tilt-translation disturbances reported by crewmembers during and following re-entry, and to evaluate a tactile prosthesis as a countermeasure for improving control of whole-body orientation during passive tilt and translation motion paradigms.
Our first specific aim is to examine the effects of stimulus frequency and different patterns of inertial sensory cues on adaptive changes in eye movements and motion perception during combined tilt and translation motion profiles. Our first hypothesis is that adaptation of otolith-mediated eye movement and perceptual responses will be greatest in the mid-frequency range where there is a crossover of tilt and translation otolith-mediated responses. We are testing this hypothesis by exposing subjects to various combinations of tilt and translation motion profiles over the frequency range from 0.1 Hz to 0.6 Hz. Changes in eye movement and perceptual tilt responses are determined by comparing pre- and post-adaptation runs performed in darkness. During first phase of this grant, we have examined adaptive changes using a 'vision aligned' paradigm with JSC's Preflight Adaptation Training laboratory's Tilt-Translation Device (TTD). This device was designed to recreate post-flight orientation disturbances by exposing subjects to matching tilt self motion with conflicting visual surround translation. While linear vection is robust during the vision aligned paradigm at 0.1 Hz, the post-adaptive changes are relatively small as predicted at these lower stimulus frequencies. We also conducted control studies for the simultaneous measurement of tilt and translation motion perception using constant velocity Off-Vertical Axis Rotation. Perceived motion was evaluated using verbal reports, a multi-axis joystick, and a simple push-button task indicating nose-up orientation. These studies are important to refine methodology to be used in subsequent adaptation experiments planned for the coming year. More importantly, these studies emphasize differences in the neural processing to distinguish tilt and translation linear acceleration stimuli between eye movements and motion perception.

Our second specific aim is to examine changes in control errors during a closed-loop nulling task before and after tilt-translation adaptation. We predict the ability to control tilt orientation will be compromised following tilt-translation adaptation, with increased control errors corresponding to changes in self-motion perception. During this past year, we reported results of control nulling experiments during roll-tilt step and pseudorandom profiles. This experiment also allowed us to initiate our third specific aim to evaluate how a tactile prosthesis might improve control performance. A simple 4 electromechanical tactor system was developed that provided 6 threshold levels of orientation information. We also examined the influence of vibrotactile feedback during computerized posturography. A significant reduction in RMS error ($p<0.05$) was observed using this simple tactile prosthesis, both during manual and balance control tasks. These results are promising in that a fairly simple device with as few as 4 tactors may prove useful to significantly improve landing performance. Both studies demonstrate how a tactile prosthesis can be optimized with feed-forward projections using velocity information.

The major effort in the first phase of the project was to design and develop a device to incorporate the 'GIF aligned' paradigm in which the chair will tilt within an enclosure that will simultaneously translate so that the resultant gravitoinertial force (GIF) vector remains aligned with the longitudinal body axis. This paradigm will result in a mismatch in which the canals and vision signal tilt while the otoliths do not. The Naval Aerospace Medical Research Laboratory in Pensacola has designed an air bearing track with dual ironless linear motors to provide the translational motion. A dual-wheel friction drive provides tilt chair motion up to 45 deg from vertical inside an 8 feet cube enclosure. During this next year, this device will be used to examine the effects of stimulus frequency on adaptive changes in otolith ocular reflexes, motion perception and closed-loop nulling performance. We will also continue to refine the simple tactile prosthesis, optimizing feed-forward information from velocity to improve control performance. The results of this study will contribute to the refinement of the tactile prosthesis to improve spatial orientation and navigation on different acceleration platforms, including landing systems used for return to Earth after long duration space travel or landing systems used during space exploration missions.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

This project will provide insight into adaptive mechanisms of otolith function, in particular as they relate to one's perception of motion and gaze stabilization reflexes. The results of this study will be relevant therefore to vestibular pathophysiology, and understanding compensatory processes following loss or disruption of otolith function in clinical applications. The closed-loop nulling tasks employed by our experiment team will provide a new means of addressing the functional implications of vestibular loss, for example, characterizing risks associated with civilian piloting or automobile driving following vestibular loss. Finally, the development of simple tactile displays will be applicable to balance prosthesis applications for vestibular loss patients and the elderly to mitigate risks due to falling or loss of orientation.

Task Progress:

In support of Specific Aim 1, we completed a study using the 'vision aligned' paradigm with NASA's Tilt-Translation Device. The results emphasize differences in the neural processing to distinguish tilt and translation linear acceleration stimuli between eye movements and motion perception. The results are also consistent with our first hypothesis in that post-adaptive changes are relatively small at lower stimulus frequencies. This study led to one scientific presentation, and a manuscript that is in preparation.
Control studies were conducted to evaluate the simultaneous measurement of tilt and translation motion perception using constant velocity Off-Vertical Axis Rotation. Perceived motion was evaluated using verbal reports, a multi-axis joystick, and a simple push-button task indicating nose-up orientation. These studies are important to refine methodology to be used in subsequent adaptation experiments planned for the coming year. These studies lead to one submitted manuscript, and another in preparation.

In support of Specific Aim 2, results of the roll-tilt nulling experiments completed in year 1 were summarized and presented at two scientific conferences. In support of Specific Aim 3, this study demonstrated how feed-forward information from velocity improved control performance. Also in support of Specific Aim 3, the results of a tactor study

	during computerized posturography were summarized and presented at another conference. This study was important to expand the application of the tactor system to balance disruption following space flight. Two manuscripts are in preparation from these tactor studies. The Naval Aerospace Medical Research Laboratory (NAMRL) Engineering Services in Pensacola has completed the device to provide the ‘GIF aligned (gravitoinertial force) paradigm. The progress on this development was delayed due to servo problems with the linear track. Both encoder and drive systems were replaced for the linear track to resolve this issue, and now the device will be operational for the initial studies at the beginning of the next project year. Due to the reduced funding, the initial studies will be conducted at Pensacola to facilitate any modifications needed prior to its relocation to NASA.
Bibliography Type:	Description: (Last Updated: 06/03/2025)
Abstracts for Journals and Proceedings	Wood SJ, Rupert AH. "Effects of vibrotactile feedback on roll-tilt control performance." 77th Meeting of the Aerospace Medical Association, Orlando, FL, May 2006. Aviat Space Environ Med. 2006 Mar;77(3):350-1. , Mar-2006
Abstracts for Journals and Proceedings	Wood SJ, Black FO, Paloski WH, Rupert AH. "Influence of vibrotactile feedback on controlling upright stance during postural perturbations." Meeting of the Association for Research in Otolaryngology, Mt. Royal, NJ, 2006 February. Assoc Res Otolaryngol Abstracts 2006 Feb;2006:1338. , Feb-2006
Articles in Peer-reviewed Journals	Wood SJ, Reschke MP, Clement G. "Tilt and translation motion perception during Off-Vertical Axis Rotation." Experimental Brain Research. Submitted for Publication, July 2006. , Jul-2006