Fiscal Year:	FY 2007	**Task Last Updated:**	FY 02/01/2008
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 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:	5	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: End date changed to 2/28/2009, from 8/31/2008, per NSBRI (10/7/08)		
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. 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 0.01 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. Baseline eye movements and motion perception elicited during various combinations of tilt and translation stimuli have compared across multiple acceleration platforms. Constant velocity off-vertical axis rotation (OVAR) provides a continually changing head and body orientation relative to gravity where the equivalent linear acceleration is a function of tilt angle and the frequency is a function of rotation rate. Variable radius centrifugation (VRC) is another technique that allows low frequency linear acceleration by combining the centripetal acceleration and sled acceleration to achieve the desired resultant linear acceleration amplitude. Tilting about an Earth horizontal axis and translation along a linear track or sled are the final two motion paradigms that have been used to characterize how the brain interprets linear acceleration at different frequencies. The key findings of these studies have been that the neural processing to distinguish tilt and translation differs between eye movements and motion perception. These findings have an important impact in assessing tilt-translation disturbances following space flight or the adaptation experiments that are planned for the final year. Adaptive changes using a 'vision aligned' paradigm have been conducted by exposing subjects to matching tilt self motion with conflicting visual surround translation. The optimal phase relationship between body tilt and scene translation was examined at 0.1 Hz in the pitch plane using JSC's Tilt-Translation Device (TTD, designed to recreate post-flight orientation disturbances. This study demonstrated that a 180 deg phase relationship should be employed during subsequent studies, although asymmetric stimuli may provide the most robust changes in the pitch plane. Similar studies in the roll plane are in progress at Legacy Health System in Portland OR using a hydraulic powered tilt chair with a chair-mounted horizontal optokinetic stimulus. Finally, a new Tilt-Translation Sled was recently installed at JSC to implement a 'GIF aligned' paradigm in which the chair will tilt within an enclosure that will simultaneously translate, resulting in a mismatch in which the canals and vision signal tilt while otoliths do not. 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. Roll tilt nulling was implemented using the hydraulic tilt chair with both step and pseudorandom stimuli in darkness. Future studies are planned using tilt nulling with a constantly moving visual scene to simulate the brown-out conditions that were encountered during the initial lunar landings. Our third specific aim is 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. During the final year, experiments integrating all three specific aims will be conducted using the Tilt-Translation sled at JSC to provide the 'GIF-aligned' paradigm and the hydraulic chair at Legacy to provide the 'visual-aligned' paradigm. 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:	Our first specific aim has focused on the effect of both stimulus frequency and different patterns of inertial motion cues on various acceleration platforms. Otolith-mediated responses during off-vertical axis rotation (OVAR) demonstrate that while a change in stimulus frequency alone elicits similar changes in the amplitude of both self motion perception and eye movements, differences in the phases suggest that neural processing strategies to distinguish tilt and translation differs between ocular and cognitive processes (Wood et al., 2007). Modeling the OVAR motion perception results is nearing completion (Holly et al, in preparation). Direct comparisons of eye movements and motion perception are also ongoing between four different motion platforms: OVAR, variable radius centrifugation, tilt about an Earth-horizontal axis and translation along a linear track. These motion paradigms will be employed in pending ESA post-flight experiments. Initial adaptation experiments have been conducted using a visual-aligned paradigm in which passive tilt is coupled with moving scene translation. The initial study performed with JSC's Tilt Translation Device in the pitch plane demonstrated that the visual scene otion with 180 deg phase results in a significantly reduced perceived tilt and increase linear vection and vergence eye movements compared to pre-exposure tilt stimuli in darkness (O'Sullivan et al, 2006). A second study is in progress using roll tilt stimuli coupled with a horizontally moving visual scene. Another study was implemented this past year to optimize the use of passive dynamic visual acuity as a dependent measure of visual performance changes (Wood et al, 2007). Our second specific aim has focused on changes in control errors during a closed-loop nulling task before and after tilt-translation adaptation. Roll tilt nulling demonstrated that control performance was compromised by low-frequency bias during pseudorandom stimuli in darkness (Wood et al., 2006). Preliminary findings suggest that these types of manual control task are sensitive to underlying changes in sensorimotor physiology. A follow-up study is examining the influence of low frequency visual scene motion to simulate the effect of brown-out conditions reported during lunar landings. Our third specific aim is 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. A significant reduction in RMS error ($p<0.05$) was observed using this simple tactile prosthesis, both during manual (Rupert et al., 2006) and balance control tasks (Wood et al., 2006). These results are promising in that a fairly simple device with as few as 4 tactors may prove useful to significantly improve landing performance.
Bibliography Type:	Description: (Last Updated: 03/08/2024)
Articles in Peer-reviewed Journals	Wood SJ, Reschke MF, Sarmiento LA, Clément G. "Tilt and translation motion perception during off-vertical axis rotation." Exp Brain Res. 2007 Sep;182(3):365-77. Epub 2007 Jun 13. PMID: 17565488 , Jun-2007