Fiscal Year:	FY 2009	**Task Last Updated:**	FY 05/12/2010
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		
Program/Discipline--Element/Subdiscipline:	NSBRI--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:**	NRA-03-OBPR-04
Start Date:	09/01/2004	**End Date:**	02/28/2009
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	2	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	2
No. of Bachelor's Candidates:	6	**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)		
Grant/Contract No.:	NCC 9-58-NA00405		
Performance Goal No.:			
Performance Goal Text:			

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 were 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. Aim 1 was to examine the effects of stimulus frequency (0.01 - 0.6 Hz) on adaptive changes in eye movements, motion perception and cognition during combined tilt and translation motion profiles. We hypothesized that adaptation of otolith-mediated responses will be greatest in the mid-frequency range where there is a tilt-translation crossover. Our findings emphasized differences in the neural processing to distinguish tilt and translation between eye movements and motion perception. Specifically, during dynamic linear stimuli in the absence of canal and visual input, a change in stimulus frequency alone elicits similar changes in the amplitude of both self motion perception and eye movements. However, in contrast to the eye movements, the phase of both perceived tilt and translation motion is not altered by stimulus frequency over this limited range. Our findings also suggest that the frequency at which there was a crossover of perceived tilt and translation gains appeared to vary across different motion paradigms (e.g., near 0.3 Hz during off-vertical axis rotation and near 0.15 Hz during sled translation). Adaptation experiments conducted below this cross-over frequency using the 'vision-aligned' paradigm have resulted in modest changes to both eye movements and motion perception, consistent with our first hypothesis. Adaptation experiments conducted around this cross-over frequency range using the 'GIF-aligned' paradigm demonstrated a significant effect of stimulus frequency on both motion sickness and spatial cognitive performance. Aim 2 was to examine changes in control errors during a closed-loop nulling task before and after tilt-translation adaptation. We hypothesized that 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 both step and pseudorandom stimuli in darkness. Our findings suggest that these types of manual control tasks are sensitive to underlying changes in sensorimotor physiology, and specifically to changes in the brain's interpretation of linear acceleration stimuli. Aim 3 was 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. Aim 4 was to examine how spatial awareness is impaired with changing gravitational cues during parabolic flight, and the extent to which vibrotactile feedback of orientation can be used to help improve spatial awareness. Our findings suggest that tactile cueing may improve navigation in operational environments, such as extravehicular activities on a lunar surface. This type of sensory feedback may also prove beneficial as a navigation aid in patient populations, providing non-visual, non-auditory feedback of orientation or desired direction heading.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	This project provides insight into adaptive mechanisms of otolith function, in particular as they relate to one's perception of motion and cognitive function. The results of this study are 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 provides 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 is applicable to balance prosthesis applications for vestibular loss patients and the elderly to mitigate risks due to falling or loss of orientation.
Task Progress:	During the final year of the grant we completed three major studies. The first study compared roll-tilt and lateral translation motion perception in 12 subjects across four different motion paradigms: Off-Vertical Axis Rotation, Variable Radius Centrifugation, Earth-horizontal Axis Rotation, and Lateral Sled Translation. The second study utilized a Tilt-Translation Sled as a space-flight sensorimotor analog to examine adaptive changes following exposure to conflicting tilt-translation stimuli. Fourteen subjects were tilted within a lighted enclosure that simultaneously translated at one of 3 frequencies. Each subject participated in 6 sessions including a familiarization session, passive pitch at 0.15, 0.3 and 0.6 Hz and roll at 0.3 Hz, and active pitch at 0.3 Hz. A new spatial cognitive test was developed from previous match-to-sample and mental rotation tasks. The third study utilized parabolic flight to examine acute changes in spatial navigation during the weightless phase. Six student researchers participated on the Reduced Gravity Student Program, using a virtual spatial navigation task during parabolic flight and during baseline ground tests. In both the sled and parabolic analog studies, vibrotactile feedback was implemented as a sensory countermeasure to improve spatial awareness.
Bibliography Type:	Description: (Last Updated: 03/08/2024)
Articles in Peer-reviewed Journals	Holly JE, Wood SJ, McCollum G. "Phase-linking and the perceived motion during off-vertical axis rotation." Biol Cybern. 2010 Jan;102(1):9-29. PMID: 19937069 , Jan-2010
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. PMID: 17565488 , Sep-2007

Articles in Peer-reviewed Journals	Clément G, Beaton KH, Reschke MF, Wood SJ. "Effects of motion paradigm on human perception of tilt and translation." Sci Rep. 2022 Jan 26;12(1):1430. https://doi.org/10.1038/s41598-022-05483-6 ; PMID: 35082357; PMCID: PMC8792002 , Jan-2022
NASA Technical Documents	Wood SJ. "Reduced gravity education flight program." Houston, Tex. : NASA Lyndon B. Johnson Space Center, p., 27-28, 2009. , Dec-2009
Papers from Meeting Proceedings	Clement G, Harm, DL, Rupert AH, Beaton KH, Wood SJ. "Ambiguous tilt and translation motion cues in astronauts after space flight." Human Research program Investigators' Workshop, League City, Tex.., February 2-4, 2009. Human Research Program Investigators' Workshop, 2009. , Feb-2009
Significant Media Coverage	Myers C. "What's a sensor belt? Three-part news story on the NSBRI student project on the parabolic flight program." KTRK-TV, Houston, Texas, April 2009., Apr-2009
Significant Media Coverage	Jeffs B. "Scientist probes workings of the inner ear." JSC Roundup , p. 10-11, Vol 47, No 8, August 2008., Aug-2008