

<b>Fiscal Year:</b>	FY 2010	<b>Task Last Updated:</b>	FY 09/07/2010
<b>PI Name:</b>	Moore, Steven T. Ph.D.		
<b>Project Title:</b>	Head-eye Coordination during Simulated Orbiter Landings		
<b>Division Name:</b>	Human Research		
<b>Program/Discipline:</b>	HUMAN RESEARCH		
<b>Program/Discipline--Element/Subdiscipline:</b>	HUMAN RESEARCH--Physiology		
<b>Joint Agency Name:</b>		<b>TechPort:</b>	No
<b>Human Research Program Elements:</b>	(1) <b>HHC:</b> Human Health Countermeasures		
<b>Human Research Program Risks:</b>	(1) <b>Sensorimotor:</b> Risk of Altered Sensorimotor/Vestibular Function Impacting Critical Mission Tasks		
<b>Space Biology Element:</b>	None		
<b>Space Biology Cross-Element Discipline:</b>	None		
<b>Space Biology Special Category:</b>	None		
<b>PI Email:</b>	<a href="mailto:s.moore@cqu.edu.au">s.moore@cqu.edu.au</a>	<b>Fax:</b>	FY
<b>PI Organization Type:</b>	UNIVERSITY	<b>Phone:</b>	212-241-1943
<b>Organization Name:</b>	Mount Sinai School of Medicine		
<b>PI Address 1:</b>	Human Aerospace Laboratory		
<b>PI Address 2:</b>	Department of Neurology		
<b>PI Web Page:</b>			
<b>City:</b>	New York	<b>State:</b>	NY
<b>Zip Code:</b>	10029	<b>Congressional District:</b>	14
<b>Comments:</b>	NOTE: PI moved to Central Queensland University, Australia, July 2016.		
<b>Project Type:</b>	Ground	<b>Solicitation / Funding Source:</b>	2003 Biomedical Research & Countermeasures 03-OBPR-04
<b>Start Date:</b>	05/15/2004	<b>End Date:</b>	05/31/2010
<b>No. of Post Docs:</b>	2	<b>No. of PhD Degrees:</b>	
<b>No. of PhD Candidates:</b>	0	<b>No. of Master' Degrees:</b>	
<b>No. of Master's Candidates:</b>	0	<b>No. of Bachelor's Degrees:</b>	
<b>No. of Bachelor's Candidates:</b>	0	<b>Monitoring Center:</b>	NASA JSC
<b>Contact Monitor:</b>	<b>Contact Phone:</b>		
<b>Contact Email:</b>			
<b>Flight Program:</b>			
<b>Flight Assignment:</b>	NOTE: Gap added per HRP Master Task List information dtd 3/14/12 (Ed., 4/13/12) NOTE: Received NCE to 5/31/2010 (from 6/01/2009) per J. Dardano/JSC (12/08)		
<b>Key Personnel Changes/Previous PI:</b>			
<b>COI Name (Institution):</b>	MacDougall, Hamish ( Mt Sinai School of Medicine ) Clark, Jonathon ( NASA Johnson Space Center ) Lesceu, Xavier ( Airbus ) Speyer, Jean-Jacques ( Airbus )		
<b>Grant/Contract No.:</b>	NNJ04HF51G		
<b>Performance Goal No.:</b>			
<b>Performance Goal Text:</b>			

<p><b>Task Description:</b></p>	<p>Up to 90% of crewmembers experience spatial disorientation during reentry and landing of the Orbiter, with prevalence proportional to the length of the mission. The possibility of extending shuttle missions is currently under investigation, and it is likely that the incidence and severity of spatial disorientation during reentry will increase with flight duration. This is a critical issue, as Orbiter landing data shows a decrement in performance following microgravity exposure compared to simulated landings in the Vertical Motion Simulator (VMS) at NASA Ames and the NASA Shuttle Training Aircraft. Despite the potential impact on landing operations, the basis of microgravity-related spatial disorientation is poorly understood. The aim of this proposal is to obtain basic data on the characteristics of head and eye movements during simulated Orbiter landings. This information will be used to determine landing tasks that may induce spatial disorientation. In addition, we will model spatial disorientation due to microgravity exposure using a ground-based analogue of post-flight sensorimotor deficits developed during the course of this project. The system uses Galvanic vestibular stimulation (GVS) to modulate vestibular input to the brain with a pseudo-random current waveform. Preliminary results suggest that per-GVS exposure generate symptoms of spatial disorientation comparable to space flight. Simulated landings in the VMS will be performed with GVS, to test the hypothesis that spatial disorientation diminishes head-eye coordination and landing performance. This may serve as a model for the deterioration in pilot performance during reentry, and provide a training regimen to allow commanders and pilots to experience spatial disorientation in a simulator.</p> <p>To develop a model of spatial disorientation (SD) due to microgravity exposure that can be used to familiarize shuttle pilots with SD symptoms during simulated landings, as well as a training tool to improve landing performance after space flight.</p> <p>This project addresses several questions from the Bioastronautics roadmap concerning disorientation and vertigo during g-level transitions, such as experienced during landing. Development of a ground-based model will help improve shuttle landing performance in the in the short term and will significantly improve mission safety, as several SD incidents impacting Orbiter safety during landing have been documented. In the long term, the SD model developed by this project will have application to future long-duration missions to ensure pilots can monitor automatic landings, and can take manual control of the space craft in off-nominal situations. The SD model may also be used to train astronauts for emergency egress and EVA on a planetary body after g-level transitions.</p>
<p><b>Rationale for HRP Directed Research:</b></p>	
<p><b>Research Impact/Earth Benefits:</b></p>	<p>Development of a training regime incorporating a model of spatial disorientation (SD) is of potential use in commercial and military aviation, where significant losses of aircraft and life occur each year due to SD-related mishaps.</p>
<p><b>Task Progress:</b></p>	<p>Up to 90% of crewmembers experience spatial disorientation during reentry and landing of the orbiter, with prevalence proportional to the length of the mission. This is a critical issue, as orbiter landing data shows a decrement in performance following microgravity exposure compared to simulated landings in the Vertical Motion Simulator (VMS) at NASA Ames and the NASA Shuttle Training Aircraft. Despite the potential impact on landing operations, the basis of microgravity-related spatial disorientation is poorly understood. The primary aims of this proposal were to:</p> <ol style="list-style-type: none"> <li>1) obtain basic data on the characteristics of head and eye movements during simulated orbiter landings,</li> <li>2) and develop a ground-based analog of the effects of microgravity exposure on pilot performance after spaceflight.</li> </ol> <p>Fulfillment of the project aims was carried out in four phases.</p> <p>Phase I: Measurement of head and eye movement during vehicle operation</p> <p>We developed a laptop-based system which simultaneously measures 6 degree-of-freedom (6DOF - triaxial angular rate and triaxial linear acceleration) head movement (using Inertial measurement Units, IMUs), 3D eye movement (yaw, pitch and roll), and 6 DOF motion of a vehicle (or simulator cabin, using an IMU), published as:</p> <p>MacDougall HG, Moore ST (2005) Functional assessment of head-eye coordination during vehicle operation. Optom Vis Sci 82: 706-715.</p> <p>Phase II: Head-eye coordination during simulated shuttle landings</p> <p>We obtained head and eye movement data from six pilots during simulated shuttle landings in an Airbus A340 level-D flight simulator at the Airbus flight training centre in Toulouse, France. In addition, head and eye movements were obtained from a NASA test pilot performing a shuttle landing in the VMS at NASA Ames. Results: during the HAC maneuver (where the shuttle banks around a virtual cylinder to align with the runway) the head and eyes rolled towards the visual horizon with a combined gain of 0.14 of bank angle. Pilots alternated fixation between the instruments and the runway during final approach, almost exclusively focusing on the runway after preflare. Optokinetic nystagmus was observed during rollout. During final approach a Heads-Up Display (HUD) reduced pitch head and eye movement. Conclusions: roll tilt of the head and eyes during the HAC tended to align the retina with the visual horizon. Overlaying critical flight information and the approaching runway with the HUD reduced pitch head and eye movement during orbiter final approach in the VMS relative to the A340 (no HUD installed). Published as:</p> <p>Moore ST, MacDougall HG, Lesceu X, Speyer JJ, Wuyts F, Clark JB (2008) Head-eye coordination during simulated orbiter landing. Aviat Space Environ Med 79: 888-898.</p> <p>Phase III: Development of ground-based analog of spatial disorientation after spaceflight In the initial project description we proposed using long-term (60 min) 3 Gx centrifugation (3-g linear acceleration applied along the naso-occipital axis) to replicate the sensorimotor effects of microgravity exposure, as developed by a Dutch group at TNO. Although centrifuged subjects exhibited sensorimotor effects consistent with those observed post-flight the effects were short-lived (&lt;60 min) and often accompanied by motion sickness; 40% of veteran astronauts tested experienced nausea and vomiting following 1-hr of 3-Gx centrifugation (Nooij et al. 2004). The logistical complexity of hyper-g centrifugation and the high incidence of motion sickness limited its value as an analog of post-flight sensorimotor deficits. We therefore developed a novel system utilizing electrical stimulation of the vestibular nerve (Galvanic vestibular stimulation - GVS) to replicate the effects of spaceflight on neurological function. The current waveform used in our GVS analog, a pseudorandom sum of sines, was devised such that sensorimotor performance of normal subjects exposed to acute GVS replicated post-landing data from shuttle and International Space Station (ISS) astronauts, namely</p>

postural sway, locomotor impairment and decrements in dynamic visual acuity. Subjective validation was provided by seven veteran astronauts (5 shuttle, 1 ISS, 1 Skylab), who reported that the motor effects and illusory sensations of movement generated by the GVS analog were remarkably similar to their post-landing experience. Published as:

MacDougall H, Moore ST, Curthoys IS, Black FO (2006) Modeling postural instability with Galvanic vestibular stimulation. *Exp Brain Res* 172: 208-220.

Moore ST, MacDougall H, Peters BT, Bloomberg JJ, Curthoys IS, Cohen H (2006) Modeling locomotor dysfunction following spaceflight with Galvanic vestibular stimulation. *Exp Brain Res* 174: 647-659.

NSBRI (2006) Galvanic Vestibular Stimulation Countermeasure Demonstrated to Astronauts. In: NSBRI Explorer, July 2006.

#### Phase IV: Validation of GVS as an analog of post-flight spatial disorientation

The aim of this study was to validate an analog of the sensorimotor effects of microgravity, utilizing pseudorandom bilateral bipolar Galvanic vestibular stimulation (GVS), during shuttle landing simulations. Pilot (N=11) performance was assessed during simulated shuttle landings in the Vertical Motion Simulator at NASA Ames (used for shuttle pilot training). Subjects performed 8 pairs of identical landing profiles (final approach and touchdown) with and without GVS, presented in a pseudorandom order. Target touchdown speed was on target (204 kts) without GVS but increased significantly ( $P=0.02$ ) during GVS exposure and was at the upper limit (209 kts) of the target range. Unsuccessful (crash) landings increased from 2.3% without GVS to 9% with GVS. Hard landings, with touchdown speed in the 'red' (unacceptable) range ( $>214$  kts), almost doubled from 15.9% without GVS to 30.7% with GVS. GVS was an effective analog of decrements in post-flight shuttle pilot performance. The ability of GVS to replicate a wide range of post-flight sensorimotor deficits (postural, locomotor, oculomotor, fine motor) supports the hypothesis that central changes in processing of low-frequency otolith input underlie space adaptation syndrome. Submitted for publication:

Moore ST, Dilda V, MacDougall HG (2010) Galvanic vestibular stimulation as an analog of spatial disorientation after spaceflight. *Exp Brain Res*, in review.

#### Deliverables:

- 1) We have developed and validated a portable laptop-based system for evaluation of visuo-motor function during complex operational tasks, such as landing the orbiter.
- 2) We have developed an ambulatory, reversible, ground-based analog (GVS) capable of accurately replicating the sensorimotor (postural, locomotor, oculomotor and fine-motor) effects of spaceflight, suitable for astronaut training.
- 3) We have validated the GVS analog in an operational setting (VMS shuttle landings).

<b>Bibliography Type:</b>	Description: (Last Updated: 09/07/2020)
Articles in Peer-reviewed Journals	MacDougall HG, Moore ST. "Functional assessment of head-eye coordination during vehicle operation." <i>Optom Vis Sci</i> . 2005 Aug;82(8):706-15. <a href="#">PMID: 16127336</a> , Aug-2005
Articles in Peer-reviewed Journals	MacDougall HG, Moore ST, Curthoys IS, Black FO. "Modeling postural instability with Galvanic vestibular stimulation." <i>Exp Brain Res</i> . 2006 Jun;172(2):208-20. <a href="#">PMID: 16432695</a> , Jun-2006
Articles in Peer-reviewed Journals	Moore ST, MacDougall HG, Peters BT, Bloomberg JJ, Curthoys IS, Cohen HS. "Modeling locomotor dysfunction following spaceflight with Galvanic vestibular stimulation." <i>Exp Brain Res</i> 2006 Oct;174: 647-59. <a href="#">PMID: 16763834</a> , Oct-2006
Articles in Peer-reviewed Journals	Moore ST, MacDougall HG, Lesceu X, Speyer JJ, Wuyts F, Clark JB. "Head-eye coordination during simulated orbiter landing." <i>Aviat Space Environ Med</i> . 2008 Sep;79(9):888-98. <a href="#">PMID: 18785358</a> , Sep-2008
Articles in Peer-reviewed Journals	Moore ST, Dilda V, MacDougall HG. "Galvanic vestibular stimulation as an analog of spatial disorientation after spaceflight." <i>Exp Brain Res</i> , in review. August 2010. , Aug-2010