Fiscal Year:	FY 2021	**Task Last Updated:**	FY 03/31/2021
PI Name:	Reschke, Millard F Ph.D.		
Project Title:	Straight Ahead in Microgravity		
Division Name:	Human Research		
Program/Discipline:			
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		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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City:	Houston	**State:**	TX
Zip Code:	77058-3607	**Congressional District:**	36
Comments:			
Project Type:	Flight	**Solicitation / Funding Source:**	OTHER
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No. of Post Docs:	0	**No. of PhD Degrees:**	0
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No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Brocato, Becky	**Contact Phone:**	
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Flight Program:	ISS		
Flight Assignment:	ISS NOTE: End date changed to 2/13/2021 per L. Taylor/JSC (Ed., 7/29/2020) NOTE: End date changed to 9/30/2020 per L. Taylor/JSC (Ed., 8/23/18)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Clement, Gilles Ph.D. (ESA PI: Lyon Neuroscience Research Center, France) Wood, Scott Ph.D. (NASA Johnson Space Center)		
Grant/Contract No.:	Not available		
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Task Description:	Drs. Millard Reschke and Scott Wood are the U.S. Co-Investigators on this European Space Agency (ESA)-sponsored project (updated September 2019); ESA Principal Investigator is Gilles Clément, Ph.D., Lyon Neuroscience Research Center, France. The subjective straight-ahead direction is a very basic perceptual reference for spatial orientation, movement, and locomotion. The perceived straight-ahead along the horizontal and vertical meridian is largely determined by both otolith and somatosensory inputs. Otolith and somatosensory inputs are altered in microgravity and will change this reference point. Adaptive processes are taking place within the central nervous system to take into account the new environment and compute new spatial egocentric and world-centered representations or frames of reference. This project will measure and monitor how these frames change over time by investigating eye movements and perceptual reports. The three specific aims include: Specific Aim 1: Near & Far Fixation. The first aim is to examine binocular eye movements when subjects fixate on actual targets (normal vision) and then imagine these same targets (occluded vision) in the straight-ahead direction relative to their heading. Initially, the subjects' gaze direction and fixation distance will be recorded as they explore the space around them using eye movements in darkness. Next, they will be asked to fixate on straight ahead head-fixed targets located at a near distance (arm's length, ~0.5 m) and far distance (beyond 2 m). Responses will be compared with different tilt orientations, including pitch tilt forward and backward up to 15 deg. During separate trials, subjects will attempt to maintain fixation on a far Earth-fixed target with and without a vibrotactile sensory aid that indicates how far one has tilted relative to the straight ahead direction. Specific Aim 2: Eye and Arm Movements. The second aim is to examine directed horizontal and vertical eye and arm movements, relative to Earth coordinates and relative to the subject's head/body reference. This task will be performed with the subject upright and then tilted in roll directions up to 30 deg. The trajectory of the directed eye and arm movements made in darkness are expected to reflect perceptual tilt errors. Specific Aim 3: Near and Far VOR. The third aim is to examine the influence of target distance on the vestibulo-ocular reflex (VOR) during vertical translation movements. Subjects will stare at actual visual targets (normal vision) at various distances (near and far) in the straight-ahead direction while passively translated up and down using a spring-loaded chair. Vision will then be occluded, and the VOR will be recorded as the subject continues to fixate on the same target locations during translation. In addition to these periodic oscillations (~2.0 Hz), eye movements will also be recorded with vision during unpredictable passive head thrusts up and down using the spring-loaded chair. For each of our specific aims above, our general hypothesis is that responses will be influenced by how accurately subjects perceive their spatial orientation. We will test this hypothesis by comparing responses with and without visual feedback. We also hypothesize for Specific Aim 1 that a vibrotactile sensory aid of tilt position will improve spatial orientation and this reduces gaze fixation errors. Study Participants: Eight International Space Station (ISS) crewmembers were recruited to participate in three preflight sessions (between 120 and 60 days before launch) and then three postflight sessions on R+1 day, R+4 (±2) days, and R+8 (±2) days. Sixteen ground-based subjects were recruited to participate in a ground control study for up to 3 sessions. This study was implemented by the European Space Agency and is not carried in the U.S. ISS utilization plans. Risk Characterization, Quantification\Evidence: This task will contribute to gap closure by providing information regarding any changes in an individual's egocentric reference that might have negative consequences on evaluating the direction of an approaching object or on the accuracy of reaching movements. This information is important for understanding the problems associated with the long-term effects of microgravity on astronauts and how they re-adapt to the return of gravitational forces on Earth or other planetary surfaces. Countermeasure\Prototype Hardware or Software: This task will contribute to gap closure by evaluating how vibrotactile feedback of reference frames can be used to improve spatial orientation of fixation on space-fixed targets.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	This study addressed adaptive changes in spatial orientation as assessed by oculomotor and pointing measures related to the subjective straight ahead, and the use of a vibrotactile sensory aid to reduce perceptual errors. On Earth, there is evidence that patients with vestibular or cerebral lesions present a deviation in their subjective straight-ahead direction. We have confirmed that a sensory aid countermeasure, vibrotactile stimulation, improves spatial awareness in astronauts after return from spaceflight. This countermeasure may be also useful for clinical populations. The results of our flight study have also practical implications in the design of man-machine interfaces. Changes in line of sight in reduced gravity affect crew posture and reach, display orientation, and other visual cues, which should be considered in hardware and operations design.
	Subjects: Eight International Space Station (ISS) crewmembers were recruited to participate in three preflight sessions (between 120 and 60 days before launch) and then three postflight sessions on R+1 day (+24 hrs following direct return to Johnson Space Center-JSC), R+4 (± 2) days, and R+8 (± 2) days. An informed consent briefing has been delivered to 26 ISS crewmembers between March 2014 and May 2018. The last crewmember was recruited on May 2018 after which the enrollment was closed. Preflight data was initiated in 2015 following approval for this study to be implemented for pre- and post-flight testing only. One subject was withdrawn from the study due to changes in post-flight test plans. Eight ISS crewmember (5 male, 3 female; mean age 49.6 ± 9.3 years) have completed pre- and post-flight data collection. The mean duration of their spaceflight was 188 ± 79 days.219 Specific Aim 1 The amplitude of perceived tilt during passive tilt in roll (± 25º) significantly increased on R+1 compared to preflight. However, the amplitude of perceived tilt during passive tilt in pitch (± 15º) did not change significantly on R+1 compared to preflight. The perceived amplitude of translation tended to increase during roll tilt and during pitch tilt after spaceflight. The perception of distances of visual targets ranging from 0.5 m to ~2 m was affected by target distance, with greater errors with near targets =1 m. However, the distance of a visual target was not affected by spaceflight within the timeframe of our tests. The eye movement data indicate that the amplitude of ocular counter-rolling during tilt in roll was reduced for several days after return from long-duration spaceflight. This decrease in amplitude was not accompanied by changes in the asymmetry of OCR between right and left head tilt (Reschke et al. 2018).

Task Progress:	Specific Aim 2 When subjects imagined a laboratory-fixed target while being tilted in pitch at angles varying from 15º backward to 15º forward, the vertical eye position shifted downward ~5º compared to when they were actually looking at the target, thus indicating a downward shift of the subjective straight-ahead. The addition of a vibrotactile feedback of tilt when the subjects imagined the targets partially compensated for this downward shift of the subjective straight-ahead. This result confirms that a vibrotactile feedback is a useful countermeasure after landing for mitigating the effects of spaceflight on spatial disorientation and manual control (Clément et al. 2018; Reschke & Clément 2018). Specific Aim 3 The translational vestibulo-ocular reflex (tVOR) measurements during vertical oscillations were analyzed using a method that has been recently published (Clément et al. 2019). The tVOR at high frequency is an important otolith-mediated response to stabilize gaze during natural locomotion. The tVOR was significantly increased with near viewing of actual targets. This effect was less pronounced with subjects imagining these targets in darkness. A decrease in the tVOR gain was observed in some subjects, which could potentially alter gaze fixation during locomotion. Therefore, the results of this study confirm the potential contribution of a spaceflight-adapted vestibular system in locomotion impairment after spaceflight. CONCLUSIONS The results of this study indicate that after spaceflight, there is an over-estimation of perceived roll tilt, but that there is no change in perceived pitch tilt. Also, the perceived amplitude of translation tends to increase during roll and pitch tilt after spaceflight. Ocular counter-rolling during roll tilt decreases after long-duration spaceflight. The subjective straight-ahead shifts downward after spaceflight (~ 5º). A vibrotactile feedback of tilt partially compensates for this downward shift in some subjects. One primary limitation of this study is the delayed testing due to the time required for direct return to JSC. Recent field tests (Reschke et al. 2020) suggest that any impairments observed following +24 hrs underestimate the initial decrement soon after landing. The observed changes in egocentric reference might impair an individual's ability to evaluate the direction of an approaching object or the accuracy of their reaching movements or locomotion. The use of vibrotactile sensory aid partially compensates to correct the representation of the body tilted relative to gravity and could partially help in mitigating risks caused by this loss of spatial orientation. References Reschke MF, Wood SJ, Clément G (2018) Ocular counter rolling in astronauts after short-and long-duration spaceflight. Scientific Reports 8: 7747. Clément G, Wood SJ, Paloski WE, Reschke MF (2019) Changes in gain of horizontal vestibulo-ocular reflex during spaceflight: Journal of Vestibular Research 29: 241-251. Clément G, Reschke MF, Wood SJ (2018) Vibrotactile feedback improves manual control of tilt after spaceflight. Frontiers in Physiology 9: 1850. Reschke MF, Clément G (2018) Vestibular and sensorimotor dysfunction during spaceflight. Current Pathobiology Reports6 (3): 177-183. Reschke MF, Kozlovskaya IB, Lysova N, Kitov V, Rukavishnikov I, Kofman IS, Tomilovskaya ES, Rosenberg MJ, Osetsky N, Fomina E, Grishin A, Wood SJ. (2020) [Joint Russian-USA field test: Implications for deconditioned crew following long duration spaceflight]. Aviakosm Ekolog Med. 2020;54(6):94-100.
Bibliography Type:	Description: (Last Updated: 06/03/2025)
Articles in Other Journals or Periodicals	Goswami N, White O, Blaber A, Evans J, van Loon JWA, Clément G. "Human physiology adaptation to altered gravity environments." Physiological Reviews, in press as of April 2021. , Apr-2021
Articles in Peer-reviewed Journals	Macaulay TR, Peters BT, Wood SJ, Clément GR, Oddsson L, Bloomberg JJ. "Developing proprioceptive countermeasures to mitigate postural and locomotor control deficits after long-duration spaceflight." Front Syst Neurosci. 2021 Apr 27;15:658985. Review. https://doi.org/10.3389/fnsys.2021.658985 ; PMID: 33986648; PMCID: PMC8111171 , Apr-2021