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Project Title:	(ZAG/Otolith) Ambiguous Tilt and Translation Motion Cues After Space Flight / Otolith assessment during postflight re-adaptation
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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.
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Contact Monitor:	Baumann, David — **Contact Phone:**
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Flight Assignment:	ISS STS-123 (ZAG only), STS-128, STS-129, STS-130, STS-132, STS-134 NOTE: End date is now 4/30/2012 per HRP Master Task List dated 7/12/2011 (Ed., 8/4/2011) NOTE: Received extension to 9/30/2011 per PI (10/2010)
Key Personnel Changes/Previous PI:	
COI Name (Institution):	Clement, Gilles (International Space University) Rupert, A. (U.S. Army Aeromedical Research Laboratory) Harm, Deborah (NASA Johnson Space Center) Andrew, Clarke (Charité Medical School)
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Task Description:	Adaptive changes during space flight in how the brain integrates vestibular cues with other sensory information can lead to impaired movement coordination, vertigo, spatial disorientation, and perceptual illusions following G-transitions. Two collaborative NASA-ESA (European Space Agency) studies examined both the physiological basis and operational implications for disorientation and tilt-translation disturbances following space flight. These experiments shared a variable radius centrifuge, and therefore their centrifuge protocols were integrated although they remained separate experiments. 1. Ambiguous Tilt and Translation Motion Cues after Space Flight (See also http://www.nasa.gov/): This experiment utilized a unique motion paradigm on NASA's Tilt-Translation Sled (TTS) in which the resultant gravitoinertial vector remained aligned with the body longitudinal axis during tilt motion (referred to as the Z-axis gravitoinertial or ZAG paradigm). One specific aim was to examine the effects of stimulus frequency on adaptive changes in eye movements and motion perception during independent tilt and translation motion profiles. The TTS provided pitch tilt combined with fore-aft translation. The variable radius centrifuge (VRC) provided lateral translation during rotation, resulting in illusory roll-tilt. We hypothesized that the greater adaptive changes will occur in the mid-frequency range where there is a crossover of tilt and translation otolith-mediated responses. Another specific aim was to employ a closed-loop nulling task in which subjects used a joystick to null out tilt motion disturbances on these two devices. The stimuli consist of random steps or sum-of-sines stimuli, including the ZAG profiles on the TTS. We hypothesized the ability to control tilt orientation would be compromised following space flight, with increased control errors corresponding to changes in self-motion perception. A final specific aim was to evaluate how sensory substitution aids (e.g., vibrotactile feedback) could improve manual control performance. We hypothesized that performance on the closed-loop tilt control task would be improved with tactile display feedback of tilt orientation. Repeated measures were conducted on 12 Shuttle crewmembers during 3 preflight sessions and during 4 postflight sessions within the first week using both VRC and TTS devices. Critical landing day data on the VRC were obtained on 7 subjects. There was an increase in static roll tilt perception on landing day while later measures in roll and pitch were the same as preflight levels by R+1 day. There was an increase in translation perception in both roll and pitch planes that persisted for several days on the sled. This increase in translation gain relative to changes in tilt gain may reflect a shift in the cross-frequency between the two types of responses consistent with our hypothesis of a frequency-dependent adaptation of otolith-mediated responses. In the absence of vision, decrements in nulling performance were observed on landing day but appeared to recover by the initial runs on the sled on R+1. Fatigue on landing day was a contributing factor. A simple vibrotactile sensory aid improves manual control performance within the limited range tested. Most significantly, the nulling performance on landing day with the tactors was not significantly different than preflight nulling performance without the tactors. 2. Otolith Assessment during Post-flight Re-adaptation (See also http://www.nasa.gov/): This experiment utilized two experiment paradigms that allowed unilateral assessment of otolith utricular and saccular function. During unilateral centrifugation (constant rotation at 400 deg/s), subjects were displaced by 3.5 cm so that one utricle is located off-axis while the opposite side is centered over the axis of rotation. A second protocol utilized the vestibular evoked myogenic potentials (VEMP) as an indicator of unilateral saccule function via vestibulo-collic pathways. One specific aim was to examine the variability (gain, asymmetry) in both otolith-ocular responses and the subjective visual vertical to unilateral centrifugation (UC), and measure the time course of post-flight recovery. Similarly, another aim was to assess the variability in amplitude and latency of VEMPs. This study tested the otolith asymmetry hypothesis as an explanation of individual variability for sensorimotor adaptation. Repeated measures were conducted on 10 Shuttle crewmembers during 3 preflight sessions and during 4 postflight sessions within the first week using both VRC and VEMP measures. Critical landing day data were obtained on 6 subjects on the VRC and 7 subjects on the VEMP. A general increase in asymmetry of otolith responses was observed on landing day relative to pre-flight baseline, with a subsequent reversal in asymmetry within 2-3 days. Recovery to baseline levels was achieved within the first week. This fluctuation in the asymmetry measures appeared strongest for SVV, in a consistent direction for OOR, and in an opposite direction for the saccular cVEMP. These results are consistent with our hypothesis that space flight results in adaptive changes in central nervous system processing of otolith input. Adaptation to microgravity may reveal asymmetries in otolith function upon to return to Earth that were not detected prior to the flight due to central nervous system compensatory mechanisms.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

Otolith function is critical for spatial orientation, gaze stabilization, and postural stability. This project examined adaptive mechanisms of otolith function, in particular how decrements in otolith function may increase the risk of impaired ability to maintain control of vehicles and other complex systems. Both experiments addressed a research gap regarding functional recovery of otolith function data following space flight. Changes measured in these otolith-mediated reflexes provided insight into the high inter-subject variability in sensorimotor impairment observed during and following G-transitions. The closed-loop nulling tasks employed during the ZAG experiment provided a new means of addressing the functional implications of vestibular loss. These measures are relevant to how impairments in otolith processing may affect other vehicular control tasks, such as driving with vestibular impairments. The refinement of a tactile prosthesis to improve spatial orientation will serve as a countermeasure for tilt-translation disturbances on a variety of acceleration platforms. Validation of simple sensory aids 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:

Study Schedule: Repeated measures were conducted on 12 Shuttle crewmembers for ZAG and 10 Shuttle crewmembers for Otolith. Measurements were obtained for each experiment pre-flight at L-120 (±30), L-90 (±30), and L-30 (±10) days and post-flight at R+0, R+1 (TTS only), R+2 or 3, R+4 or 5, and R+8-10 days. The specific Shuttle missions included: STS-123 (1 ZAG only), STS-126 (3 each), STS-128 (1 each), STS-129 (1 each), STS-130 (2 ZAG and 1 Otolith), STS-132 (2 each), STS-133 (1 each), and STS-134 (1 each). An integrated protocol on the variable radius centrifuge was implemented for subjects participating in both experiments. Ground control measures on most measures were also obtained on 8 normative subjects.
ZAG Variable Radius Centrifugation: Constant velocity variable radius centrifugation (VRC) was utilized to elicit otolith reflexes in the lateral plane without concordant roll canal cues. Subjects were restrained on a chair that was mounted on a small translation stage fixed to a rotator. Subjects donned an elastic belt with vibrotactile stimulators used to provide orientation cues when the chair position exceeded pre-set threshold levels. Subjects wore a lightweight mask with video cameras and near-infrared illumination to allow eye movement recording in darkness. A joystick mounted directly in front of the subject was used for both motion perception and manual control tasks (nulling chair translation). This session was initiated with a slow acceleration (3°/s2) to a constant velocity of 216°/s, typically after the Otolith VRC was performed. Subjects continued to rotate for 60 s to allow the initial per-rotatory response to decay. After the subjects no longer sensed the rotation, the chair was offset at various positions to obtain verbal reports of tilt perception with chair positions corresponding to ±5°, ±10° and ±15°. Subjects then used the joystick to control the chair orientation. Two closed-loop nulling runs were performed (with and without vibrotactile feedback) in which subjects attempted to maintain the chair centered over the axis of rotation (no tilt) during the same random step protocol. The maximum chair translation was limited to ±20 cm. The primary dependent measures for the manual control runs was the root mean square (RMS) position error, and the amount of the disturbance that was effectively corrected referred to below as "nulling gain." During the final part of this session, subjects oscillated along the track at three discrete frequencies (0.15, 0.3, and 0.6 Hz). The amplitude of the chair translation at each frequency was adjusted so that the tilt stimuli (resultant of translation and centripetal accelerations) was ±10°. Subjects reported their perception of roll tilt and lateral translation at each frequency using the joystick and verbal reports. The primary dependent measures for the sinusoidal data are the amplitude and phase of both eye movements and motion perception.

We hypothesized that adaptation of otolith-mediated responses will be greatest in the mid-frequency range where there is a crossover of tilt-translation responses. Motion perception was obtained using both static and dynamic roll tilt stimuli. All subjects tested on landing day (7 of 12) reported an increased sense of static roll tilt. This increase in tilt perception recovered by the time testing resumed at Johnson Space Center (JSC) 2-3 days after landing. During the sinusoidal VRC oscillations, all subjects reported an increased sense of translation at higher frequencies. This difference between translation and tilt perception was even greater on landing day. Quadric fits through the average responses at each frequency suggest that the cross-over frequency shifted from ~0.25 Hz preflight to ~0.12 Hz on landing day. As with the static tilt perception, these adaptive changes in dynamic translation perception tended to recover by the time testing resumed at JSC 2-3 days after landing.There were clear deficits in some crewmembers' ability to null out tilt disturbances during VRC on landing day. On landing day the manual control performance without vibrotactile feedback was reduced by >30% based on the gain or the amount of tilt disturbance successfully nulled. A similar effect is observed for RMS position and velocity error. Manual control performance tended to return to baseline levels within 1-2 days following landing. Nulling gain was significantly improved with vibrotactile feedback. It is important to note that the landing day performance with tactors was as good as preflight performance without tactors.

ZAG Tilt-Translation Sled: This session flow was similar to the ZAG VRC, except that the linear acceleration stimuli are directed along the pitch plane using the Tilt-Translation Sled (TTS) that provides various combinations of tilt and translation stimuli. Subjects were restrained on a tilt chair that was mounted inside a light-tight enclosure. The tilt motion was provided by dual-wheel friction wheels using direct drive servo motors and a pivoting yoke assembly to provide up to ±20° dynamic displacement. The translation motion along the air bearing track was generated by three linear motors operated in series in a single magnet track. During this session, subjects were oriented so that translation was along the fore-aft direction while tilts were in the sagittal plane. The vibrotactile stimulators were located on the back and front of the torso to provide orientation cues of pitch tilt. Subjects were restrained in the chair with straps and padding around the shoulders and waist. The chair height was adjusted so that the head (interaural axis) was aligned with the tilt axis, and the head was maintained in an upright orientation. Noise cancelling headphones were used to mask auditory cues. As with the VRC, a chair-mounted joystick was used for both motion perception and manual control tasks (nulling chair tilt). The session started with subjects providing verbal reports of perception during a random step profile with tilts at ±2.5°, ±5°, and ±7.5°. Subjects then used the joystick to control the chair tilt orientation during the same random step protocol. This closed-loop nulling run was performed with and without vibrotactile feedback. During the next part of this session, subjects either translated along the track or tilted at ±10° in the pitch plane at three discrete frequencies (0.15, 0.3, and 0.6 Hz). The amplitude of the translation at each frequency was adjusted so that the acceleration was ±1.73 m/s2, equivalent to ±10°. Subjects reported their perception of pitch tilt and fore-aft translation at each frequency using the joystick to indicate phase and verbal reports to indicate amplitude. The final two runs utilized concomitant tilt and translation motion phased such that resultant gravitoinertial vector remained aligned with the body longitudinal Z axis, thus it was referred to as Z-axis gravitoinertial stimulus paradigm, or ZAG. During these runs, which utilized a sum-of-sinusoids between 0.01 and 0.6 Hz, subjects were asked to maintain their tilt orientation Earth vertical, thus nulling out any tilt disturbance. The runs were performed with and without the vibrotactile feedback. The primary dependent measures for the TTS ZAG session are similar to the VRC session.

The first opportunity for these tests were on R+1 following the crew return ceremony. As with the VRC, motion perception was obtained using both static and dynamic tilt stimuli. There were no significant changes in the static pitch tilt runs. As described above, the increase in VRC static roll tilt perception was only observed on landing day. Therefore, the lack of a difference between preflight and postflight static pitch tilt may be due to the delay in testing. Since the pitch tilts were accomplished using rotation about an Earth-horizontal axis, these differences may also be attributed to the fact that the tilts were signaled by both otolith and canal cues on the TTS. While there may be axis specific differences between pitch and roll, the roll tilts on the VRC involved otolith cues only. Another difference was the range of tilts between the VRC (±15°) and the TTS (±7.5°). While changes in static perception were stronger in roll on the VRC versus in pitch on the TTS, there was an opposite effect for the dynamic runs. As with the VRC, all subjects reported an increased sense of translation at higher frequencies. However, this difference between translation and tilt perception was not only greater on R+1, but persisted longer post-flight. Quadric fits through the average responses at each frequency suggest that the cross-over frequency shift persisted until the last postflight test sessions. This is in contrast to the VRC crossover shifts which tended to recover by the second test 2-3 days after landing. Preflight the nulling gain and RMS position error were similar for the TTS static pitch tilt runs as for the VRC static roll tilt runs. However, in contrast to the landing day VRC manual control runs, there were no deficits in manual control performance during the TTS static pitch runs by R+1. Taken together, these data suggest that the decrements in nulling static disturbances in tilt orientation following short-duration flight are recovered by R+1. As during the VRC, the vibrotactile feedback improved manual closed-loop nulling performance across all sessions except the initial familiarization session. The overall manual control performance during the ZAG profiles on the TTS was poor compared to the static tilt profiles. This was expected since the tilt and translation motion were synchronized to minimize the sense of tilt, and since these profiles include frequency components beyond the ability to nulling out tilt disturbances (see for example, Merfeld 1996). While the performance was improved with vibrotactile feedback, the overall nulling gain remained significantly below the static nulling trials.

Otolith Variable Radius Centrifugation: The VRC session for Otolith was initiated with a slow acceleration (3°/s2) to a constant velocity of 400°/s, typically before the ZAG VRC session was performed (see above). Subjects continued to rotate for ~2 min to allow the initial per-rotary response to decay. After the subjects no longer sensed the rotation, the otolith-mediated perception and eye movement responses were obtained with the chair centered, and then offset to either left or right eccentric positions. The displacement (±3.5 cm) was designed to place one ear over the axis of rotation with the other one offset, thus evoking unilateral otolith (utricular) responses from the linear (centripetal) acceleration to the offset ear. The Subjective Visual Vertical (SVV) was measured by having subjects use the hand-controller to align a luminous line along the perceived gravitational vertical, thus providing an estimate of tilt perception. The otolith-ocular reflex (OOR) was then measured for up to 10 cycles using the eye tracker while the chair position continued to alternate between center and left/right eccentric positions. The primary dependent measures consisted of SVV tilt perception amplitude and asymmetry, and the ocular torsion amplitude and asymmetry.

When subjects on the VRC were positioned and maintained at an eccentricity of ± 3.5 cm to their right or to their left during eccentric centrifugation at 400 deg/s, they experienced the typical somatosensory illusion of being statically tilted in roll. In addition to the SVV measures, this perception was assessed by verbal reports of the amplitude of perceived tilt. Before the flight, this amplitude of perceived tilt was close to that of the tilt of the GIF relative to gravity, i.e., 10 deg. After the flight there was a clear increase in the perceived tilt angle in roll (+25% relative to pre-flight). Note this increase in roll tilt perception on landing day is consistent with the ZAG static tilt perception runs performed at lower centrifuge velocity.The distribution of the preflight SVV asymmetry ratios were within normal limits. Postflight changes in asymmetry ratios were normalized so that a positive change represented in increase in asymmetry in the same direction as demonstrated preflight, while a negative change represented a reversal in asymmetry. Changes in the SVV asymmetry ratios increased in the same direction for the 6 of 10 subjects tested on landing day. All subjects showed a reversal in asymmetry during subsequent postflight testing with a return to baseline levels within the first week postflight. The distribution of the preflight OOR asymmetry ratios were also within normal limits. While the changes in OOR asymmetry values were not as striking postflight, they did follow a similar pattern with a reversal in asymmetry during the R+2/3 tests and subsequent return to preflight levels within the first week following the short-duration flights.

Otolith Vestibular Evoked Myogenic Potential: The Vestibular Evoked Myogenic Potential (VEMP) measured otolith saccular function indirectly through a vestibulo-collic reflex. The saccule is just under the middle ear stapes footplate, and is sensitive to acoustical stimulation. Brief (0.1 ms) auditory clicks gave rise to a short-latency inhibition of activity in the contracted neck (sternocleidomastoid) muscle. Muscle activity in the neck was recorded with surface electrodes as subjects were supine and lifted their heads to contract the sternocleidomastoid muscle. Auditory stimuli were presented monaurally to the same side as the measured neck muscle (e.g., measured from the right side of the neck during auditory stimuli to the right ear). The auditory stimuli were presented through headphones. Responses were averaged across sets of 150 auditory clicks (5 clicks per second) presented at levels from 120 to 140 dB SPL (sound pressure level) during tonic contraction. The primary dependent measure consisted of the peak-to-peak amplitude from the positive peak occurring at ~13 msec following each click to the negative peak occurring ~10 msec later.

The distribution of the preflight VEMP asymmetry ratios were also within normal limits. In contrast to the utricular measures, the the changes in saccular VEMP asymmetry values were in the opposite direction postflight. The changes were not significantly different by the R+2/3 test sessions.

Bibliography Type: Description: (Last Updated: 06/03/2025)

Abstracts for Journals and Proceedings

Clarke AH, Schönfeld U, Wood SJ. "Modification of otolith reflex asymmetries following space flight." 35th MidWinter Meeting of the Association for Research in Otolaryngology, San Diego, CA, February 25-29, 2012. Association for Research in Otolaryngology Abstracts. 2012;35:23. Abstract 63. , Feb-2012

Abstracts for Journals and Proceedings

Clément GR, Wood SJ. "Motion perception during tilt and translation after spaceflight." 18th IAA Humans in Space Symposium, Houston, TX, April 11-15, 2011.
18th IAA Humans in Space Symposium, Houston, TX, April 11-15, 2011. , Apr-2011

Abstracts for Journals and Proceedings

Danielson RW, Wood SJ. "Auditory and vestibular issues related to human spaceflight." Audiology NOW! 22nd Annual Convention of the American Academy of Audiology, San Diego, CA, April 14-17, 2010.
Audiology NOW! 22nd Annual Convention of the American Academy of Audiology, San Diego, CA, April 14-17, 2010. , Apr-2010

Abstracts for Journals and Proceedings

Holly JE, Zhang G, Wood SJ. "Gravito-inertial force resolution in perception of synchronized tilt and translation." 41st Annual Society for Neuroscience Meeting, Washington D.C., November 12-16, 2011.
41st Annual Society for Neuroscience Meeting, Washington D.C., November 12-16, 2011. Program#/Poster#: 580.13/FF34. Abstract available at
http://www.abstractsonline.com/Plan/ViewAbstract.aspx?sKey=079425ca-7e0f-440f-9ac1-e7a3f918c2d9&cKey=bf015e89-70e8-4771-a542-a5c128f16708&mKey=%7b8334BE29-8911-4991-8C31-32B32DD5E6C8%7d
; accessed 5/2/2012. , Nov-2011

Abstracts for Journals and Proceedings

Wood SJ, Rupert AH, Vanya RD, Esteves JT, Clément GR. "Influence of vibrotactile feedback on controlling tilt motion after spaceflight." 18th IAA Humans in Space Symposium, Houston, TX, April 11-15, 2011.
18th IAA Humans in Space Symposium, Houston, TX, April 11-15, 2011. , Apr-2011

Abstracts for Journals and Proceedings

Wood SJ, Vanya RD, Esteves JT, Rupert AH, Clément GR. "Modification of motion perception and manual control following short-duration spaceflight." 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012.
2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. , Feb-2012

Articles in Peer-reviewed Journals

Clément G, Harm DL, Rupert AH, Beaton KH, Wood SJ. "Ambiguous tilt and translation motion cues in astronauts after space flight (ZAG)." J Gravit Physiol 2008;15(1):P13-4. , Jan-2008

Articles in Peer-reviewed Journals

Paloski WH, Oman CM, Bloomberg JJ, Reschke MF, Wood SJ, Harm DL, Peters BT, Mulavara AP, Locke JP, Stone LS. "Risk of sensory-motor performance failures during exploration-class space missions: A review of the evidence and recommendations for future research." J Gravit Physiol 2008;15(2):1-29. , Aug-2008

Articles in Peer-reviewed Journals	Clément G, Wood SJ. "Motion perception during tilt and translation after space flight." Acta Astronautica. 2013 Nov;92(1):48-52. (Originally reported in May 2012 as 'In Press, Corrected Proof, Available online 4 April 2012.') http://dx.doi.org/10.1016/j.actaastro.2012.03.011 , Nov-2013
Articles in Peer-reviewed Journals	Clément G, Wood SJ. "Eye movements and motion perception during off-vertical axis rotation after spaceflight." Journal of Vestibular Research. 2013;23(1):13-22. (Originally reported in May 2012 as 'Submitted as of May 2012.') http://dx.doi.org/10.3233/VES-130471 ; PubMed PMID: 23549051 , Jan-2013
Articles in Peer-reviewed Journals	Reschke MF, Wood SJ, Cerisano JK, Harm DL, Bloomberg JJ, Paloski WH, Schlegel TT, Clément G. "Contributions of the space shuttle program to spaceflight related sensorimotor research." Journal of Gravitational Physiology. Submitted, as of May 2012. , May-2012
Articles in Peer-reviewed Journals	Clément G, Wood SJ. "Rocking or rolling--perception of ambiguous motion after returning from space." PLoS One. 2014 Oct 29;9(10):e111107. e Collection 2014. http://dx.doi.org/10.1371/journal.pone.0111107 ; PubMed PMID: 25354042; PubMed Central PMCID: PMC4213005 , Oct-2014
Books/Book Chapters	Clément G, Wood SJ. "Space physiology." in "Primer on the Autonomic Nervous System. 3rd edition." Ed. D. Robertson, editor in chief; I. Biaggioni et al. Amsterdam ; Boston : Elsevier/AP, 2012. p. 283-286., Jan-2012
Books/Book Chapters	Harm DL, Reschke M, Wood SJ. "Spatial orientation and motion perception in microgravity." in "Cambridge Handbook of Applied Perception Research. Cambridge Handbooks in Psychology." Ed. R.R. Hoffman et al. New York : Cambridge University Press, 2015. p. 912-929. , Jan-2015