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Oral Session 8: Gaze, Posture and Locomotion

8–1 [#3029]

Perceptual roll tilt thresholds demonstrate visual-vestibular fusion

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Sensory fusion, the process of combining noisy and sometimes ambiguous signals, is disrupted is spaceflight. This study examined visual-vestibular fusion during roll tilt using three conditions:

1. VESTIBULAR ONLY: subjects rotated in the dark.
2. VISUAL ONLY: subjects at rest while observing a rotating scene.
3. VESTIBULAR+VISUAL: subjects rotated with the lights on.

Subjects (3 F, 4 M) were screened for normal vestibular function. We measured thresholds using an adaptive staircase (3-down 1-up) in which subjects tilted left or right and indicated perceived tilt direction. A range of frequencies (0.05, 0.1, 0.2, 0.5, 1, 2, 5 Hz) allowed us to use differing dynamic properties to separate the contribution of different sensory cues. Motions consisted of a single-cycle of sinusoidal angular acceleration yielding a sigmoid-like displacement.

With VESTIBULAR ONLY, gravitational tilt measured by the otoliths dominated at low frequencies while the SCC contribution increased at higher frequencies. Threshold at 0.05 Hz was 1.32°. As frequency increased, threshold was reached with smaller tilt angles, dropping to 0.05° at 5 Hz. VISUAL ONLY thresholds were lower than VESTIBULAR ONLY between 0.1 and 2 Hz, greater at 5 Hz, and the same at 0.05 Hz. VESTIBULAR+VISUAL thresholds between 0.1–1 Hz were reduced versus VESTIBULAR ONLY (ANOVA; $p < 0.005$) and similar to VISUAL ONLY, while at 5 Hz VESTIBULAR+VISUAL was similar to VESTIBULAR ONLY thresholds. We conclude that the predominance of vestibular and visual cues varies with frequency, and roll-tilt motion thresholds are smaller when vestibular and visual cues are combined, consistent with maximum-likelihood estimation.

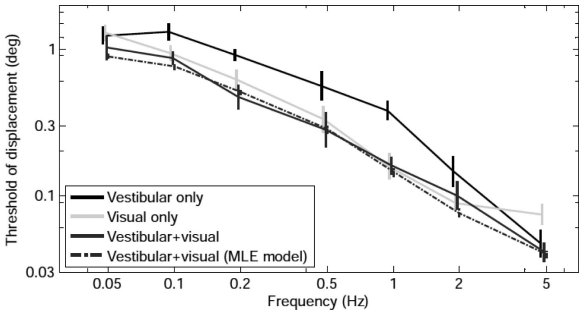

Fig. 1. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/VES-2010-0409)

8–2 [#3050]

Is postural stability controlled through punctuated equilibrium?

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Postural stability deficits following spaceflight are a well established phenomenon typically quantified

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through forceplate sway analytics; yet current measures may have limited resolution if test subjects fail to reach a fall or near fall. Furthermore, current control models fail to account for both individual variations in stability and the feedback control necessary for stability during movement generation. We propose a control model of punctuated equilibrium where the region of equilibrium can be redefined by a dynamic "escape" trajectory. This model uses Hidden Markov Model (HMM) techniques to classify our two states: 1) related COM trajectories identifying a series of stable equilibria and 2) dynamic "escape" trajectories.

In this study we test the theoretical HMM framework by identifying local stability equilibria and postural control failures during quiescent standing in astronauts pre- and postflight by quantifying the dwell time, size, and shape of the equilibria, the dynamic trajectories, and the equilibria region as a whole. The COM trajectories observed consistently demonstrated punctuated equilibrium, characterized by alternating patterns of temporary equilibrium followed by transient escape. Immediately after spaceflight, equilibrium periods were shorter in duration and more diffuse in area. The same algorithm was also able to distinguish quiescent standing from dynamic activities, such as squatting or arm-lifting. This capability to identify intentional perturbations further facilitates the classification of intentional, controlled COM shifts from unintentional, destabilizing shifts in COM. Thus, we suggest our punctuated equilibrium model can offer detection of postural instability in a greater range of testing or operational scenarios.

8–3 [#3017]

Changes in vestibular-ocular interaction in long-term space flights

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Introduction: The aim of the study was to examine effects of long-duration exposure to weightlessness on characteristics of horizontal and vertical gaze fixation reaction.

Methods: Nine cosmonauts – members of 186–198 days mission on "Mir" station – participated in the study. The subjects were to perform the target acquisition task on targets that appeared at a distance of 16 angular degrees in a random order right- left, up- and down from the center. Test sessions were performed 4 times before launch, once a month during flight, and twice after landing.

Results: In BDC sessions time of gaze fixation reaction in all the cosmonauts didn't exceed 650 ms. During space flight (SF) it extended up to 900–1000 ms and more. The velocities of head movement in space decreased, the velocities of eye counterrotation decreased also but to a less degree. This difference resulted in increase of VOR gain up to 2,3 values, that was especially pronounced during the 1st month of flight; further it decreased reaching the values of 0,5–0,7 on the 5th month of SF. After landing VOR gain increased greatly again, and the time of reaction up to the 5^d postflight session remained high. The described dynamic of changes had the same direction for both horizontal and vertical reactions, being more expressed in vertical ones.

Conclusions: These results are in agreement with the data of I. Kozlovskaya, M. Sirota et al., which showed in the experiments with monkeys that VOR gain increased together with redundant inadequate responses of vestibular nucleus on vestibular stimulation and that in the course of adaptation to these conditions central nervous system inhibited vestibular input from the motor control systems ("vestibular neglect", Kozlovskaya et al., 1985-1987) .

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8–4 [#3014]

Effect of passive horizontal totations and vertical oscillations on dynamic visual acuity

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Astronauts experience sensorimotor disturbances after long-duration spaceflight. These crewmembers may need to egress the vehicle within a few minutes for safety and operational reasons in various sea state condi-

tions following a water landing. Exposure to even low frequency motions induced by sea conditions surrounding a vessel can cause significant fine and gross motor control problems affecting critical functions. The objective of this study was to document human motor and visual performance during simulated wave motion in the 0.1 to 2.0 Hz range. We examined, in 12 healthy subjects, the changes in accuracy when performing a seated visual target acquisition task in which the location of target was offset vertically during horizontal full-body rotation at an oscillating frequency of 0.8 Hz (peak velocity of 160 deg/s). The main finding was that the accuracy of performance degraded in 7 of 12 subjects when acquiring vertical targets at perturbing frequencies of 0.8 Hz in the horizontal plane by one step size. We also examined, in a separate study on 12 healthy subjects, seated dynamic visual acuity (DVA) task performance during vertical full-body oscillations at perturbing frequencies of 2 Hz (peak-to-peak motion of 5 cm). The main finding was that DVA was significantly reduced when acquiring targets at perturbing oscillations at frequencies of 2 Hz in the vertical plane by approximately 1 chart line. Thus, low frequency perturbations in the horizontal and vertical planes can cause decrements in visual performance.

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8–5[#3005]

Eye movements and motion perception during off-vertical axis rotation after spaceflight

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Constant velocity off-vertical axis rotation (OVAR) provides dynamic linear acceleration stimuli that can be used to assess otolith function. Eight astronauts were rotated in darkness about their longitudinal axis 20° off vertical at low (0.125 Hz) and high (0.5 Hz) frequencies, and their responses were compared before and after 10–14 days spaceflight on board the Space Shuttle. Eye movements were recorded using infrared videography and perceived motion was evaluated using a joystick with four degrees of freedom – pitch and roll tilt, front-back and lateral translation. Low-frequency OVAR generates tilt otolith-induced responses – modulation of ocular counter-roll and counter-pitch with perceived conical motion path – whereas high- frequency OVAR generates translational otolith-induced responses – modulation of horizontal slow phase velocity and vergence with perceived cylindrical motion path. No major changes were seen in the eye movements after adaptation to weightlessness. However, there was an increase in sensitivity to motion perception after spaceflight. The experiment also indicated that sensitivity to motion sickness was reduced during OVAR immediately after spaceflight. These results confirm that some otolith reflexes may not be altered by short-duration spaceflight – or may readapt very quickly – and that the resolution of sensory conflict associated with postflight recovery involves higher-order neural processes.

8–6 [#3051]

Walk on Floor Eyes Closed Test as a measure of postflight ataxia

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Introduction: Astronauts returning from space flight universally exhibit impaired posture and locomotion. Measurement of this impairment is an evolving process. The walk on the floor line test with the eyes closed (WOFEC) provides a unique procedure for quantifying postflight ataxia. Data from a modified WOFEC were obtained as part of an ongoing NASA interdisciplinary pre- and postflight study (Functional Task Test, FTT) designed to evaluate astronaut postflight functional performance.

Methods: Seven astronauts (5 short duration with flights of 12-16 days; two long duration crewmembers with flights of 6 mo) were tested twice before flight, on landing day (short duration only), and 1, 6, and 30 days after flight. The WOFEC consisted of walking for 10 steps (repeated twice) with the feet heel to toe in tandem, arms folded across the chest and the eyes closed. The performance metric (scored by three examiners from video) was the percentage of correct steps

completed over the three trials. A step was not counted as correct if the crewmember sidestepped, opened their eyes, or paused for more than three seconds between steps.

Results/conclusions: There was a significant decrease in percentage of correct steps on landing day (short duration crew) and on first day following landing (long duration) with partial recovery the following day, and full recovery beginning on day sixth after flight. Both short and long duration fliers appeared to be unaware of foot position relative to their bodies or the floor. Postflight, deviation from a straight path was common, and the test for two crewmembers elicited motion sickness symptoms. These data clearly demonstrate the sensorimotor challenges facing crewmembers after returning from spaceflight. The WOFEC test has value providing the investigator or crew surgeon with a simple method to quantify vestibular ataxia, as well as providing instant feedback of postural ataxia without the use of complex test equipment.