Modification of Eye Movements and Motion Perception during Off-Vertical Axis Rotation

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BACKGROUND: Constant velocity Off-Vertical Axis Rotation (OVAR) imposes a continuously varying orientation of the head and body relative to gravity. The ensuing ocular reflexes include modulation of both torsional and horizontal eye movements as a function of the varying linear acceleration along the lateral plane, and modulation of vertical and vergence eye movements as a function of the varying linear acceleration along the sagittal plane. Previous studies have demonstrated that tilt and translation otolith-ocular responses, as well as motion perception, vary as a function of stimulus frequency during OVAR. The purpose of this study is to examine normative OVAR responses in healthy human subjects, and examine adaptive changes in astronauts following short duration space flight at low (0.125 Hz) and high (0.5 Hz) frequencies. METHODS: Data was obtained on 24 normative subjects (14 M, 10 F) and 14 (13 M, 1F) astronaut subjects. To date, astronauts have participated in 3 preflight sessions (n=14) and on R+0/1 (n=7), R+2 (n= 13) and R+4 (n= 13) days after landing. Subjects were rotated in darkness about their longitudinal axis 20 deg off-vertical at constant rates of 45 and 180 deg/s, corresponding to 0.125 and 0.5 Hz. Binocular responses were obtained with video-oculography. Perceived motion was evaluated using verbal reports and a two-axis joystick (pitch and roll tilt) mounted on top of a two-axis linear stage (anterior-posterior and medial-lateral translation). Eye responses were obtained in ten of the normative subjects with the head and trunk aligned, and then with the head turned relative to the trunk 40 deg to the right or left of center. Sinusoidal curve fits were used to derive amplitude, phase and bias of the responses over several cycles at each stimulus frequency. RESULTS: Eye responses during 0.125 Hz OVAR were dominated by modulation of torsional and vertical eye position, compensatory for tilt relative to gravity. While there is a bias horizontal slow phase velocity (SPV), the modulation of horizontal and vergence SPV is negligible at this lower stimulus frequency. Eye responses during 0.5 Hz OVAR; however, are characterized by modulation of horizontal and vergence SPV, compensatory for translation in the lateral and sagittal planes, respectively. Neither amplitude nor bias velocities were significantly altered by head-on-trunk position. The phases of the ocular reflexes, on the other hand, shifted towards alignment with the head. During the lower frequency OVAR, subjects reported the perception of progressing along the edge of a cone. During higher frequency OVAR, subjects reported the perception of progressing along the edge of an upright cylinder. In contrast to the eye movements, the phase of both perceived tilt and translation motion is not altered by stimulus frequency. Preliminary results from astronaut data suggest that the ocular responses are not substantially altered by short-duration spaceflight. However, compared to preflight averages, astronauts reported greater amplitude of both perceived tilt and translation at low and high frequency, respectively, during early post-flight testing. CONCLUSIONS: We conclude that the neural processing to distinguish tilt and translation linear acceleration stimuli differs between eye movements and motion perception. The results from modifying head-on-trunk position are consistent with the modulation of ocular reflexes during OVAR being primarily mediated by the otoliths in response to the sinusoidally varying linear acceleration along the interaural and naso-occipital head axis. While the tilt and translation ocular reflexes appear to operate in an independent fashion, the timing of perceived tilt and translation influence each other. We conclude that the perceived motion path during linear acceleration in darkness results from a composite representation of tilt and translation inputs from both vestibular and somatosensory systems.

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