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WHEELCHAIR HEAD IMMOBILIZATION PARADIGM: A GROUND-BASED ANALOG FOR POST-SPACEFLIGHT ASTRONAUT SENSORIMOTOR IMPAIRMENT

Abstract

PURPOSE: During exposure to microgravity, astronauts experience sensorimotor adaptations that impair balance, locomotion and manual control upon return to Earth, or presumably another gravity-rich environment. The implications of these impairments have generally been overlooked, as there has almost always been access to ground support upon landing. However, during initial exploration of new planetary bodies without ground support, sensorimotor impairments will likely degrade mission critical tasks such as piloted landing and emergency vehicle egress, both of which could lead to loss of crew. Countermeasures that could address this severe problem have yet to be developed for two key reasons: 1) there is currently no Earth-based analog to replicate neurovestibular cues experienced in microgravity, and; 2) post-spaceflight measures cannot capture the worst impairments, with unavoidable delays in reaching the crew of hours to days after reentering Earth-gravity. Here, we propose and aim to validate a novel paradigm aimed at decoupling tilt and translation cues as experienced in microgravity, in one axis, as an analog for spaceflight-induced sensorimotor impairment.

METHODS: Subjects lie on their sides on a bed with their head immobilized in a custom-molded facemask. The bed is mounted on a motorized wheelchair. The wheelchair head immobilization paradigm (WHIP) has the following critical similarities to microgravity exposure: 1) WHIP prevents the vestibular organs from experiencing normal, coupled rotation and tilt relative to gravity. 2) Through wheelchair motion, WHIP allows for normal rotation stimulation without concurrent tilt stimulation in the pitch-axis, and 3) normal x-axis translation stimulation. 4) Finally, WHIP removes the tonic loading of the otoliths in the z-axis direction, as is normally experienced on Earth during erect posture. Functional pre- and post-test measures similar to those assessed in returning astronauts are used to validate performance decrements post-WHIP.

RESULTS: We have tested 4 paradigm-subjects and 1 head-unconstrained control subject to date. All 4 paradigm subjects experienced perceptual illusions post-WHIP ranging from swirling sensations to consistent feelings of tilt and/or translation. Additionally, all 4 paradigm subjects had substantial performance decrements post-WHIP in one or more functional tasks, while the control maintained baseline performance.

CONCLUSION: Initial tests have shown that WHIP causes substantial decrements in sensorimotor performance tasks, similar to those quantified post-spaceflight. Subjective responses were also analogous to illusions reported by astronauts during and after landing. Following further validation of this analog, the community can begin to address the question: ”How can this be leveraged to develop effective countermeasures?”