

## INTEGRATED LOCOMOTOR FUNCTION TESTS FOR COUNTERMEASURE EVALUATION

J.J. Bloomberg<sup>1</sup>, A.P. Mulavara<sup>2</sup>, B.T. Peters<sup>3</sup>, H.S. Cohen<sup>2</sup>, E.C. Landsness<sup>4</sup>, F. O. Black<sup>4</sup>

<sup>1</sup>Neuroscience Laboratories, NASA-Johnson Space Center, Houston, TX, <sup>2</sup> Bobby R. Alford Department of Otorhinolaryngology and Communicative Sciences, Baylor College of Medicine, Houston, TX, <sup>3</sup>Wyle Life Sciences, Houston, TX, <sup>4</sup>Legacy Health System, Portland, OR

Following spaceflight crewmembers experience locomotor dysfunction due to inflight adaptive alterations in sensorimotor function [1]. Countermeasures designed to mitigate these postflight gait alterations need to be assessed with a new generation of tests that evaluate the interaction of various sensorimotor sub-systems central to locomotor control. The goal of the present study was to develop new functional tests of locomotor control that could be used to test the efficacy of countermeasures. These tests were designed to simultaneously examine the function of multiple sensorimotor systems underlying the control of locomotion and be operationally relevant to the astronaut population. Traditionally, gaze stabilization has been studied almost exclusively in seated subjects performing target acquisition tasks requiring only the involvement of coordinated eye-head movements. However, activities like walking involve full-body movement and require coordination between lower limbs and the eye-head-trunk complex to achieve stabilized gaze during locomotion. Therefore the first goal of this study was to determine how the multiple, interdependent, full-body sensorimotor gaze stabilization subsystems are functionally coordinated during locomotion. In an earlier study we investigated how alteration in gaze tasking changes full-body locomotor control strategies. Subjects walked on a treadmill and either focused on a central point target or read numeral characters. We measured: temporal parameters of gait, full body sagittal plane segmental kinematics of the head, trunk, thigh, shank and foot, accelerations along the vertical axis at the head and the shank, and the vertical forces acting on the support surface. In comparison to the point target fixation condition, the results of the number reading task showed that compensatory head pitch movements increased, peak head acceleration was reduced and knee flexion at heel-strike was increased [2]. In a more recent study we investigated the adaptive remodeling of the full-body gaze control systems following exposure to visual-vestibular conflict. Subjects walked on a treadmill before and after a 30-minute exposure to 0.5X minifying during which self-generated sinusoidal vertical head rotations were performed while seated. Following exposure to visual-vestibular conflict subjects showed a restriction in compensatory head movements, increased knee and ankle flexion after heel-strike and a decrease in the rate of body loading during the rapid weight transfer phase after the heel strike event. Taken together, results from both studies provide evidence that the full body contributes to gaze stabilization during locomotion, and that different functional elements are responsive to changes in visual task constraints and are subject to adaptive alterations following exposure to visual-vestibular conflict. This information provides the basis for the design of a new generation of integrative tests that incorporate the evaluation of multiple neural control systems relevant to astronaut operational performance.

### Near and Far Dynamic Visual Acuity (DVA) Test

Astronauts returning from spaceflight experience reduced visual acuity during body motion of the kind experienced during walking due to alterations in gaze stability caused by inflight sensorimotor adaptive changes. These changes in acuity have significant operational implications. The inability to see clearly during body motion can impair the ability to operate spacecraft, conduct EVAs and perform an emergency egress soon after landing following a long-duration spaceflight. In a gaze control task, the relative contributions of the canal and otolith organs are modulated with viewing distance. The ability to stabilize gaze during locomotion on visual targets placed at different distances from the head may therefore provide independent insight into the function of these systems. In our newly developed DVA test subjects walk at 6.4 km/h on a motorized treadmill while identifying optotypes displayed either on a laptop computer located 4m (FAR) or on a micro-display placed 50cm (NEAR) from the eyes [3]. Custom-written software controls the display of Landolt C optotypes of varying sizes and determines the acuity threshold based on a psychophysical methodology. This test was evaluated in both normal subjects and in patients with bilateral vestibular impairment. Results showed a significant ability to reliably differentiate normal from clinical behavior. This test has been implemented for the first time with the Expedition 11 crew.

[1] Bloomberg J.J. and Mulavara, A.P. (2003) *IEEE Engineering in Medicine and Biology Magazine*, 22(2): 58-62.

[2] Mulavara A.P. and Bloomberg, J.J. (2003) *Journal of Vestibular Research*, 12: 255-269.

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