ADAPTIVE EFFECTS ON LOCOMOTION PERFORMANCE FOLLOWING EXPOSURE TO A ROTATING VIRTUAL ENVIRONMENT

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INTRODUCTION

During long-duration spaceflight, astronauts experience alterations in vestibular and somatosensory cues that result in adaptive disturbances in balance and coordination upon return to Earth. These changes can pose a risk to crew safety and to mission objectives if nominal or emergency vehicle egress is required immediately following long-duration spaceflight. At present, no operational countermeasure is available to mitigate the adaptive sensorimotor component underlying the locomotor disturbances that occur after spaceflight. Therefore, the goal of this study is to develop an inflight training regimen that facilitates recovery of locomotor function after long-duration spaceflight. The countermeasure we are proposing is based on the concept of adaptive generalization (Bloomberg, et al., 2001; Roller, et al., 2001). During this type of training the subject gains experience producing the appropriate adaptive motor behavior under a variety of sensory conditions and response constraints. As a result of this training a subject learns to solve a class of motor problems, rather than a specific motor solution to one problem, i.e., the subject learns response generalizability or the ability to "learn to learn." under a variety of environmental constraints. We are developing an inflight countermeasure built around treadmill exercise activities. By manipulating the sensory conditions of exercise by varying visual flow patterns, body load and speed we will systematically and repeatedly promote adaptive change in locomotor behavior. It has been shown that variable practice training increases adaptability to novel visuo-motor situations.

While walking over ground in a stereoscopic virtual environment that oscillated in roll, subjects have shown compensatory torso rotation in the direction of scene rotation that resulted in positional variation away from a desired linear path (Warren et al., 1996). Thus, postural sway and locomotor stability in 1-g can be modulated by visual flow patterns and used during inflight treadmill training to promote adaptive generalization. The purpose of this study was to determine if adaptive modification in locomotor performance could be achieved by viewing simulated self-motion in a passive-immersive virtual environment over a prolonged period during treadmill locomotion.

METHODS

Subjects (n = 30) walked on a motorized treadmill at 4.0 km/h for 24 minutes while viewing the interior of a 3D virtual scene projected onto a screen 1.5 m in front of them. The virtual scene depicted constant self-motion equivalent to either 1) walking around the perimeter of a room to one's left (Experimental group) 2) walking down the center of a hallway (Control group). The forward tangential velocity of the rotating room and the forward velocity

of the virtual hallway were equivalent. The scene was static for the first 4 minutes, and then constant rate self-motion was simulated for the remaining 20 minutes. Subjects were instructed to immerse themselves in the virtual scene as best they could while wearing goggles to block out the surround.

Five step trials were completed both before and after the treadmill locomotion adaptation period. During step trials, subjects marched in place to the beat of a metronome at 90 steps/min while blindfolded in a quiet room. The subject's final position (x, y) and heading direction (°) were measured for each trial. Means and 95% confidence intervals were calculated.

RESULTS AND DISCUSSION

The mean difference between pre- and post-adaptation final heading angles for the control group was not significant [mean = -0.9°, 95% confidence interval (CI, -21.2°, 19.4°)]. There was also no significant difference between pre- and post-adaptation final x-position for this group. However, for the experimental group there was a significant difference between pre- and post-adaptation heading angles [mean = 62.6°, 95% CI = (19.6°, 105.7°)]. A significant difference between pre- and post-adaptation final x-position was also found ($p < .05$). The variance in final heading angles was not significantly different between trials in either epoch, however, the rotating scene caused a significant decrease in the variance of heading angles during post-adaptation step trials. Thus, viewing a rotating virtual environment for 24 min. during treadmill walking causes adaptive/plastic modification in locomotor performance. We infer that viewing simulated rotary self-motion during treadmill locomotion causes adaptive modification of sensory-motor integration and reflects functionally adaptive changes in the integration of visual, vestibular, and proprioceptive cues. This central

sensorimotor reorganization will help in promoting adaptive generalization and hence facilitate recovery in locomotor function during adaptive transitions between gravito-inertial environments.
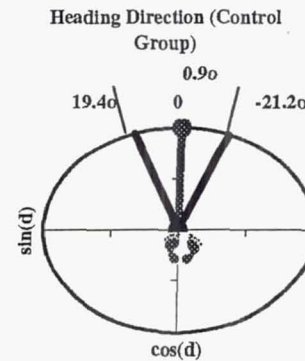

Heading Direction (Control Group)

Figure 1: This graph shows the mean (± 95% CI) heading direction difference across all subjects that were exposed to walking down the center of a hallway.
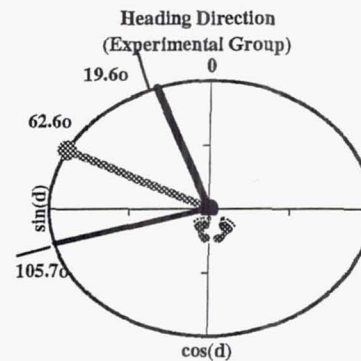

Heading Direction (Experimental Group)

Figure 2: This graph shows the mean (± 95% CI) heading direction difference across all subjects that were exposed to the rotating scene.

REFERENCES

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