Enhancement of Sensorimotor Performance with the Application of Stochastic Vestibular Stimulation

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Astronauts experience sensorimotor changes during spaceflight, which may degrade their operational capabilities. A sensorimotor countermeasure that mitigates these effects would improve crewmember safety and decrease mission risk. The goal of this research was to investigate the potential use of electrical stochastic vestibular stimulation (SVS) as a sensorimotor aid to lower vestibular thresholds and improve manual control. We hypothesized that low-level, subsensory electrical white noise (±200-700 μA) passed between surface electrodes located on the mastoid bone behind each ear would enhance perceptual sensitivity to physical motions due to the phenomenon of stochastic resonance (SR). The goals of this research were to 1) demonstrate that SVS can significantly reduce vestibular direction recognition thresholds, 2) investigate whether the SR phenomenon involves stimulation of the semicircular canals, otoliths or both, and 3) demonstrate that SVS can improve perception-based manual control performance in a task relevant to piloting during planetary landing, docking, or other vehicle maneuvers.

In a first experiment, upright roll tilt direction recognition thresholds, which elicit responses from both the semicircular canals and otoliths, were measured with varying levels of SVS applied. Upright roll tilt direction recognition thresholds exhibited characteristic SR dependency on current level that was statistically significant in 6/12 subjects. However, SR repeatability across days was found to be weak, only present in 3/12 subjects.

In a second experiment, supine roll rotation (primarily stimulating the semicircular canals) and inter-aural translation (primarily stimulating the otoliths) direction recognition thresholds were measured with varying levels of SVS applied. SR was exhibited in inter-aural translation (6/11 subjects) but not supine roll rotation (1/12 subjects), suggesting that stimulation of the otolith organs may be vital to vestibular perceptual SR. Simulations of the experimental test procedure were used to create a dataset of direction recognition thresholds with several predefined underlying SR exhibition levels. A comparison of the results form Experiment 1 and 2 to the simulations allowed us to more confidently draw conclusions from data that are prone to the existence of false positives.

In a third experiment, subjects used vestibular information to null out pseudo-random vehicle disturbance in a manual control task. SVS (±300 μA) improved the group mean position variability when motions were near threshold and extended the range of frequencies in which motions could be nulled out.

The results of this research are consistent with the concept that SVS is able to extend the operating range of the vestibular perceptual system in some individuals. In the context of human spaceflight, results from this research will further our understanding of how SVS may be practically implemented in the future as a component of a comprehensive spaceflight countermeasure plan.