IMPROVING SENSORIMOTOR FUNCTION USING STOCHASTIC VESTIBULAR STIMULATION

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Astronauts experience sensorimotor changes during spaceflight, particularly during G-transition phases. Post flight sensorimotor changes may include postural and gait instability, spatial disorientation, and visual performance decrements, all of which can degrade operational capabilities of the astronauts and endanger the crew. Crewmember safety would be improved if these detrimental effects of spaceflight could be mitigated by a sensorimotor countermeasure and even further if adaptation to baseline could be facilitated. The goal of this research is to investigate the potential use of stochastic vestibular stimulation (SVS) as a technology to improve sensorimotor function. We hypothesize that low levels of SVS will improve sensorimotor performance through stochastic resonance (SR). The SR phenomenon occurs when the response of a nonlinear system to a weak input signal is optimized by the application of a particular nonzero level of noise. Two studies have been initiated to investigate the beneficial effects and potential practical usage of SVS. In both studies, electrical vestibular stimulation is applied via electrodes on the mastoid processes using a constant current stimulator.

The first study aims to determine the repeatability of the effect of vestibular stimulation on sensorimotor performance and perception in order to better understand the practical use of SVS. The beneficial effect of low levels of SVS on balance performance has been shown in the past [1]. This research uses the same balance task repeated multiple times within a day and across days to study the repeatability of the stimulation effects. The balance test consists of 50 sec trials in which the subject stands with his or her feet together, arms crossed, and eyes closed on compliant foam. Varying levels of SVS, ranging from 0-700 µA, are applied across different trials. The subject-specific optimal SVS level is that which results in the best balance performance as measured by inertial measurement units placed on the upper and lower torso of the subjects. Additionally, each individual's threshold for illusory motion perception of suprasensory electrical vestibular stimulation is measured multiple times within and across days to better understand how multiple SVS test methods compare.

The second study aims to demonstrate stochastic resonance in the vestibular system using a perception based motion recognition task. This task measures an individual's velocity threshold of motion recognition using a 6-degree of freedom Stewart platform and a 3-down/1-up staircase procedure [2,3,4]. For this study, thresholds are determined using 150 trials in the upright, head-centered roll tilt motion direction at a 0.2 Hz frequency. We aim to demonstrate the characteristic bell shaped curve associated with stochastic resonance with each subject's motion recognition thresholds at varying SVS levels ranging from 0 to 1500 µA. The curve includes the individual's baseline threshold with no SVS, optimal or minimal threshold at some mid-level of SVS, and finally degraded or increased threshold at a high SVS level. An additional aim is to formally retest each subject at his or her individual optimal SVS level on a different day than the original testing for additional validity. The overall purpose of this research is to further quantify the effects of SVS on various sensorimotor tasks and investigate the practical implications of its use in the context of human space flight so that it may be implemented in the future as a component of a comprehensive countermeasure plan for adaptation to G-transitions.

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