EXHIBITION OF STOCHASTRIC RESONANCE IN VESTIBULAR PERCEPTION

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Astronauts experience sensorimotor changes during spaceflight, particularly during G-transitions. Post flight sensorimotor changes include spatial disorientation, along with postural and gait instability that may degrade operational capabilities of the astronauts and endanger the crew. A sensorimotor countermeasure that mitigates these effects would improve crewmember safety and decrease risk. 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 perception through the phenomenon of stochastic resonance (SR), when the response of a nonlinear system to a weak input signal is enhanced by the application of a particular nonzero level of noise. This study aims to advance the development of SVS as a potential countermeasure by 1) demonstrating the exhibition of stochastic resonance in vestibular perception, a vital component of sensorimotor function, 2) investigating the repeatability of SR exhibition, and 3) determining the relative contribution of the semicircular canals (SCC) and otolith (OTO) organs to vestibular perceptual SR.

A constant current stimulator was used to deliver bilateral bipolar SVS via electrodes placed on each of the mastoid processes, as previously done [1]. Vestibular perceptual motion recognition thresholds were measured using a 6-degree of freedom MOOG platform and a 150 trial 3-down/1-up staircase procedure [2,3,4]. In the first test session, we measured vestibular perceptual thresholds in upright roll-tilt at 0.2 Hz (SCC+OTO) with SVS ranging from 0-700 µA. In a second test session a week later, we re-measured roll-tilt thresholds with 0, optimal (from test session 1), and 1500 µA SVS levels. A subset of these subjects, plus naive subjects, participated in two additional test sessions in which we measured thresholds in supine roll-rotation at 0.2 Hz (SCC) and upright y-translation at 1 Hz (OTO) with SVS up to 700 µA. A sinusoidal galvanic vestibular stimulation (GVS) perceptual threshold was also measured on each test day and used to normalize the SVS levels across subjects.

In roll-tilt thresholds with SVS, the characteristic SR curve was qualitatively exhibited in 10 of 12 subjects, and the improvement in motion threshold was significant in 6 subjects, indicating that optimal SVS improved passive body motion perception in a way that is consistent with classical SR theory. A probabilistic comparison to numeric simulations further validated these experimental results. On the second test session, 4 out of the 10 SR exhibitors showed repeated improvement with SVS compared to the no SVS condition. Data collection is ongoing for the last two test sessions in which SCC and OTO only perceptual motion recognition thresholds are being measured with SVS. The final results of these test sessions will give insight into whether vestibular perceptual SR can occur when only one type of vestibular sensor is sensing motion or if it is more evident when sensory integration between the SCC and OTO is occurring during the motion. The overall purpose of this research is to further quantify the effects of SVS on various sensorimotor tasks and to gain a more fundamental understanding of how SVS causes SR in the vestibular system. In the context of human space flight, results from this research will help in understanding how SVS may be practically implemented in the future as a component of a comprehensive countermeasure plan for G-transition adaptation.

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