OPTIMAL STIMULUS AMPLITUDE FOR VESTIBULAR STOCHASTIC STIMULATION TO IMPROVE SENSORIMOTOR FUNCTION

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Sensorimotor changes such as postural and gait instabilities can affect the functional performance of astronauts when they transition across different gravity environments. We are developing a method, based on stochastic resonance (SR), to enhance information transfer by applying non-zero levels of external noise on the vestibular system (vestibular stochastic resonance, VSR). Our previous work has shown the advantageous effects of VSR in a balance task of standing on an unstable surface [1]. This technique to improve detection of vestibular signals uses a stimulus delivery system that is wearable or portable and provides imperceptibly low levels of white noise-based binaural bipolar electrical stimulation of the vestibular system. The goal of this project is to determine optimal levels of stimulation for SR applications by using a defined vestibular threshold of motion detection.

A series of experiments were carried out to determine a robust paradigm to identify a vestibular threshold that can then be used to recommend optimal stimulation levels for SR training applications customized to each crewmember. Customizing stimulus intensity can maximize treatment effects. The amplitude of stimulation to be used in the VSR application has varied across studies in the literature such as 60% of nociceptive stimulus thresholds [2]. We compared subjects' perceptual threshold with that obtained from two measures of body sway. Each test session was 463s long and consisted of several 15s sinusoidal stimuli, at different current amplitudes (0-2 mA), interspersed with 20-20.5s periods of no stimulation. Subjects sat on a chair with their eyes closed and had to report their perception of motion through a joystick. A force plate underneath the chair recorded medio-lateral shear forces and roll moments. First we determined the percent time during stimulation periods for which perception of motion (activity above a pre-defined threshold) was reported using the joystick, and body sway (two standard deviation of the noise level in the baseline measurement) was detected by the sensors. The percentage time at each stimulation level for motion detection was normalized with respect to the largest value and a logistic regression curve fit was applied to these data. The threshold was defined at the 50% probability of motion detection. Comparison of threshold of motion detection obtained from joystick data versus body sway suggests that perceptual thresholds were significantly lower, and were not impacted by system noise. Further, in order to determine optimal stimulation amplitude to improve balance, two sets of experiments were carried out. In the first set of experiments, all subjects received the same level of stimuli and the intensity of optimal performance was projected back on subjects' vestibular threshold curve. In the second set of experiments, on different subjects, stimulation was administered from 20-400% of subjects' vestibular threshold obtained from joystick data. Preliminary results of our study show that, in general, using stimulation amplitudes at 40-60% of perceptual motion threshold improved balance performance significantly compared to control (no stimulation). The amplitude of vestibular stimulation that improved balance function was predominantly in the range of ±100 to ±400 μA. We hypothesize that VSR stimulation will act synergistically with sensorimotor adaptability (SA) training to improve adaptability by increasing utilization of vestibular information and therefore will help us to optimize and personalize a SA countermeasure prescription. This combination will help to significantly reduce the number of days required to recover functional performance to preflight levels after long-duration spaceflight.

[1] Mulavara A.P. et al (2011) *Exp Brain Res* 210, 303-312. [2] Yamamoto Y. et al. (2005) *Ann Neurol* 58, 175-181.

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