Development of Vestibular Stochastic Resonance as a Sensorimotor Countermeasure: Improving Otolith Ocular and Motor Task Responses

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Introduction: Astronauts experience disturbances in sensorimotor function after spaceflight during the initial introduction to a gravitational environment, especially after long-duration missions. Stochastic resonance (SR) is a mechanism by which noise can assist and enhance the response of neural systems to relevant, imperceptible sensory signals. We have previously shown that imperceptible electrical stimulation of the vestibular system enhances balance performance while standing on an unstable surface. The goal of our present study is to develop a countermeasure based on vestibular SR that could improve central interpretation of vestibular input and improve motor task responses to mitigate associated risks.

Methods: Eye movement data were collected from 10 subjects during variable radius centrifugation (VRC). Subjects performed 11 trials of VRC that provided equivalent tilt stimuli from otolith and other graviceptor input without the normal concordant canal cues. Bipolar stochastic electrical stimulation, in the range of 0–1500 microamperes, was applied to the vestibular system using a constant current stimulator through electrodes placed over the mastoid process behind the ears. In the VRC paradigm, subjects were accelerated to 216 °/s. After the subjects no longer sensed rotation, the chair oscillated along a track at 0.1 Hz to provide a maximum tilt stimulus of 10°. Eye movements were recorded for 6 cycles while subjects fixated on a target in darkness. Ocular counter roll (OCR) movement was calculated from the eye movement data during periods of chair oscillations. Data will also be presented for balance tasks on unstable surface.

Results: Preliminary analysis of the data revealed that 9 of 10 subjects showed an average increase of 28% in the magnitude of OCR responses to the equivalent tilt stimuli while experiencing vestibular SR. The signal amplitude at which performance was maximized was in the range of 100–900 microamperes.

Discussion: These results indicate that stochastic electrical stimulation of the vestibular system can improve otolith specific responses. This may have a significant impact on development of vestibular SR delivery systems to aid recovery of function in astronauts after long-duration spaceflight or in people with balance disorders.