Improving Early Adaptation Following Long Duration Spaceflight by Enhancing Vestibular Information

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Stochastic Resonance (SR) - adding noise enhances performance via increased information transfer

Collins et al., Journal of Neurophysiology, 76(1), July 1996: Noise-enhanced Information Transmission in Rat slowly adapting SA1 Cutaneous Mechanoreceptors via SR

Stochastic noise stimulation via proprioceptive or vestibular systems enhances performance across the cardiovascular, sensorimotor and muscle systems

**Vestibular SR aids arterial pressure control**


**Proprioceptive/Vestibular SR aids human balance control during standing and walking**


**Proprioceptive aids force control and muscle strength rehabilitation**

Recovery of functional mobility to 95% of preflight level took 15 days.

Functional mobility after long duration space flight (ISS)

Significant positive correlation between measures of early motor learning and long term recovery.

We hypothesize that detection of time-critical imperceptible sensory signals will improve strategic early motor learning during crewmembers’ re-adaptation to Earth G via sensory augmentation.
Vestibular SR - adding noise to vestibular system enhances information transfer

2" x 4" electrodes
Axelgaard manufacturing Co.,
Fallbrook, CA

Portable Constant Current Stimulator

Stimulation Profile : 0-30 Hz

Stimulation Period

Baseline Window
Stimulus amplitude = 0 µA

Stimulus Window
Stimulus amplitude = 0 - 700 µA

Baseline Period
(20 seconds)

Stimulation Period
(20 seconds)
Vestibular SR improves performance during standing and walking

On an unstable surface - *balance performance*


On an actively moving surface - *walking performance*


In a canal/otolith mismatch paradigm – both *perceptual* and *physiological performance*

**Motion perception/recognition** - an individual’s threshold of motion recognition using a 6-degree of freedom Stewart platform and a 3-down/1-up staircase procedure

Noisy stochastic vestibular stimulation in rat model for Parkinson’s Disease

- Vestibular SR improved locomotion and increased targeted neurotransmitter γ-aminobutyric acid (GABA) release in the Substantia Nigra (SN) in 6-hydroxydopamine (6-OHDA) hemilesioned rat model of Parkinson’s Disease

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**Noisy Galvanic Vestibular Stimulation Promotes GABA Release in the Substantia Nigra and Improves Locomotion in Hemiparkinsonian Rats**

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**Abstract**

**Background:** The vestibular system is connected to spinal, cerebellar and cerebral motor control structures and can be selectively activated with external electrodes. The resulting sensation of disturbed balance can be avoided by using stochastic stimulation patterns. Adding noise to the nervous system sometimes improves function. Small clinical trials suggest that stochastic vestibular stimulation (SVS) may improve symptoms in Parkinson’s disease. We have investigated this claim and possible mechanisms using the 6-hydroxydopamine (6-OHDA) hemilesion model of Parkinson’s disease.

**Methodology/Principal Findings:** Animals were tested in the accelerating rod test and the Montoya staircase test of skilled forelimb use. In 6-OHDA hemilesioned animals, SVS improved rod performance by 56±11 s. At group level L-DOPA treatment had no effect, but positive responders improved time on rod by 60±19 s. Skilled forelimb use was not altered by SVS. To investigate how SVS may influence basal ganglia network activity, intracerebral microdialysis was employed in four regions of interest during and after SVS. In presence of the γ-aminobutyric acid (GABA) transporter inhibitor NNC 711, SVS induced an increase in GABA to 150±15% of baseline in the substantia nigra (SN) of unlesioned animals, but had no effect in the pedunculopontine nucleus (PPN), the striatum or the ventromedial thalamus (VM). Dopamine release remained stable in all areas, as did GABA and amine concentrations in the SN of unstimulated controls. Following SVS, a sustained increase in GABA concentrations was observed in the ipsilesional, but not in the contralesional SN of 6-OHDA hemilesioned rats. In
Noisy stochastic vestibular stimulation promotes targeted GABA release in the Ipsilesional SN and improved locomotion in hemi-parkinsonian rats

- SVS increases GABA release in the SN, dopamine independent
- There is less imbalance between SN GABA release after SVS than after L-DOPA treatment
- SVS increases rod performance as much as and more reliably than L-DOPA but did not alter forepaw function

**Results**

6-OHDA hemi-lesioned rats
- Differential response to SVS in Ipsilesional vs Contralesional SN

- SVS increases GABA release in the SN, dopamine independent
- There is less imbalance between SN GABA release after SVS than after L-DOPA treatment
- SVS increases rod performance as much as and more reliably than L-DOPA but did not alter forepaw function

**Locomotor Task**

+L-DOPA or +SVS

Vestibular SR improves balance and motor symptoms in patients with Parkinson’s Disease

- Short term use (~ 3 - 4 Hrs) of Vestibular SR is safe, improves corrective postural responses and has a positive effect on motor symptoms in patients with Parkinson’s Disease
Sensorimotor adaptability (SA) training for Rehabilitation

Promote “learning to learn” and enhance ability to adapt to novel sensory experiences

SA training provides multiple sensory challenges

Sensory augmentation using vestibular/proprioceptive SR can enhance strategic learning during SA training

Adaptive Response to novel sensory environment

State 1

State 2

Level of Performance

100%

SR augmentation + SA training

With SA training

nominal
Thank You

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