

Selected Studies Using Stochastic Resonance



Stochastic resonance (SR) is essentially a statistical phenomenon resulting from an effect of noise on information transfer and processing that is observed in both man-made and naturally occurring nonlinear systems. There is a wide body of evidence studying SR in various fields, including human rehabilitation. The following is a selected list of studies that explain the concept and then apply it in varied categories as noted. Not all studies listed here are with Accelerera's SR-100 and/or its precursor devices.

Stochastic Resonance - What is it?

**Moss, Frank et al. "Stochastic resonance and sensory information processing: a tutorial and review of application." Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology vol. 115,2 (2004): 267-81.
doi:10.1016/j.clinph.2003.09.014**

Review of the stochastic resonance phenomena observed in sensory systems and to describe how a random process "noise" added to thea subthreshold stimulus can enhance sensory information processng and percpetion.

Cordo, Paul, et al. " Noise in Human Muscle Spindles." Nature, vol.383, no.6603, Oct. 1996, pp.769-770, 10/1038/383769a0

Explanation of Stochastic Resonance as it relates to muscle spindles.

Collins, J.J., et al. "Noise-Enhanced Human Sensorimotor Function." IEEE Engineering in Medicine and Biology Magazine, vol. 22, no.2, Mar.2003, pp.76-83, 10.1109/memb.2003.1195700

Somatosensory feedback is an important component of the balance control system. Older adults, patients with diabetic neuropathy and patients with stroke exhibit a marked deficit in the perception of cutaneuos and proprioceptive stimuli. Here is a review on works about input noise and applications.

Stochastic Resonance and Balance

Dettmer, Marius et al. "Effects of aging and tactile stochastic resonance on postural performance and postural control in a sensory conflict task." *Somatosensory & motor research* vol. 32,2 (2015): 128-35. doi:10.3109/08990220.2015.1004045

Studied postural performance and control in older adults vs younger and noted significant improvement in the older adult group using SR applied to the soles of the feet

Gravelle, Denise C., et al. "Noise-Enhanced Balance Control in Older Adults." *NeuroReport*, pp. 1853–1856, 10.1097/00001756-200210280-00004.

SR was applied around the knee in older adults, and results showed noise based devices may be effective in improving balance control in elderly.

Miranda, Daniel L., et al. "Sensory Enhancing Insoles Modify Gait during Inclined Treadmill Walking with Load." *Medicine & Science in Sports & Exercise*, vol. 48, no. 5, May 2016, pp. 860–868, 10.1249/ mss.0000000000000831.

Investigators looked at the strain/fatigue that happens with walking under a load (i.e backpack hiking) and stride width and double limb support time to increase control and stability. The addition of SR further improve stride width for stability.

Priplata, Attila A, et al. "Vibrating Insoles and Balance Control in Elderly People." *The Lancet*, vol. 362, no. 9390, Oct. 2003, pp. 1123-1124, 10.1016/s0140-6736(03)14470-4.

Subsensory noise applied to the feet of quietly standing individuals leads to enhanced feedback and reduced postural sway

Priplata, Attila A., et al. "Noise-Enhanced Balance Control in Patients with Diabetes and Patients with Stroke." *Annals of Neurology*, vol.59, no. 1, 2005, pp. 4–12, 10.1002/ana.20670.

Somatosensory function declines with diabetic neuropathy and stroke, resulting in diminished motor performance. Applications of "noise" resulted in statistically significant reduction in each of the 8 sway parameters in subjects with diabetic neuropathy, stroke and elderly subjects.

Stochastic Resonance and Balance cont'd

Priplata, Attila, et al. "Noise-Enhanced Human Balance Control." *Physical Review Letters*, vol 89, no. 23, 13 Nov 2002, 10.1103/physrevlett.89.238101.

Noise enhancement effect may be sufficiently large to offset age related declines in balance control

Zhou, J., et al. "Noise Stimuli Improve the Accuracy of Target Aiming: Possible Involvement of Noise- Enhanced Balance Control." *Experimental Mechanics*, vol. 54, no. 1, 12 Feb. 2013, pp. 95–100, 10.1007/s11340013-9728-3.

Use of SR insoles with healthy subjects suggests this is beneficial for the complex postural control process during the specific task of aiming during standing.

Stochastic Resonance and Neuropathy

Cloutier, Rachel, et al. "Prolonged Mechanical Noise Restores Tactile Sense in Diabetic Neuropathic Patients." *The International Journal of Lower Extremity Wounds*, vol. 8, no. 1, 3 Feb. 2009, pp. 6–10, 10.1177/1534734608330522.

This study demonstrates that improvements in diabetic sensitivity, as measured by VPT as a result of SR stimulation, are maintained over a 60-minute continuous stimulation period. It also confirms the findings of our previous study which demonstrated acute improvement in tactile sensation immediately after application of SR stimulation.

Khaodhiar, Lalita, et al. "Enhancing Sensation in Diabetic Neuropathic Foot with Mechanical Noise" *Diabetes Care*. vol.26, no.12, 1 Dec 2003, pp. 3280-3283, 10.2337/diacare.26.12.3280

Subjects had moderate to severe neuropathy, and showed improved vibratory and fine touch sensitivity with SR. Results indicated application of SR improves function of nerve fibers not directly stimulated by the device.

Priplata, Attila A., et al. "Noise-Enhanced Balance Control in Patients with Diabetes and Patients with Stroke." *Annals of Neurology*, vol.59, no. 1, 2005, pp. 4–12, 10.1002/ana.20670.

Somatosensory function declines with diabetic neuropathy and stroke, resulting in diminished motor performance. Applications of "noise" resulted in statistically significant reduction in each of the 8 sway parameters in subjects with diabetic neuropathy, stroke and elderly subjects.

Stochastic Resonance and Pain

Elfering, Achim. "Stochastic Resonance Whole Body Vibration Reduces Musculoskeletal Pain: A Randomized Controlled Trial." *World Journal of Orthopedics*, vol. 2, no. 12, 2011, p. 116, 10.5312/wjo.v2.i12.116

Using SR-WBV, researchers noted a small but significant negative association between training day (with SR) and pain, indicating less pain with (SR) training progress

Elfering, Achim et al. "Stochastic Resonance Whole Body Vibration, Musculoskeletal Symptoms, and Body Balance: A Worksite Training Study." *Safety and Health at Work*, vol. 4, no. 3, Sept. 2013, pp. 149–155, 10.1016/j.shaw.2013.07.002.

Using SR-WBV musculoskeletal well being and surefootedness improved as well as noting a pain decrease in those with low back pain complaints prior to beginning SR. Significant body balance increase was noted.

SR-100 and Cerebral palsy

Lynn, Jessica, et al. "Effects of Stochastic Resonance Stimulation on Manual Function in Children with Hemiplegic Cerebral Palsy: A Pilot Clinical Trial." *PM&R*, 8 Apr. 2022, 10.1002/pmrj.12788.

Using the SR-100, children with CP demonstrated improved unimanual abilities and improved hand function on bimanual tasks

Stochastic Resonance and Stroke

Seo, Na Jin et al. "Effect of remote sensory noise on hand function post stroke." *Frontiers in human neuroscience* vol. 8 934. 17 Nov. 2014,

Using SR C3 tactors on the wrist, hand dexterity and strength improved in subjects with chronic stroke deficits, suggesting a wristband type device to complement hand rehabilitation for stroke survivors with sensorimotor deficits.

Priplata, Attila A., et al. "Noise-Enhanced Balance Control in Patients with Diabetes and Patients with Stroke." *Annals of Neurology*, vol.59, no. 1, 2005, pp. 4–12, 10.1002/ana.20670.

Somatosensory function declines with diabetic neuropathy and stroke, resulting in diminished motor performance. Applications of "noise" resulted in statistically significant reduction in each of the 8 sway parameters in subjects with diabetic neuropathy, stroke and elderly subjects.

Performance Benefits of Stochastic Resonance

Dauids, K. "Essential Noise - Enhancing Variability of Informational Constraints Benefits Movement Control: A Comment on Waddington and Adams (2003)". *British Journal of Sports Medicine*, vol. 38, no.5, 1 Oct 2004, pp. 601-605, 10.114/bjism.2003.007327

Stochastic resonance has been studied in many physical and biological systems and evidence has emerged to support its beneficial role in supporting functional behaviour. This commentary provides such a theoretical rationale and raises the awareness of sports medicine specialists to the potential value of functional noise or variability in training and therapeutic programmes.

Miranda, Daniel L., et al. "Sensory Enhancing Insoles Improve Athletic Performance during a Hexagonal Agility Task." *Journal of Biomechanics*, vol. 49, no. 7, May 2016, pp. 1058–1063, 10.1016/j.jbiomech.2016.02.022.

Athletes incorporate afferent signals from the mechanoreceptors of their feet to provide information about posture, stability, and joint position. Balance and proprioception are correlated with improved athletic performance. Athletic performance benefits in this study are an average decrease with SR ON of 0.12s. The 0.12 s time difference for our 3 circuit hexagonal agility task represents a 10–20 percentile ranking difference for NCAA Division I athletes.

Ross, S. E. "Noise-Enhanced Postural Stability in Subjects with Functional Ankle Instability." *British Journal of Sports Medicine*, vol. 41, no. 10, 1 Oct. 2007, pp. 656–659, 10.1136/bjism.2006.032912.

Study to determine the effects of SR on postural stability in those with functional ankle instability (FAI). Conclusion that SR may enhance signal detection of sensorimotor signals associated with postural stability and increases in postural stability may decrease ankle sprain injuries

Ross, Scott E, et al. "Enhanced Balance Associated with Coordination Training with Stochastic Resonance Stimulation in Subjects with Functional Ankle Instability: An Experimental Trial." *Journal of Neuro Engineering and Rehabilitation*, vol. 4, no. 1, Dec. 2007, 10.1186/1743-0003-4-47.

Poor postural stability has been associated with FAI, and clinicians rehabilitate balance deficits to prevent ankle sprains. Subsensory noise known as stochastic resonance has been used with coordination training to improve **dynamic** postural instabilities with FAI. This study is to examine the effects on **static** postural stability. Findings indicate SR as an adjunct to coordination training enhanced postural stability deficits. Treatment effects associated with SR are greater than effects associated with coordination training alone.

Ross, Scott E, et al. "Customized Noise-Stimulation Intensity for Bipedal Stability and Unipedal Balance Deficits Associated with Functional Ankle Instability." *Journal of Athletic Training*, vol. 48, no. 4, 1 July 2013, pp. 463–470, 10.4085/1062-6050-48.3.12.

Study with young adults with functional ankle instability (FAI) comparing intensities of SR and noting balance improvements in those studied.

Ross, Scott E, et al. "Noise-Enhanced Eversion Force Sense in Ankles with or without Functional Instability." *Journal of Athletic Training*, vol. 50, no. 8, 1 Aug. 2015, pp. 819–824, www.ncbi.nlm.nih.gov/pmc/articles/PMC4629938/, 10.4085/1062-6050-50.5.06.

SR reduced magnitude and variability of force sense errors and may enhance muscle tension ability in those with functional ankle instability (FAI), which could have treatment implications for ankle instability.

Ross, Scott E., and Brent L Arnold. "Postural Stability Benefits from Training with Stochastic Resonance Stimulation in Stable and Unstable Ankles." *Athletic Training & Sports Health Care*, vol.4, no. 4, 31 July 2012, pp.207-212, 10.3928/01484834-20120731-03.

This study examined the effects of stochastic resonance and balance training on static, single leg balance. SR is an effective therapy for improving balance earlier and to a greater extent than traditional rehabilitation with those with functional ankle instability (FAI).

Performance Benefits of Stochastic Resonance cont'd

Ross, Scott, and Brent Arnold. "Noise-Enhanced Dynamic Single Leg Balance in Subjects with Functional Ankle Instability." *Journal of Sport and Health Science*, vol. 1, no. 2, Sept. 2012, pp. 102–106, 10.1016/j.jshs.2012.06.001.

SR therapy has been shown to improve **static** single leg balance in subjects with FAI. The purpose of this study was to determine effects of SR on **dynamic** single leg balance. It concluded clinicians might use SR to facilitate balance improvements with sagittal plane **dynamic** exercises that patients may not be able to perform otherwise.

Ross, Scott E., and Kevin M Guskiewicz. "Effect of Coordination Training with and without Stochastic Resonance Stimulation on Dynamic Postural Stability of Subjects with Functional Ankle Instability and Subjects with Stable Ankles." *Clinical Journal of Sport Medicine*, vol. 16, no. 4, July 2006, pp. 323–328, 10.1097/00042752-200607000-00007.

To examine the effects of coordination training with and without SR on dynamic postural stability. Coordination training can improve dynamic postural instability associated with FAI. SR may be an alternative therapy for FAI as it might improve dynamic postural stability more quickly and to a greater extent than coordination training without SR.

Stochastic Resonance and Dexterity

Hoskins, Robert et al. "Use of stochastic resonance methods for improving laparoscopic surgery performance." *Surgical endoscopy* vol. 30,10 (2016): 4214-9. doi:10.1007/s00464-015-4730-8

The purpose of this study was to determine if vibrotactile feedback (VIB) and SR would improve performance (accuracy, speed) in a laparoscopic palpation task. The results of the data analysis showed significant improvement in accuracy in the SR group only. When the same analyses were performed on the time variable, no evidence was found to suggest that time to tumor detection was affected by practice or feedback. This lack of speed–accuracy trade-off further emphasized the effect of SR in improving accuracy in tumor detection.

Stochastic Resonance and Parkinson's Disease

Kaut, Oliver et al. "Postural Stability in Parkinson's Disease Patients Is Improved after Stochastic Resonance Therapy." *Parkinson's disease* vol. 2016 (2016): 7948721. doi:10.1155/2016/7948721

Postural instability in Parkinson's disease (PD) increases the risk of falls and is not improved by pharmacological therapy. Stochastic resonance therapy significantly enhanced postural stability even in individuals with increased risk of falling.

Kaut, Oliver et al. "Stochastic resonance therapy induces increased movement related caudate nucleus activity." *Journal of rehabilitation medicine* 48 9 (2016): 815-818 .

Our findings suggest that increased movement-related caudate nucleus activity contributes to SR-WBV effects. They fit well with the previous observation of others and our group, that a disease such as PD affecting basal ganglia including the caudate nucleus (17) responds positively to vibration therapy.