## Abstract

Hypokinesia, or decreased movement amplitude, is a hallmark of Parkinson's disease (PD). The general hypothesis underlying hypokinesia is that there is an overactive indirect basal ganglia pathway, resulting in nearly constant thalamic inhibition, and the inability to select the desired motor plan. The functional manifestations include impaired gait with slow, small steps and postural instability. *Our therapeutic approach to gait impairments in PD is to tap into the ability of music to stimulate rhythmical movement.* Music is a complex stimulus, involving everything from pitch to rhythm, and melody to volume. Consequently, it is not processed in a single area of the brain. Music based rehabilitation has been guided by the finding that the majority of the brain regions and networks that are activated by listening to music are not exclusive to music listening, but also process auditory perception, elements of cognition, and motor control. Entrainment is thought to result from direct and dynamic neuronal coupling between the auditory and motor systems. We have shown that musically-delivered motor guidance mitigates hypokinetic tendencies in the gross movements involved in gait through concurrent music listening and real-time auditory feedback. Through a combination of sensors and machine learning we hope to create an individualized therapeutic treatment of hypokinetic gait dysfunction for people with PD (PwPD) that can run on a smartphone.

PI Muratori and her team are seeking funding for the next phase of the development of an individualized gait rehabilitation system. Dr. Muratori is a neuroscientist and physical therapist who specializes in PD and has an extensive network of PwPD. The interdisciplinary team is uniquely qualified to advance personalized treatment for gait impairment in PwPD. Our intervention, Wearable Sonification Therapy Equipment for Parkinson's (WeSTEP), uses two innovative approaches: the use of error signals rather than correct movement cueing, and a multivariate, gait-sonification algorithm that can provide real-time auditory feedback. Using our WeSTEP system, we are creating an individualized model for each person with PD based on their own target optimal walking pattern. From acquired body-worn sensor data, the applied machine learning method aims to learn the parameters of the individualized model used for detecting distortions in gait. The learning amounts to optimizing the parameters of the model with respect to an adopted cost function.

This project started with Muratori and Schedel, a musician with expertise in sonification or turning data into sound, and an external sensor company. Based on feedback from a previously scored NIH STTR grant submission, we have added team members fully within Stony Brook University and developed an initial proof of concept phase to our study. Our new team includes 1) Djuric, an electrical engineer specializing in machine learning as well as in signal and information processing; 2) Jain who has developed a low-profile/low-cost sensor for wearable health sensing; and 3) Plotkin a neurobiologist using a mouse model of PD to understand the mechanisms underlying the basal ganglia role in error-based learning. Dr. Ramakrishnan, a computer scientist specializing in AI and healthcare is serving as our senior personnel on the project.

In 2023 Muratori, Ramakrishnan, and Schedel presented "WeStep: An Individualized Neurorehabilitation Gait System using Music and AI" at the NSF-Disability and Rehabilitation Engineering (DARE) Conference on Computational Modeling for Neurorehabilitation. NSF has specific grants relevant to our work that will enable us to collect more data before applying for a large NIH grant. Smart Health and Biomedical Research in the Era of Artificial Intelligence and Advanced Data Science (SCH) and The Mind, Machine and Motor Nexus (M3X) Program, which supports research into embodied reasoning as mediated by bidirectional sensorimotor interaction between human and synthetic actors, are likely targets based on the feedback we received. The addition of Plotkin to investigate the neural mechanism foundational to our theoretical framework will significantly strengthen that application. As a further step toward securing M3X funding, we have partnered with the New York Hall of Science for the public outreach component.