



Wearable Haptic Devices for Sensorimotor Rehabilitation

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Background

My research focuses on human-machine systems, including wearable devices and haptics. These unique forms of technology allow machines to be closely connected to the human body, and thus have enormous potential in the fields of healthcare and human augmentation. While most researchers use wearable devices for sensing, my work explores technology as an intervention -- to improve learning, health, or rehabilitation. Evaluation of these interventions in turn provides new data on mechanisms of the body and mind, leading to new questions in physiology and human-machine interaction.

Passive Haptic Training

Wearable technology provides unique advantages that enable haptic stimulation 1) for extended periods of time, and 2) in the background of other tasks. Prior work defined a method of skill training using repeated tactile cues applied to the body parts (passive haptic training). This training method was applied to help train Braille, typing, rhythmic codes, and piano.

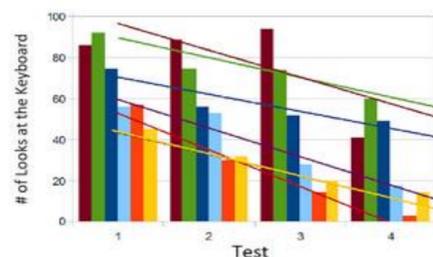


FIGURE 1: The number of times participants looked at the keyboard through four sessions of haptic training as measured by an eye tracking system.

Wearable Vibrotactile Stimulation for Sensorimotor Rehabilitation

Stroke is the leading cause of adult disability worldwide. However, rehabilitation methods remain limited and require extensive time-on-task. Traditional methods of therapy are based on exercise of the affected limbs, but up to 50% of survivors are not eligible due to low residual movement. Stimulation is an accessible modality of therapy, and there is promising preliminary evidence that mechanical stimulation may improve limb function. Wearable devices can now be designed to apply and study this mechanical stimulation method over time.

Clinical Trial Using the VTS Glove

Objective: Evaluate the feasibility and potential impacts on hand function using a wearable stimulation device (the VTS Glove) which provides mechanical, vibratory input to the affected limb of chronic stroke survivors.

Methods: A double-blind, randomized, controlled feasibility study including sixteen chronic stroke survivors (mean age: 54; 1-13 years post-stroke) with diminished movement and tactile perception in their affected hand. Participants were given a wearable device to take home and asked to wear it for three hours daily over eight weeks. The device intervention was either (1) the VTS Glove, which provided vibrotactile stimulation to the hand, or (2) an identical glove with vibration disabled. Participants were equally randomly assigned to each condition. Hand and arm function were measured weekly at home and in local physical therapy clinics.

Results: Participants using the VTS Glove showed significantly improved Semmes-Weinstein monofilament exam, reduction in Modified Ashworth measures in the fingers, and some increased voluntary finger flexion, elbow and shoulder range of motion

Conclusions: Vibrotactile stimulation applied to the disabled limb may impact tactile perception, tone and spasticity, and voluntary range of motion. Wearable devices allow extended application and study of stimulation methods outside of a clinical setting.



FIGURE 2: The computerized glove that provides vibrotactile stimulation for this study.

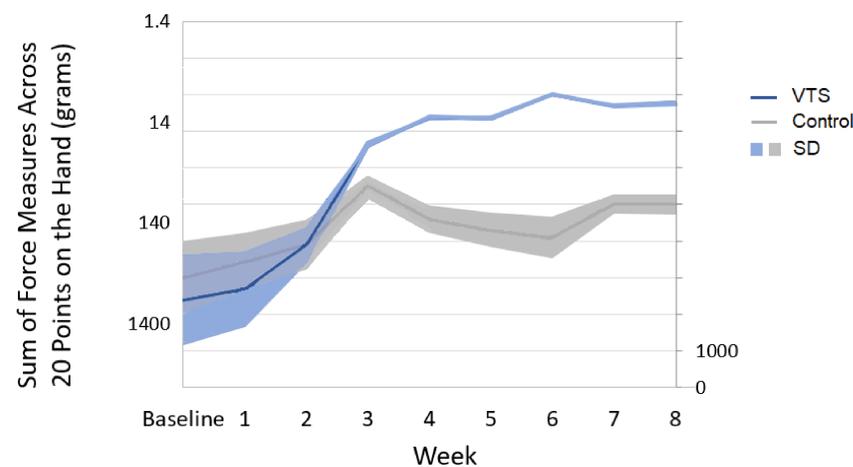


FIGURE 3: Trajectory of Semmes-Weinstein Monofilament Exam results over eight weeks for both conditions. This graph shows the group's average sum of perceived forces across 20 locations on the hand. Smaller perceived force values equate to greater tactile perception. Shaded regions indicate the standard deviation over time (secondary y-axes and major grid lines, linear scale).

Spastic Hypertonia

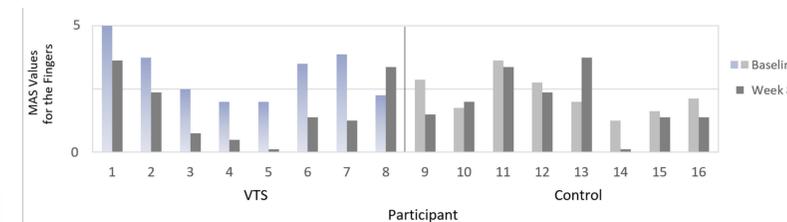


FIGURE 4: Modified Ashworth values for the fingers (average of PIP and MCP joint) at baseline and after eight weeks. The MAS rating scale is reported here as a scale of 0-5. Lower scores are better.

A significant change in involuntary muscle tone and contractions was found in the treatment group. Few effective treatments exist for this symptom (spastic hypertonia) though it affects millions of patients - 20-40% after stroke 72-91% with cerebral palsy, and 62-78% in spinal cord injury.

Device Design, Feasibility, and Tolerance

Current clinical work aims to examine the impact of wearable stimulation on spastic hypertonia. In addition, recent studies have defined design considerations for a wearable device to be used by a post-stroke population. These include physical accommodations that allow donning and doffing using one able hand, and haptic considerations such as the tolerance of vibrotactile signals in an older population.



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