Somatosensory Hindlimb Stimulator

Stephan Blanz, Royal Oakes, John Beckman, Jinyuxuan Guo
Advisor: Jeremy Rogers, Ph.D.[1]
Clients: Aaron Dingle, Ph.D.[2], Aaron Suminski, Ph.D.[1]
[1] University of Wisconsin-Madison, Department of Biomedical Engineering, [2] University of Wisconsin-Madison, Department of Surgery

ABSTRACT

Currently, no methods exist to test the efficacy of sciatic nerve repair on rodent models based on responsiveness to hindlimb somatosensory stimulation. The proposed device produces somatosensory stimulations through vibrations induced on the hindlimb of a conscious rat. By isolating the stimulation to either left or right hindlimb, the subject is presented a two-alternative forced choice (2AFC). A healthy rat is trained to conditionally respond to the stimulus by indicating on which limb the stimulus was felt. Once the rat is trained, the nerve is surgically deafferented and repaired. During recovery the rat is presented with the same 2AFC at various time points to determine the length of recovery of sensory function.

PROBLEM DEFINITION

MOTIVATION

Various surgical repair methods, as well as pre and post-operative care have resulted in inconclusive changes to recovery times (Figure 1). The clients therefore wish to test various surgical methods on rodent models. Currently there is no commercially available device which can test the somatosensory perception of a rodent at various times pre and post-surgery. Creating such a device would allow the clients to measure the efficacy of various treatments.

Goal: To design a device that uses vibration to safely and precisely stimulate one limb of a rat.

BACKGROUND

The clients for this project are currently researching surgical nerve repair in rats, specifically repair of the Sciatic nerve, which extends from the lumbar and sacral plexus and branches to the tibial and common fibular nerve. The nerve serves a crucial role in connecting the muscles of the leg and foot as well as sensory nerves to the spinal cord and brain [1]. Conventional methods of nerve stimulation include heat and electric shock. However, more humane options are desired, such as vibration.

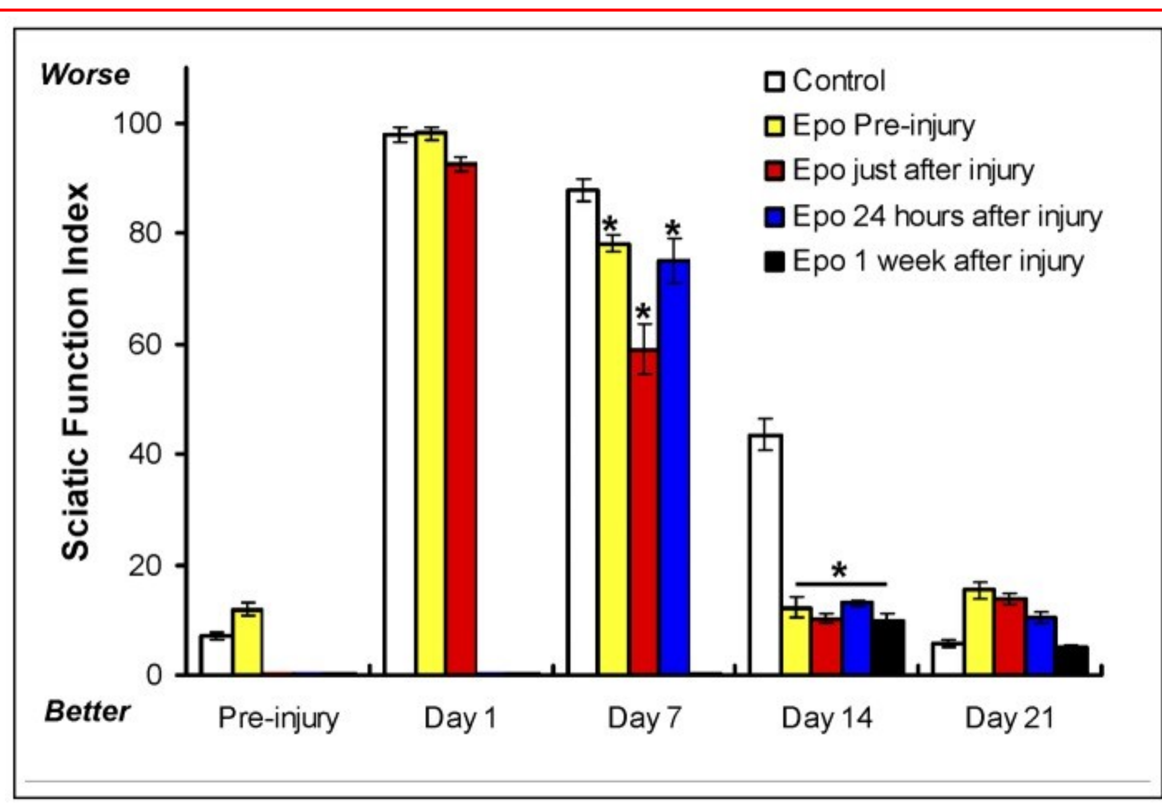

Figure 1. A study regarding erythropoietin on sciatic function at various times post-procedure shows the variable efficacy of current treatments [2]. There is considerable variation in sciatic function over time.

DESIGN CRITERIA

- Provide a vibrational stimulus to a rats hindlimbs
- Variable frequency, 20 - 150 Hz.
- Single limb stimulation
- Final design must fit on a lab bench
- GUI for user control of frequency
- Water/Urine resistant
- Computer controlled

DESIGN TESTING

Procedure

To test the output of the eccentric rotating mass (ERM) cylindrical and linear resonant actuator (LRA) coin motor, we measured the vibrations from each motor at various voltages using an accelerometer. Each motor was placed in three topologies (Figure 2) with the accelerometer and measured at various voltages. The Arduino and MATLAB code collected 128 samples with a sampling frequency of 1000 Hz and computed the Fourier transform of the data. MATLAB was then used to generate the plots of the Fourier transforms.

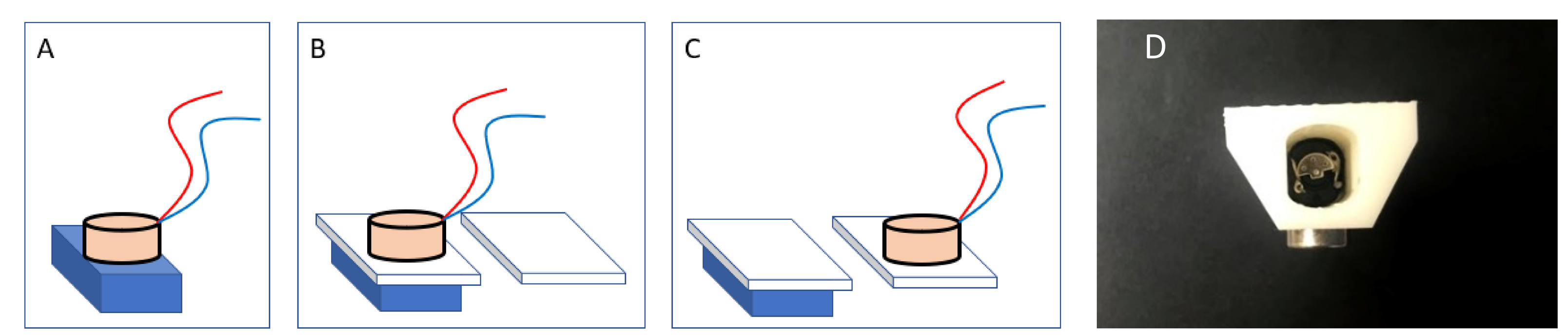

Figure 2. Topologies for the accelerometer (blue) and the motor (beige). (A) The direct placement topology, where the motor is placed directly on the accelerometer. (B) The dampened topology, where the motor is separated from the accelerometer by a strip of foam (white). (C) The off-target topology, where the motor is placed on a different foam pad than the accelerometer. (D) A real image of the ERM cylindrical motor (top) and the (LRA) coin motor (bottom).

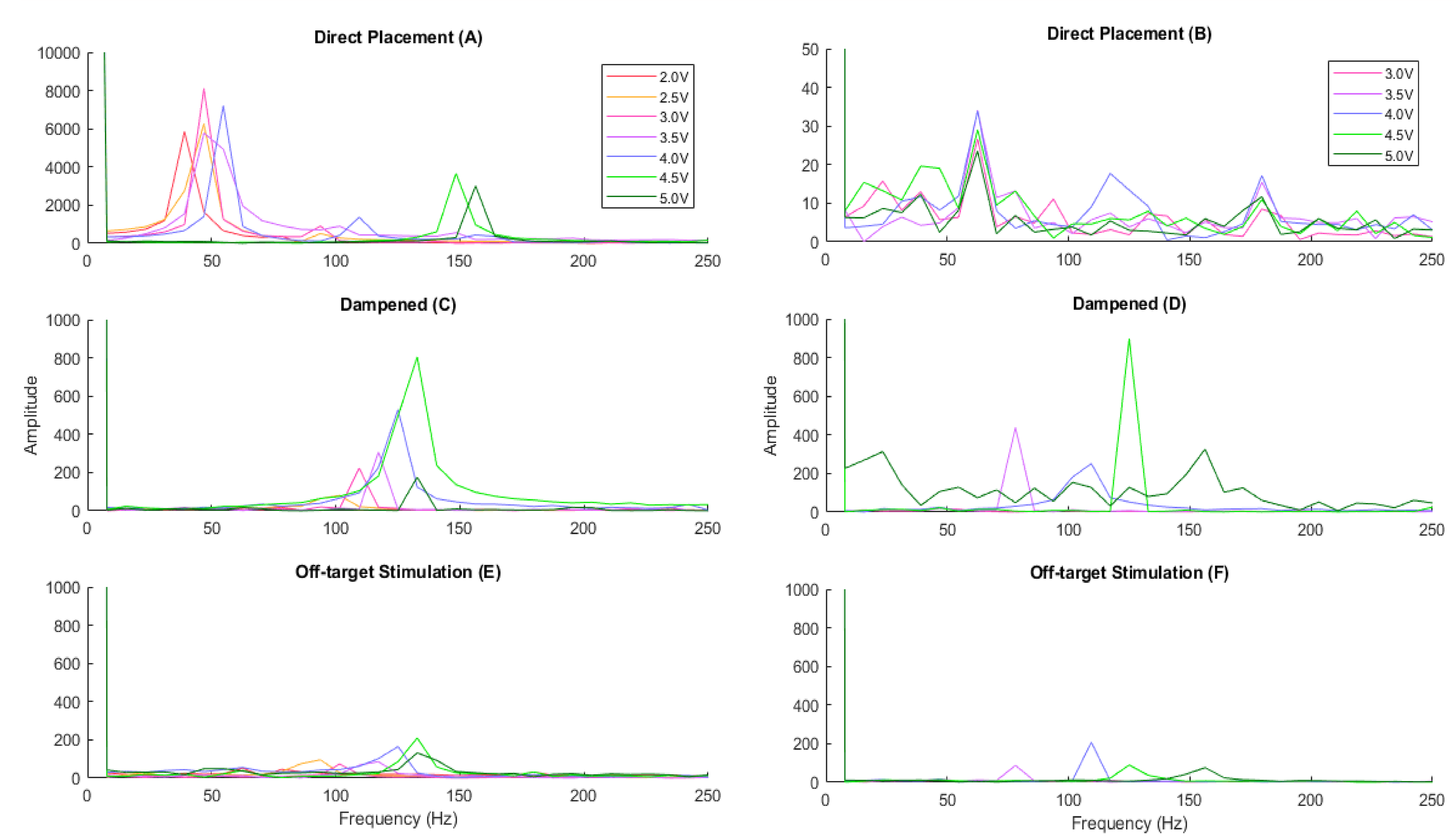

Figure 3. The Fourier transforms for the coin motor (A,C,E) and the cylindrical motor (B,D,F). The three topologies for each motor are shown from top to bottom: direct placement (A,B), dampened (C,D), and off-target stimulation (E,F). The axis for the dampened and off-target stimulation are scaled the same values for easy comparison. The plots for the cylindrical motor have a low signal-to-noise ratio due to issues securing the motor to the accelerometer.

DISCUSSION

Using a combination of the LRA and ERM motors allowed for a greater coverage of the desired frequency range. As expected, lower frequencies displayed lower amplitudes (Equation 1). Given these limitations, a secondary device was created utilizing a voice coil, allowing for adjustable frequency and amplitude.

To present an alternative given these limitations, a device utilizing a voice coil was created. This device was created as a secondary option, as it does not meet all of the client's primary needs.

FINAL DESIGN

Progress

- Combination of LRA & ERM motors to cover desired frequency range

Results

Table 1 Frequency ranges of various motors and configurations

	LRA	ERM
Direct Placement of accelerometer on motor	50 Hz, 150 Hz	60 Hz, 175 Hz
Motor damped by platform Accelerometer placed on platform	100 - 150 Hz	75, 125 Hz
Amplitude of off-target vibrations felt on adjacent pad *	25%	10% - 25%

* Based on selected prominent frequencies

Force generated

The amplitude of an ERM is correlated to the force (F) generated by a rotating mass (m) about an orbit of radius (r) at an angular velocity (ω).

$$F = m\,r\,\omega^2$$

$$F = 3.73\times10^{-4}\ \text{N} \qquad (1)$$

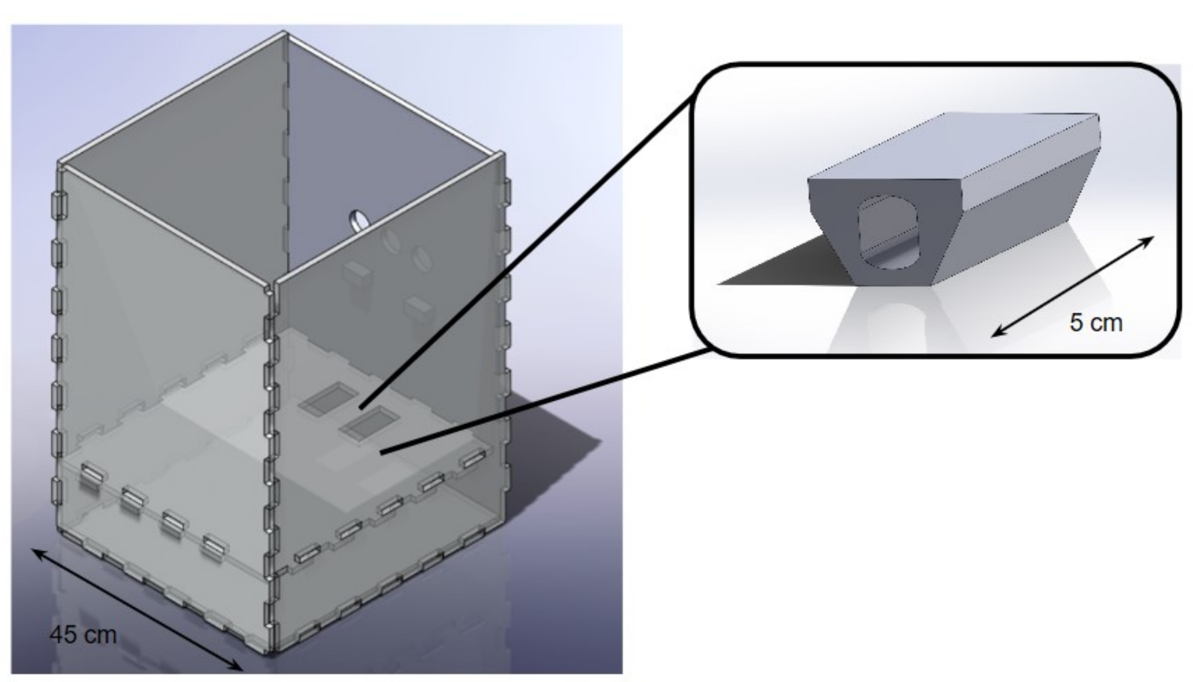

Figure 4. Rodent enclosure (left) featuring cut-outs which house platforms (right). The platforms feature both LRA and ERM motors as can be seen in Figure 2D.

FUTURE WORK

- Communication with client regarding current motor limitations, as well as other alternatives.
- Decrease cross platform vibrational stimulation; currently less than 25% of the amplitude experienced by the opposite pad.
- Develop standoffs for the voice coils, as well as a method of attaching these to the rats feet.
- Need to test amplitude, and various frequencies with the animals to determine if they can sense it.
- GUI creation

REFERENCES

[1]S. G. Yeomans, "Sciatic Nerve and Sciatica." [Online]. Available: https://www.spine-health.com/conditions/sciatica/sciatic-nerve-and-sciatica. [Accessed: 07-Oct-2018].
[2]J. C. Elfar, J. A. Jacobson, J. E. Puzas, R. N. Rosier, and M. J. Zuscik, "Erythropoietin accelerates functional recovery after peripheral nerve injury.," J. Bone Joint Surg. Am., vol. 90, no. 8, pp. 1644–53, Aug. 2008.