Somatosensory Hindlimb Stimulator

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UW BME Design

ABSTRACT

We created a device to stimulate the lower limbs of a rodent in order to assess the efficacy of nerve repair. The device provides vibrotactile stimulation by the use of transducers, a small motor capable of producing precise mechanical vibrations. The device is capable of producing vibrational stimulation from 20 - 200 Hz and varying vertical displacement.

BACKGROUND/MOTIVATION

The most important clinical outcome following nerve repair is functional ability. Despite advances in microsurgical technique, poor functional outcomes are frequent. Unfortunately, the cause for outcome variability is unknown and functional outcome is difficult to assess and measure experimentally [1].

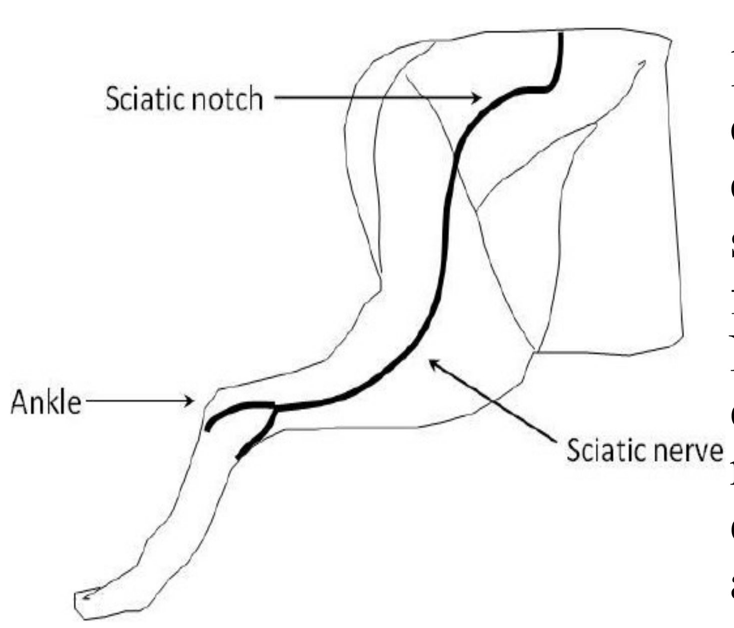

Fig 1. Diagram of the sciatic nerve (dark black line) in a rodent hindlimb. [3]

The sciatic nerve extends from the lumbar and sacral plexus of the spinal cord and branches to the tibial and common fibular nerve (fig. 1). The nerve serves a crucial role in relaying sensation from the leg and foot to the Central Nervous System [1]. When testing the efficacy of nerve repair, conventional methods of stimulation such as heat or electric shock could cause great harm in an animal that has not yet regained somatosensation of its hind limb. Therefore, a more humane method, vibration, is desired.

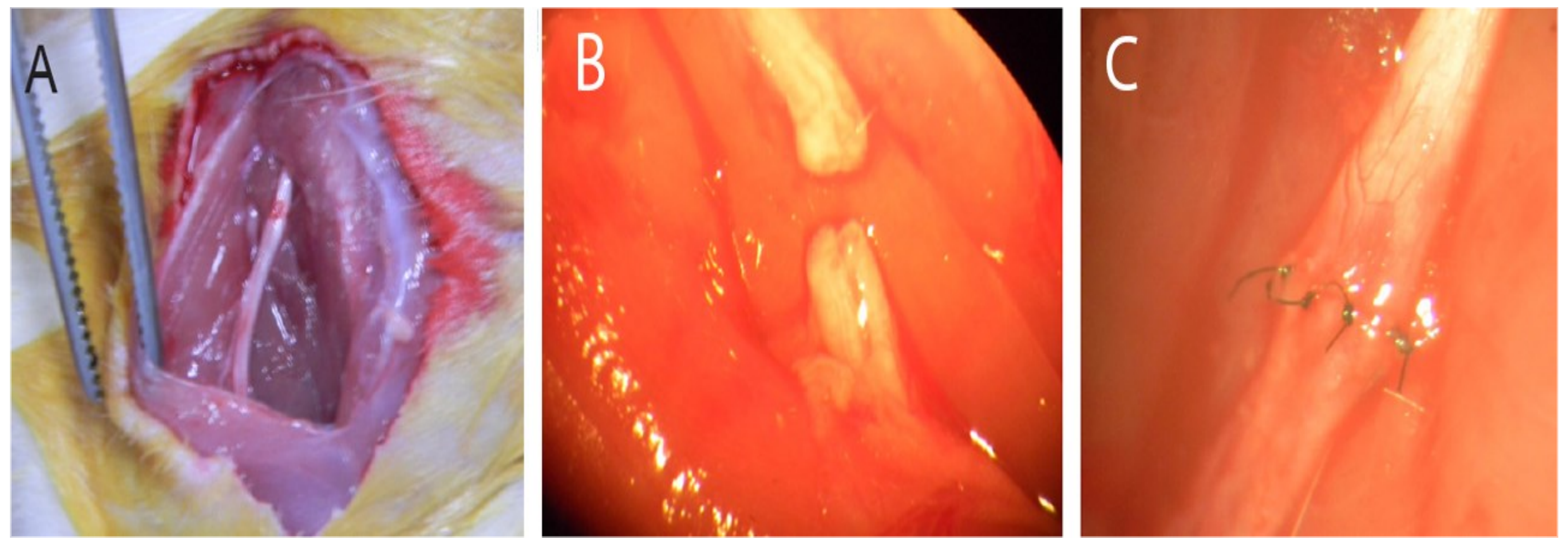

Fig 2. Examples of sciatic nerve research. (A) A sciatic nerve in an adult rat. (B) A sciatic nerve after being severed. (C) The post-injury sciatic nerve after being sutured [4].

DESIGN CRITERIA

- Provide an isolated 20 - 200 Hz vibrational stimulus to desired hindlimb
- Self imposed: Variable displacement
- Water/Urine resistant
- Design must be of size and weight to reasonably fit on a lab benchtop
- GUI for user control stimulation parameters

REFERENCES

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[3]S. A. Shankarappa, "Forced-Exercise Alleviates Neuropathic Pain in Experimental Diabetes: Effects on Voltage-Gated Calcium Channels." Order No. 3422313, Loyola University Chicago, Ann Arbor, 2010.

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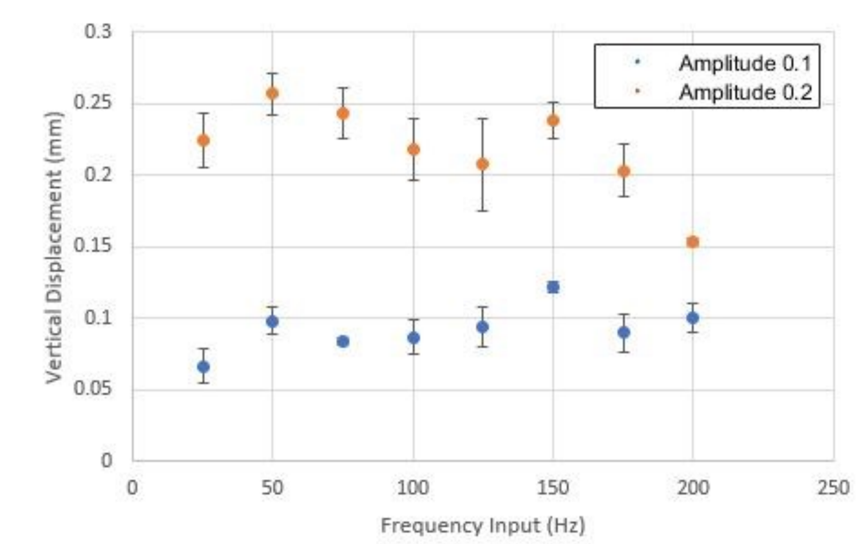
DESIGN TESTING

Frequency Testing: The transducer was tested at input frequencies of 50 Hz, 100 Hz, and 150 Hz. A microphone was used to collect sound waves from the transducer's vibrations. The audio files were processed using a fast Fourier transform (FFT) in MATLAB to determine output frequencies.

Displacement Testing: A white disk was attached to the top of a transducer to serve as a marker and placed against a dark background. Video recordings were taken of the oscillating disk at frequencies from 25-200 Hz and at amplitude scales determined by MATLAB.

Bleed Testing: An accelerometer was placed on either the platform connected to the active speaker (direct configuration) or to the platform adjacent to the active speaker (bleed configuration). We played the speaker at various frequencies and recorded the accelerometer data over 0.6 seconds.

RESULTS



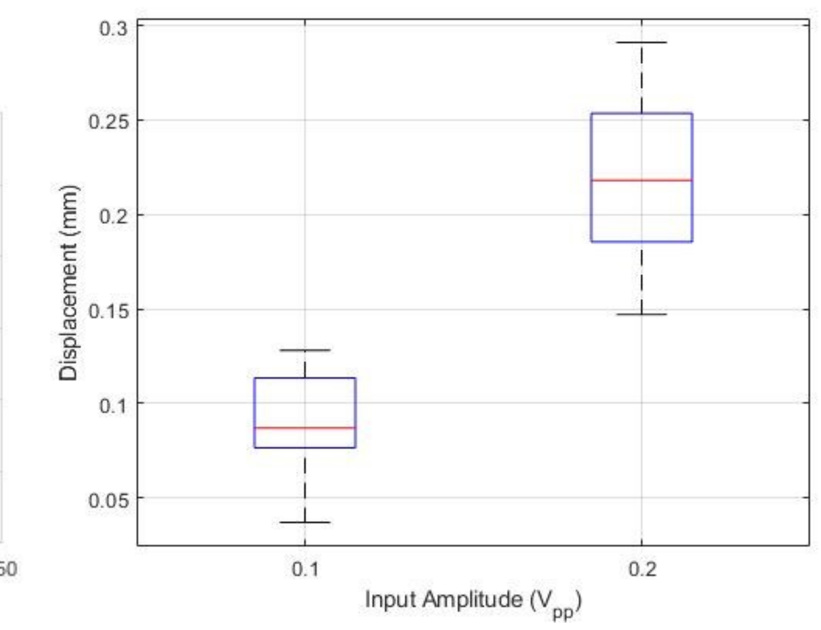
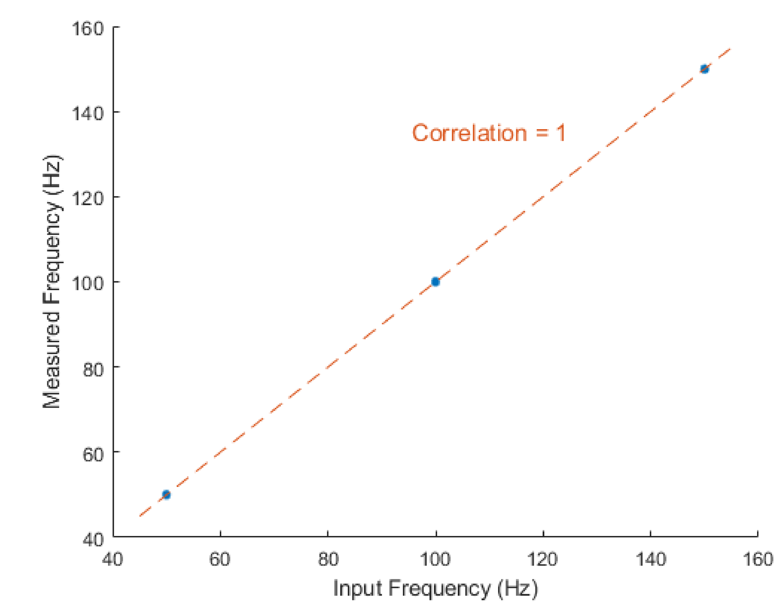


Fig 3 (Left). Relationship between displacement and frequency. The vertical displacement at an amplitude of 0.1 and 0.2 was computed at frequencies between 25 Hz and 200 Hz (n=3 for each trial). There is no statistically significant difference in displacement between frequencies within 0.1 amplitude, X^2 (7, N = 24) = 0.01858, p > 0.99, or within 0.2 amplitude, X^2 (7, N = 24) = 0.03269, p > 0.99. In a paired t-test there is a statistical significance between the 0.1 and 0.2 amplitude samples p < 0.0001 (N = 24). Error bars represent ± 1 SE.

Fig 4 (Right). Relationship between displacement and voltage. A summary of the results of the uncoupled displacement measurements of the transducer. These results are sampled at a range of different frequencies (25-200 Hz), and highlights the statistical results of figure 3.



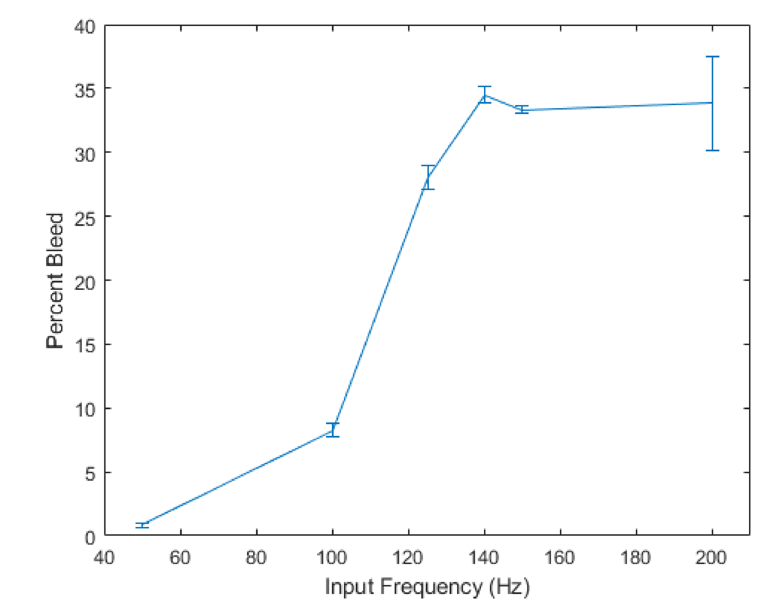
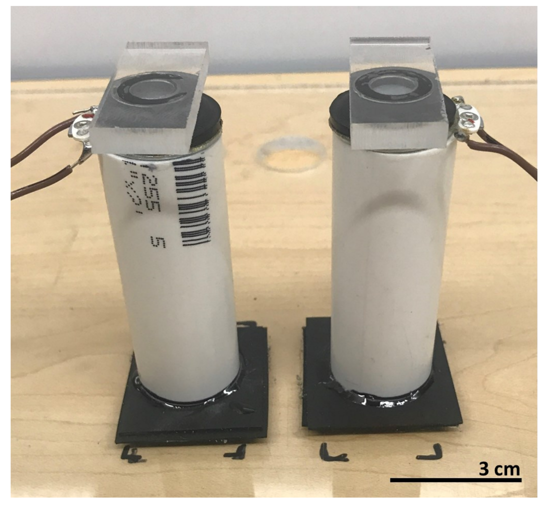


Fig 5 (Left). Frequency verification. Samples were taken at 50 Hz, 100 Hz, and 150 Hz (n=5 for each). There is a positive correlation between the input frequency and the measured frequency. The pearson's correlation coefficient is 1.

Fig 6 (Right). Bleed between platforms. The percent bleed between the two platforms was calculated at several frequencies (n=5 for each). There is a noticeable drop off in percent bleed between 100 Hz and 125 Hz. Error bars represent ± 1 SE.

FINAL DESIGN



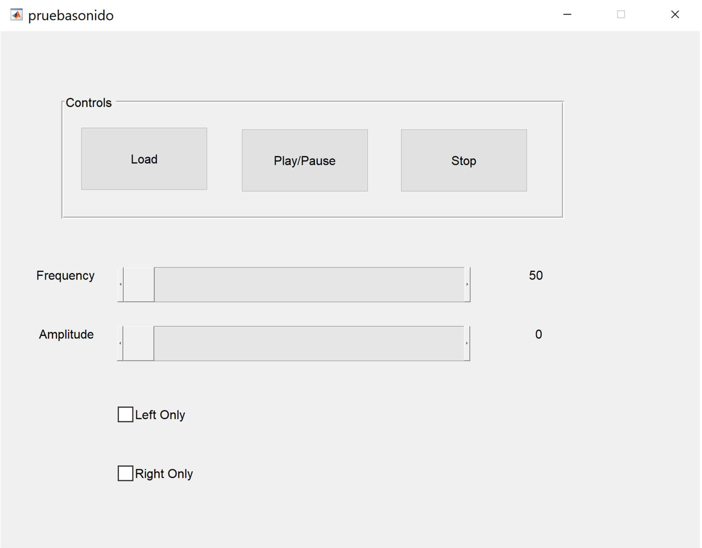


Figure 7 (Left). A plexiglass cage with holes cut out of the bottom where the transducers will couple with rubber mat on the bottom of the cage. Included in the cage is a water resistant rubber mat in case of rodent waste. Additionally, the circuitry and transducers will be safe from harm underneath the cage, with the only cords coming out of this section of the enclosure being an 3.5 mm headphone jack, as well as a power cord for the amplifier. The transducers are also in this bottom section of the enclosure where they are coupled to the rubber mat due to the cement and PVC standoffs built for them so that the transducers fit properly into the platform cutouts in the bottom of the cage.

Figure 8 (Top Right). The standoff, transducers, and acrylic platforms, which together provide the vibrational stimulus to the enclosure. This set up allows the platforms to properly sit in the cut outs at the bottom of the cage where the rodent's feet will be placed while in the enclosure.

Figure 9 (Bottom Right). The graphical user interface (GUI) was created in MATLAB. The GUI allows the user to modify the frequency of the vibration from 50 to 200 Hz and the relative amplitude from 0 to 0.2. Additionally, the user can select if a single transducer or both transducers will produce the desired stimulus.

DISCUSSION

The frequency as well as amplitude of vibration can be independently controlled, giving researchers access to a large parameter space. Currently, the device is capable of producing stimuli from 20 - 100 Hz with minimal bleed-over to the non-stimulating platform. Measurements taken with an accelerometer indicate that larger stimulation frequencies require faster accelerations within the transducer to achieve the desired output frequency. Bleed-over therefore is believed to be caused by the acceleration of the transducer membrane.

This device has the potential to lead to novel findings in nerve repair and regeneration. The implications of these results will be applicable for a variety of research topics in the future, ranging from anesthesiology to muscle and tissue repair.

FUTURE WORK

1) Create an amplifier with a constant output, not a variable knob.
2) Animal testing to determine the most effective stimulus parameters.
3) Work with clients to develop future protocols assessing the effectiveness of various nerve repair methodologies.