BME Design-Fall 2018 - Stephan Blanz
Complete Notebook

PDF Version generated by

Stephan Blanz

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Team contact Information

▪ Stephan Blanz ▪ Oct 10, 2018 @11:33 AM CDT

Last Name	First Name	Role	E-mail
Rogers	Jeremey	Advisor	jeremy.rogers@wisc.edu
Dingle	Aaron	Client	dingle@surgery.wisc.edu
Blanz	Stephan	Leader	blanz@wisc.edu
John	Beckman	Communicator	jbeckman3@wisc.edu
Oakes	Royal	BSAC /BWIG	soakes@wisc.edu
Guo	Rick	BPAG	jguo77@wisc.edu

Project description

▪ Stephan Blanz ▪ Oct 09, 2018 @10:35 PM CDT

Course Number:

BME 400

Project Name:

Somatosensory stimulation apparatus for rodent cages

Short Name:

Hindlimb Stimulator

Project description/problem statement:

Peripheral nerve injuries are common, debilitating and costly. Approximately 2.8%-5% of all trauma patients in the US sustain such an injury with nearly 100,000 peripheral nerve repairs being performed annually costing approximately 150 billion dollars. The most important clinical outcome following nerve repair, is functional ability, and 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.

The goal of this project is to design and validate an experimental apparatus that can provide somatosensory stimulation (i.e. vibration) to the hindlimb of a rodent would greatly improve the ability to assess nerve regeneration in rats for a wide range of studies- including but not restricted to, surgical repair methods, tissue engineering and neural interfacing.

About the client:

Dr. Aaron Suminski is a scientist with the University of Wisconsin, Department of Biomedical Engineering. He collaborates with Dr. Aaron Dingle, a post-doctoral researcher, with the University of Wisconsin, Department of Surgery, Poore lab. The Poore lab’s research focus is clinical and experimental microsurgery, with an emphasis on peripheral nerve regeneration and repair. Together they are researching the effectiveness of various treatments and methods of nerve repair.

2018/09/21-Client Meeting

▪ Stephan Blanz ▪ Oct 09, 2018 @10:41 PM CDT

Title: Advisor Meeting Notes

Date: 9/21/18

Content by: Stephan Blanz

Present: Stephan Blanz, Royal Oaks, Rick Guo

Goals: Initial Meeting with client. Determine immediate priorities and set expectations

Content:

Injured nerves leads to a level of disability.
Rodents have historically been a model for nerve repair.
Vibrational stimulation of varying magnitudes
Old design: 3 nose poke holes (yes, no, maybe; left, right, don't know)
Design -> cause injury to nerve, test progress of rehabilitation
Next step: implant electrodes that replace function (artificial signal in nerve through electrode)

Look into foot physiology for sense

Independently vibrate two feet. Isolate to only feet, not other parts of the body.
Be able to get into device by themselves. (can put whatever in device to fix them in desired position)

Two alternative forced choice experiment

Come up with repeatable, reliable computer stimulation

Interface needs to be on a computer (think about TTL input)

Cleaning think bleach safe.

Conclusions/action items:

- Research rodent hindlimb anatomy to determine which **vibrations** it is sensitive to
- When frequencies have been determined, ensure that the product can be **user controlled** over the range of frequencies

2018/09/14-Advisor Meeting Notes

▪ Stephan Blanz ▪ Sep 21, 2018 @01:52 PM CDT

Title: Advisor Meeting Notes

Date: 9/14/18

Content by: Stephan Blanz

Present: Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

Goals: Meet with advisor to discuss progress

Content:

In **progress reports**, highlight pertinent changes.

Have prepared agenda for **client meeting**. Think: design specifications, quantitative metrics, IP concerns. Do background research on relevant literature and existing devices. Brainstorm on how to solve the problem. Think about emailing agenda to the client.

Conclusions/action items:

Meet with client

2018/09/21-Advisor Meeting Notes

▪ Stephan Blanz ▪ Sep 21, 2018 @01:54 PM CDT

Title: Advisor Meeting Notes

Date: 9/14/18

Content by: Stephan Blanz

Present: Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

Goals: Meet with advisor to discuss progress

Content:

Update website with group picture, progress reports and deliverables as required.

On progress reports if there is not much change, highlight it. Put important info in an email as well.

Progress report should show a trajectory of progress. Both where you are and where you plan on going.

Use as a tool to schedule. Set overall deadlines and then work your way back to where you are to establish schedules.

Ask if the vibrations from limb could be felt elsewhere in the body at certain points during client meeting – would this influence design specifications.

Think about which stimuli we would like to use on rodent.

Continuous stimulation vs tap for stimulation.

Could we use cold to stimulate?

Conclusions/action items:

Meet with client and develop PDS.

2018/09/28-Advisor Meeting Notes

▪ Stephan Blanz ▪ Oct 09, 2018 @10:45 PM CDT

Title: Advisor Meeting Notes

Date: 9/28/18

Content by: Stephan Blanz

Present: Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

Goals: Meet with advisor to discuss progress

Content:

Advisor agrees with defining short term goal of vibrational stimulation. Plan to find several commercially available devices that can achieve this and use these for a design matrix. Use pictures in design matrix.

Conclusions/action items:

- Determine range of vibrations
- Find suitable commercial product that an end-user can manipulate the output within the prescribed range

2018/10/4-Design Matrix

▪ Stephan Blanz ▪ Oct 10, 2018 @12:16 AM CDT

Title: Design Matrix Creation

Date: 10/4/18

Content by: Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

Present: Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

Goals: Create Design Matrix Criteria

Content:

Each motor was rated according the the following criteria (weights in parentheses):

Segregation of Stimulation (25): The degree to which the vibrational stimulation is localized to one hindlimb of the rat. A score of 5 would imply that any vibration applied to one hind-leg platform would be undetectable in the other hind-leg platform. A score of 3 would imply that when vibration is applied to one hind-leg platform there is a measurable vibration in the other hind-leg platform between 0 and 0.1 times the amplitude of the applied vibration. A score of 1 would imply that when a vibration is applied at one hind-leg platform there is a measurable vibration at the other hind-leg platform between 0.5 and 1 times the applied vibration.
Frequency Range (20): How closely the vibration range of the motor matches the desired vibration range. A score of 5 would imply that the motor has a range larger than but including 70 Hz to 100 Hz. A score of 3 would imply that the motor has a range of 70 Hz to 100 Hz but has limited resolution within this range. A score of 1 would imply the motor does not produce vibrations within the 70 Hz to 100 Hz range.
Ease of Integration (15): The ease of creating an interface between the motor and the rat. A score of 5 would imply that the interface could be designed within two weeks. A score of 3 would imply the interface could be designed within a month. A score of 1 would imply that it would take more than one month to design the interface.
Size (15): The design must be able to fit on a laboratory bench and hold one adult rat. The cage has a minimum size of 30 cm × 30 cm × 60 cm. A score of 5 would imply the motor could be used with a cage of dimensions 30 cm × 30 cm × 60 cm. A score of 3 would imply the motor could be used with a cage of dimensions 35 cm × 35 cm × 60 cm. A score of 5 would imply the motor requires a cage larger than 40 cm × 40 cm × 60 cm.
Ease of Achieving Desired Effect (5): The ease of controlling the motor. We will need to create code that will manipulate the motor. A score of 5 would imply that there is a sufficient amount of documentation on how to control the motor. A score of 3 would imply that there is a some documentation on how to control the motor. A score of 1 would imply that there is little to no documentation on how to control the motor.
Safety (5): The safety of the design. The design should not harm or cause discomfort for the user or rat. A score of 5 would imply that there is little to no chance that the rat or user will be harmed. A score of 3 would imply that there is some chance that the rat or user will be harmed. A score of 1 would imply that there is a high likelihood that the rat or user will be harmed.

Criteria	(Weight)	Linear Actuator 		Micro Vibration Motor 		Precision Vibration Motor 	
Segregation of stimulation	25	5/5	25	4/5	20	4/5	20
Frequency range	20	3/5	12	3/5	12	5/5	20
Ease of integration	15	3/5	9	2/5	6	3/5	9
Size	15	3/5	9	4/5	12	5/5	15
Ease of acchieving desired effect	5	5/5	5	3/5	3	4/5	4
Cost	5	3/5	3	5/5	5	4/5	4
Total	**85**		**63**		**58**		**72**

Conclusions/action items:

- Precision Vibration Motor wins

2018/09/07-Sense Feeling

▪ Stephan Blanz ▪ Oct 09, 2018 @10:55 PM CDT

Title: Research Notes on Sensory Cells

Date: 9/7/18

Content by: Stephan Blanz

Present: Stephan Blanz

Goals: Determine the effects various cells have on "feeling"

Content:

How do we sense feeling?

The tactile corpuscles (also known as Meissner corpuscles) respond to light touch, and adapt rapidly to changes in texture (vibrations around 50 Hz).

The bulbous corpuscles (also known as Ruffini endings) detect tension deep in the skin and fascia.

The Merkel nerve endings (also known as Merkel discs) detect sustained pressure.

The lamellar corpuscles (also known as Pacinian corpuscles) in the skin and fascia detect rapid vibrations (of about 200–300 Hz).

- The **Rapidly Adapting (RA) or Meissner corpuscle end-organ mechanoreceptor** underlies the perception of flutter[6] and slip on the skin.[7] They have small receptive fields and produce transient responses to the onset and offset of stimulation.
- The **Pacinian corpuscle or Vater-Pacinian corpuscles or Lamellar corpuscles**[8] underlie the perception of high frequency vibration.[6][9] They also produce transient responses, but have large receptive fields.

Conclusions/action items:

- Two frequency ranges: ~ 50Hz and 200 - 300 Hz
- Document contains hyperlinks in case I need a refresher

2018/09/28-Hindlimb Stimulation methods

▪ Stephan Blanz ▪ Oct 09, 2018 @10:53 PM CDT

Title: Research Notes on Techniques Currently Used to Stimulate Rodents

Date: 9/28/18

Content by: Stephan Blanz

Present: Stephan Blanz

Goals: Determine what is currently being used to stimulate rodents

Content:

Hindlimb stimulation

via 50 ms air-puff [1]

thin acupuncture needles (0.14 mm) were inserted into the paws and a 0.2–1 mA, 1 ms electrical pulse was delivered [2]

10-150 Hz [3]

g.USBamp (g.tec) and the coin motor (YBI027, Φ=10 mm, YB motors, Republic of Korea) for stimulation system is operated through NI cDAQ operation of the vibration motor is managed by Data Acquisition Toolbox (MathWork, U.S.A.) 4 second stimulation in anesthetized mice [4]

Typically, the sensation of warm is elicited at temperatures of 34–37°C, while the sensation of pain is elicited at temperatures of 42–48°C [5]

The sensation of pleasant or innocuous cooling is typically elicited at temperatures of ~23–29°C, while the sensation of cold pain is significantly variable, with multimodal distribution of the cold pain threshold recently reported, corresponding to modal threshold temperatures of 23.7°C, 13.2°C and 1.5°C, respectively [5]

[1] M. Murayama and M. E. Larkum, “Enhanced dendritic activity in awake rats.,” *Proc. Natl. Acad. Sci. U. S. A.*, vol. 106, no. 48, pp. 20482–6, Dec. 2009.

[2] M. H. Mohajerani *et al.*, “Spontaneous cortical activity alternates between motifs defined by regional axonal projections.,” *Nat. Neurosci.*, vol. 16, no. 10, pp. 1426–35, Oct. 2013.

[3] J. H. Edwards and G. C. Reilly, “Vibration stimuli and the differentiation of musculoskeletal progenitor cells: Review of results in vitro and in vivo.,” *World J. Stem Cells*, vol. 7, no. 3, pp. 568–82, Apr. 2015.

[4] C. Yeon, D. Kim, K. Kim, and E. Chung, “Sensory-evoked potential using a non-invasive flexible multi-channel dry EEG electrode with vibration motor stimulation,” in *IEEE SENSORS 2014 Proceedings*, 2014, pp. 519–522.

[5] J. R. Deuis, L. S. Dvorakova, and I. Vetter, “Methods Used to Evaluate Pain Behaviors in Rodents.,” *Front. Mol. Neurosci.*, vol. 10, p. 284, 2017.

Conclusions/action items:

- Using Vibration: 10-150 Hz
- Refer back to this in case we decide to stimulate using other methods

2018/10/04-Touch Screen

▪ Stephan Blanz ▪ Oct 09, 2018 @11:32 PM CDT

Title: Touch Screen Chamber

Date: 10/4/18

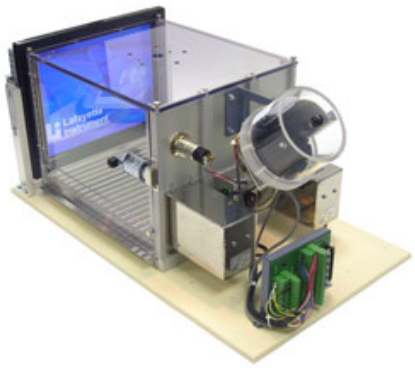
Content by: Stephan Blanz

Present: Stephan Blanz

Goals: Competition Research

Content:

Lafayette instruments provides various rodent enclosures for use in training. They have one in particular where the rat can be trained to touch a "touch screen." However, they have no product that stimulates hindlimbs.



Link: http://lafayetteneuroscience.com/products/rat-touch-screen-chamber

Conclusions/action items:

- We have a novel item.
- We might be able to incorporate an existing product for additional features

2018/10/04-Precision Vibration Motor

▪ Stephan Blanz ▪ Oct 09, 2018 @11:16 PM CDT

Title: Advisor Meeting Notes

Date: 10/4/18

Content by: Stephan Blanz

Present: Stephan Blanz

Goals: Potential Source of Vibration

Content:

Precision Microdrives has a motor that seems to operate within the frequency range our preliminary research has led us to believe we'll see a rodent response.

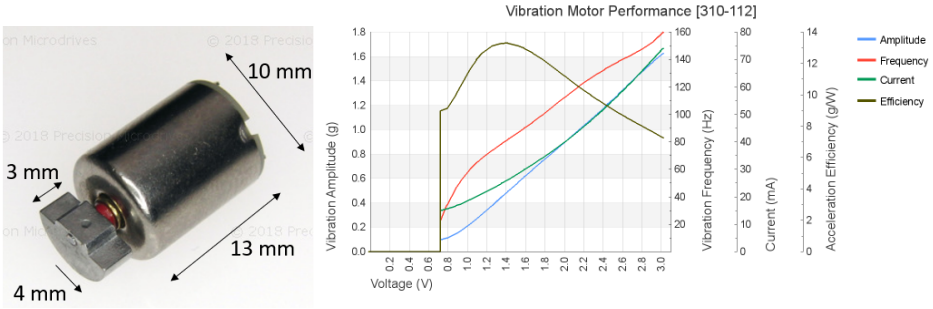


Figure 1 a(left) Vibrational motor based on rotating weight which creates vibrations when spun. b(right) Frequency vs Voltage curve will be used to establish ranges when testing.

Conclusions/action items:

- Produces ~30 Hz to ~160 Hz vibrations

2018/10/05-Slide-in for Vibrational Motor

▪ Stephan Blanz ▪ Oct 09, 2018 @11:08 PM CDT

Title: Possible Design Idea for Securing Motor

Date: 10/05/18

Content by: Stephan Blanz

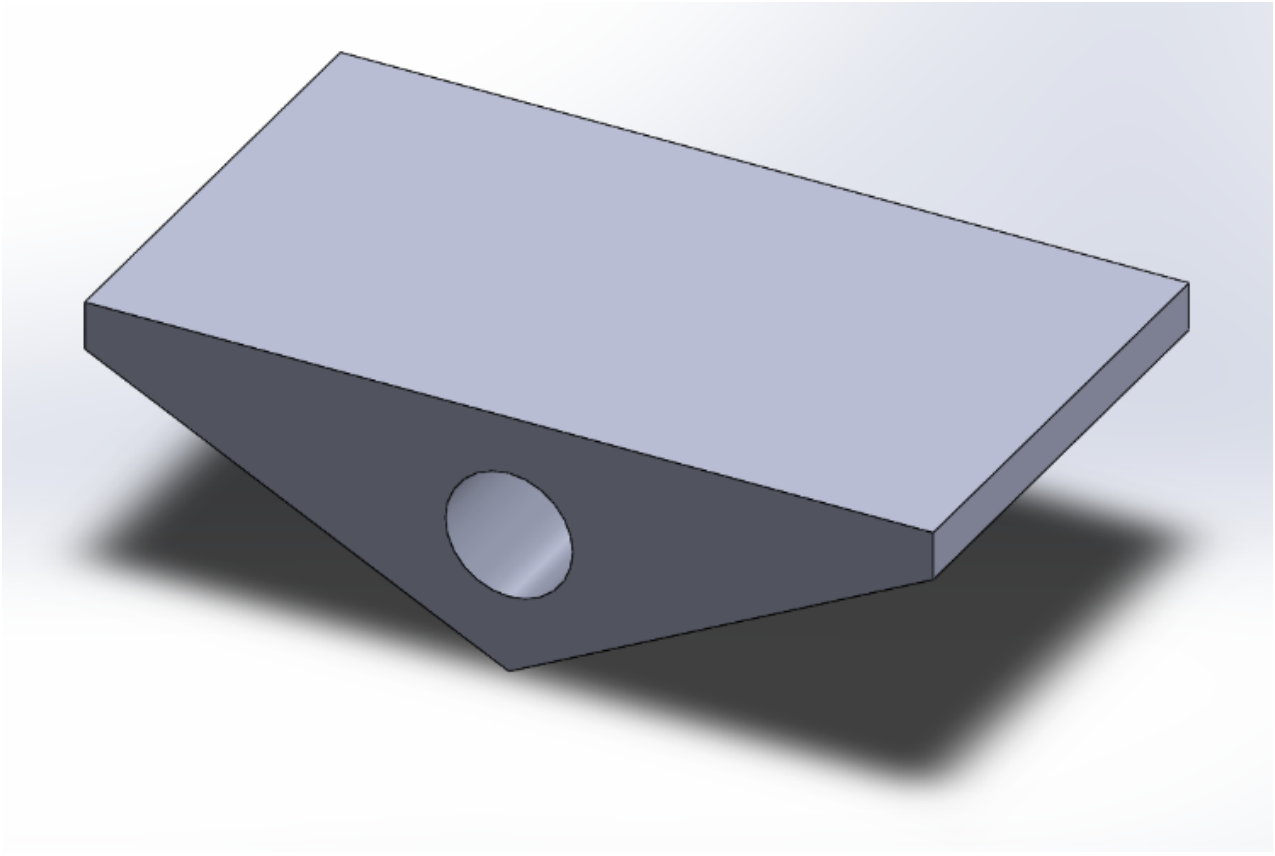
Present: Stephan Blanz

Goals: Design and evaluate a method of attaching motor

Content:

After finding the motor, I wanted to create a method of attaching this to the platform. Since the motor functions by rotating a semi-circular weight, it should be possible to create a platform with a cylindrical cut-out in which the motor could slide into. The vibrations of the motor would be transferred on contact to the platform.

Limitations are it might not be a 1:1 transfer.



Also, dimensions at this point are still variable. However, should be small enough to fit a rodent foot pad.

Conclusions/action items:

- If used, need to test that vibrations are transferred 1:1. If not, create tuning curve.

2018/10/09-As of this Date RARC Classes

▪ Stephan Blanz ▪ Oct 09, 2018 @10:58 PM CDT

Title: RARC Training Completed as of this date

Date: 10/9/2018

Content by: Stephan Blanz

Present: Stephan Blanz

Goals: Proof of Training

Content:

– RARC Classes

Completed		
Class	**Supplemental Materials**	**Date**
Mouse -- Covers: mouse c : mus	yes	02/07/18
Lab Animal Surgery		02/01/18
Rat -- Covers: rat c : rattus	yes	01/10/18
LAS Aseptic Technique		12/12/17
LAS Anesthesia		12/12/17
Anesthesia Machine User Guide		12/12/17
Medical Records		12/12/17
Controlled Substances		12/12/17
Animal User Orientation		12/04/17

Conclusions/action items:

None

Neural Regeneration

▪ John Beckman ▪ Oct 10, 2018 @01:24 PM CDT

Title: Mammalian Neural Regeneration

Date: 9/14/18

Content by: John Beckman

Present: N/A

Goals: To better understand how Neural Regeneration works in a mammals nervous system

Content:

- Neural Regeneration is almost impossible in the CNS due to the glial scar tissue that forms following nerve damage in the CNS. This is because of the Astrocytes that will cut off the damaged nerve from the rest of the CNS.
- In the PNS however, through a series of processes, Wallerian Degeneration, and axon regeneration allows for the damaged nerves to be encapsulated in the myelin of a Schwann cell. These Schwann cells will also release growth factors after the macrophages clean all the debris out of the space between the damaged neuron and the cell body.

S. Rotshenker, “Wallerian degeneration: the innate-immune response to traumatic nerve injury.,” *J. Neuroinflammation*, vol. 8, p. 109, Aug. 2011.

E. Huebner and S.M. Strittmatter, “Axon Regeneration in the Peripheral and Central Nervous Systems,” N.p., 27, Mar. 2010. Web.

Conclusions/action items:

The clients are studying how effective nerve regeneration surgery is. For in some situations the nerve is significantly more damaged, and requires a more invasive surgical procedure. Surgery can be used to help guide the axons to the cell body.

Surgical Repair of PNS nerves

▪ John Beckman ▪ Oct 10, 2018 @02:13 PM CDT

Title: Advisor Meeting Notes

Date: 9/20/18

Content by: John Beckman

Present: N/A

Goals: Research how surgical repair of neurons is different than the process of wallerian degeneration

Content:

There are four main steps to surgical repair of nerves in the peripheral nervous system

1. Preparation: removal of necrotic tissue leaving the ends as two normal looking nerve ends.
2. Approximation: The nerve ends are mobilized and brought together leaving a minimal gap by applying appropriate tension. Tensionless repairs have shown to have better results.
3. Alignment: The blood vessels must be aligned, and proper rotational alignment undertaken.
4. Maintenance: Sutures are placed in the epineurium, which is where they are held together. The sutures need to be properly inserted to avoid malrotation of the nerves.

G. M F, M. M, H. S, and W. S. Khan, “Peripheral nerve injury: principles for repair and regeneration.,” *Open Orthop. J.*, vol. 8, pp. 199–203, 2014.

Conclusions/action items:

This form of nerve repair is slightly different than wallerian degeneration, and requires a significant amount of invasive operations to complete. However the general procedure is similar, removal of necrotic tissue, followed by growth to the opposite end. The major difference occurs in the lack of growth occurring in the surgical repair, which can lead to a less successful repair than Wallerian Degeneration can provide.

Linear Actuator

▪ John Beckman ▪ Oct 10, 2018 @02:31 PM CDT

Title: Linear Actuator Motor for vibrational stimulus

Date: 10/01/18

Content by: John Beckman

Present: N/A

Goals: Find a potential motor to create the desired vibrational stimulus

Content:

A linear actuator or linear servo will allow for a direct linear motion. Utilizing coding to power the actuator we could use a delay to create a varrying vibrational frequency.

Some example Linear actuators or servos can be seen below.

Conclusions/action items:

Add this design to the design matrix, and then evaluate all of the other motors to determine which best meets our design specifications.

2018/10/09: Vibration Effects On Rats

▪ Steven Oakes ▪ Oct 09, 2018 @11:23 PM CDT

Title: Vibration Effects on Rats

Date: 10/09/2018

Content by: Royal Oakes

Present: NA

Goals: Describe the effects of vibrations on rats.

Content:

For this project we need to design a rat cage that can stimulate the hind limbs of the rodent with vibrations. It seems appropriate that I conduct preliminary research to understand what frequencies of vibration can elicit a behavioral response from rats. This page will contain citations to the article in IEEE format followed by bullet points indicating important points from the article.

A. M. Garner, J. N. Norton, W. L. Kinard, G. E. Kissling, and R. P. Reynolds, “Vibration-induced Behavioral Responses and Response Threshold in Female C57BL/6 Mice,” Sep-2018. [Online]. Available: https://www-ingentaconnect-com.ezproxy.library.wisc.edu/contentone/aalas/jaalas/2018/00000057/00000005/art00003. [Accessed: 30-Sep-2018].

- Rats were subjected to a range of frequencies between 20-190Hz. The greatest behavioral response came from frequencies between 70-100Hz.
- All four limbs of the rats were stimulated.
- Behavioral changes included freezing, hunched posture, and surveying the cage.

Conclusions/action items:

Find more sources on the effect of vibrations on rats.

Vibration research

▪ jinyuxuan guo ▪ Oct 10, 2018 @03:40 PM CDT

Title: Vibration Research

Date: 9/18/18

Content by: Rick Guo

Present: Rick Guo

Goals: To find a proper frequency range to stimulate the rodents' hindlimbs

Content:

What I found is that vibrations on hindlimbs at 35 Hz(according to article 1 below) to 90 Hz(according to article 2 below) can do good to rats' intervertebral disk and strengthen their hindlimbs' muscle. Therefore, I believe vibrations at 35 to 90 Hz will be safe to use on rats. And also according to a article found by Stephan, vibrations with a frequency of 50 to 150 Hz can stimulate the rodents effectively.

Here are the articles:

Local vibration enhanced the efficacy of passive exercise on mitigating bone loss in hindlimb unloading rats.
https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S009457651630875X

Low-intensity vibrations partially maintain intervertebral disc mechanics and spinal muscle area during deconditioning
https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S152994301300123X?via%3Dihu

Conclusions/action items:

According to the research, a frequency ranges from 35 Hz to 93 Hz may be appropriate to stimulate the rodents without hurting them.

Client meeting notes

▪ jinyuxuan guo ▪ Oct 10, 2018 @03:50 PM CDT

Title: Client meeting notes

Date: 9/21/18

Content by: Rick Guo

Present: Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

Goals: Meet with clients to discuss project

Content:

The clients want a device that can hold one rodents and use vibration to stimulate one of its hindlimbs.

It should be:

Fit on a laboratory bench

Has controllable frequency

Stimulates only one leg

Does not injure rodents

Computer controlled

Hold one rodent at a time

Waterproof and easily sanitizable

Conclusions/action items:

Meet with client

competing design research

▪ jinyuxuan guo ▪ Oct 10, 2018 @03:46 PM CDT

Title: Competing design research

Date: 9/16/18

Content by: Rick Guo

Present: Rick Guo

Goals: To find out designs that compete with our project

Content:

There are different types of rodent cages in the market currently. Most of them are not be able to stimulate the rodents. Some of them that can stimulate the rodents mainly uses electric shots or heat. However, cages that can stimulate rodent limbs through vibrations, as required by the clients, are not found. Since the cage will have to fulfill the unique and specific needs of the clients' experiments, competition of this project is limited.

Conclusions/action items: Very Limited competing designs(especially using vibrations to stimulate the rodents)

Micro cell phone vibration motor

▪ jinyuxuan guo ▪ Oct 10, 2018 @03:35 PM CDT

Title: Micro cell phone vibration motor

Date: 9/27/18

Content by: Rick Guo

Present: Rick Guo

Goals: To come up with a design idea

Content:

Cell Phone Micro Vibration Motor.

Retrieved from: https://www.amazon.com/uxcell-9000RPM-Yellow-Micro-Vibration/dp/B016VQSZ7Q/ref=pd_sbs_60_4?_encoding=UTF8&pd_rd_i=B072L7SRRS&pd_rd_r=8a9f34bd-c676-11e8-ac03-51a7059c8938&pd_rd_w=XL7Ej&pd_rd_wg=DZII7&pf_rd_i=desktop-dp-sims&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=53dead45-2b3d-4b73-bafb-fe26a7f14aac&pf_rd_r=PKTM989KJF13PWXBNRDW&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&refRID=PKTM989KJF13PWXBNRDW&th=1

1.Produces a vibration through the spin of a head with unbalanced weight

2. Can only work with fixed frequency, 3 motors are needed to control frequency(53Hz 86Hz 150Hz).

3.Cheap, about 1.2 dollars each

Conclusions/action items:

one possible way to develop a vibrational platform using this motor

2016/09/05-Entry guidelines

▪ John Puccinelli ▪ Sep 05, 2016 @01:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

▪ Stephan Blanz ▪ Sep 21, 2018 @01:51 PM CDT

Title: Advisor Meeting Notes

Date: 9/14/18

Content by: Stephan Blanz

Present: Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

Goals: Meet with advisor to discuss progress

Content:

In **progress reports**, highlight pertinent changes.

Have prepared agenda for **client meeting**. Think: design specifications, quantitative metrics, IP concerns. Do background research on relevant literature and existing devices. Brainstorm on how to solve the problem. Think about emailing agenda to the client.

Conclusions/action items:

Meet with client