

**RESNA Conference Proposal**

**Hand Sensory Rehabilitation Device**

**Sponsored by:  
Texas Biomedical Device Center**

**Touch**

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## **Problem Statement**

Texas Biomedical Device Center (TxBDC) was founded to help clinical research move from the lab to patients in an efficient fashion. Currently, TxBDC works on the rehabilitation of motor function, rather than sensory function, for patients who have suffered from a stroke. TxBDC now wants a device that can be used in conjunction with therapy to rehabilitate sensory function that has been lost in the hand. This device will work paired with Vagus Nerve Stimulation (VNS) to help re-establish the neural pathways in the fingers and palm. The initial goal is to create a device for the researchers at TxBDC to use in the lab, and have it transition to physical therapists to use with patients in clinics or even at home.

The device will deliver randomized therapeutic input to, at minimum, the tip of the thumb and forefinger. These inputs will consist of an applied force, vibration, temperature, and/or a two-point discrimination test. The general function of the device is to find the threshold of sensation in each of these areas through randomized stimulation, and then use VNS therapy to reduce the threshold of sensation over the time of treatment.

A two-point discrimination test evaluates how sensitive an area of skin is with respect to sensing distinct points applied to the skin. During the test, the participant will have to decide if two separate points feel like two distinct points or one point. The sensitivity can be measured by how far apart these two points actually are when the individual decides they feel two points. The device will administer the two-point discrimination test by measuring the participant's threshold of sensation. The two points would be separated by a measurable distance and increment by one or two millimeters until the separation distance is ten millimeters. The test begins at the lowest distance. The participant's area being tested, such as a fingertip, is pushed onto by the device administering the two-point test. If the participant does not feel two distinct points, the therapist will increase the distance between the two points and repeat the same process. The test will repeat, increasing the distance each time, until the participant feels two distinct points. Once two distinct points are felt, the distance between the two points is measured. The measurement is seen as a gauge for how sensitive that area of your body is with respect to being able distinguish one applied force versus two applied forces.

## **Design Alternatives**

The process consisted of each team member coming up with several different ways to implement a force, vibration, and two point discrimination test in a device. The team ranked the methods for each test based on feasibility, cost efficiency, size, and aesthetic quality. Through this ranking system, the team was able to determine a preliminary design in the shape of a box with a grid. In each unit on the grid was one of the three tests described above.

Feasibility was the most important constraint to consider. One of the initial designs with pumps, was poor in this part of the ranking. The pump was going to be used to implement all three tests. The team found though, soon into the design, that it was going to be difficult to measure a force on the system, change the pressure fast enough to induce a vibration, and to add pins to the pump tubes for two point discrimination. The team eventually came to the idea of creating each test from a separate mechanism rather than relying on one source to produce each test. Thus the force test motion would be created from a linear actuator, the vibration test from a pancake piezoelectric disk, and the two point discrimination test would be created from a rotating pentagonal wheel with each side of the pentagon having a different specified distance between pins. We then realized how difficult the box design would be with these new methods of implementation, so we created a mouse shaped casing with multiple “fingers” each holding a different test. This was when the team realized a complication for the two point discrimination test. The two point discrimination test requires the wheel to move up and down so that when it turns, it does not scrape the surface of the casing and/or the patient’s finger. This adds a layer of complexity to the code and budget because it could require another Arduino as well as another can-stack motor, which is an expensive add-on. Thus, to simplify the code and design, the team consolidated the two point discrimination test and the force test by adding a sixth side to the two point discrimination wheel with a single blunt point. For the vibration test, as long as a direct linear relation existed between increasing voltage and increasing vibration, the disk satisfied our requirements. The vibrating ERM actuator was tested lab and found to meet those requirements.

The selected concept is in essence, two enlarged computer mice with “fingers” that contain one of the two tests: force/two point discrimination in one dome, and vibration in the other. The team chose this design because it presented to be the most feasible and cost efficient design. The force and two point discrimination tests are consolidated onto one octagonal wheel. On one side of the wheel there will be a single blunt point that will act as the force test. On the other five sides of the wheel, there will be two points that increase by a distance of two millimeters per each side. The difference between the two point discrimination test and the force test will be accounted for in the programming of the GUI. The vibration test will be controlled by a dial in the GUI that will increase the voltage to increase the vibration.

After meeting with our project sponsor, he wanted us to focus on one dome to ensure we completed it within the time constraints. Therefore, we chose the force and two-point discrimination dome. We moved the vibration dome into the stretch goals. After lab testing and prototyping, we fine tuned the design.

### **Final Design**

The final design concept consists of a dome casing with varying electrical and mechanical components housed within. A force and two-point discrimination dome was created to satisfy the

problem statement. Our final design will be able to test all five fingers of the right hand. The overall size of the device fits within a sheet of standard printer paper.

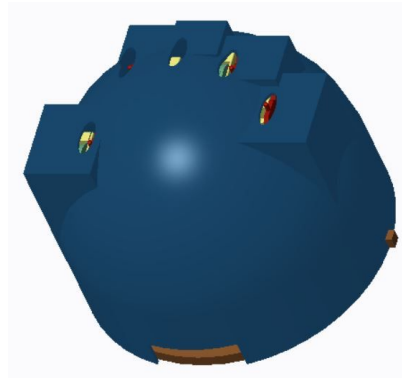


Figure 1 | CAD Rendering of Device

In Figure 1, it can be seen that the participant will not be exposed to most of the mechanical parts within the dome. The device will be placed on a desktop or tabletop, while the participant will be seated at a comfortable height during the test. Inside the dome, there will be five canstack linear actuators, five stepper motors, ten slot detectors, five force sensors, and five octagonal wheels along with one Arduino Uno and five motor driver shields. The Arduino and shields will be in the center of the casing with the motors along the edges lined up with the finger cutouts. The major components, which will be explained below, are the casing, the linear actuator, the motor stand, the stepper motor and the octagonal wheel.

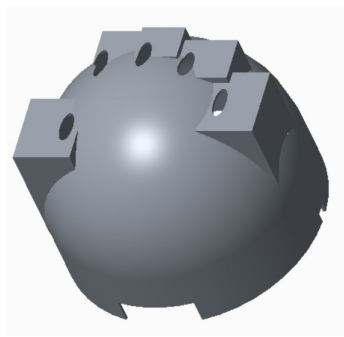


Figure 2 | Design of Casing for Force/2 Point Discrimination

### *Casing*

The casing is made out of 3D printed ABS plastic, as shown in Figure 2. The casing is designed to allow the patient's palm to rest on the top of the dome with their fingers laying on the cutouts. There are five finger cutouts for all five fingers being tested for force and two-point discrimination tests. The cutouts are used so the patient will be able to feel the stimuli put out by

the components inside without being fully exposed to all of the mechanics. The bottom of the casing is open to allow easy access for setting up the internal assembly.

### *Two Point Discrimination Wheel*

The part that will directly interface with the patients is the octagonal wheel from Figure 3. The octagonal wheel will be made of 3D printed ABS plastic. The wheel administers the two-point discrimination test and the force test. One side of the wheel is left empty due to stepper motor rotational angles. If we rotate clockwise from the blank side of the wheel, the first side is the force test side. The prong is wider than the rest, since the force test does not require distinction between one or two points. The next five sides are used for the two-point discrimination test. The one next to the force test side is spaced two millimeters apart. The next four sides increase by two millimeters until the ten millimeters is reached.

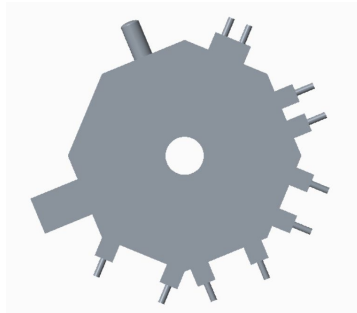


Figure 3 | Octagonal design including two point discrimination and force

### *Stepper Motor*

The stepper motor will be able to rotate the octagonal wheel to perform a two point discrimination test as well as apply force. The motor will be purchased from a vendor. The stepper motor will increment a fixed number of steps to change the sides of the wheel.

### *Motor Stand*

The stepper motor is held in place by the motor stand. The motor stand keeps the stepper motor anchored by attaching itself to the linear actuator. The motor stand is composed of two different pieces. The top piece holds the stepper motor. The bottom piece attaches to the linear actuator and holds the force sensor.

### *Linear Actuator*

The linear actuator will allow the whole motor subassembly to move up and down to interact with the participant's finger. The linear actuator will be purchased from a vendor. The linear actuator is comprised of two different pieces. The moving part is the lead screw. The fixed part is the motor itself. The lead screw will be attached to the motor stand, while the motor is screwed into the base of the system.

### *Two-Point Discrimination Test*

For the two point discrimination test, the stepper motor will rotate so the two points closest together on the octagonal wheel will be facing up towards the patient's finger. The canstack will then raise the stepper motor up until there is pressure applied to the finger. If the patient cannot feel two separate points, then the canstack will lower the stepper motor, and the octagonal wheel will rotate to the next set of points that are two millimeters further apart. The process repeats until the patient is able to discriminate between two points. Once the patient feels two distinct points, they will push down with the finger they felt the two points on. The test will stop as soon as the force sensor passes the maximum threshold.

### *Force Test*

This design also incorporates the force component by having the stepper motor rotate the octagonal wheel so the thicker, single pin is facing up, and then the canstack will raise the stepper motor to push on the patient's finger. Once the patient feels the force, they will push down with the finger they felt the force on. The test will stop as soon as the force sensor passes the maximum threshold.

### **Outcome**

At this time, we have been unable to test the device on individuals. We are currently awaiting IRB approval to start testing. However, all mechanical testing has been done. The device works to our desired requirements. Our device has been modified to the best of our ability to satisfy the customer and the comfort of the user.

With IRB Approval, the device will be tested on individuals that have not been affected by stroke. This testing will allow for patients who have had a stroke to be compared to those who have not. Testing of non-stroke individuals will help get a better understanding of the calibration and accuracy of the hand sensory rehabilitation device. From individuals participating in the testing, their feedback will be taken into account when determining the future of the device (i.e. aesthetics, ergonomics, noise, etc.).

### **Cost**

The summarized project cost can be seen in Figure 4. Our capstone project budget was \$2,000. After copious amounts of lab testing and producing the current prototype, we spent \$1,900. Most of this lab testing cost can be designated to previous design concepts. After refining the design, the estimated cost of production of the prototype would be around \$1,200. This cost can vary based on 3D printing costs. Most of our device is 3D printed. In our case, our corporate sponsor had onsite printers. We did not incur any printing costs due to this fact. Our estimate of 3D printing is based on the average cost for time and materials used by most companies. Without 3D

printing cost, the manufactured part cost is \$1,000. Based on the cost to produce the prototype, the price of the device to the consumer or commercial consumer would be around \$2,000. We believe that the cost and price of the device could lower due to mass production techniques.

Beginning Balance	\$2,000.00
Lab Testing & Production of Prototype	\$1,900.00
Estimated Cost of Production	\$1,200.00
Estimated Cost of Product	\$2,000.00

Figure 4 | Summary of Cost

### Significance

Each year approximately 800,000 people have a stroke, which is the equivalent number of people that live in North Dakota. From these strokes, many of the people have side effects afterwards. A major side-effect is paralysis and loss of sensation of the limbs. These people that are affected by stroke who suffer paralysis and loss of sensation can no longer hold the hands of their loved ones. They can no longer take full care of themselves. They are now dependent on others to do everyday tasks for them.

With current rehabilitation methods, people affected by stroke can at least regain the motor function of their hands. Motor function allows them to move their hands to wave at someone or to place their hand on a table. Without sensory function, they might burn their hands or not feel their phone vibrate when their loved one calls them. With our device, patients have the ability to gain some or all of their sensory function. They will have the ability to feel their loved one's hand again. They will be able to prevent damaging burns on their hands because they can feel the temperature change. They will answer their calls on the first couple of rings because they feel the vibration.

There is no guarantee that our device will return full function of the patient's hands. We believe that any progress that they make is moving in the right direction. Returning any portion of their life back to people affected by stroke fulfills the purpose of our design.

### Product Photo

