A Point Vibration Therapy Device for Individuals on the Autism Spectrum

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1. INTRODUCTION

The Autism Society of America estimates that 1 in 150 American children struggle with Autism Spectrum Disorders (ASD). ASD is a neurological condition characterized by abnormalities in social interactions, communication, and imaginative functioning. Seventy-five percent of children with ASD are also affected by Sensory Processing Disorders (SPD). These disorders cause some children to have difficulty processing the sensory input from the world around them and difficulty determining the spatial positioning of their bodies. This increases anxiety and often results in repetitive, distracting behaviors that hinder participation in classroom settings. Our objective is to help children with ASD integrate into classroom settings by reducing this disruptive behavior.

Previous studies have shown that apparatuses designed for sensory stimulation, such as Professor Grandin's "Squeeze Machine," are successful in decreasing self-stimulatory behavior in children with ASD. A study performed by Goodall and Corbett found that intermittent vibration also decreased self-stimulatory behavior. However, many of the current sensory stimulation apparatuses are prohibitively large, expensive, and conspicuous. A need exists for a sensory stimulus device that helps children regulate sensory input without removing themselves from the classroom.

To provide discreet sensory stimulation to a student in a classroom environment, a Point Vibration Therapy Device (PVTD) was designed to apply a vibration stimulus to the wrist or upper arm. The PVTD is approximately the size of a large wristwatch. Its power system is designed to last for an average school day without needing to be recharged. The sensory stimulus is intended to provide enough sensation to balance the sensory input of a child with sensory modulation difficulties and to "remind" the child of the spatial positioning of their body.

2. HYPOTHESIS

Normal individuals naturally integrate incoming information from multiple sensory modalities. Visual, auditory, proprioceptive, and vestibular information must be organized and interpreted meaningfully to allow an individual to perform adaptively. Autistic individuals, however, have difficulty bringing different cognitive functions together in an integrated way. Often, autistic individuals resort to repetitive motions or verbal patterns to seek local coherence in a world that, to them, appears to be horrifyingly random. It is these spatial awareness problems that can lead to the often symptomatic behaviors of autistic individuals. Spinning, biting, scratching, flailing of limbs, and head banging help them to determine where their bodies are in space. These self-stimulatory behaviors serve a "sensory modulating" function, allowing children to regulate their level of arousal when experiencing environmental sensory stimulation. However, such behavior is often harmful to the individual and distracting to peers and educators in classroom settings. Because of these problems, a majority of autistic individuals usually require long-term care and special education services. Nationally, the direct cost for the care and education of autistic patients was $35,000,000,000 in 2006. The cost of a specially structured education program for an autistic child is approximately $30,000 per year per child .

The goal of the proposed project is the development of an assistive device that permits an individual to discreetly apply vibration to a specific body area. Such a device would be used to replace conspicuous self-stimulatory behaviors (i.e., hand flailing and head banging), allowing individuals greater control over anxiety stemming from SPD. Significant research has been performed in the application of general pressure and massage techniques for the relaxation and spatial determination of autistic individuals. However, there is no study or body of work specifically examining if point vibration therapy can be unobtrusively applied with beneficial results. Therefore, the general question to be examined is as follows: Can local point vibration therapy provide a discreet, unobtrusive method for self-stimulation and spatial determination for autistic children and facilitate their integration into traditional classrooms?

3. DEVICE DESIGN

The present PVTD design (see Figure 1 and Figure 2) was developed by a senior design team during the 2008-2009 academic year. It consists of five major subsystems: 1) Stimulus Source, 2) Control, 3) Interface, 4) Power, and 5) Housing and Attachment. An exploded view of the PVTD is shown in Figure 3.

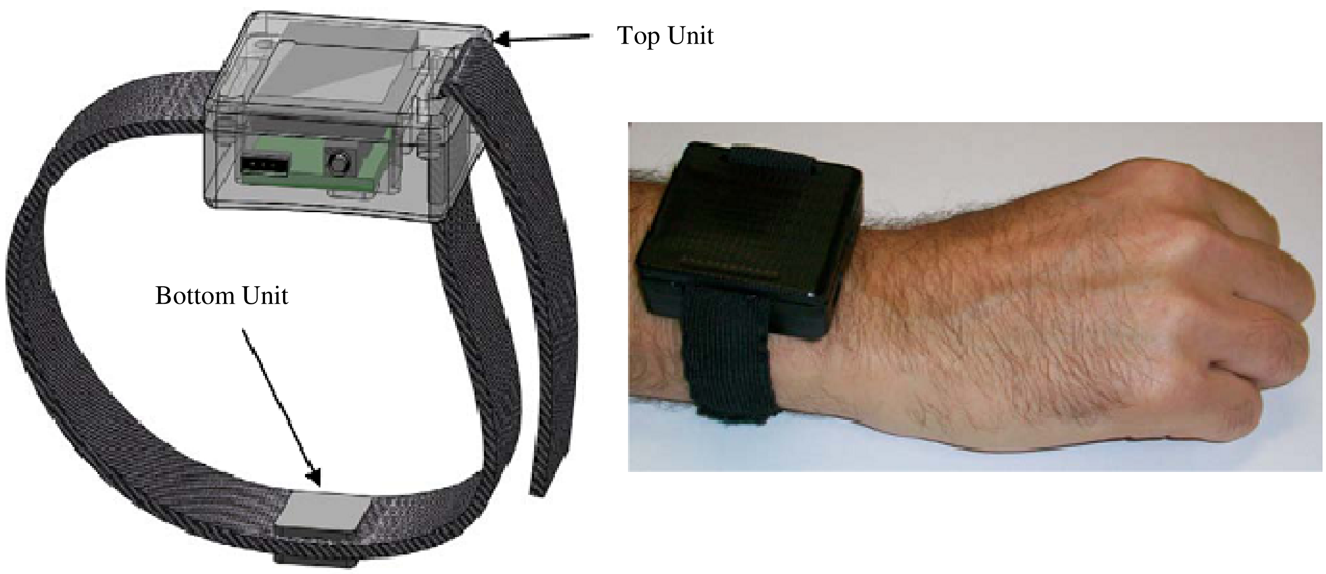

Figure 1. Point Vibration Therapy Device, Drawing and Photograph on Patient

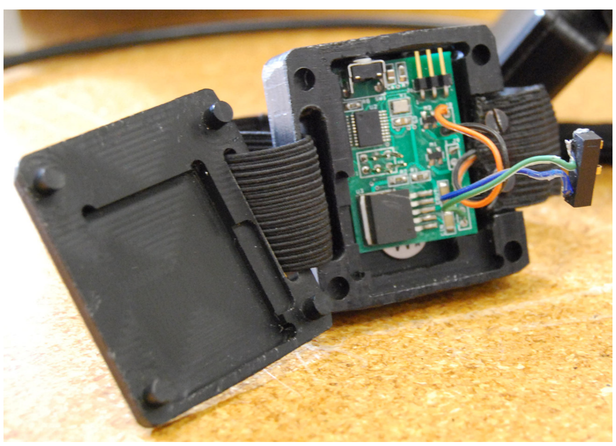

Figure 2. Point Vibration Therapy Device, Top Unit, Internal View.

The Stimulus Source subsystem refers to the device that applies a sensory stimulus to the user. In the PVTD, this stimulus is the vibration of two weighted disk motors, (Precision Microdrives Type 312-103). Weighted disk motors like these provide the "vibration" response in cell phones and traditional paging systems. Technically, the nominal frequency of the disk motors is 20Hz at 3.3V with a nominal acceleration of 0.75g, where g is the gravity acceleration constants, 9.8m/s^2. One motor is housed inside the top unit and the second inside the bottom unit, as shown in the exploded view in Figure 3.

The latest version of the PVTD is designed to be worn on the wrist. This strategically places the two weighted disk motors at the base of the hand (see Figure 1) and positions the weighted disk motors near the carpal bones (see Figure 4.) When the weighted disk motors are on, the PVTD vibration is conducted through the carpal, metacarpal, and the phalange bones in the hand. Depending upon the PVTD's programmable intensity level, the vibration can be acutely felt at the distal phalanges at the tip of each finger.

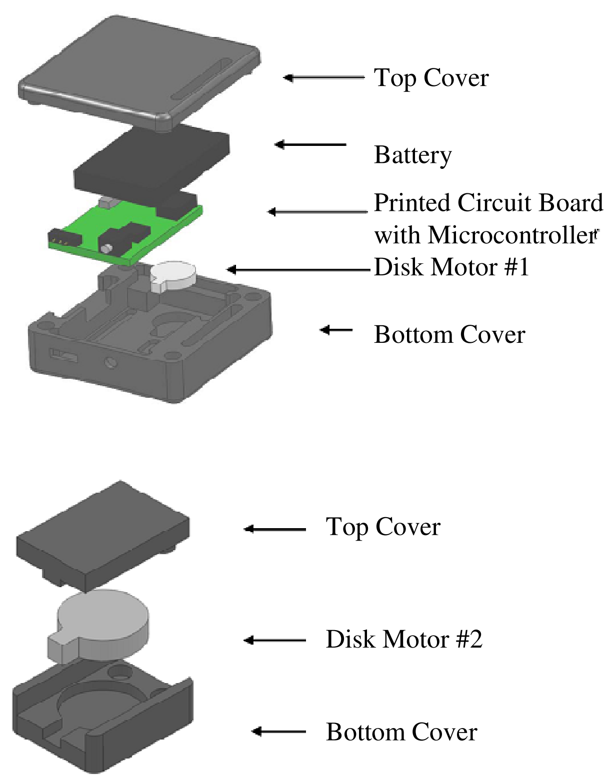

Figure 3. Exploded View of the Point Vibration Therapy Device Top and Bottom Unit

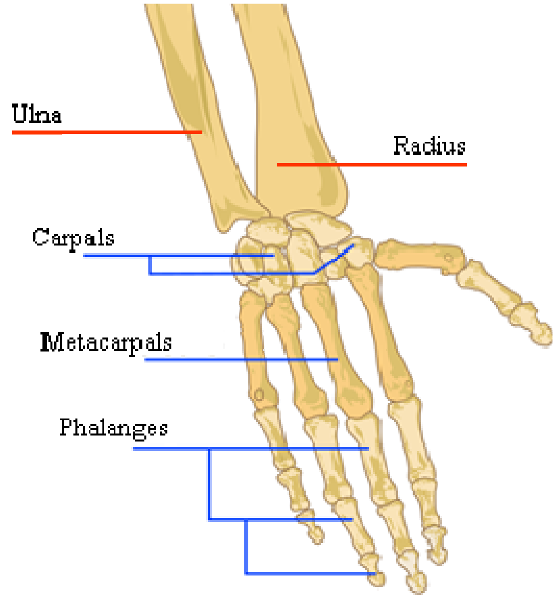

Figure 4. Bones in the Human Hand.

The Control subsystem's primary function is to turn on and off the weighted disk motors. The subsystem was designed to provide the maximum flexibility when a developing a optimal vibration sequence for individual patients. Options for individualizing the vibration sequence are shown in Table 1.

Table 1. Description of Stimulus Source Parameters

Option #	User-Friendly Terminology
1	Number of consecutive pulses
2	Length of standby time between consecutive pulse train
3	Duration of vibration
4	Duration of time between vibrations
5	Intensity of vibration

Figure 5 shows an example oscilloscope plot of the voltage applied to the weighted disk motors by the Control subsystem. In Figure 5, two pulse trains of ten pulses each are shown (Option 1 in Table 1). Each pulse train is ten seconds long. The standby time between each pulse train (Option 2 in Table 1) is ten seconds. Therefore, in this example, the PVTD's Control subsystem has been programmed to vibrate ten times in a ten second interval. The Control subsystem then enters a standby mode wherein the weighted disk motors are turned off for ten seconds. After the standby time, the Control subsystem starts another ten vibration pulse train.

Next, Figure 6 shows a 200ms/division oscilloscope plot of the ten vibration pulse train. Here, parts of three

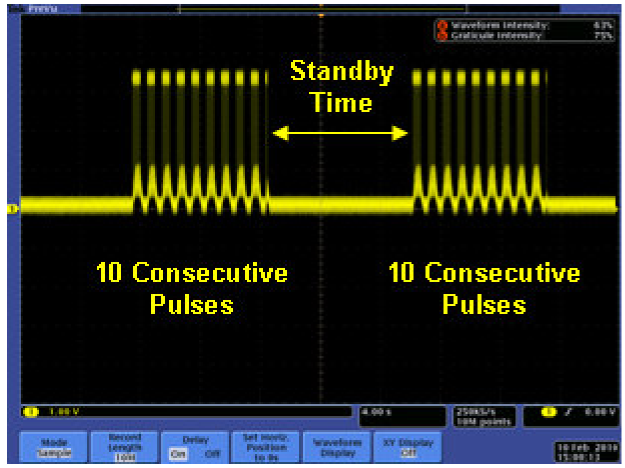

Figure 5. Oscilloscope Plot (4s/div) Showing Voltage Applied to Weighted Disk Motors.

vibration pulses are shown. In Figure 6, the duration of a vibration is shown (Option 3 in Table 1). In both Figure 5 and Figure 6, the duration of each vibration pulse is 0.5 seconds. In addition, the time between vibration pulses is also shown (Option 4 in Table 1). In Figures 5 and 6, the duration between vibration pulse is also 0.5 seconds.

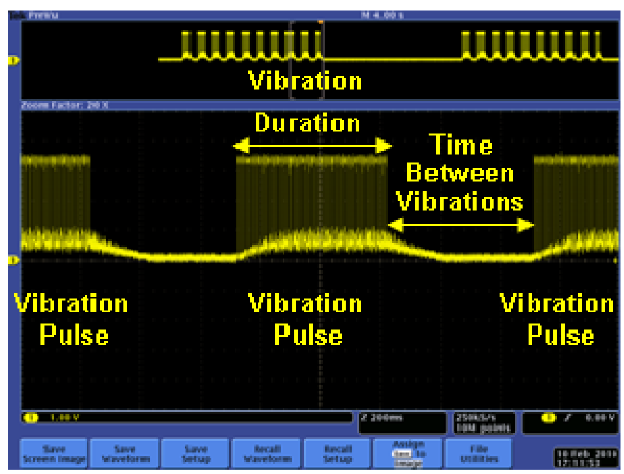

Figure 6. Oscilloscope Plot (200ms/div) Showing Voltage Applied to Disk Motors During a Pulse Train.

Figure 7 (at 100ms/division) shows a single vibration pulse. However, for the first time, it is visible that the Control subsystem is pulse width modulating the voltage applied to the weighted disk motors. This is shown at 4ms/division in Figure 8. In both Figure 7 and Figure 8, the Control subsystem is turning the weighted disk motors on and off at a frequency of 118 Hz with a duty cycle of 30%. Effectively, the voltage applied to the weighted disk motors is 30% of the 3.3V supply voltage resulting in an intensity of 30% (Option 5 in Table 1). Finally, Figure 8 illustrates a PVTD with a Control subsystem using a 90% duty cycle (90% maximum intensity).

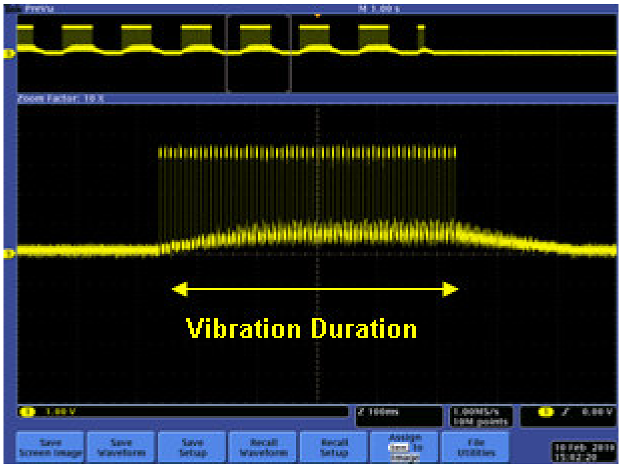

Figure 7. Oscilloscope Plot (100ms/div) Showing Voltage Applied to Motors During an Individual Pulse.

Figure 7. Oscilloscope Plot (4ms/div) Showing Voltage Applied to Disk Motors During an Individual Pulse with a 30% Duty Cycle.

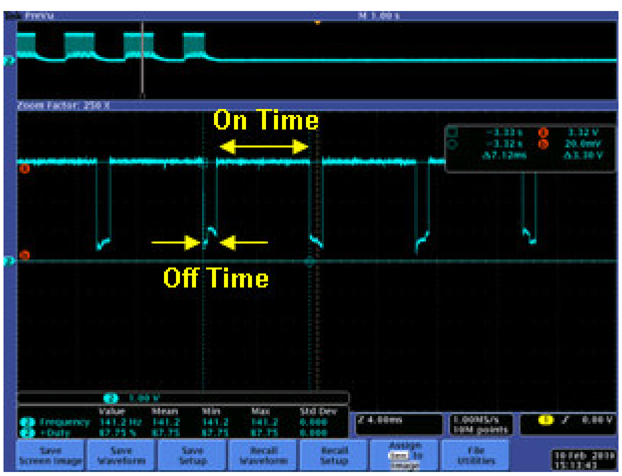

Figure 8. Oscilloscope Plot (4ms/div) Showing Voltage Applied to Disk Motors During an Individual Pulse with a 90% Duty Cycle.

The Interface subsystem allows for communication between a desktop or laptop computer and the PVTD. This communication is necessary for programming of the vibration patterns and consists of both hardware and software components. The hardware components include an Infineon XC866 development board (SK-XC866) and a National Instruments data acquisition (DAQ) system (USB-6221). The DAQ communicates with the development board, which transmits the data to the microcontroller in the PVTD. The PVTD includes its own software package that works in conjunction with the hardware. The software includes a graphic user interface (GUI) created using the National Instruments LabVIEW software package which allows the user to select new settings and transmit them to the PVTD (see Figure 9). This simple interface allows non-technical personnel to program the PVTD without rewriting the Control subsystem's algorithm. The GUI also allows the user to create combinations of parameters, allowing for more customized use.

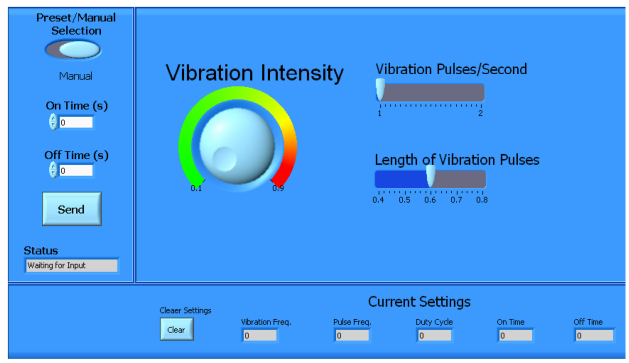

Figure 9. Device graphic user interface.

The Power subsystem consists of a rechargeable, 3.7V, 600mA-hour lithium ion battery (Kodak KLIC7002) and a voltage regulation circuit. The voltage regulation circuit uses a National Semiconductor LP38503-ADJ low dropout linear voltage regulator to provide 3.3V to the Control subsystem and the weighted disk motors. When both motors are on, the PVTD draws approximately 160mA of current. The LP38503-ADJ's typical dropout voltage at these current levels is less than 40mV. This allows the PVTD to operate for approximately one day before the battery must be recharged.

The Housing subsystem is responsible for supporting and protecting the other four subsystems as well as providing attachment to the patient. Unlike the other PVTD subsystems, the housing and attachment subsystem is visible when the device is fully assembled and is the only subsystem that physically contacts the device user.

As shown in Figure 1 and Figure 3, the Housing subsystem consists of two rigid housing units. They are made of a high density polyethylene (HDPE) material from Quadrant EPP. This material was chosen based on several qualities. First, it is non-toxic and meets FDA/USDA food handling guidelines. HDPE is chemical- and corrosion-resistant. Finally, it is also lightweight and non-staining.

The top and bottom units provide support to the other four subsystems. Also, the Housing subsystem completely conceals the other four subsystems, protecting them, to a degree, from external contamination such as water and sand. It also serves as a protective case for the other four subsystems, such that if the device were mishandled physically it would help to prevent damage to any of the interior components.

A single strap is used to attach the two housing units together and attach the PVTD to the user. The strap is fastened to one side of the top housing unit. The other end of the strap will wrap around the user's wrist, be woven through a slot in the other side of the top housing unit, and attach to itself using a hook-and-loop fastener. There is a break in the nylon portion of the strap located where the strap approximately makes contact with the bottom of the patient's wrist. At this location the break in nylon is replaced with a cotton cloth material that forms a pouch, which is sewn shut around the bottom housing unit. The power leads to the motor in the bottom housing unit run within the channel created between this double layered portion of the strap.

4. RESULTS

As the initial phase of development and construction of the PVTD was completed, our team sought permission to conduct empirical tests of the device. A proposal for the first phase of our investigation was submitted to the Valparaiso University Institutional Review Board for approval. Approval has been received, and additional units are being manufactured to conduct the empirical tests.

The tests will be conducted in several phases. Our first investigation will examine participants' initial reaction to the vibrating stimulus. We have proposed to include children of elementary age in the study and, in fact, have several volunteers who are eager to participate as soon as the additional PVTDs are complete. We expect that results from this first investigation will assist us in: (1) defining the parameters of vibration intensity and frequency that are comfortable for the children, (2) discerning whether the children will desire to wear the PVTD for a reasonable amount of time.

Once the initial phase of research is complete, we will seek approval to conduct a series of single subject investigations. These empirical investigations will explore the effectiveness of the device in relieving behavioral symptoms associated with sensory dysfunction (i.e., repetitive self-stimulation). For example, we may conduct several trials with a child who exhibits excessive hand-flapping, to see if the device may provide discreet and safe alternative stimulation and so reduce the occurrence of the disruptive behavior. A similar study may be carried out with another child who exhibits maladaptive biting. There is a wide range of self-stimulatory behaviors that may be exhibited by children with autism. Therefore, each investigation will be designed to address the specific needs of the research participant. These investigations will be completed prior to the 2010 Bio- and Medical Informatics and Cybernetics (BMIC) conference.

Long-range research goals for the project include the generation of several publications describing the effectiveness of the device. Moreover, we anticipate a productive collaboration with parents and professionals affiliated with a local school corporation. Such a partnership will allow us greater opportunity to assist a population of children with special needs and the adults who teach and care for them.

5. CONCLUSION

This report describes a project to develop a discreet device to provide sensory stimulation to children suffering from autism spectrum disorder. The goal of this device is to help these children better integrate into standard classroom settings. The current point vibration therapy device is approximately the size of a wrist watch and is worn on the wrist. Two vibrating motors provide stimulation that can be modified in intensity or the pattern of stimulation. The point vibration therapy interfaces with a graphical user interface on a personal computer where pertinent parameters can be set. The current point vibration therapy device has received Institutional Review Board approval, and units are being manufactured to begin patient testing.