DAMA: DESIGNING A MULTISENSORY GLOVE

MARIEL FRANCESCA I. REYES

Faculty of Information and Communication Studies

University of the Philippines

OPEN UNIVERSITY

College, Laguna

Philippines

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ACCEPTANCE PAGE

This special project titled Dama: Designing a Multisensory Glove is hereby accepted by the Faculty of Information and Communication Studies in partial fulfillment of the requirements for the Bachelor of Arts in Multimedia Studies.

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Adviser

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Date

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Program Chair

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Date

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Dean
Faculty of Information and
Communication Studies

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Date

BIOGRAPHICAL SKETCH

Mariel Francesca Reyes is a fourth-year student under the Bachelor of Arts Multimedia Studies program at the University of the Philippines Open University. A full-time student who resides in Santa Rosa City, Laguna.

ACKNOWLEDGMENTS

I would like to thank and acknowledge my thesis adviser, Diego Maranan for allowing me to adapt the Haplos technology for this project and for also allowing to use the UPOU Makerspace Lab.

Thank you to several of my relatives who inspired me to design a tool that they can use. To my friends and family who continue to support and encourage me in pursuing my program in UPOU.

And special thanks and mention to Dianne Dacio whose thesis gave me an idea on what to do with my special project.

Dedicated to:

My Mom. Thanks for the inspiration.

ABSTRACT

The special project intends to design a glove that incorporates vibrotactile technology for sensorimotor rehabilitation. The project is based on several previous works on the use of vibrating motors on the human body.

The project aims to answer the question if it is possible to design a tool that will help a person rehabilitate a part of themselves, and in the case for this project, it will be used on their hands since it is the most common sensorimotor organ.

The glove's design is based on several universal principles of design; perceptibility, operability, and prevention. This also includes the principle of Aesthetic-Usability Effect. The motors will be fastened on the joints and are controlled over a Wi-Fi connection through a software programmed in processing that uses patterns. The program or the software is a collaboration with a previous work called "Haplos" that also uses vibrotactile motors. The project combined the

use of motors and the LED lights that will create a multisensory stimulation (auditory, tactile and visual).

The focus on this project will be on the process of designing the glove itself, the testing process for the work will be considered for further the research.

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Chapter 1

INTRODUCTION

1.1. The idea behind the project

Stroke a common sensorimotor problem, this is one of the common diseases and the 2nd leading cause of death here in our country. It also includes a huge amount of money for the rehabilitation of the affected limbs (Baroque II, 2014).

The sense of touch is common to be related to the hands. It is also used to convey body language and sign language. It is therefore important that we have to maintain the hands to work, otherwise, it will be harder for us to feel, move or even communicate with everything around us. Although, it could not help that there are situations that we can lose our sensory and motor skills of the hands.

Since it would be a project by a multimedia student, the challenge will be to apply what I learned in the last four years I spent in UPOU. That would include for it to be something that uses new media technology while retaining its original purpose.

Ideally, it would be tested here in the Philippines, I noted several things such as is it economical? Is it relevant to our society? Will it encourage people to use my design?

My goal for this special project is to design a device that answers all of those questions. That is why I created the glove called “Dama”. Dama in Filipino means “sense” or “a feeling”, it is the root word for the Filipino term “ipadama” or “to feel”.

“Dama” is adapted from a previous work called “Haplos”, a vibrotactile technology that aims to enhance body awareness by applying vibrations on the back (Maranan, 2017).

Chapter 2

LITERATURE REVIEW

2.1. The Hand: a sensory and a motor organ

The somatosensory system is concerned with our perception of touch, pressure, pain, temperature, position, movement, and vibration. These are all felt through the muscles, joints and skin and tissues (Gleveckas-Martens, 2013).

A model created by Wilder Penfield called the “Cortical Homunculus” in 1923 represents how the somatosensory systems work and how our brain “sees” the different parts of our body. The distorted homunculus model describes the importance of the various body parts by how large they are represented. The larger the body part of the model, the important they are for the motor and sensory functions of our body (Inglis-Arkell, 2010).

The largest part of the homunculus is the hands. It is because they take up a lot of brain space to functionBenedetti (1994) stated that the hand is a sensory and a motor organ. It is both because the sensory functions of this organ should not be separated from its motor function. He then further explains that since we explore the world using most of our hands, the tactile information that travels from our hands to our brain plays a vital part in our motor skills.

The “active touch” or “haptics” is the continuous flow of the sensory input and the motor output. This meant that the organ uses the muscles, joints, and nerves as tools for acquiring information from its surroundings. The hand is used as a sensory organ if it is stationary and an object is moved across (“passive touch”), it is a motor organ if it is in motion (grasping, holding, pinching). Hence, the hand is truly a sensory and a motor organ (Benedetti, 1994).

The sensory functions of the hand utilize three main nerves, the Ulnar, Median, and Radial nerve. The Ulnar nerve (runs through the pinky, ring finger and half of the palm in the dorsal side) powers the most of the muscular functions of the hand and gives sensations to the forearm, small and ring finger. The Median nerve (half of the palm, middle finger, pointer finger, and thumb) is the one responsible for flexing and bending of the wrist and the fingers that it runs through. The Radial nerve (thumb and half of the palm in the dorsal side) straightens the wrist and fingers (ASSH, 2019).

The Motor functions use three types of joints at most, Proximal Interphalangeal Joint (PIP), Metacarpophalangeal Joint (MCP) and Carpometacarpal Joint (CMC). PIP joint's function is to bend and extend the finger while the MCP joint is responsible for gripping and pinching techniques and CMC joint is used to stabilize these motor skills (ASSH, 2019).

2.2. Vibrotactile Response

The skin is the largest organ in the human body system and touch is perceived as the easiest way to acquire information in the environment. There are two types of touch, the kinesthetic and the cutaneous.

Kinesthetic touch is our sensory receptors that are composed of the muscles, joints, and tendons that provide bodily motion. Cutaneous touch, on the other hand, is the "mechanoreceptor". Mechanoreceptors are the ones behind the ability of the skin to feel the pressure or touch. Combining the two sub-senses, it creates the "Haptic" interface.

The Haptic interface is "the communication of information through the sense of touch by the application of pressure, vibration or force" (Alahakone & Senanayake, 2009). The Haptic interface can be also classified into three displays, the tactile, kinesthetic and the vibrotactile. For this project, the focus is on the vibrotactile display.

"Vibrotactile displays are composed of vibrating components that deliver information through temporal parameters in the signal such as frequency, amplitude, waveform or duration" (Alahakone & Senanayake, 2009). The first vibrotactile feedback systems are introduced in the 1960s. It was applied to the rehabilitation for the hearing and visually impaired.

2.3. Vibrotactile Applications

Listed below are the different applications of vibrotactile displays.

2.3.1. Controlled Functional Electronic Stimulation

A study by the researchers from Arch Phys Med Rehabilitation made use of controlled electronic stimulation for vibrotactile rehabilitation of the hands of three patients in a clinic.

The device is controlled by the patients, giving them free rein to control the amount or the intensity of the stimulation. The purpose of the electronic stimulation was to test the subjects' maximum voluntary finger extension, maximum isometric finger extension, and finger movement control (Knutson, Harley, Hisel & Chae, 2007).

The protocol was to stimulate the hand within six weeks, each session was to test the volitionally opening of the unimpaired contralateral hand (Knutson, Harley, Hisel & Chae, 2007). While using electrical stimulation, the subjects are asked to perform different repetitive hand exercises for two hours.

The results produced positive reviews, there is an increase in the maximum voluntary finger extension, an increase in the maximum isometric finger extension and an improved finger movement control after one month in the rehabilitation technique.

However, the researchers noted that there is a decline in the subjects' improvement three months after. They suggest furthering the investigation of the study.

2.3.2. Potential effect on a vibrotactile glove rehabilitation

A study was conducted in Taiwan by a group of researchers to test the motor skills of the patients and to improve their upper limb functions. A vibrotactile glove was used for the rehabilitation system that is connected to a computer. The vibration motors are placed in the PIP (Proximal Interphalangeal) joint and MCP (Metacarpophalangeal) joint sewed in the glove.

There is a magnetic plate underneath the subject's hand for them to interact with the computer. This is equipped with a force sensor to gauge the pressure it is pressed by a finger (Ching-Wu et. al, 2017).

The subjects are engaged in a human-computer interaction game for thirty minutes twice a week for five weeks. Their motor performance was evaluated by a physical therapist every session.

They are also given a questionnaire to answer about the interest, duration, comfort, effectiveness and continuing participation.

The results produced a high satisfaction rate, eight out of nine subjects thought that the system is interesting, seven out of nine felt comfortable and eight felt that it was an effective way of rehabilitation. However, it did not yield any significant results that the vibrotactile glove improve the subjects' motor performance. They concluded that this is because of the short duration of the study (five weeks), small sample size and there was no control group (Ching-Wu et. al, 2017).

2.3.3. Haplos

Haplos ("caress" in Filipino) is a low-cost wearable technology for body-awareness. The device is made up of small motors weaved through a ribbon (it makes it more flexible than most of the vibrotactile technologies).

It is inspired by different researches in clothing design and human-computer interaction. As the name suggests, it is meant to caress the back where the motors are located. The technology works on patterns generated by software that controls the motors. The patterns are sent over the internet via WIFI module found on the hardware component.

The reason for the patterns is for the predictability of where the next stimulation will come from. After the stimulation, the subjects are asked to stand and walk around to have a feel of their body after the process. They are also asked to report if there are notable differences that they will feel to which are often noted.

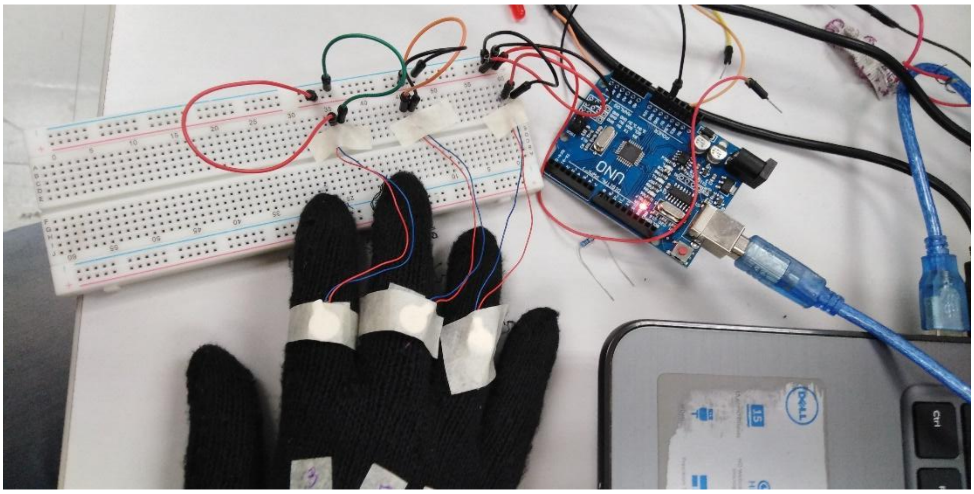
Haplos aims to enhance the human senses, particularly on how we perceive our bodies. Currently, there are two uses of Haplos, for body-awareness and for food cravings (Maranan, 2017).

Chapter 3

METHODOLOGY

3.1. The old prototype

The first prototype of this project is different from the current one. The original idea was to have eight motors attached to a glove. Each motor had a particular position according to the small research I conducted.



(Fig 1. Motor Testing)

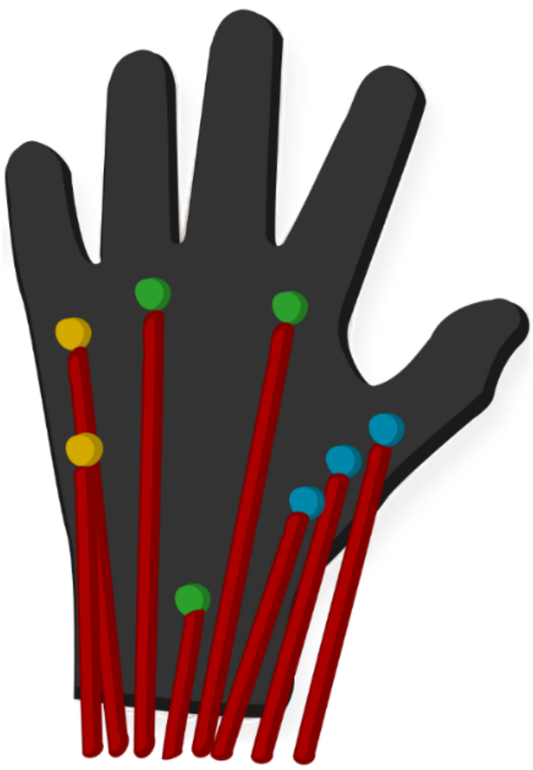
Motor one to three were to be set on the center of the wrist (one), on the base of the small finger (two), and on the base of the thumb (three). Motor five is on top of motor two and motors four and six is on top of motor three. Motor seven and eight are placed on the top of motor one.

These are placed according to the pressure points found in the hand. The first glove is focused on the muscles. There are three muscles that I have discovered to be important in hand movement, the interossei, the hypothenar, and the thenar.

The Interossei is the muscle that bends the MCP joints, the dorsal interossei pull the fingers apart while the palmar interossei pull it together. It is also the one responsible for the strength and the stability of a pinch (ASSH, 2019).

The Hypothenar and the thenar are the muscles that are responsible for the grasp motion. The hypothenar muscle is found at the side of the small finger and the thenar muscle is found on the side of the thumb (ASSH, 2019).

The idea behind those placements is that if the muscles are subjected to a vibrotactile stimulation it can rehabilitate the hand to regain a portion of the movement.



(Fig 2. The old prototype: motors are colored according to what type of muscle are they going to affect, the yellow motors for hypothenar muscles, green for interossei muscles and the thenar muscles in blue.)

However, there is a study that explains the difference of the application of the motors on the muscles and on the joints.

According to Frenzel et. al (2015), vibration, when applied to a tissue such as the plantar fascia, causes the relaxation and lessens the plantar stiffness. The project is not concerned with plantar stiffness, it is curious about the effects of the vibrotactile motors that can rehabilitate the hand and regain motor skills. Therefore, I changed a few things.

Another article states that vibration, when applied to the tendons, can an increase in muscle tonus. This is called the tonic vibration reflex (Park & Martin, 1993). An experiment concerning the tonic vibration reflex called the whole-body vibration attaches the vibration motors on the soles of the feet throughout the body rather than directly through the muscles.

As specified by the study, there is a slow tonic muscle contraction and low plantar-flexion force, however, when applied to the Achilles tendon there is an increase of both factors (Zaidell, Mileva, Sumners & Bowtell, 2013). The effect is more direct than the first one, hence, the reason to switch from attaching the motors on the muscles to fastening them on the joints.

3.2. The new prototype

The last glove was too simple. I began to think of ways to improve it aesthetically without losing its use.

The new glove is stitched manually. It is made from cotton ribbons that come in three colors. The motors will be fastened with the use of button-snap fasteners. Velcro is also attached for it to be adjustable to adapt to the different hand sizes.

The new design is based on the several universal principles of design. The first principle that is incorporated in the glove was accessibility.

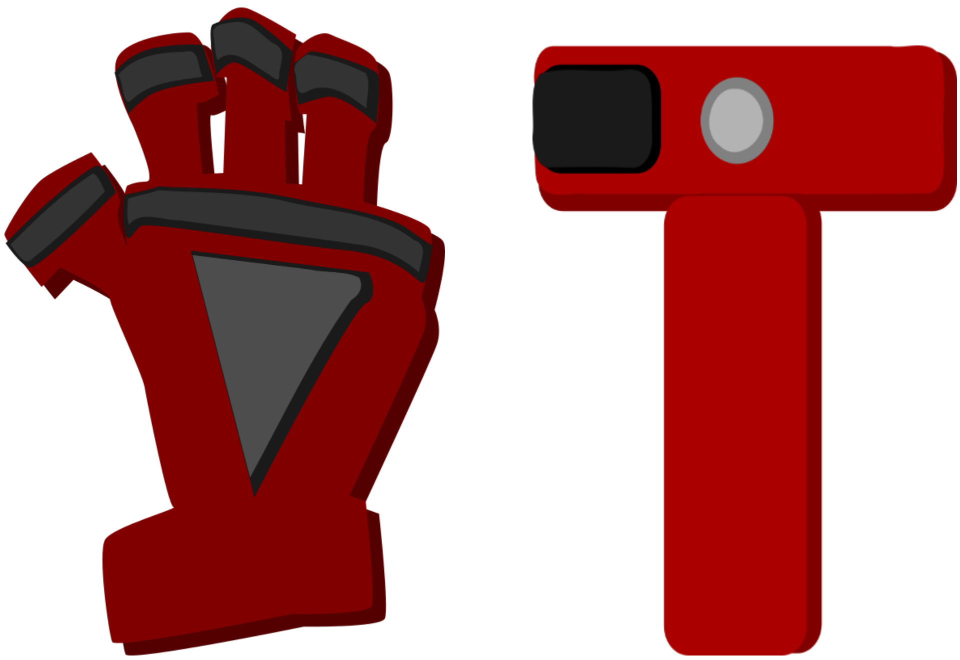
According to Lidwell et. al (2003), accessibility claims that designs should be able to be used by people who varied on abilities. Although originally it was intended for a person with a disability, accessibility nowadays should benefit anyone capable or not.

There are four characteristics of accessibility that I integrate into my design. Perceptibility (the design is easily perceived), the glove was made be seen clearly by combining colors that make them stand out. Operability (the design is easy to use), the glove has Velcro which is easy for the user to put on the glove and metal fasteners for the motors to be placed without difficulty. Simplicity (the design is simple, follows “less is more”) the glove is designed without complicated features and includes only the necessary parts. Adaptability (the design minimizes errors that it may encounter by adapting to suit what the person may need), the glove is reversible to prevent having to create a multiple and it is adjustable to suit different hand sizes.

The second principle would be the Aesthetic-usability effect. Aesthetic designs are effective at bringing up positive attitudes. They also look easier to use than non-aesthetic designs because attractiveness based on a study makes it tolerant of the problems the design can encounter (Lidwell, Holden & Butler, 2003).

The motors on the first design were planned to be placed on the muscles, the second one is placed in the joints.

Motors one to three is placed on the PIP joints, the ones responsible for the fingers to bend and extend. The motors four to seven are on MCP joints, the ones in charge of the grip and pinch motion. Motors eight and nine are on the CMC joints, responsible for the stabilization of the hand motions.



(Fig 3. Sketch for the new model of the glove prototype. On the left is the whole model and on the right is what it will look on the inside where the motor will be attached (the black part is the Velcro and the silver part represents the metal fasteners.)

The second prototype is hand sewed and it is created with the use of cotton tape for the whole structure, Velcro for the glove to be strapped to the fingers and the wrist, and metal fasteners for the motors to be attached in the glove.

It is noticeable that there are only four bands for the fingers stitched in the glove. The reason behind this is to test the study of an article for *The Journal of Neuroscience*. According to O’ Callaghan (2009), smaller fingertips are more sensitive because it has a denser sensory receptor due to the less surface area.

The research conducted an experiment by testing the index fingers of different people and it is found that smaller fingertips are more sensitive because of its lesser surface area, the receptors are closer together, thus, it will have a finer sense of touch (O’ Callaghan, 2009).

However, instead of the index finger, I chose the pinky finger to experiment, since it is the smallest finger it would have a finer sense of touch because of its lesser surface area. If we would attach the motors on the remaining fingers, it will be felt by the pinky finger regardless. It would also bring character to the glove and might draw in curiosity from others from the way it was designed.

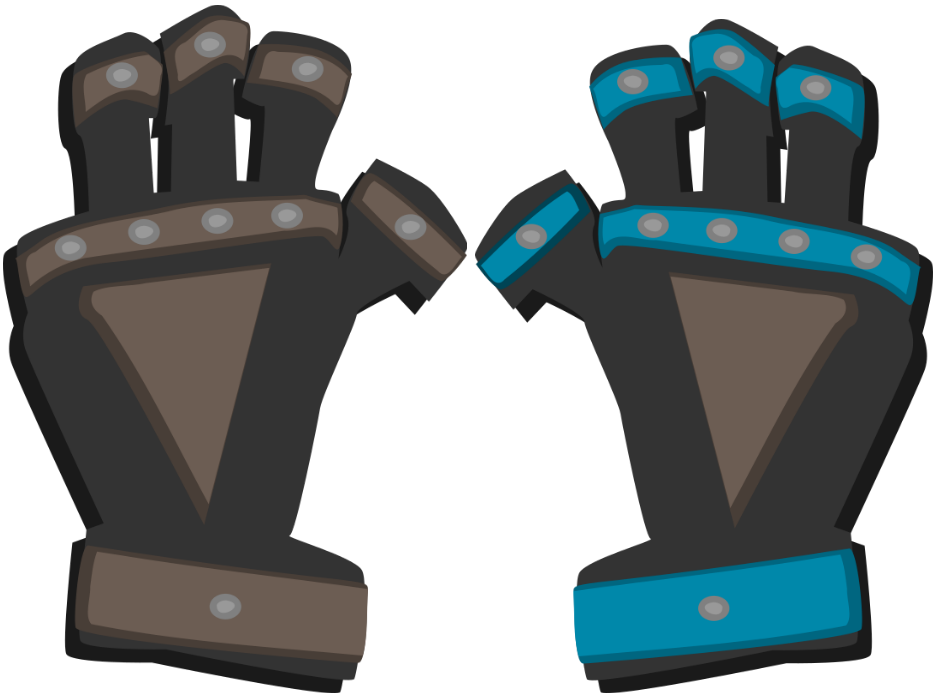
(Fig 4. The second prototype made from cotton tape and was manually sewn by hand.)

Above is the photo of the actual prototype in dorsal view. The first prototype did not have an actual model because I changed the plan before I made it into a real one.

3.3. Reversibility

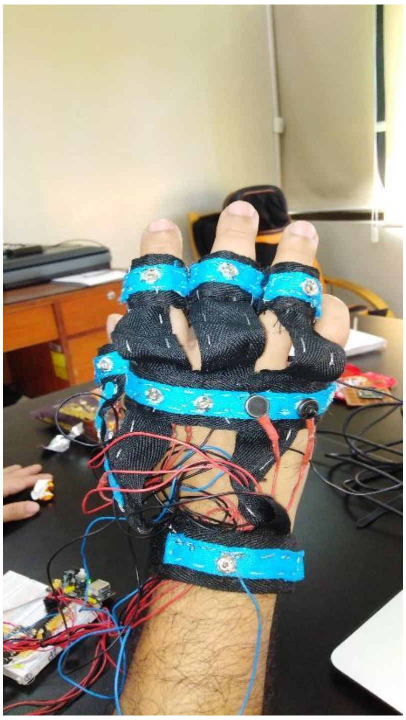
The second prototype can only be worn on the right hand. After I received feedback from my project adviser, I decided to follow the advice and make it something that can be both worn on either left or right hand. It should be reversible to save materials and time effort on the production and wearing process.

To be able to distinguish which side is for the left and for the right hand, I added a color code function by reusing the black bands in the glove as an indication rather than a mere décor for the reversibility purpose of the prototype glove.



(Fig 5. Reversible glove)

The cotton bands that are colored gray are to indicate that this portion is to be used on the left hand when it is faced upwards and the blue cotton bands on the right hand. This way it will be easier for the user to use either side without any confusion on their part, this saves their time and effort to put the glove on.

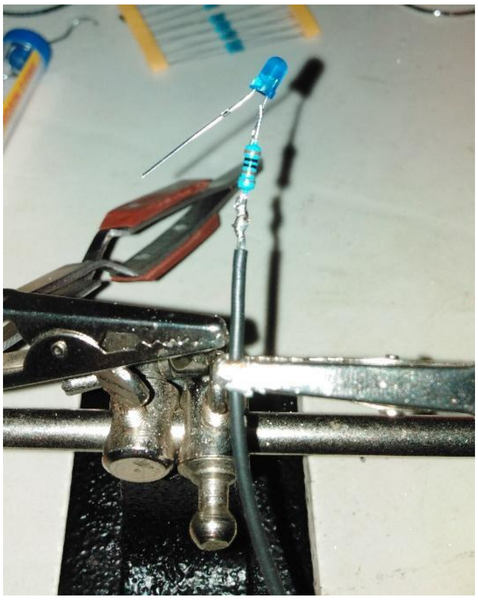


(Fig 6. The actual model of the reversible version of the glove (left) and what it looks like when worn by the subject (right).)

The motors are still attached on the metal fasteners underneath the glove. Motor wires will be banded together for it to look pleasant and neat.

3.4. LED Lights

Aside from the motors, I attached a couple of LED lights on the opposite side of where the motors might be. They will act as an indicator that the motors are working fine and will reduce the time of troubleshooting them.



(Fig 7. An LED light with a soldered resistor to be attached on the glove.)

LED lights combined with the Haptic motors can create a multisensory stimulation. Multisensory stimulations are the modern way of rehabilitating the sensorimotor functions. According to Johansson (2012), the brain has a large capacity to automatically process stimulations and integrate sensory information.

When we combine some of the information from our senses together, it will be easier to detect, discriminate and recognize the sensory stimuli that the brain processes for us (Johansson, 2012).

By stimulating both the eyes and the hands with the use of the LEDs and the motors, the rehabilitation process will be more effective when applied.

3.5. Collaborations

For the software part of the program, I collaborated with Diego Maranan, the creator of the Haplos Technology to create a program for the prototype glove that I now called E-Dama.

The main program for the glove is created in processing, open-source software that acts as a sketchbook for new media programmers and visual artists.

The firmware for the program is then uploaded in a circuit board called particle photon through its WIFI module. The program code and its firmware are both modeled from the original code for Haplos with certain changes to accommodate its new function as a sensory-motor rehabilitation device.

The program will use patterns. These patterns are used so that the users can anticipate where the next motor will vibrate.

In addition, the patterns are based on music. Music, when used in rehabilitation, can be effective because according to Antonietti (2009), it can relax a person, they can be motivated with the positive attitude that music induces. Moreover, it can activate the behavior and mental operations that are needed to be rehabilitated. Music, as Antonetti stated, is a “visuospatial” component that can translate audio into images (Antonietti, 2009). Thus, by applying music into the patterns the subject can envision the patterns in their head.

3.6. Ideal Protocol

The vibration patterns will be administered for two minutes. After trying the glove, myself, applying vibration for more than three minutes, at the least, on the skin caused slight itchiness. To avoid any other discomforts the time was narrowed down to two minutes after applying tests.

After the two-minute mark, the subject will be asked to rest their hand (the one that the glove is placed) for half a minute. The researcher then would ask if they felt any discomfort or any sudden changes. Afterward, the researcher will ask the subject to slowly open their hands.

The vibration will be applied several times then after the resting time, the subject will be tasked to do simple gestures from the simple open-hand process to gradually gripping an object.

Feedbacks about what they feel and rating their difficulty in doing the task will be recorded to further the improvement of the glove.

Chapter 4

THE CONCLUSION

I learned new ideas from this project. This also challenged me to think outside the box. That is how I answered the questions from the start as I go along with the project. I designed a low-cost reversible glove to be used by a large population in our country that is able to adapt to different hand sizes and it is easy to use, thus, the people who will use it will not be hesitant to try.

The next step would be to test the glove itself. The test will include the use of the ideal protocol and the data that will be collected will help to improve it. It will pose new questions. Questions such as will it work on a person to regain some of their sensorimotor skills? If not, what will be the other ways to be applied for it to work? Moreover, the design could change depending on newfound ideas as the research is explored further in the future.

Nevertheless, vibrotactile technology, indeed, has come a long way yet it is a new concept that will open new doors for different uses. From its use on videogames to the medical field of rehabilitation, this kind of technology will fit in the ever-changing society that we live in today.

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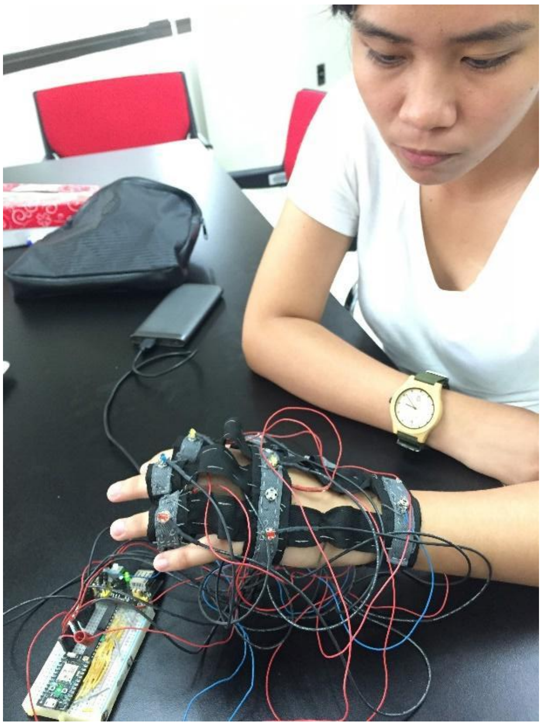
APPENDIX

(Fig 8. Materials for the “Dama” project.)

(Fig 9. Gray over blue indicates to use the left hand.)



(Fig 10. Test the combined use of LED lights and vibrotactile motors.)

(Fig 11. The wires are banded together)

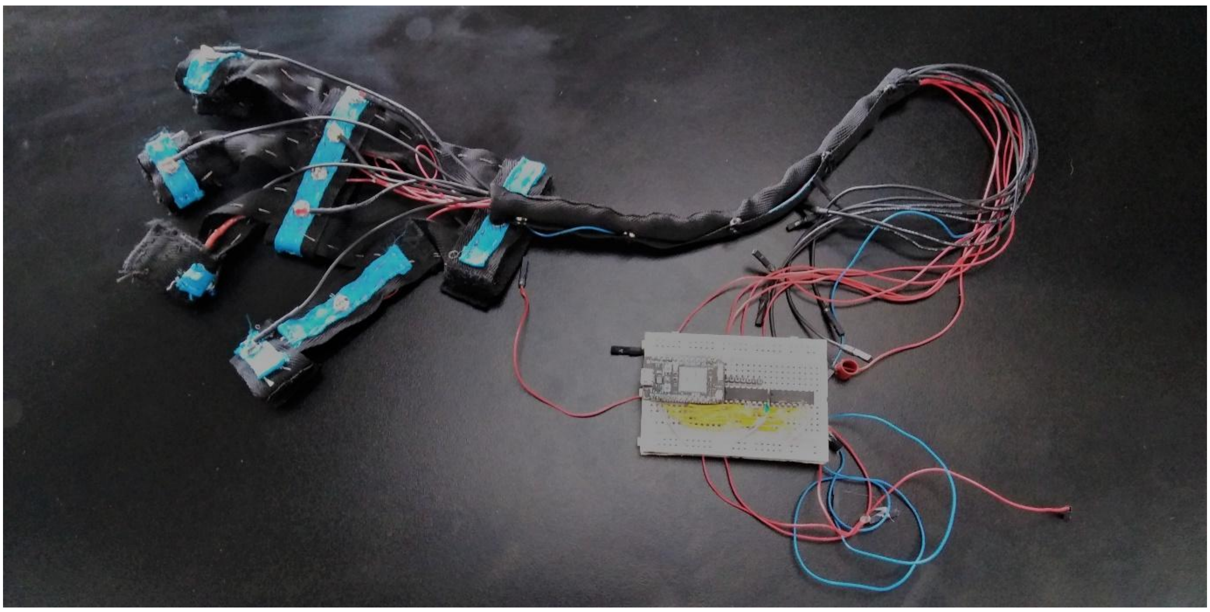


Fig 12. Full view of the project “Dama”.)