SOFT ROBOT DESIGN TO SUPPORT COMMUNICATION FOR CHILDREN WITH AUTISM SPECTRUM DISORDER

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Soft Robot Design to Support Communication for Children with Autism Spectrum Disorder

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Our study investigates the advantages of using soft robots to help children with Autism Spectrum Disorder advance their social skills focusing on speech development. The field of developing robots for therapeutic use is still relatively new. The studies thus far have had positive responses and progressive data with majority of the users. Further investigation of their application in varying clinic settings will be important in aiding those with intellectual and developmental disabilities. Autism Spectrum Disorder is a chronic disease however many patients have proven that varying practices and therapeutic activities can help advance their motor and communication skills no matter their level of disability. We designed a soft robot utilizing mechanical motion and sound appealing to our target users. The prototypes we created test varying interactive components encompassing visual responses, sound features and kinetic movement. Our varying iterations of prototypes explore the best visual feedback for engaging the user and enticing them to continue speaking. We believe our developed soft robot when interacting with the ASD children will help improve their speech and communication development and relax them in stressful environments.

CHAPTER I

INTRODUCTION

Children with Autism Spectrum Disorder share a fundamental inability to relate to other people, a failure to convey meaning with language and an obsessive desire with sameness. This is a chronic disease, but not static; therefore, each child diagnosed with autism has the potential to progress and develop their skills in terms of inter-personal relations and communication. Our research is centered on developing tangible, soft robots that can help children with autism feel more comfortable interacting in their daily lives.

Motivation

We believe soft robots will be able to help autistic children with both speech development and relaxation in stressful everyday events. Children from the ages 6-12 face many transitions from familiar routines to new learning environments, new peers and new adult figures. This can pose as particularly challenging for kids with autism because they have an inclination to want everything to stay the same in their daily routines. By pursuing research in developing soft robots for children with autism, our prototypes can be used to help them feel more comfortable and accepting of change when these transitions occur.

As stated in *Interactive Technologies for Autism,* it is widely accepted that computing applications in multiple domains are largely successful when used by individuals with autism. Because various interactive works have been proven to be effective in the past, we are confident that our developed soft robot will help aid children with autism. Using robots to interact with children with autism allows for abstracted information, more predictable and repeated interactions, routine that is explicit with consistent rewards/consequences, and ability to change interaction based upon an individual's particular cognitive skill level. These abilities combined are what help make the robotic interaction more calming and relatable for the children with Autism Spectrum Disorder. With the completion of our research, we suspect to see progressive results in relaxation and skill development in our user studies with our soft robot.

Research goals and questions

Through designing and developing a soft robot for children with ASD, we hope to accomplish the following tasks in the course of our research. We aim to understand the current research trends in soft robots for children with ASD. Researching designs and prototypes that have been developed in the past can give us insight into how effective different approaches will be once implementing them into our robot design, so we will spend time learning about what's been done already and how we can build onto that. Our next goal will be to develop a soft robot to help autistic children with speech development and relaxation. As we explore different designs and kinetic movement in our soft robot, we will also experiment with various soft materials and hopefully develop a speech application that will be integrated with the soft robot. Once we have various prototypes made, we will aim to create a finalized design for a prototype that will both be engaging and will promote speech communication in children with autism. After the completion of this research, we hope to continue our studies to test our finalized design in user studies at the local Autism Clinic in Bryan, TX. We hope to explore the effectiveness of the soft robot in creating an interactive and productive environment for the children.

CHAPTER II

BACKGROUND AND RELATED WORK

According to Morbidity and Mortality, Weekly Report of Centers for Disease Control and Prevention in 2014, it's estimated that 1 in 68 children have been identified as having Autism Spectrum Disorder (ASD). Approximately 1 in 6 children have a developmental disability, ranging from "mild disabilities such as speech and language impairments to serious developmental disabilities, such as intellectual disabilities, cerebral palsy, and autism." [5] As shown in the article reviewing the various methods that have been thus theorized and explored in order to help children with ASD, many approaches have been taken.

Many methods that have been explored have tested the relationship of children with ASD and the primary source of information or instruction. Most research studies, explorations, and anecdotal evidence tends to agree that those on the Autism spectrum tend to respond better to robots due to an intrinsic fascination with technology [1]. Because of this, there are robots that have been created with the express purpose of helping those with ASD in the pursuit to improve many intellectual and developmental disabilities. *NAO Evolution Robot* focuses on mimicking actions and movements as well as interactions that help with motor skills and communication [6]. A humanoid robot, *Milo* explores the idea of delivering lessons to children with ASD in hopes that delivery of material by a robot will be more effective in teaching than a human interaction would. They've taken many steps to make *Milo* somewhat realistic so that it helps bridge the gap between robot and human interaction [7]. Both these robots, among others are geared to help social, cognitive, and motor behaviors of children with ASD.

Touch interaction

As stated in the "Sensory Integration" article, many autistic children are hypersensitive to touch [2]. Observations have shown they will often gravitate towards "...smooth wood, plastic and soft fur" to run their hands over for hours [2]. Similar to young children growing up, soft materials such as blankets, pillows, stuffed animals, etc. are objects that make them feel safe and comforted. Creating the exterior of the robot to be made of soft materials will entice the children to touch and play with it for an enhanced interactive experience. Some robots have already been developed with a similar approach. *Paro*, a baby seal robot developed to calm elderly patients, has a soft fur exterior to make the interaction with the robot enjoyable for the users [4]. Having an exterior that is inviting in the eyes of the user draws them in to interact with the robot.
Not only will a robots pleasant exterior entice users to play with it, but the interactive movement will as well. Studies have shown that "...individuals with ASD prefer interactive robots compared to passive toys" [1]. A soft robot named *Huggable* was developed for therapeutic purposes at Boston Children's Hospital. A young patient was able to interact with the bear by talking and hugging it. In turn, it interacted with her by responding with movements and sound. This was very effective in making her stay calm in the hospital environment when "...normally she would go off the walls"[3].

Research has also shown that children with ASD tend to respond well to touch-based programs on hardware such as a tablet or computer screen. The portability of smartphones, tablets, and toys tend to make them all very accessible for teaching and learning with those with ASD and therefore sometimes more preferred than stationary methods. Interactive and touch technologies allow the children to integrate their learning into their everyday lives. These robots and mobile applications also allow for the children to develop language and social skills through shared interfaces and social imitation. These compelling reasons for touch interaction beg more research to be done in the area of soft touch, kinetic methods of teach and learning.

Kinetic design

As stated in *Interactive Technologies for Autism*, thus far in research, the primary focus has been the study of socially assistive robots. These robots are to enable individuals with autism to learn, engage in, and enhance social-emotional skills. The interaction children have with robots does not have to only be with touch. There are many developed robotic toys that can move location as well as move body parts when reacting to touch or sound. One of the more successful kinetic robots that are available to the public would be MiP by WowWee. This is an interactive robot that self-balances on two wheels to move around the space therefore has a wider range of interactive possibility and character because of this added level of movement. Robots that are stationary that can only react to touch can only mimic social interactions up to a certain level. Robots that have kinetic movement, such as moving location and moving certain elements of their body, will have a more engaging social interaction with the autistic children.

Kinetic movement is an important aspect to develop in robots for children with autism because it makes the gap between robot interaction and human interaction much closer. Children with autism have shown to interact better with robots than their fellow peers because they feel more comfortable with that type of interaction. This gives researchers the ability to understand their reactions and development more clearly because robots "...can collect more qualitative data rather than biased qualitative observed data"[8]. Robots also have more consistent actions and stimuli than humans making the data collected more reliable and repeatable. Further studying children with autism and their social interactions with robots can help lead to furthering their social skills with their fellow peers. Imitation is an important aspect of mediating social interactions and robots that can more closely mimic human interaction is shown to help develop these skills. Developing robots that can have a wide range of interactive feedback will be more effective in progressing these skills therefore kinetic movement is key to developing robots that can help enhance social interaction skills in children with autism.

CHAPTER III

METHODOLOGY

We created various iterative soft robot prototypes for children with ASD primarily through the exploration of visual feedback. We believe that the best way to determine which soft robot will be most successful is to fully develop each iterative prototype idea and create functioning robots to test. Because we are creating a soft robot for children with varying levels of communicative ability and developmental disabilities, we have to consider how they would interact and react with our prototypes depending on their different cognitive and speech levels. Having a tangible prototype that you can personally test all different scenarios of interaction with our target audience is the approach we are going to take when trying to determine how effective the robots are in their interactive communication.

Based on our research and preliminary observation, we plan to first pursue light as one of our primary forms of visual feedback for the children. These prototypes will utilize various LED lights, soft fabrics, and triggering methods. By exploring all these different materials and aspects, we will have a good knowledge of what combinations of materials work best for engaging children with autism. After creating a design for the exterior of the tangible artifact, we will then explore different mechanics of how the child will be able to interact with the artifact in order to trigger the LED lights as a visual response to their interaction. Specifically, we hope to trigger the LEDs as a reaction to any verbal inputs. There are many components such as buttons, wireless remotes and possible audio Bluetooth chips that we plan to explore and test to see which is the most effective in giving light responses to the child as they progress in their speech skills.

The second visual feedback we plan to pursue is kinetic movement. This visual will be a direct response after the child has been vocal to their therapist or parent to continue encouraging them to speak. We plan to start by constructing a robot from an Omni Wheel Kit. After having this robot functioning at its foundation level, we will then start developing our designs for the various prototypes further. While exploring and cultivating our designs, we will also develop different movements that we can use as different responses to different speech elements. We plan to further research different mechanics to trigger and control the robot's movement from Bluetooth chip, mobile phone app, and wireless remote.

After exploring as many iterations of both light and kinetic movement feedback as possible, we will then determine which mechanics and materials will serve best in creating a soft robot to help children with autism develop speech and communication skills. We will then complete our research by creating and developing our final prototype design to present and hopefully progress to user studies after the completion of this research.

While we are not able to complete user studies in the scope of this research, this is how we plan to approach them in the future. We plan to gather and record data regarding the effectiveness of our soft robot prototype for children with ASD primarily through a participatory design. We believe that the best way to determine how successful we have been with our design is to receive information directly from the people involved in using the robot, including the children, parents, and therapists. All active participants will be recorded both in the use of qualitative and quantitative methods.

The Soft Interaction Lab led by Dr. Seo has been working with a local Autism Clinic in Bryan, which is where we would primarily recruit our clients for our research. Because we are limited to the Bryan/College Station area, we are limited in our sample population in which to conduct our studies. However the children present at the Autism Clinic exhibit a large range from high functioning autistic children to non-verbal children, therefore providing us a good selection of children with varying speech communication and developmental disabilities to have interact with our robot and record our data from.

To recruit our participants, we will send out an initial email describing the study to gather eligible children to come partake in the study. After the parents of the children respond back with their interest to participate, we will have them fill out a survey before showing up the day of the study. The survey will request basic information such as age and gender of their child as well as information more directly related to their level of functioning in everyday activities. We will ask for them to describe the range of our client's disabilities in social engagement and speech development. Our desired candidate will range between low functioning to non-verbal children with autism.

Upon the participants arriving the day of the study we will first talk with the child's parents as well as the therapist to get to know the child's normal reaction to new environments so we can take precautions to make them feel comfortable. The user will then be given the robot to play with while we gather observational data of their interactions with the tangible robot. Personality or mood changes, facial expressions, sounds or speech expressed, and the extent to which the child touches or physically interacts with the robot are just some of the observations we will be recording. The robot will have customizable parts that the user will be bale to change at any point in time they desire which may change the process of their interaction and engagement with the robot. After we feel the child has had an appropriate amount of time with the prototype, we will talk to the therapist and the parents to gather and record their observations and insight on the child's response changes they felt the robot did or did not generate.

The quantitative data gathered will include information received from surveys given to the clients following the child interacting with the robot. The survey will include question's prompting the clients to record the varying speech communication and responses they felt were enhanced and encourage because of the robot's interaction with their child as well as any other behavior they felt was effected or stayed the same during the interaction. There will be video, audio and photographs taken during the duration of the study session to record the interactions of the children for further review when looking at all the data recorded.

CHAPTER IV

DESIGN STUDIES

In order to address the issue at hand, we found it important to explore different practical and design solutions for the problem. Through various brainstorming sessions, prototypes, and iterations as well as a lot of trial and error, we have made great strides in helping children on the Autism Spectrum with social and communication skills.

Prototypes

We started our design process with a couple of different prototypes. Our first prototype used a pillow-based design. Our goal was to create a pillow that specifically worked with children on the Autism Spectrum who were mostly or completely non-verbal in communication. We planned to design the pillow with a LilyPad Arduino board and sew-on LEDs in order to have it light up when it received some sort of input. The pillow would have the LEDs sewn onto the front side of the pillow with a case covering for the pillow, allowing the lights to shine through the fabric with an ambient glow. The LilyPad Arduino would be sewn to the back of the pillow and connected to the LEDs using conductive thread.

Our second prototype focused on a soft, kinetic robot. A lot of studies have shown that children with ASD tend to respond well to kinetic stimulus, so we wanted to explore this method for improving social and communicative skills by creating a toy that would respond specifically to audio input. However, with the robot, as compared to the pillow, it would physically move instead of just lighting up. We decided to use an Omni wheel robot kit that we planned to create a soft cover for in the shape of a gumdrop.

Iterative design process

The first iteration of our pillow design utilized a star shaped pillow covered with a water-resistant, purple fabric that allowed our pink lights to shine through in a complimentary color. The child we were told would be using this pillow tended to have issues with putting things in his mouth, so we thought a water-resistant fabric would be best to insure that none of the componentry of the pillow were at risk nor would the child be at risk of any electrical malfunction—however rare that would have been. We also wanted to explore irregular, interesting shapes for the pillow itself so we though a star shaped pillow would be worth exploring. For this iteration, we included a long cord with a button switch that would allow the therapist to trigger the lights when the child attempted to use verbal forms of communication instead of an actual auditory trigger.

Upon receiving feedback from the child's therapist we learned some useful information. Firstly, the lights somehow calmed the child enough that he had no desire to put the pillow in his mouth. This meant that we did not have to limit our fabric options as much. Secondly, while the star shape was interesting, the therapist said that the child responded very well to a character named Daniel Tiger, and she said it would be interesting to explore the inclusion of this character in the next iteration of the pillow design.

For the second iteration of our pillow design, we used a circle shape in order to allow space for an appliqué of Daniel Tiger's face, shown in Figure 1. We also felt that the round shape of the pillow was more familiar for the child and gave him more to hold onto during the therapy sessions. We chose bright blue and a yellow fabric with a subtle pattern for the pillow itself in a cotton material. We used yellow lights framing Daniel Tiger's face to compliment these colors. This iteration included a Bluetooth connection that still allowed the therapist to manually trigger the lights when the child attempted verbal communication, but without the cumbersome wire.

Figure 1: The above image shows the second iteration of the pillow prototype designs. They both have light feedback and use various wireless remotes to trigger the light patterns.

For the kinetic robot design, our initial prototype was built from an omni wheel kit. The interior hardware of the robot consists of an Arduino Uno board, a MasterShield board and a battery pack to power the devices. The program coded for this prototype had the robot move along a preset path that looked like random meandering from a third party viewer so as to be more interesting than a simple circle path. The robot moves within a set five foot by seven-foot space yet the robot can move along this path in a continuous loop ending where it would begin. The omni wheels are attached to the M1, M2, and M3 inputs on the MasterShield while the battery's positive and negative lines are attached to the Vin and the Ground pins on the Arduino Uno board. The Robot can move forward turning in both directions and have various speeds however it cannot be changed from this pre-set path.

The second iteration of the kinetic robot consists of the same hardware materials however with the addition of a Bluetooth chip attached to the Arduino Uno as seen below in Figure 2. The Arduino is loaded with a program that has the robot respond through the microphone input of an

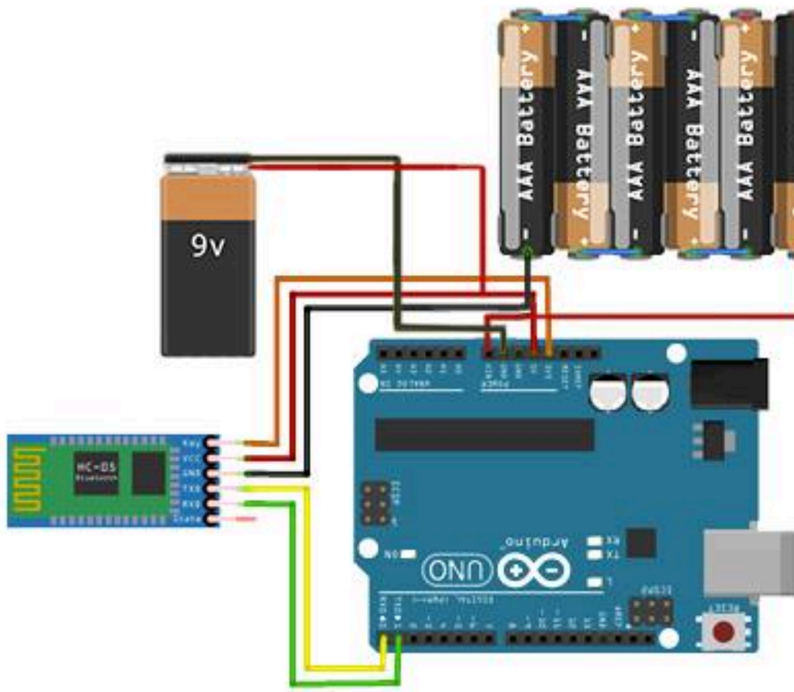

Figure 2: The above image is a circuit diagram of the final kinetic robot hardware wiring. It includes an Arduino Uno, triple A batteries, a nine volt battery, and a Bluetooth chip.

Android phone by connecting with the Bluetooth chip attached. The robot still moves along the pre-set path however with the varying sound levels recorded into the microphone of the Android phone the robot will move at a faster pace with the corresponding level of vocal recognition. The user will be able to see the changes in the robot's motion and speed corresponding to their speech vocalization, which will entice them to be more responsive in hope of watching the robot change and move faster.

For the soft cover of the kinetic robot we went through many ideas. One of the first ideas that we explored included an octopus. We even talked about including hats for the octopus to wear. We then moved on to more familiar animals such as a cat or a rabbit. We thought that these animals might be limiting, as children tend to have more set opinions for commonplace animals. So we ended up spending much more time fleshing out designs for a fish and designs for a bird. We ultimately planned to use the fish design because we decided that the movement of the robot itself best matched the movement of a fish. We also thought it would be fun to explore the idea of removable, customizable pieces for the fish.

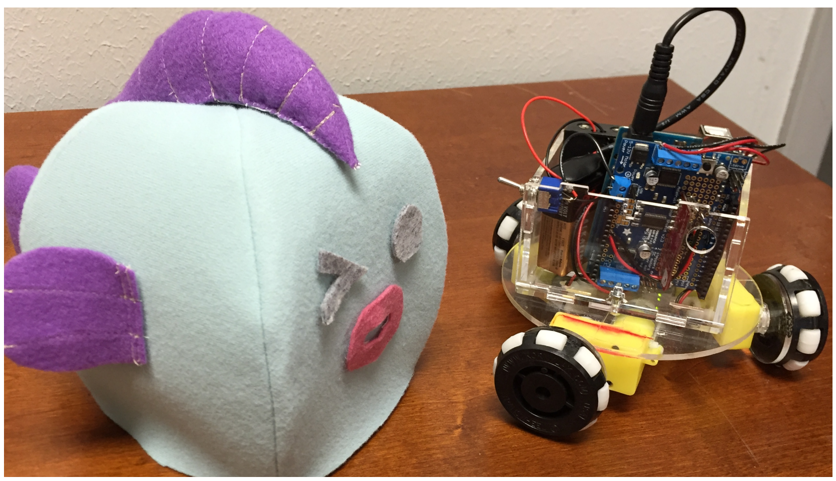

Figure 3: Above is the final exterior of the kinetic robot design on the left and its interior hardware shown on the right.

Final design

Our final soft robot design is a dome shaped exterior with customizable options for the child to choose and make the robot their own. The exterior will be made of a soft material called Veltex that will allow the removing and adding of features to be simple because it acts similar to the soft side of Velcro. As seen in Figure 3, the current primary pieces that can be attached to the dome consist of fish attributes, but hopefully in the future we will be able to create other animal attributes as well. Adding this level of customization between different fins, facial features, and tails the child will become more attached and engaged with the robot before being prompted to speak to see it move. The kinetic movement for the robot will be that it remains immobile until the child speaks to trigger its movement. To control the movement the child will speak into an Android phone that is running our app. In the app that we've developed, the interface consists of one button that they or their parent/therapist can press to hold up to the child's ear to then record the audio level of their speech. This mechanic of talking into the phone is very familiar in our society today therefore it should be an easy motion that the children will be comfortable with. The threshold for the audio is customizable. It can be catered toward each individual client depending on their speech abilities and how loud their speech levels commonly are. If the audio recorded into the phone is above the preset threshold then the robot will move in a weaving circle. If the child does not speak above the threshold then the robot will shake back and forth as if saying no but still encouraging them to want to see more movement. The children will be able to interact and watch their customized robot move around the room controlled by their verbal skills.

CHAPTER VI

CONCLUSION

Through our research and initial interaction with a child on the Autism spectrum, we learned that developing social and communicative skills in children with ASD is an important task. We also found through this process that children with ASD tend to respond most to kinetic stimuli in comparison to both auditory and visual stimuli. Because of these findings we thought it most prudent to finalize our design and conduct our future studies using the Omni wheel robot and the soft cover currently designed to resemble a fish.

Our pillow prototypes with the visual light feedback were successful in creating an interesting visual response for the child after they gave vocal responses. With this design we were able to gather user feedback from a therapist who works at the Autism Clinic in Bryan. The star prototype with the wired button trigger was used with a child with autism by the therapist. This prototype with the light patterns seemed to create a calming effect and the child seemed very relaxed while watching the light responses. Our pillow prototypes, such as this one, were not successful in having hands on interaction from the child to robot because the therapist was the one who determined when the pillow would light up. This system of having the therapist decide when the child's speech was acceptable for visual feedback was effective in giving a visual response to the child for encouragement however it created a disconnect between the direct interaction of the child and the robot.

Our kinetic prototypes with kinetic movement feedback we believe will be successful in creating an engaging environment for the child to interact in. We're confident that the final soft robot design with the Bluetooth connection to the Android phone will create a direct connection between the child and the robot based off of preliminary research and observation. The users will personally be able to control the robot by giving vocal responses into the phone without the need of the therapist or parent to trigger the robot. The customization of the robot's exterior design enhances the hands on experience and connection the children with autism will be able to have with the robot. This type of one-on-one connection we believe is the most effective approach in encouraging the children with ASD to give vocal feedback. Because the robot will have a set threshold value that the child has to reach to see the robot weaving in a circle, it creates consistent visual feedback when they do not reach that threshold. Having familiar responses from the robot the child learns through repetition what vocal levels they need to reach in order to see the direct response of movement. This process helps encourage communication skills with the robot as well as enticing them to continue speaking out loud and developing their speech skills.

Based on the research and current feedback, we're confident that our soft robot designs can positively affect the world of Autism therapy. We're hopeful that in the near future and beyond we'll be able to conduct our user studies in order to glean even more information and feedback with regard to the current research and designs we have in order to better inform our future iterations. Our hope is that the results we'll be able to discover through user studies can affect the way therapists; parents, educators, and other people who interact with children on the Autism spectrum interact with and teach those children on a daily basis. Hopefully this improves daily life not just for children with ASD, but also for everyone around them as they learn to better communicate and engage in social behaviors.

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