Customizable Textured Tablet Case and Magnetic Prompting System to Improve Communication for Children with Autism Spectrum Disorder

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Customizable Textured Tablet Case and Magnetic Prompting System to Improve Communication for Children with Autism Spectrum Disorder

by

Christina Maragioglio

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

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December 2017

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Abstract

As Autism Spectrum Disorder diagnoses increase in prevalence, there is a growing need for assistive devices to help meet the communication needs of each person and their own unique set of challenges. Autism is a neurological disorder which most prominently impacts communication and social skills but can impact each person differently by way of coupled conditions. Of these conditions, two of the most common with Autism are Sensory Processing Disorder (SPD) and Motor Skill delays. Additionally, to help with communication and language development, Augmentative and Alternative Communication (AAC) techniques are often used, with tablet AAC applications being one of the most portable and economical solutions in alternative communication available today. With the current options for tablet cases, specifically for AAC communication, the coupled conditions of Sensory Processing Disorder and Motor Skill delays were not considered in their design or functionality. In order to make tablets with AAC applications more accessible for the children using them, an assistive tablet case was created. This tablet case design incorporated a magnetic overlay to provide motor skill assistance and prompting without unnecessary sensory input, interchangeable textures to improve sensory experience as well as stability features including a shoulder strap, stand and handle. Trials with a functional prototype and a tactile sensory board were performed with a Speech-Language Pathologist in the context of her therapy session. From the functional prototype trial, it was found that cursor prompting system was effective in providing elevated prompts when necessary and that an interest in the texture may be based on the maturity and diagnosis of the user. From the sensory study, it was found that there were trends of preferences for both texture and interaction type. Additionally, it was proven that the textures provided could be used for effective self-regulation. The design of this tablet case and study of its use create opportunities for the improvement of assistive devices in emerging technologies as well as exploring the concept of prompting without the use of human interactions.
Acknowledgements

I would like to first thank Dr. Schrlau for having confidence in my project and taking on the challenge of learning about Autism with me. Although at times my project would require intense brainstorming and some wood and hot glue prototypes, you were always there to support the small victories and keep me motivated along the way. By giving me the opportunity to work on my own project, you have given me both the freedom and confidence to forge my own path at RIT and in the future. Thank you for being a such a strong advocate for all members of the NBIL and always empowering us to succeed.

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This project would not have been possible without the wonderful members of the Rochester community who have provided me with the opportunity to gain experience with these children and help me learn from them through testing. Especially, I would like to thank the Brown Family Foundation for their generous funding, AutismUp for giving me the opportunity to help with community programs and Tina Frank, SLP, for having faith in my device and testing it in her classroom.

I am also incredibly grateful for the wonderful people I have met through the NBIL. My many lab mates throughout my time in this lab – Anna, Ryan, Olivia, Adeel, Devarsh, James, Koby, Shkenca, Peter, Leah, Neil and Atrisa – have been great company during my research and prototyping. Thank you for making sure I am safe from hazardous chemicals and answering all of my biology-related questions. I will miss our trips to Indian buffet!

Ultimately, I would not have been able to complete this project without the support I have received from my family. To my mother, Diane, I thank you for always supporting and encouraging me, no matter what crazy plans I have. To my grandmother, Catherine, I thank you for always checking in on me and making sure that, no matter how busy I get, I always make time to talk about the weather with you. To my partner in crime, Dylan, I thank you for all the long nights in the library, for sticking with me no matter what life throws at us and for keeping my sane. Finally, to my father, Izzy, for inspiring me to start tinkering and ultimately go into the engineering field. I hope I am making you proud!
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### Nomenclature

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<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AAC</td>
<td>Augmentative and Alternative Communication</td>
</tr>
<tr>
<td>ABS</td>
<td>Acrylonitrile Butadiene Styrene</td>
</tr>
<tr>
<td>ASD</td>
<td>Autism Spectrum Disorder</td>
</tr>
<tr>
<td>AMDI</td>
<td>Advanced Multimedia Devices</td>
</tr>
<tr>
<td>BSID II</td>
<td>Bayley Scales of Infant Development – 2\textsuperscript{nd} Edition</td>
</tr>
<tr>
<td>DCD</td>
<td>Developmental Coordination Disorder</td>
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<tr>
<td>DLS</td>
<td>Daily Life Skills</td>
</tr>
<tr>
<td>LTM</td>
<td>Least-to-Most Prompting</td>
</tr>
<tr>
<td>PDMS 2</td>
<td>Peabody Developmental Motor Scales – 2\textsuperscript{nd} Edition</td>
</tr>
<tr>
<td>PLA</td>
<td>Polylactic Acid or Polylactide</td>
</tr>
<tr>
<td>SGD</td>
<td>Speech Generating Device</td>
</tr>
<tr>
<td>SLP</td>
<td>Speech Language Pathologist</td>
</tr>
<tr>
<td>SPD</td>
<td>Sensory Processing Disorder</td>
</tr>
<tr>
<td>VOCA</td>
<td>Voice Output Communication Aid</td>
</tr>
</tbody>
</table>
1.0 Problem Introduction

In recent years, tablet cases have become a thriving market as tablets have emerged as a more affordable and portable alternative to the traditional laptop computer. However, assistive tablet cases have not received a great deal of attention from industry leaders in device protection. Therefore, the assistive or even customizable tablet case options are far more limited in selection and scope than their solely protective counterparts. This lack of options greatly impacts children with disabilities who use tablets for communication, with Autism being one of the most prevalent conditions. Although Autism is becoming increasingly more relevant, as diagnoses increase by up to 30% per year (Centers for Disease Control and Prevention, 2016), there has not been a focus on this large group of users. In nonverbal individuals with Autism, tablets are less of a toy and more of a life tool, allowing them to communicate with the outside world through picture to speech applications. By creating an assistive tablet case which focuses on individuals with Autism as well as common coupled conditions associated with this disorder, these users who utilize tablets for communication purposes will be able to do so more quickly and comfortably. Also, by creating this device which can be modified to fit needs of the user, the tablet case may be appealing to other children with disabilities both for communication assistance and for use with recreational electronics.

**Autism**

Autism is a neurological disorder which primarily affects behavior, communication, and socialization. It is estimated that 1 in 68 children have Autism and that 20-50% of those individuals do not develop functional and/or natural speech (Centers for Disease Control and
Prevention, 2016, Lord et al, 2004, National Research Council, 2001). This disorder is made up of a spectrum, meaning each case is unique as to what degree any or all of these affects are present. Generally speaking, people with Autism exhibit many common characteristics including a need for order, sameness, and exactness as well as a bond with technology. As shown in Figure 1, children with Autism often define playing much differently than a neuro-typical child (Price, 2007). By lining up their toys in an order that makes sense to them, they are relaxed, in control and happy to play in this manner. However, if this order is eliminated, it will frustrate the child greatly.

Figure 1: Lineup of Toys from a Child with Autism Playing. Lining up toys and other objects by size or color is an example of how play may differ for children on the Autism spectrum as compared to neurotypical children. Since children with Autism thrive with order, sameness and routine, lining up toys based on criteria they understand is enjoyable and relaxing. Adapted from Price, 2007.

Relating to bonds with technology, the nature of these bonds with children on the Autism spectrum are different and often more intense than those of their neurotypical counterparts. Since technology is currently integrated into most aspects of everyday life, it does not seem that a bond
with technology would be out of the ordinary for any child. However, in the case of a child on the spectrum, this bond differs greatly in its motivation. For most people, their bond with technology may stem from the enjoyment that they experience while playing a game, connecting with family, or looking at pictures. Although individuals with Autism enjoy these activities as well, they will also bond with the technology due to its systematic and logical nature. Since these individuals have difficulty with social interactions, having a platform to control and which will react in a rational manner, is an extremely comforting prospect.

Although Autism is often defined solely by its primary effects, this disorder is extremely complex and has many coupled conditions associating with it as shown in Figures 2 and 3 (Learning Assessment and Neurocare Centre UK, 2016, Centers for Disease Control and Prevention, 2015). The primary coupled conditions with which this assistive tablet case will focus on are motor skill difficulties (labeled as Developmental Coordination Disorder) and Sensory Processing Disorder (also known as Sensory Integration Disorder) (STAR Institute for Sensory Processing Disorder, 2017, Autism Society, 2016).
Figure 2: Autism Spectrum Disorder Coupled Conditions. There are many coupled conditions which can be associated with Autism, with some individuals exhibiting symptoms of multiple conditions and others have little to no symptoms outside of their primary diagnosis. This tablet case focuses on the common coupled conditions of Sensory Processing Disorder (labeled as Sensory Integration Disorder) and Motor Skill difficulties (labeled as Developmental Co-ordination Disorder). Adapted from the Learning Assessment and Neurocare Centre UK, 2016.
Figure 3: Visual Autism Spectrum. Autism is best represented as a spectrum of different characteristics which change based on the person affected. These characteristics can be represented by the six main categories of Measured Intelligence, Social Interaction, Communication, Behaviors, Sensory and Motor. In the case above, the person has mild intellectual disability, is not very interested in social interactions and is primarily nonverbal. The individual also has frequent repetitive behaviors or stims, is not very sensitive to pain but is sensitive to sound. Additionally, their motor skills are poor for fine movements but are better coordinated for gross movements. Adapted from Centers for Disease Control and Prevention, 2015.
Motor Skill Difficulties

Among individuals on the Autism spectrum, it is common to notice seemingly clumsy and sporadic movements present. These perceptions can be attributed to the different ways in which people with Autism receive signals from their senses and process these stimuli (Versfeld, 2015). Due to these differences, people on the spectrum commonly struggle with motor planning, accuracy, and stability. These difficulties affect each person differently and, in some cases, do impact the ease of using common items and performing basic life skills.

For children with Autism, motor planning can be especially difficult since this process combines processing sensory input and controlling the movement of their bodies. Motor planning can be defined by the preparation which is done prior to making a movement to perform a task (Wong et al, 2014). In order to perform this task, the body must take in information about its environment and its own location in relation to the environment. The environmental information can often be discerned using the five senses of taste, sight, touch, smell and hearing. However, the location of the body in terms of spatial orientation and movement known as proprioception (The American Heritage Dictionary of Medicine, 2015), is regarded as intuitive for the neurotypical majority. In the case of a child on the Autism spectrum, this is not the case. The proprioceptive sensation, often referred to as kinesthesia in the context of motion (Stillman, 2002), is yet another sensory input that children on the Autism spectrum must receive and process. In addition to proprioception, in the case of gross motor movements, the vestibular system also contributes to the input which the brain must interpret. Similar to proprioceptive sensation, the processing of sensations related to the vestibular system are also seen as intuitive in most cases (Dunn 1999). The vestibular system controls balance and spatial cognition in a person, which can be a process that is not intuitive for a child with Autism. Since
processing sensory input in general can be challenging for these children, the added two proprioceptive and vestibular inputs can make motor planning much more difficult. When you add in distracting sensory input such as bright lights and loud noises, this task can become incredibly overwhelming. Visual representations of Motor Planning for both Neurotypical people and people with Autism can be seen below in Figure 4.

Specifically, when utilizing a picture to speech application, a great deal of motor planning is necessary to form a sentence and communicate. In many of Augmentative and Alternative Communication (AAC) applications, words are often nested in a series of categorically organized folders. Although folders are increasingly more necessary for users with a wide vocabulary, they also require more movement and coordination to select each desired word. These movements, in addition to being challenging for some users, also decrease the speed at which users can form sentences and communicate in a conversation. By addressing the motor skill challenges associated in operating an AAC application, it is hoped that users will be able to communicate at a pace closer to that of verbal conversations.
Figure 4: Neurotypical Motor Planning Compared to Motor Planning with Autism. Motor planning is the process of planning a motion by receiving information from the environment. Since this process involves receiving and interpreting sensory input, it can often be difficult for individuals with Autism. A) Neurotypical Motor Planning: Sensory input is received and processed with relative ease. The desired motion is performed. B) Motor Planning with Autism: Sensory input has a more dramatic effect and is processed differently. A motion will most likely be performed but may not be the desired action.
Sensory Processing Disorder

Sensory Processing Disorder (SPD) can impact the intake and processing of stimulus for any person, however this condition is very common in people on the Autism spectrum. The stimuli that can impact these individuals with this disorder differently are really anything that can be taken in by the five senses and two intuitive senses of proprioception and input from the vestibular system. Therefore, taste, touch, smell, sight and hearing as well as motion and balance can be impacted. There are a range of different ways in which SPD can be observed in people, including having opposing reactions when faced with the same stimulus (STAR Institute for Sensory Processing Disorder, 2017). An example of these opposing reactions is shown in the sensory-seeking vs. sensory avoiding manifestations of SPD. Sensory-seeking individuals may exhibit behaviors such as wanting to play music loudly, not noticing if they are bumping into objects or people, loving spicy or extremely flavorful foods, enjoying strong scents, and staring at the sun or other bright objects without noticing any pain or damage. Conversely, sensory-avoiding behaviors may include covering their ears, recoiling from certain textures, being extremely picky eaters, becoming nauseous easily and closing their eyes when a setting is bright. (Baranek et al, 1997, Kientz and Dunn, 1997). Since these two examples show two vastly different illustrations of the same disorder, it is crucial to have a variety of different sensory stimuli, in the form of toys and other objects, available to fit the needs of each child. In the scope of a tablet case, it is also necessary to offer options in tactile stimulus in order to help all users comfortably operate their devices.
Summary

The current market contains assistive tablet cases which offer users stands for desktop work, a handle for security and, in a few instances, for mobile use. While these features are very helpful for users, especially when traveling and communicating in a school setting, they do not address the situations which users may face if they are sensitive to tactile stimuli and have difficulties with motor planning. There is a great need for research into general texture preferences and the design of a component to assist in operating a tablet, to empower these valuable members of society to communicate in the way in which they can best express themselves.
2.0 Background and Literature Review

2.1 Autism Spectrum Disorder

2.1.1 Sensory Processing Disorder

Sensory Processing Disorder has been proven to profoundly impact the lives of many people with Autism. Sensory Processing Disorder (SPD), formerly “Sensory Integration Disfunction” is a disorder which causes the signals or stimulus which are received from the outside world to be difficult or, at times, impossible to interpret for the person affected. This disorder is present in between 1 in 20 (Ahn et al, 2004) and 1 in 6 (Ben-Sasson et al, 2009) children in a manner dramatic enough to impact their daily lives. SPD is a spectrum disorder, similar in nature to Autism, where cases range from sensory-avoiding to sensory-seeking based on the reaction of a person to different stimuli. Generally, people who identify on the sensory-avoiding end of the SPD spectrum may appear to “over-respond” to a stimulus, while others who are sensory-seeking may not notice the exact same stimulus (STAR Institute for Sensory Processing Disorder, 2017). These responses from sensory-avoiding and sensory-seeking individuals can be described as hyper-sensitive and hypo-sensitive reactions, respectively (Baranek et al, 1997, Kientz and Dunn, 1997). SPD as a whole also impacts motor planning, which is the translation of visual stimulus into muscle movement to direct a body part to its desired location (Versfeld, 2015).

In the case of SPD and Autism, studies have shown that 94-95% of children with Autism tested had atypical reactions to sensory stimulus (Jasmin et al, 2008, Tomchek and Dunn, 2007). The other main finding of the study conducted by Tomchek and Dunn states that a majority of the children with Autism tested were sensitive to tactile sensory input (Tomchek and Dunn,
2007). Additionally, there is a correlation between high sensory reactivity and the practice of over-fixation as well as difficulty motor planning in individuals with Autism (Liss, 2006).

2.1.2 Motor Skills and Planning

In addition to Sensory Processing Disorder, motor skill difficulties can also profoundly impact the lives of people with Autism. These difficulties can be characterized as affecting fine motor skills, small and precise movements, and gross motor skills, large and approximate movements. In many cases, these difficulties are not always diagnosed formally but can be described as Developmental Coordination Disorder, also known as Motor Dyspraxia (Dyspraxia Foundation, 2013, Versfeld 2015). This condition is used as an umbrella term for motor difficulties and can encompass both problems in accuracy of movements and the learning of new movements (Versfeld, 2015). In addition to motor skill difficulties, motor planning difficulties are also under the Motor Dyspraxia umbrella of symptoms. The difference between difficulties with motor skills and planning is solely based on whether the movement which occurred was desired. In the case of hopping on their right leg, if the child begins hopping on both legs or on the opposite leg, the motion of hopping is still executed. However, the resulting execution is not the motion that the child attempted to do. In all of the symptoms relating to motor skills and planning, its impact on children with Autism is both well-known and well-documented.

Two prominent studies relating to these difficulties are from Jasmin et al. and Provost et al. In the case of Jasmin et al, the study was geared towards studying the daily life skill (DLS) abilities of children with Autism. Another purpose of this study was to gain a greater
understanding of the impact that SPD and motor skill difficulties had on the successful completion of these tasks. There were 35 children tested with each one being 3-4 years old and having an Autism diagnosis. Each child was given specific motor skill and DLS tasks to complete by an Occupational Therapist while caregivers provided information regarding their child’s sensory and motor skill behaviors and trends. From this testing, the resulting data indicated that the children with Autism had poor fine motor skills and problems with fine motor planning as compared to the neuro-typical sample (Jasmin et al, 2008). In the case of Provost et al, fifty-six children were included who fit into one of the following three categories, children with Autism who had motor delays, children with Autism without motor delays and children without Autism or motor delays. These children were assessed using both the Bayley Scales of Infant Development - 2nd edition (BSID II) and the Peabody Developmental Motor Scales – 2nd edition (PDMS 2) and were videotaped for analysis by a pair of experienced pediatric physical therapists. From these assessments, it was found that, although motor skill delays are not included in the formal diagnosis criteria for ASD, all children with ASD in this study showed delays in gross motor skills, fine motor skills or both. These findings also correlate with those of Jasmin et al. (Provost et al, 2007).
2.2 Prevalence of Tablets for Communication Purposes

2.2.1 Use of Technology among Individuals with Autism

The use of technology to facilitate social interactions has proven, in numerous studies, to be more comfortable and natural for people with Autism than social interactions in a traditional setting. In the case of Hourcade et al., this concept was tested using the tablet applications Music, Untangle, Drawing and Photogoo, to evaluate the social interactions of children with Autism. These results were then compared to those of traditional methods of social interactions. In the case of the application Drawing, the researchers utilized this application for children to draw on the tablet screen with their finger. The observations from this activity were then compared to the observations noted when giving the children with physical tools, such as markers and paper, to perform the same task. It was concluded, through statistical analysis, that the number of sentences per minute spoken by the children on the Autism Spectrum increased by using the applications. Also, encouraging comments on the work of their peers increased significantly in Music and Untangle applications, but did not differ significantly for Drawing or Photogoo. Additionally, there was a greater amount of physical interactions, either taking turns or working together, with the applications as compared to the activities without the tablet as seen in Figure 5 (Hourcade, 2013).
There are also known cases in which children have not been able to communicate prior to being given technology (Fleischmann, 2012, Polk, 2015). To support the conclusions reached by these studies and known circumstances, organizations such as Hacking Autism (Hacking Autism, n.d.) embrace the known bond which people on the spectrum have with technology to help them find success in this industry. By assisting these individuals in hackathons, technology grants and job training, the presence of technology has the potential to ease the transition between formal education and a career.

In order to train individuals with Autism to perform a job or even daily life skills, technology is seen as an essential tool in communication, especially in nonverbal cases.
Kagohara et al. complied a sample of various well-known intervention studies, as seen in Table 1, which utilized iPads/iPods and, in many cases, Proloquo2Go (Kagohara et al, 2013).

Proloquo2Go is one of many picture-to-speech applications which allows the user to select a picture and form sentences to communicate without speaking. Both the iPad/iPod platform and these applications have become more popular, cost effective and mainstream options for AAC as compared to specialized devices whose sole purpose is alternative communication.
<table>
<thead>
<tr>
<th>Domain</th>
<th>Study</th>
<th>Number of participants</th>
<th>Target behavior</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic</strong></td>
<td>Kagohara, Sigafous, Achmadi, O'Reilly, and Lancia (2012)</td>
<td>2 (10, 12)</td>
<td>Check the spelling of words on a computer word processor.</td>
<td>iPad Touch® delivered instructional video on how to check the spelling of words.</td>
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<td><strong>Communication</strong></td>
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<td>1 (17)</td>
<td>Request preferred stimuli by selecting icons from an iPod Touch®.</td>
<td>iPod Touch® with Proloquo2Go™ software was used as a SGD.</td>
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<td></td>
<td>van der Meer et al. (2011)</td>
<td>3 (13-23)</td>
<td>Request preferred stimuli by selecting icons from an iPod Touch®.</td>
<td>iPod Touch® with Proloquo2Go™ software was used as a SGD.</td>
</tr>
<tr>
<td></td>
<td>Achmadi et al. (2012)</td>
<td>2 (13, 17)</td>
<td>Turn on iPod Touch®, unlock screen, navigate to correct icon page to request preferred stimuli.</td>
<td>iPod Touch® with Proloquo2Go™ software was used as a SGD.</td>
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<td></td>
<td>Flores et al. (2012)</td>
<td>5 (8-11)</td>
<td>Request preferred stimuli by selecting icons from an iPad®.</td>
<td>iPad® with Pick a Word software was used as a SGD.</td>
</tr>
<tr>
<td></td>
<td>Kagohara, van der Meer, et al. (2012)</td>
<td>2 (13, 17)</td>
<td>Name pictures by selecting icons from iPod Touch or iPad®.</td>
<td>iPod Touch® and iPad® with Proloquo2Go™ software used as SGD.</td>
</tr>
<tr>
<td></td>
<td>van der Meer, Kagohara, et al. (2012)</td>
<td>4 (5,5-10)</td>
<td>Request preferred stimuli using either manual signs or by selecting icons from an iPod Touch®.</td>
<td>iPod Touch® with Proloquo2Go™ software used as a SGD.</td>
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<tr>
<td></td>
<td>van der Meer, Delden, et al. (2012)</td>
<td>4 (6-13)</td>
<td>Request preferred stimulating manual signs, picture exchange, or by selecting icons from an iPod Touch®.</td>
<td>iPod Touch® with Proloquo2Go™ software used as a SGD.</td>
</tr>
<tr>
<td></td>
<td>van der Meer, Sutherland, O'Reilly, Lancia, and Sigafous (2012)</td>
<td>4 (4-11)</td>
<td>Request preferred stimulating manual signs, picture exchange, or by selecting icons from an iPod Touch®.</td>
<td>iPod Touch® with Proloquo2Go™ software used as a SGD.</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td>van Laarhoven, Johnson, van Laarhoven-Myers, Grider, and Grider (2006)</td>
<td>1 (17)</td>
<td>Complete three tasks (cleaning bathroom, mop floor/empty garbage, clean kernels).</td>
<td>iPad® used to deliver instructional video showing how to complete tasks.</td>
</tr>
<tr>
<td></td>
<td>Burke, Andersen, Bowen, Howard, and Allen (2010)</td>
<td>6 (18-27)</td>
<td>Perform 63 scripted responses as part of fire safety training.</td>
<td>iPad Touch® and iPhone® used to deliver instructions.</td>
</tr>
<tr>
<td><strong>Leisure</strong></td>
<td>Hammond, Whatley, Ayres, and Cast (2010)</td>
<td>3 (12-14)</td>
<td>Operate an iPod® to listen to music, watch video, and look at pictures.</td>
<td>iPod Nano® used as multimedia device including music, video, and pictures.</td>
</tr>
<tr>
<td></td>
<td>Kagohara (2011)</td>
<td>3 (15-19)</td>
<td>Operate an iPod Touch® to watch entertainment video.</td>
<td>iPod Touch® used to deliver instructional video on how to operate the iPod Touch® to watch several entertainment videos.</td>
</tr>
<tr>
<td></td>
<td>Kagohara et al. (2011)</td>
<td>3 (15-20)</td>
<td>Operate an iPod Touch® to listen to music/songs.</td>
<td>iPod Touch® used to deliver an instructional video showing how to operate the iPod Touch® to access preferred music/songs.</td>
</tr>
<tr>
<td><strong>Transitioning skills</strong></td>
<td>Chia, Fahrenkrog, Ayres, and Smith (2010)</td>
<td>4 (6-8)</td>
<td>Transition between school locations.</td>
<td>iPad® used to deliver instructional video, involving video self-modeling, on how to transition.</td>
</tr>
</tbody>
</table>

Table 1: Summary of AAC Studies involving iPods and iPads. In this review by Kagohara et al, a table of studies involving iPods and iPads was compiled. In this table, it was found that AAC applications, specifically Proloquo2Go, were used frequently in these studies for communication.
2.2.2 Augmentative and Alternative Communication Techniques

For individuals with nonverbal Autism, Augmentative and Alternative Communication (AAC) gives them the invaluable ability to communicate their needs, wants and opinions. Prior to the creation of applications for this purpose, users often exchanged or sequenced cards with specific tasks, subjects, or items on them in order to communicate effectively. This system is called the Picture Exchange Communication System (PECS) (Pyramid Educational Consultants, n.d.). Although this system can be extremely effective and impactful for children beginning the process of acquiring language or those with a relatively small vocabulary, this system becomes quite cumbersome as the child expands their vocabulary. Since each word has its own card corresponding to it, the sheer number of cards needed to hold a complex conversation become increasingly less portable and difficult to use in daily life, specifically in group conversations. Devices, such as the Dynavox, were created to eliminate this lack of portability but can cost families thousands of dollars (Tobii Dynavox, 2017). With the increased relevance of Autism research and the development of tablet applications, many Picture to Speech and Text to Speech applications have been created to help nonverbal users communicate with relatively inexpensive tablets. This need for inexpensive AAC solutions is present throughout the world, including in Turkey where research was conducted to create their own picture sequencing application to help Turkish children with Autism communicate as seen in Figure 6. It was found in this study that each participant improved in sequencing by way of in-app prompts or a mixture of in-app and external prompts. These results provided a much-needed insight in how to improve the group’s tablet application to make it more effective in teaching sequencing and promoting communication. (Doenayas et al, 2014).
When creating such an AAC application for any population, one must consider the three necessary criteria. These criteria include the skills of the user, the device architecture as well as the demands of communication tasks. The skills of the user would include, but are not limited to, their gross and fine motor skills, cognitive abilities, and sensory challenges present (Sampath et al, 2012). In the case of device architecture, the display layout of onscreen buttons and similar controls as well as the means of selecting the controls are relevant. Finally, the demands of communication tasks can be determined based on the number of people present in the conversation. An example of a prototype AAC application can be seen in Figure 7.
2.2.3 Current Market for Assistive Tablet Cases

Currently, when a caregiver or user searches the internet to purchase an assistive tablet case, selection is both limited and often split between being overpriced and lacking quality. Many assistive tablet cases on the market feature a handle for mobile use while some also include a stand and/or carrying strap for added functionality and portability. According to a study by Pereira et al., the handle feature is indeed an important aspect which has been observed improving overall usability and decreasing muscle fatigue in users (Pereira et al, 2013).

Upon initial search, the two most well-publicized assistive tablet cases found were to be the KAYSCASE KidBox and ibaggs Traveler cases. The KidBox case, as seen in Figure 8, features a convertible handle/stand feature and a soft bumper made from EVA foam (AAC Language Lab, 2013, Amazon, 2017). Although this material claims to be shock-proof, water resistant and sound insulating, there are no examples to prove this. Additionally, upon further
research, it was found that the company website for this tablet case is no longer in service, therefore preventing the customer from receiving additional information on the material used and the validity of its claims. This extensive knowledge of the product may be perceived as a bit excessive, however, if the child using this case stims orally, the material and its properties could be valuable information in the case of ingestion. An example of this tablet case after 6 months of wear can be found in Figure 9 (AAC Language Lab, 2013). At a $19.99 price point via Amazon.com, this product is on the lower end of the assistive tablet case market (Amazon 2017). However, with minimal proof that this case will withstand use from a child, it is a risky purchase. Additionally, upon further investigation, it is clear that multiple companies are selling the exact same or strikingly similar tablets cases, further confusing the consumer.
Figure 8: KidBox Tablet Case with Strap and Keyguard. In this instance, the KidBox tablet case was modified by a professional who works with children on the Autism spectrum to better fit their needs. This modification reinforces the need for more customizable solutions for assistive tablet cases. The KidBox tablet case currently costs $19.99 with an additional cost of approximately $30 for the keyguard. Adapted from AAC Language Lab, 2013.

Figure 9: KidBox Case after 6 Months of Use. Although KidBox tablet cases are a popular option for children, it is shown above that, after 6 months of use, this tablet case is visibly damaged on the corners. This damage can be due to dropping the tablet or chewing on the case’s soft foam exterior, a popular stimming behavior amongst children with Autism. Adapted from AAC Language Lab, 2013.
A similar situation in terms of vendor accountability was encountered when researching the ibaggs Traveler tablet case, which can be seen in Figures 10 and 11 (Amazon 2017). This case includes features such as dual-directional handles, a cross-body carrying strap and a foldable stand. This case has a Neoprene exterior with a Velcro closure, which makes this case less focused on durability and more on portability. However, when further research into the company was attempted, their website was no longer in service as well. This case was originally sold for $59.99, which is fairly expensive considering there is no shock-absorbing feature to this case. This case is now solely available through the Amazon Marketplace by one seller at the price point of $35.99.
Figure 10: Front of ibaggs Traveler II Tablet Case. This front view shows the neoprene sleeve of the ibaggs case as well as the shoulder strap attachment. Providing this attachment to assist with independent transport is crucial to the continued use of AAC applications for consistent communication. This case initially cost $59.99 but is now available for $35.99 through a 3rd party seller. Adapted from Amazon, 2017.
After finding a lack of consistency in the assistive tablet case companies, research was conducted to find some more well-established companies catering to this market. From this search, the companies RJ Cooper & Associates and Advanced Multimedia Devices (AMDI) were identified.

RJ Cooper & Associates was founded by an engineer who purchases KidBox tablet cases and adapts standard iPad accessories to create his own assistive tablet cases. An example of his “iPad Ultimate II Case w/ Folding Stand” can be found in Figure 12. This case ranges in price
from $89.00 to $99.00 depending on the size of the tablet and includes an attached shoulder strap and table stand in addition to the standard Kid Box tablet case (RJ Cooper & Associates, 2017).

Figure 12: iPad Ultimate II Case with Folding Stand. This tablet case was created by an engineer to add features to the KidBox tablet case to make it more portable and versatile. With the addition of an integrated table stand, this tablet case will assist in classroom use of AAC communication. This case is currently being sold for between $89 and $99. Adapted from RJ Cooper & Associates, 2017.

AMDI is a very different example of an assistive device company which operates on a much larger scale as compared to RJ & Associates. AMDI has their own line of iAdapter assistive tablet cases, which include the usual handle and table stand, in addition to a volume-boosting speaker for AAC communication in a loud setting, as seen in Figure 13 (Advanced
Multimedia Devices, 2017). The latest model of this case, the iAdapter 6, are sold either separately for $285.00 per case for a full-size iPad or as a bundle with other accessories for the case. These bundles can include switches, screen guards, shoulder straps and carrying bag but range from $365.00-$585.00. (Advanced Multimedia Devices, 2017) This price point could make this well-developed case out of reach for many families, especially when considering that, if other adaptive accessories are needed, these would have to be purchased through additional vendors.
After this initial search for assistive tablet cases, the research into keyguards began. Keyguards are clear acrylic sheets in which holes are cut out to fit the placement of icons in an AAC application. This tablet accessory is used to decrease the fine motor skills and planning needed to select the correct icon. In order to understand and test this accessory further, one was purchased through a Lased Pics Assistive Technologies, a popular vendor which specializes in

![iAdapter 6 Case](image)

Figure 13: iAdapter 6 Case. This tablet case is marketed as less of an accessory and more of an assistive device. It contains a handle and stand, as well as amplified speakers with rechargeable battery. This case currently sells for $285, making this device one of the more expensive solutions. Adapted from Advanced Multimedia Devices, 2017.
keyguards. A picture of this keyguard with Sonoflex Lite AAC software can be found in Figure 14. This specific keyguard costs $29.95, however these accessories range in price from $23.95 to $66.95, which does not include the cost of a case to protect the tablet and keyguard (Lasered Pics Assistive Technologies, 2017) Additional keyguards can be purchased through the vendor Silver Kite, however, the selection of compatible applications is very limited (Silver Kite, n.d.).

![Figure 14: iPad 2 with Sonoflex Lite and Keyguard. The Sonoflex Lite application was the first application used in the design of the tablet case in this project. The keyguard displayed was purchased through Lasered Pics Assistive Technologies for $29.95 and was added to the iPad 2 used for prototyping in order to better understand the current techniques to improve icon selection accuracy.](image-url)
Overall, it can be concluded that the assistive tablet cases which are currently available are limited and, if one is found, the quality of the material as well as longevity of the founding company can be questionable. Additionally, in order to create their own assistive tablet cases, it is necessary for caregivers and professionals working with these children to purchase and combine protective cases and accessories to give the children the full functionality of their device (RJ Cooper & Associates, 2017). This practice can increase the price of the case significantly while, at times, still not including all the necessary features.

Another factor to consider is the impact which tactile sensory has on the selection of a tablet case for children with Autism. Since much of the assistive tablet cases found were sold via online platforms, it can be difficult for children with SPD to know that they are comfortable with, let alone enjoy, the texture which will surrounding their primary mode of communication. It has also been found that other physical characteristics of AAC devices, such as color, can make the device more or less appealing to use (Son et al, 2006, Sigafoos et al, 2005). Providing individuals with Autism the opportunity to give their input on their AAC intervention and device can empower them to exert more control over their lives and promote self-determination (Sigafoos, 2006, Van der Meer, 2011). If they are not included fully in the decision-making process or do not receive the expected texture for their case, the result could be a lack of interest in their AAC device. This lack of interest could pose a problem in terms of academic progress and language development if this situation is not corrected (Koegel et al, 1987, Van der Meer et al, 2011). Also, if this process is not revisited over time as the user matures and preferences change, a similar effect can occur (Stafford, 2002).

Similarly, if the child does not have access to their device at all times, they are not able to communicate in the manner which they are being taught, which could also hinder in
development of communication with their AAC device (Sigafoos et al, 2004). The definition of “access” in this situation is not clearly defined and thus the portability of AAC devices has not been a focus. In a study performed by Sigafoos et al, this concept of accessibility and portability of AAC devices is studied since often AAC devices without proper accessories are difficult to carry for ambulatory users. In this study, students with various developmental disabilities are given the task of using their AAC device to request preferred snacks. However, in this situation, their AAC device is placed in different areas of the room instead of on their desk for easy access. The students were then required to find their device then select the correct icons in order to receive their preferred snack. It was found that the students would rather use gestures, such as pointing and reaching, to show their desire for the reward as opposed to finding their device to communicate this. Only after they realized that this behavior did not result in access to the reward did they attempt to locate their device and ask for the reward with it. It was found that, although within the confines of the experiment students did start to seek out their devices, for overall communication needs without a tangible reward, if the device is not within reach it is less likely to be used for communication (Sigafoos et al, 2004).

2.3 Early Intervention and Prompting with AAC

When it is initially determined that a child is having difficulties with verbal communication, many different approaches to communication are presented to parents from professionals in the Speech-Language Pathology field. These approaches to communication can range from different types of speech exercises to modes of AAC to test out with the child. When parents are first introduced to the idea of utilizing AAC as a basis for language development, a
common question arises: Will the use of AAC prevent or decrease the likelihood of my child communicating orally in the future? While this question is often coming from a valid place of concern from parents, studies has shown that AAC actually assists in language development overall and can also increase socialization among peers (Romski et al, 2010, Trembath et al, 2009). This combination of AAC and peer interactions also proved effective in a study by Calculator, where peers were given opportunities to communicate with AAC users. During these interactions, peers often assisted in modeling the use of AAC and encouraged higher expectations for their peers’ communication goals (Calculator, 2009).

With respect to communication evaluations and goals, these decisions are often based on assessment via specific criteria relating to current language development, communication potential and physical abilities (Light et al, 1998, American Speech-Language-Hearing Association, 2017). These criteria are relevant in evaluating whether the user will be able to utilize the AAC technique effectively. An example of this evaluation is the concept of cost versus communication potential. Voice Output Communication Aids (VOCAs) or Speech Generating Devices (SGDs) are more expensive than other AAC alternatives and therefore, if the child does not show enough progress to form more complex sentences in the future, they will most likely be recommended a more simplistic and cost effective AAC alternative (Sigafoos et al, 2004). This recommendation for a simpler and less expensive solution is often seen as a viable option for users with the potential to communicate with main ideas, short phrases and yes or no answers. However, as their abilities improve, it is necessary to reevaluate. Once reevaluated, a shift to electronic AAC devices could be beneficial since it has been shown that the use of electronic AAC devices can impact the user positively by creating more precise statements, therefore decreasing misunderstandings and frustration in communication (Sigafoos
et al, 2004). Also, the motor skill abilities of the user can assist in both formal assessment of needs and informal evaluation of preferences for their AAC solution (Van der Meer et al, 2011, Light et al, 1998).

Once this assessment for which AAC technique is most appropriate is completed, the learning process of using AAC begins. This learning process involves professionals such as Speech Language Pathologists and Special Education Teachers as well as the parents of the learner. The involvement of both parties is necessary for the child to have consistent and meaningful use of their device for communication. In the case of the professionals teaching the child the initial steps in operating their device, it is crucial to evaluate the style in which each professional is approaching teaching and ensure that these styles are consistent with one another. It has been documented that the variability of training, experience and teaching methods of professionals may impact the effectiveness of AAC interventions and achievement of the child’s communication goals (Barker et al, 2013). In the case of parental involvement, this portion of the learning process requires consistent use of the child’s AAC device for communication outside of the school setting. For some parents, particularly with children who are older and are just learning effective communication, it is tempting to utilize the methods of nonverbal communication, such as pointing, which have been utilized up until this point. However, the language development for their child using their AAC device can be influenced greatly by use in the home and parental modeling of device operation (Romski and Sevcik, 2003).

In order to teach a child with Autism how to operate their AAC device, prompting is an effective and commonly used tool (MacDuff et al, 2001). Prompting can be defined as support which simplifies the use of a specific skill (Neitzel and Wolery, 2009). A common type of prompting used for AAC with children on the Autism spectrum is called Least-to-Most
prompting (LTM). This technique is a progression of cues to the child from the facilitator which begin with the least intrusive form and evolve to more intrusive cues until the target action is performed (Ault and Griffen, 2013). In general, LTM features a prompt hierarchy which is used in sequential order and is stopped when the child has exhibited the desired action. These levels include independent (giving the child the opportunity to respond independently), gestural (pointing or giving nonverbal clues), verbal (asking a question or giving a hint), modeling (stating answer and/or showing how to select the answer) and physical assistance (assist child in moving hand to choose correct response) (Neitzel and Wolery, 2009). While using LTM with a student, it is favorable to avoid physical assistance when possible, which can result in repetition of previous prompts in the hierarchy prior to moving to this level.

In a study conducted by Biederman et al, the effectiveness of different types of prompting were investigated as well as the effect that the sensory input associated with prompting has on the learner. In this study, students were taught a skill they had not previously acquired using passive prompting, such as modeling, and active prompting, such as hand-over-hand physical assistance. These sessions were conducted in two types of settings, benchmark being with a controlled and strict regulation of verbal prompts similar to those present in a session with a Speech-Language Pathologist and standard being with more informal verbal prompts similar to those present in a special education classroom. The graph below, Figure 15, details how effective the two prompting strategies were in each of the two settings studied (Biederman et al, 1998).
From this study, many notable conclusions were made in relation to the effectiveness of hand-over-hand prompting or full physical assistance prompts overall. From both settings studied it was found that passive prompting was more effective than active prompting in five out of six children and for all three children in the benchmark setting. Additionally, there was no difference found in the effectiveness of passive modeling as opposed to the verbal prompting used in a more informal setting. In addition to results on effectiveness, there were also findings relating to
the way in which students respond to verbal prompting and rewards. In the case of verbal prompting it was found that, when involved in complex activities such as communication, utilizing continuous and/or rapid prompts may not be effective if the child is not given enough time to think prior to repetition. Additionally, some children in this study had difficulty processing the sensory input meant as verbal rewards. In some cases, this input was confusing to the children and it was proposed that these rewards may distract the students and hinder their progress (Biederman et al, 1998). In a separate study, Mirenda and Dattilo had another finding relating to the overuse of verbal and physical prompts. However, in this instance, it was found that this repetition caused the children to become dependent on the prompt which greatly limited their spontaneous and independent communication with their device (Mirenda and Dattilo, 1987).

These conclusions can be directly applied to children on the Autism Spectrum with the coupled condition of Sensory Processing Disorder. If these children receive a great deal of auditory sensory input while being required to perform a mentally demanding communication task, they may not be able to process this information as hints to help them complete the task. These verbal prompts could become hinderances in answering the question at hand due to the three second expectant waiting time which is common for prompting practice. These children may need a longer expectant waiting time, less frequent verbal prompts or a different method of prompting in order to keep the amount of sensory input to process at a minimum and allow them to focus on the task at hand. Additionally, verbal rewards can also provide unnecessary sensory input for these children, especially when the lesson will be continuing after the reward is provided to them. Rather than providing a verbal reward such as saying, “Good job!”, an object or activity of interest for self-regulation may be a more effective method.
Overall, the topics of early intervention and prompting techniques are debated widely in the Autism field. Although it is clear that all children with Autism are unique and, therefore, will respond differently to specific techniques, changes can be made to the techniques used in facilitate AAC learning to reduce unnecessary sensory input and subsequently promote positive learning outcomes.
3.0 Customer Discovery and User Experience

3.1 First-Hand Experience with Potential Users

In order to better understand the behaviors, interests and challenges of children with Autism, I began volunteering with a local Autism organization called AutismUp. This organization focuses on supporting families touched by Autism with events and programs catered to their needs. Most of the founding members of this organization either have a child on the spectrum and/or are a professional in the field. As of April 2016, this organization opened a new facility, which is called the Multi-Sensory Learning Lab, to host more programs and services (AutismUp, 2017).

My involvement with AutismUp began in October 2015, when I began volunteering with the Exploring Sensations programs which was held at Altitude Trampoline Park in Rochester, NY. This facility allowed for the group to come in prior to business hours to run the program without extra sensory stimulus or children other than the program participants. During this program, each participant is paired with one or two support staff who facilitated sensory exercises based on the child’s needs and goals. These activities were participant-led, allowing the children to explore the facility and decide on the setting for their exercises. This independent aspect of the program often made the students more comfortable with the target exercise, allowing for more progress in sensory exploration and motor skill activities. Some examples of these activities could include wheelbarrow walking and frog leaps on a trampoline strip, rock climbing over a foam pit and climbing through a foam pit. These activities helped with vestibular sensing, motor skills and planning as well as learning to try touching different tactile sensory including the foam blocks and rock climbing holds.
After assisting with this program on a weekly basis through Spring of 2016, I began working for AutismUp part-time as a Support Coach at the new facility. During my time as a Support Coach, I worked with a variety of programs including Exploring Sensations, Women’s Group, Girl Power, Boys Club and Boxing class. Exploring Sensations was a similar program to that which was offered at Altitude, however, Women’s Club, Girl Power and Boys Club were social clubs for specific ages and genders. These social groups assisted in guiding appropriate social behavior while also provided a safe space for participants to discuss their experiences and interests. The experience of working with social clubs provided me with a better understanding of how individuals with Autism who are at different levels of language and social development interact with one another. Boxing class was created to help bridge the gap between children on the spectrum and fitness activities. In this class, the participants did not focus socialization and shared interests but rather worked on their focus, motor skills, motor planning and fitness overall.

After working at AutismUp for one semester of programs, it was brought to my attention that they were looking for more classes based on Daily Life Skills. Since I had experience with cooking, I suggested this as the subject. We began a full-session cooking class the following semester and kept the class in operation for two consecutive sessions. This class began as a wide age-range of participants for the first session and was run as a teen program for the following semester. I was tasked with being the Facilitator of these courses, finding recipes to make in class and providing a list of ingredients to purchase. This class provided the participants with experience with sequencing of events, turn taking and fine motor skills as well as the sensory experiences of trying new foods and smelling the ingredients during preparation. In this program,
all participants were given the opportunity to use real kitchen tools, including knives, with the appropriate amount of support and supervision which may not be available in the home setting.

Through my experience at AutismUp, I gained a great deal of behavioral knowledge about Autism and its different manifestations as well as how professionals in the field help children on the spectrum work on the skills that they may struggle with. This new knowledge helped me design this tablet case with a focus on the user to ensure that I am addressing the most prevalent difficulties. Additionally, through my participation in a variety of different programs, I learned more than ever to celebrate the quirks and small victories of each child.

3.2 Entrepreneurship Exploration

Throughout the development of this tablet case, I have worked with the entrepreneurship resources at RIT campus to learn even more about my potential users and the product development process as a whole. To begin my education in the area of entrepreneurship and business, I took a graduate course in this area called Applied Venture Creation. Through this course, I worked with the Business Model Canvas to create hypotheses and test these theories through customer discovery. Through this course, I interviewed subject matter experts in the Autism field to understand the customer base further, met with a mentor in the entrepreneurship field to go over my progress and created an investor deck to present as our final assignment. This class was a great start for my entrepreneurship education and gave me the motivation to seek out my own funding through the crowdfunding program at RIT.

As I began my search for funding, I came across the Charles S. and Millicent P. Brown Family Foundation grant. This grant was created to provide solutions to problems that people
with disabilities face, to advance technology in the field of accessibility and to further student learning in that subject. In order to complete this application, my knowledge from the Applied Venture Creation course was utilized greatly, especially in the areas of cost modeling and business plan creation. From this application, I was awarded a $3,500 grant for my work in the Autism field to further prototype and test my tablet case. These funds were utilized primarily in the prototyping phase, providing me with the materials and time to create a full functional prototype of my product. This grant was also valuable beyond its monetary value. The personal interest of the Browns in the success of my work was evident, especially when they visited me at the Imagine RIT festival to learn more about my project and its progress thus far. This support was extremely encouraging and assisted in the completion of prototyping and testing of this product.

3.2.1 NSF I-Corps Short Course

To better understand this assistive device’s potential users as well as gain a more informed perspective on the problems they face in their day-to-day activities, this project was part of the NSF I-Corps Short Course at RIT. This short course was taught by experts in the entrepreneurship field and was designed to help teams learn about their potential users through interviews and identify opportunities for funding in the future. This short course ran from June 2nd – 16th 2017 and included three in-person sessions in addition to two conference calls to discuss the progress of each team.

During the first two sessions, a review of the course, its expectations for each team and an overview of our devices from a business perspective were the focus. Since teams were
comprised of university researchers, the experts teaching the course gave us insight into how our
devices could be applicable outside of academia. With this new information, teams were then
tasked with conducting 30 interviews in the following two weeks with potential users and others
who would interacting directly with your device. From the interviews conducted, the goal was to
both reinforce the relevance of the features included currently as well as revise the design as
needed based on additional information which was not previously considered.

For this assistive tablet case, two sets of questions were created based on the two main
categories of interviewees recruited, Parents of children on the Autism Spectrum and
Professionals who work with children on the Autism Spectrum. The questions posed for each
group can be found below in List 1 and List 2. These interviews were conducted in the style of a
conversation to ensure that the interviewee felt comfortable enough during the interview to
answer some personal questions regarding the dynamics of their family and/or professional life.
Additionally, parents with children on all parts of the Autism spectrum, as well as some with
complex coupled conditions, were interviewed. Therefore, the conversation was geared towards
the experiences and difficulties of the specific family and circumstance.
Parents

- Can you please describe your current relationship with your child?
  - What frustrations do you have with your child’s current method of communication?
  - How did you find out about your child’s current communication device?
- How does your child deal with a large amount of sensory input?
  - If the child stims, what kind of stimming?
  - How are you treated when your child is stimming in public?
- Can you walk me through the process of preparing for and going on an outing with your child?
  - What is often brought on the outing?
  - How is your child’s communication method transported in public?

List 1: Questions for Parents of Children on the Autism Spectrum. Questions for parent interviews were created based on the topics of family relationships, stimming and going on an outing with their child. The responses were then used to understand the specific difficulties and topics of importance for parents of children on the Autism spectrum.

Professional

- Can you walk me through a therapy session with a nonverbal child?
  - What form of communication is used? Why is this chosen?
  - What may prevent the users from using other forms of communication?
- Can you describe the process of recommending new assistive technology?
  - What is the process of obtaining this device?
- What impact does this communication method have on their session?
  - How do the children you work with deal with the amount of sensory input during a session?
  - How do you keep the child on task?

List 2: Questions for Professionals who work with Children on the Autism Spectrum. These questions were created based on the professionals’ specialized areas of work, the assistive device acquisition process and the impact communication methods have on their interactions with children on the Autism spectrum. The responses received were used to understand the difficulties involved in obtaining an assistive device, how different professionals in the field interact with children during their sessions and how communication impacts these interactions.
Throughout the interview process, subjects were recruited primarily through reaching out to local Autism organizations and Facebook groups for parents and professionals in this field. Overall, 30 interviews were conducted with 20 of them being Parents, 9 of them being Professionals and 1 being both a Parent and a Professional in the field. For the interviewee who fit into both categories, a combination of each set of questions was used during this interview. During each interview, notes were taken either by hand or by computer to capture main ideas as well as direct quotes from these conversations.

These interviews were incredibly helpful and insightful into the daily struggles which children on the Autism Spectrum face at home, in public and in a more formal learning setting. Below are specific examples of statements and conclusions from the common topics discussed during these interviews.

Control of Sensory Input

For a child on the Autism Spectrum, Sensory Processing Disorder is often a coupled condition which is manifested in each child differently. However, the reoccurring theme surrounding sensory input during these interviews was control. Most “stims” or self-stimulatory behavior are used as a way to drown out uncontrollable sensory in exchange for a controlled and favorable sensory experience. By giving the child a choice in some aspects of their sensory experience, this new-found control will benefit the child by promoting independence and cooperation. This choice could also potentially decrease any fight or flight behavior when overstimulated. Through the tablet case created, children are given the opportunity to customize their device and change different features as their preferences grow with them. Especially when
referring to the interchangeable textures, these children may have strong preferences towards a specific tactile sensory, giving their tablet case an attractive quality to encourage them to communicate using this device.

*The Stigma around Stimming*

A stigma surrounding stimming was brought up often with both Parents and Professionals when discussing public outings and learning in the classroom. For parents, it was clear that a majority of the interviewees would prefer more subtle stimming when discussing going on outings with their child. It was also mentioned that many children with Autism will bring sensory items on outings to make the sensory input they receive less difficult to deal with. These items could include, but are not limited to, iPads or other tablets/technology, noise cancelling headphones, stuffed animals, chew necklaces, hats, sunglasses, and posable toys. However, when the children stim in public, especially in a loud manner, the parents and professionals both discussed the reactions of others as unfavorable.

Although stimming is a necessary behavior for some children on the spectrum, the lack of knowledge of the general public or even parents of newly diagnosed children can cause this stigma against these behaviors to unfortunately exist. By providing these children with a quiet tactile stim integrated into their technology, this could provide a peace of mind for parents as well as an education opportunity for the public as a whole.

Also, a common feeling of parents was that children should be encouraged to learn the characteristics of independence and self-advocacy, communicating their preferences surrounding their sensory needs and assistive device is a great place to start. One parent interviewed captured
this concept the best with this quote, “The goal of any parent of a child on the spectrum is to help teach them how to realize, “Hey, I’m getting overwhelmed. I need to handle this in an acceptable way.”.

Stages of working through an Autism diagnosis

As mentioned previously, some of the parents I interviewed had children who had recently been diagnosed with Autism. During these interviews specifically, we discussed both the learning curve of getting services and their child’s unique circumstances. It was found in some parents new to the Autism world that they did not yet accept that their child has Autism. This situation can be very difficult for the family as well as the child, to obtain the correct services and devices for successful intervention. If the parent is not ready to process that their child may need an assistive device, that child may not be permitted to gain access to this device. This principle is directly applicable to the assistive tablet case being produced.

Additionally, some children on the Autism Spectrum enjoy technology more than most toys due to its logic-based nature and favorable sensory input. Therefore, parents who feel that their child spends too much time with their technology may be opposed to AAC technology or an assistive tablet case to make this technology more attractive.

It should be noted that the reactions of parents to their child’s new diagnosis are valid and natural. It will take time for the new lingo and services to be seen in a positive light. In successful cases, these families turn to an Autism organization or school with programs to help their child and support to guide their family through this new part of their lives.
Effects of Motor Planning on Communication

During my interviews, it was found that only professionals discussed motor skill and planning limitations impacting the use of AAC devices. The two professionals who discussed this topic at length were both present in the classroom either as a Speech-Language Pathologist or as a Specialized Support Coach. Both professionals discussed the use of prompting in their work as well as the instances where they know the children know the answer to a question but answer incorrectly due to motor planning difficulties. In one conversation, a professional stated that in their 12 child class, two children have difficulty accurately selecting icons on their AAC device. Additionally, the subject of vision problems was also introduced as another factor in the accuracy of selecting icons on their device. This input was incredibly helpful to confirm the need for a prompting system which is independent of interaction from professionals to facilitate communication.

Therapy vs. Home: Utilization of Communication Device

The stark difference between using a communication device in the classroom as opposed to in daily life was touched on by both professionals and parents, but from two different perspectives.

For professionals, especially those in the Speech-Language Pathology field, this topic is a pain-point in reference to the effectiveness and richness of language development. When in a session with a child, it is common to require them to use their AAC device and to refrain from using gesturing for convenience whenever possible. These sessions are quantified and measured against the goals set forth for the child. However, at home and in daily life, variables cannot be
eliminated in the way that they can be in the classroom. Also, families are so familiar with their child that, at times, their device is not utilized due to convenience. However, the effects of not using their child’s AAC device is apparent in the progress, or lack thereof, during a subsequent therapy session.

From the perspective of the parents, their child not utilizing their device comes down to convenience and accessibility. Due to the fragile nature of electronic devices such as iPads, they are often left at home in fear of breaking them. Similarly, when a child is issued a device from their school, they are often not allowed to bring this device home for the same reason. These fears can cause a plateau in language development by not maintaining a standard practice for communication, especially in the case of children on the spectrum where routine is often critical.

In both cases, there is a common denominator; professionals and parents both want their children to succeed in communicating with the outside world. However, if the child does not have access to their device because it is not convenient to bring the device with them, their communication using this device will not improve.

Additionally, if the child cannot carry their own device, it is often less likely to be asked for to communicate a simple request. In interviews with Speech-Language Pathologists specifically, it was stated that carrying straps attached to durable cases are not commercially available to buy. The closest remedy that parents and aides have is creating homemade solutions to this widespread problem. By creating a protective case with a reliable carrying mechanism, children will be able to carry their own device, fostering improved communication and independence while giving parents the peace-of-mind that their child will have to remove the strap to drop their device.
Medical Coverage of Assistive Technology

Another common theme which I learned about from parents and professionals was the struggle of purchasing an assistive device through insurance. It was explained that, if a family acquires an assistive device through insurance, it is usually through Medicaid. The Medicaid process was also described as daunting, long and with multiple roadblocks by professionals who actively participate in this process. This process begins with a letter describing the child’s need for a device and, in most cases, is rejected. This series of events is then repeated until the insurance company is satisfied with the request. Also, in the case of Medicaid, it became clear that they will not cover an iPad as an assistive device. This policy eliminates one of the least visually isolating and most cost-effective options in electronic AAC technology.

Although the stance of Medicaid on tablets cannot be changed quickly, there is another avenue to take to gain an assistive device more quickly. Many families take this path, if they are financially well enough to do so or can obtain funding through their school or a grant. It is possible to purchase an iPad, install an AAC application and purchase a protective case in a fraction of the time that it would take for insurance to accept a claim. In short, by providing a case which has the same surface features that a dedicated AAC device may have while keeping the price affordable, this avenue can seem less daunting and more feasible for the families to give their children an opportunity to communicate now.

Key Takeaways

This short course not only added real life experience to this project, but it also created connections with individuals who can contribute greatly to it in the future. Most notably, during
the last interview, a Speech-Language Pathologist spoke so passionately about AAC technology and offered to conduct a trial with this device in her classroom.
4.0 Assistive Case Design and Prototyping

4.1 Design Iteration of Icon Selection Apparatus

Throughout the design process to produce this assistive device, there were many iterations of the icon selection apparatus in terms of its motion, its appearance, and the way in which the motion would be quantified.

Initially, the movement of this component was in the form of a crossbar reaching across the width of the tablet connected to two metal rods placed perpendicular to this crossbar and allowing for motion in the x-axis. Additionally, this design featured a slot in the center of the crossbar along its length which accommodated the y-axis motion of the button assembly. This design was first sketched, as seen in Figure 16, modeled using Autodesk Inventor software, as seen in Figure 17 and 3D printed via Makerbot 3D printer accessible through The Construct at RIT. The crossbar and a majority of the button assembly were printing in Polylactic Acid (PLA) while the selection slider was printed in Acrylonitrile Butadiene Styrene (ABS) due to its comparatively flexible nature. This flexibility was necessary in order to stretch the selection slider over the crossbar for a press fit without part failure. Assembled components of this design can be found in Figure 18.
Figure 16: Initial Sketch of Icon Selection Apparatus. This sketch features an early stage concept of the crossbar and button assemblies. This initial concept features a crossbar drawn to move along horizontal metal bars which are attached to a test rig. The tablet would be placed under the assembly so that icons can be selected with the button.
Figure 17: Initial 3D Model of Icon Selection Apparatus. The Selection Slider was later modified to increase the diameter of its hole to accommodate the button assembly. After this model was revised and a 3D print was made, the button assembly was combined with the selection slider and a spring to allow for vertical motion.
Figure 18: Overall Rail System Design. In addition to the 3D modeled parts and spring mentioned previously, the conductive wire was added to the button assembly to transfer the electric charge from the user to the stylus tip, which contacts the screen. With this new addition, the stylus could select icons on the tablet screen below by the user simply pressing down on the button while making contact with the conductive wire.
During this preliminary prototyping stage, many different prototypes of this crossbar assembly were produced, varying in tolerance between the metal rod and the hole encapsulating it. These different prototypes were then tested by attaching and aligning the metal bars to the testing apparatus and moving the cursor in the x and y directions. An example of an early prototype and one with a more refined movement setup can be seen in Figures 19 and 20 respectively.

Figure 19: Early Proof of Concept for Tablet Case. This initial prototype was created using available parts, including the spring from a pen and spare wood cut to frame the tablet. The initial crossbar prototype, shown in pink, was 3D printed and attached to the assembly. This prototype was used to prove that the crossbar would move in the x axis while the selection slider would move in the y axis as anticipated.
Once the most effective assembly was produced, it was found that the motion of the crossbar was still not smooth when operating the system with the cursor was close to the metal rods. It was apparent that, even though the dimensions of the part were correct, the interaction of materials and, thus, the coefficient of static friction between the crossbar and metal rods was too great to be overcome with a reasonable amount of force. Once this system was analyzed formally, it was also found that, when the cursor was close to the metal rods, the force applied to the button was unable to overcome the moment created by the length of the crossbar. A force diagram of this motion can be found in Figure 21. This moment created was speculated to be less
effective in preventing motion once the device had been used for a longer span of time. However, after demonstrating this device and, specifically, this component at Imagine RIT 2016, it was clear that this problem did not improve during extended use. The test setup presented at Imagine RIT 2016 was the Proof of Concept with Refined Motion Setup, Figure 20, shown above.

Figure 21: Force Diagram of Moment on Edge of Crossbar. The combination on the moment produced when the selection slider was at the end of the crossbar and the friction force caused the motion to be impeded.
Upon coming to this conclusion, different alternatives to reduce the friction within the crossbar assembly were explored, specifically with pulleys and ball bearings. To produce a more fluid motion and then add a metric for quantification later in the design, pulleys were added to the crossbar concept. This pulley system and arrows indicating its movement can be found in Figure 22.

Figure 22: Pulley Diagram with Arrows Indicating Motion. To address the movement issues in the refined motion setup, a pulley design was created to limit both friction and the tolerancing of rigid parts. A system of four pulleys was created to align with the corners of the tablet case and fit within the tablet footprint.
This pulley concept was then tested both in a large-scale model as a proof of concept, Figure 23, as well as a to-scale version, Figure 24, which could theoretically fit within the size limitations of the tablet footprint. Once this pulley system was refined at a smaller scale and the design of the tablet case to include the pulleys was in its first iteration, it was found that the case would either have to be far thicker than anticipated or the pulleys would not be completely encapsulated within the confines of the tablet case. During my customer discovery work, bulkiness of the children’s devices was a repeated pain point for parents and professionals alike, making this pulley design more unappealing to the potential customer. However, if the pulleys were outside of the tablet case footprint, risks of pinch points and physical damage to the parts were present. Additionally, ball bearings were considered briefly but were decided against based on a larger tablet case footprint and the risk of a choking hazard if the tablet case were to be broken and the bearings exposed.
Figure 23: Large-Scale Proof of Concept Pulley System. This first prototype of the pulley concept was created to prove that this design would move as expected. A new crossbar was created with ends that can be easily attached to the nylon cord surrounding the pulleys.
In addition to these concerns regarding the crossbar motion specifically, there were also questions regarding the portability of the assembly as a whole. Since the button assembly was approximately two inches taller than where the crossbar would be placed, the process of transporting this tablet case may pose as a challenge. In the case of a child carrying the device independently with a shoulder strap, they may hit the cursor assembly on themselves when walking and risk both injury to themselves and their device. In the case of the device going into the bag of an aide or parent, this large protrusion from the crossbar may break when shear forces are applied. Due to these issues, in conjunction with the desire to keep the footprint of the tablet case from increasing, it was determined that, after months of prototyping and improvement, this crossbar assembly may not be the most effective way to navigate the tablet screen.
From this discovery, the scope of the problem shifted from how to move this specific component around the screen to how to help these children utilize the tablet overall. From this change in scope, the concepts of hand-over-hand and hand-under-hand prompting, as seen in Figure 25, were found to be a current method of full physical assistance for helping children with motor planning difficulties operate a touch-based AAC device (Penzenik, 2014). Further research was performed to better understand the concept of prompting overall and how the quantifiable motion feature of the table case can theoretically provide a comparable effect. The concept of Least-to-Most prompting was researched, and it was found that this practice is effective in therapy settings. This tiered approach provided structure for how this tablet case may be utilized in the classroom. An overview of findings relating to prompting can be found in Section 2.3.1.
Based on these prompting methods, a new quantifiable motion feature was designed to provide both physical muscle support to prevent accidental selections as well as tactile feedback by way of magnetic attraction. The initial concept for this motion was to create a grid of channels containing metal disks depressed into the base of the channels indicating where the corners of the icons on an AAC application meet. The compatible cursor would feature a magnetic material for attraction to the embedded metal disks. This design was initially sketched by hand and then, based off the measurements from the Sonoflex Lite application being used, was 3D modeled using Autodesk Fusion 360. Once this design was modeled to scale and a test cursor was printed,
it was apparent that the dimensional constraints set forth by the tight spacing of icons would not allow for realistic part sizes or moving components. A model of the initial design can be seen in Figure 26.

![Figure 26: 3D Model of Initial Magnetic Design](image)

Figure 26: 3D Model of Initial Magnetic Design. This initial magnetic design was created as a grid of rail systems in the x and y directions to allow for movement to all areas of the screen. This grid was designed based off of keyguards, which are the current solution for assisting in icon selection without additional electrical components. The grid would be fitted with ferrous disks at the corners of each icon which would attract the small magnets at the corners of the cursor. This design was not pursued further due to the small scale of the parts necessary to be placed inside the rail system.

From this realization, new cursors were designed with embedded magnets in their bases while different ferrous grids were designed to test both the attraction and ease of use for these cursors. The first grid design was a wire mesh created from ferrous wire, as seen in Figures 27
and 28. The attraction of this mesh design was very strong; however, the cursors did not move easily over the grid. Then, the next grid design was comprised of lines of iron-rich paint in the x and y direction across the screen. This grid created 1” x 1” squares to represent the icons, as seen in Figure 29. However, it was found that the concentration of iron was not great enough to feel a noticeable magnetic pull when moving across the screen, although the motion was very smooth.

Figure 27: Diagram of Early Grid Design. After the rail system proved to be too small for proper functionality, a grid design was created using magnets which remained on top of the grid as opposed to being integrated inside. This new grid design combined a tactile grid, similar to the rail system design, and a ferrous grid in the center of each icon for magnetic attraction.
Figure 28: Picture of Wire Mesh Grid. An early prototype of the grid design was created using insulated wires to create a tactile grid and ferrous wires to allow for magnetic attraction. A ½” diameter disk magnet was used to test the attractive qualities of the ferrous grid. Although the ferrous grid created a strong attractive force when in contact with the magnet, the tactile grid caused the motion across the screen to be difficult. It was found that there should be one grid, which would to align with the motion of the cursor, for smooth and effective transitions between icons.
To combine the positive aspects of each previous design, the third grid design was created using small solid steel components at the corners of each icon between two layers of clear sticker paper acting as screen protectors for the iPad. Initially, these steel components were 1/8” diameter x 1/8” long set screws, since this was the smallest commercially produced part that was readily available. These set screws did serve their intended purpose in terms of magnetic pull of the cursors to the desired icons. However, when attempting to select the icons, 1/8” separation between layers made selecting icons require much more force than without this grid present. This set screw arrangement is shown in Figure 30.
From this set screw arrangement, it was apparent that the ferrous components needed would need to be minimal in length to ensure that icon selection required a comparable amount of force to this action would without the grid. From this realization, sheet metal was considered the next logical step in the prototyping phase. A circular punch and die set was used to cut out 3/16” diameter circles from the sheet metal, which were then placed in the corners of the icons as the set screws had been placed previously. The same transfer paper was used as screen protectors.
for the device. This grid was tested using the cursors and proved to be both magnetically attractive and smooth in operation. Additionally, due to the miniscule thickness of the sheet metal, the force required to make a selection with this grid was nearly equal to that needed during normal use. This sheet metal grid is shown in Figure 31.

![Figure 31: Picture of Sheet Metal Grid. With the set screws being effective in creating a large enough attractive force for use with smaller, low-pull magnets, the focus of prototyping shifted to refining this concept for smoother motion across the screen. Since the set screws were 1/8” thick, the user was required to press their finger, with additional force, an extra 1/8” beyond the bottom of the cursor, which could be difficult for children due to hand size and strength. Sheet metal was then explored since it was still solid steel, similar to the set screws, but was very thin. This final grid design proved to be effective and allow for smoother transitions between icons.](image-url)
4.2 3D Modeling of Overall Design

Although the design of the Icon Selection Apparatus required a large portion of time in the prototyping phase to create a complete proof of concept, the overall tablet case design was also a focus to create a complete product for future market introduction. This design features a hard shell which fits over a silicone sleeve for impact absorption and integrates the icon selection apparatus over the screen, a shoulder strap, interchangeable textures, a table stand and a handle.

Since the components included in the tablet case design were decided on early in the prototyping phase based on customer feedback and interviews with subject matter experts, the main challenges of this design were ensuring the tolerances of the tablet case were accurate, correctly placing holes for the tablet’s external features and combining the desired components into a cohesive design. The first step to solving these problems was to take measurements in every possible location on the model tablet and begin the case shell. The model tablet used to create this 3D model was an iPad 2. This initial shell design, as seen in Figures 32 and 33, was modeled after the common features of tablet cases for children already on the market. These common features include a series of slits for the speaker to prevent damage but also not block the sound, tapered holes for the charging port, headphone jack and camera as well as a rounded and slightly protruding edges on the backside of the case to serve as potential grips for little hands. In addition to the features pictured below, a shoulder strap will also be included with attachment points at all four corners of the shell.
Figure 32: Front of 3D Modeled Case Shell. The case shell was designed to envelope an inner silicone sleeve for impact resistance. It was also created be manufactured using a hard plastic for further exterior protection and to deter users from stimming orally on this tablet case. The front of this case shell was designed to have minimal features, outside of the clasp closure mechanisms, to allow access to this feature at all times. In the case of accidental spills or other potentially damaging occurrences, it is imperative that the caregiver is able to open the tablet case and ensure no further damage occurs.
Once this initial shell was designed, the design for the closure mechanism was explored. Many different case closures were studied, and the observed designs could be categorized into a few main archetypes. Specifically, these archetypes are slide-in, pressure fitted, and clasped. From these types, a combination of the pressure fitted and clasped types was decided upon to ensure that the case would be difficult to open for the children using it, to in turn prevent the case from being opened and tablet being damaged. This combination, as seen in Figure 34, is a two-part system with triangular extrusions on the front of the shell which fit into corresponding rectangular holes in the back side of the shell. These closures would ideally be opened either

Figure 33: Back of 3D Modeled Case Shell. The back of this case shell was designed based off of several popular features in tablet cases for children. These features include, but are not limited to, a series of slits of cover the speaker, tapered holes for access to all buttons and ports as well as rounded edges. There is a rectangular cutaway in the center of the tablet case to allow for installation of different texture plates.
using a coin or specialized tool to be included with the tablet case to pop the triangular extrusions out of the holes and open the case. This action would require a reasonable amount of force and fine motor skills, preventing children from opening the case without the proper tools or quickly enough with the tools for supervising adults to not notice.

From this clasp selection and overall shell design, the focus shifted to the integration of the texture, stand and handle into a modular yet cohesive design, to be placed in the back of the tablet case. This design was constrained by footprint, to not interfere with other features, and
compactness, to keep the thickness of the tablet case consistent and not inhibit the use of the texture. With these constraints in mind, this assembly was designed as an interchangeable rectangular plate to be set into a rectangular cut away when the tablet case is assembled. This plate, as seen in Figure 35, is covered in the desired texture and features a folding stand which recesses into plate when not in use as well as a fabric handle which both covers the pinch points created by the stand joint and provides the user with the opportunity to hold their device with one hand for mobile conversations. This plate will allow for customization for each customer, as the plate can be changed to offer the stand or the handle or neither feature, depending on the needs of the customer. Since each individual with Autism is different and has different needs, it is essential to provide this option to ensure they do not pay for and carry around features on their device which they will not utilize.
4.3 Creation of Functional Prototype for In-Class Use

After carefully considering all features of this tablet case and creating a cohesive, yet customizable design, the process of creating a functional prototype for in-class use began. It was clear that to develop and refine this tablet case design to be within reasonable tolerances and durable for testing purposes, would take many prototypes and revisions to the model. Since this functional prototype was more focused on receiving feedback on the use of the icon selection...
apparatus and texture, it was decided to modify a tablet case recommended by a parent, interviewed during the NSF I-Corps Short Course, to accommodate the necessary features. This case, the Unicorn Beetle Full Body Case for iPad 2 by Supcase, can be seen in Figure 36 (Supcase, 2017). This tablet case was purchased, in addition to a Tablet Shoulder Strap by Lapworks (Amazon, 2017), as seen in Figure 37 and a set of Screen Protectors by Designware, Inc. (Amazon, 2017).
Figure 36: Unicorn Beetle SUPCASE. This tablet case was purchased and modified to create a functional prototype for testing. It was chosen due to a strong recommendation by a parent of a child who uses this tablet case for AAC during an interview through the NSF short course. The rectangular indent on the back of the case was cut out to accommodate a texture plate and attachment points were created in the corners for the addition of a shoulder strap. Adapted from Supcase, 2017.
In order to modify the case for testing, a rectangle in the center of the back plate was cut out to accommodate the texture plate. Then, texture plates were created using cardstock, fabric and hot glue and were placed in the back of the case. Foam board was initially used to keep the texture plate rigid. However, the fit of this texture plate in the case was too tight, since the case was designed to fit snugly around the tablet. Therefore, the decision to use cardstock instead of foam board was made. Additionally, holes were drilled in the corners of the case to attach the shoulder strap in case there were any opportunities to use the tablet case outside of the classroom during the trial.
The implementation of the icon selection apparatus did not modify the case but rather added to the screen of the tablet itself. For protection, a screen protector was placed on the tablet screen prior to beginning the assembly of this apparatus. To create a ferrous grid for the magnetic cursor, steel sheet metal was cut into 1/8” circles using a block punch disc cutter and these circles were placed at each corner of the on-screen icons. The size of the circles was decreased from 3/16” to 1/8” due to the tighter spacing of icons present in LAMP Words for Life, the AAC application being used for the trial as compared to the application used in the initial design, Sonoflex Lite. These circles were then attached to the screen protector using super glue and tweezers. Once this dried, a second screen protector was placed on top to prevent any accidental movement of the circles in case the glue did not fully adhere. The tablet, with the new grid, was then installed in the front half of the case and the case was assembled. The fully assembled case, modeled on an external table stand and featuring the available cursors, can be seen in Figures 38 and 39 below.
Figure 38: Front Photo of Functional Prototype. The Unicorn Beetle SUPCASE tablet case was used combined with a sheet metal grid designed for the LAMP Words for Life AAC application. This prototype provided ample screen protection, with two screen protectors integrated into the sheet metal grid and one built into the front of the tablet case. The cursors shown were all available during the Full Prototype study.
The corresponding cursors were then created and tested to confirm that they would be attracted to the grid, despite the layers of protective film and angle of the device. Since Words for Life has much smaller icons than the Sonoflex Lite application originally used, adjustments had to be made in the cursors’ geometry and alignment to ensure that the magnets would match up with the ferrous grid. Once these adjustments were made, a small single-pane cursor was 3D printed on a Monoprice Maker Select 3D Printer in PLA. This cursor was tested for both

Figure 39: Back Photo of Functional Prototype. This part of the functional prototype features a removable table stand as well as a texture plate with the Furry texture featured. This wireframe stand was chosen so that the participant can touch the texture, as desired, while the tablet is in use during the speech therapy session. A shoulder strap was later added, with attachment points created at the grey hexagons on each corner of the case.
attraction and alignment before different designs were created. For the trial, many cursor types were created, and the four options presented. These options, as shown previously in Figure 38, were the Single Pane, which isolated one icon, the Window, the first four pane design with dividers, the Open Window, a larger rectangle which encompassed four icons instead of one, the Sunken Window, similar to the Window, but with a divider sunken into the cursor and the Window-Plate Combination, a cursor where two icons were open with a divider and two icons were covered. These icons were designed to provide multiple options based on the preferences and abilities of the child as well as the amount of prompting necessary. For example, the Window-Plate Combination may help a child who needs to rest their hand on the device during selection. This design would provide the child with the support needed while also isolating the field of view of the icons to two choices. Also, if the child needed less direction but still needed prompting outside of verbal and gestural, the Open Window, Window or Sunken Window designs may be helpful by providing the child with four choices of icons. Similarly, if the child needed more direction but did not respond well to physical assistance, the Single Pane may provide a valuable solution.

Although in the setting of a therapy session with a Speech-Language Pathologist, as is the case in this trial, the cursors will be utilized more as a prompting tool than a motor skill assistance, in independent communicative use of their device, the cursors may be utilized for a different purpose. Since the ferrous grid was designed such that it has even spacing and attractive properties, the cursors could provide a way for the child to quantify the motion of navigating the screen rather than relying on motor planning and motor skill abilities. Similarly, by the cursor snapping to the edges of the icon rather than requiring the user to perform this task, it could have the potential to promote more efficient communication through AAC applications. By designing
and revising this tablet case and its many features, it is the goal that children with Autism will utilize this device in many different ways, depending on their specific needs and desires.
5.0 Experimental Methods

5.1 Initial and Final Testing Plans

In order to test this device effectively and with realistic results, vulnerable populations were involved with the testing of this tablet case. Initially, a three-tiered testing plan was created to get feedback from three very different demographics in the same study. These demographics included neurotypical college students, adults on the Autism Spectrum and children on the Autism Spectrum. In addition to receiving feedback from different perspectives, this initial testing plan was also focused on the process of refinement in each step of the testing process. For example, the prototype given to the neurotypical college students would be the least refined functional model. However, from their feedback on the appearance, this feature could be refined. Subsequently, the adults with Autism would receive a more refined prototype and would ideally give feedback on the sensory experience of using the tablet in this case. Finally, with refined aesthetic and sensory components, this prototype would be introduced to the target users, children on the Autism Spectrum. A diagram representing this flow of testing can be found in Figure 40.
This plan was systematic in its iteration however cumbersome in its execution. Although this testing plan received Institutional Review Board approval, there were still questions, most of which relating to incentives, testing locations, and individuals performing testing for the section on working with children on the Autism spectrum. These questions were posed to ensure that families would be willing to volunteer their time and their children would be comfortable while doing so. The questions of location and individuals performing testing were associated with maintaining a level of comfort for the participant.

For many children on the Autism Spectrum, routine is essential for their overall wellbeing, including having predictable sensory input. If the participant is in a new location and/or is working with a person they are not familiar with, the child may become overwhelmed. This situation would not be beneficial for the child and may report false data to the study, therefore this situation was to be avoided. Additionally, it was found that recruiting enough participants from all three demographics, especially with children on the Autism spectrum,
proved to be challenging given the time commitment needed to gain meaningful data. However, there was a definite need for the people in the Autism community to be involved in the refinement and feedback process for this tablet case without the commitment of a full study. Receiving feedback from many different perspectives, including professionals, parents, and self-identified individuals with Autism, is imperative in understanding the needs of the users and how to address the problems they are facing rather than the problems that they are perceived to be facing.

This realization prompted involvement in the NSF I-Corps Program at RIT. In this program, 30 interviews were required with members of the Autism Community to understand the problems they face ranging from maintaining relationships with children on the spectrum to day to day communication via AAC devices and tablet applications. Findings from these interviews can be found in Chapter 3, Section 2: Entrepreneurship Exploration. In addition to these findings, which helped in modifying and refining the functional prototype, these interviews are the way in which connections were made with many other individuals with the same goal, to improve the lives of children with disabilities. Specifically, the connection established with a Speech-Language Pathologist at a local elementary school, who helped me to create and implement a new testing plan in a comfortable classroom setting with familiar adults.

This final testing plan includes two parts, a full prototype use scenario and a sensory study. These parts are both incorporated into normally scheduled Speech therapy sessions with each participant and have been designed not to interfere with their normal activities. Additionally, all adults interacting with participants throughout the study are familiar with the child and educated in the fields of Education and Speech-Language Pathology. A timeline of this testing plan can be found in Figure 41.
For use of the full functional prototype, a student was selected to participate based on demeanor, frequency of therapy sessions and use of AAC as a primary form of communication. This participant E1, age 12, has been diagnosed with Multiple Disabilities including Cerebral Palsy but not including Autism and utilizes the application Word for Life on an iPad 2 which he uses both in school and at home. E1 has four 1:1 Speech sessions per week and data was taken during each session he was present for.

During these individual sessions, E1 was given an opportunity for the first minute of the session to interact with the textured back of the tablet case. After this minute, the speech session progressed as normal, with E1 responding to requests both on his usual device and through the full prototype, using the cursors available to him as needed. The full prototype with the cursors provided to E1 can be found in Figure 38 shown previously.
Over the course of the six-week study, data was collected on texture interactions, cursor interactions and uses of the cursors in the session. An example of the data sheet used during these sessions can be found in Figure 42.
Assistive Tablet Case Data Collection Sheet

Date:______________

Section A: Texture Preferences
Texture Chosen (Circle One): Furry                    Ribbed
                                     Iridescent Bumps  Rainbow Fish

Communication of Preference (Circle All Applicable):

Pointing                       Interacting with Texture
                                   AAC device
                                   Other: ______________________________

Section B: Exploratory Play
Number of Interactions with Texture: ______________________________

Description of Interaction (Circle All Applicable):

Stroking                        Scratching
                                   Biting
                                   Poking
                                   Pulling
                                   Other: ______________________________
Section B: Exploratory Play (continued)

Additional Comments:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Section C: Cursor Introduction

Cursors Interacted with (Circle All Applicable):

- Window
- Sunken Window
- Open Window
- Window-Plate Combination

Notes on Interactions:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Section D: Tasks

Prompts:

________________________________________________________________________

________________________________________________________________________
Section D: Tasks (continued)

Number of Interactions with Texture:


Additional Comments:


Figure 42: Data Sheet for Full Prototype. This data sheet was designed to focus on texture interactions and use of the cursor as a prompt. Since the Speech-Language Pathologist (SLP) conducting the study had a student SLP working with the study participant, she assisted in guiding the student SLP and filled out one data sheet per therapy session. In addition to the categories present in the sheet, any notable occurrences or behavior changes were noted for each session.

5.3 Trial Setup and Data Collection: Sensory Texture Study

For the Sensory Texture Study, four students diagnosed with Autism Spectrum Disorder participated in the same classroom setting during each of their normally scheduled Speech sessions. The initials, genders, and ages of these four participants are in Table 2 below.
The data collection for this study occurred in the beginning of each participant’s speech session. Some of these sessions are conducted individually, while others are conducted in a group setting. In the case of the group session, each child in the room was given the opportunity to interact with the sensory board, however data was only taken for the individuals with an Autism diagnosis. During the first minute of each session, the participant was given a sensory board with four different textures. These textures all differ in sensory experience, both in tactile and other sensory inputs. The “Furry” texture is a faux-fur example which can be appealing based on familiarity if the child has a favorite stuffed animal or a family pet dog or cat. The “Rainbow Fish” Texture has a similar soft feel to the “Furry” texture but is smooth and features a slight sparkle which could be desirable visual input. The “Ribbed” Texture is not a fabric, but a heavy-weight cardstock with ridges similar to corrugated cardboard. In addition to running fingers both along and across the ribbed texture for tactile input, moving across the ribbing can provide auditory input as well. The “Iridescent Bumps” Texture is a tulle with bumps incorporated into the fabric. When this texture is moved in the light, the bumps become brighter.

<table>
<thead>
<tr>
<th>Student</th>
<th>Gender</th>
<th>Age</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>Female</td>
<td>9</td>
<td>Multiple Disabilities (including Visual Impairment and Autism)</td>
</tr>
<tr>
<td>S</td>
<td>Female</td>
<td>8</td>
<td>Autism</td>
</tr>
<tr>
<td>E2</td>
<td>Female</td>
<td>10</td>
<td>Other Health Impairment and Autism</td>
</tr>
<tr>
<td>M</td>
<td>Male</td>
<td>10</td>
<td>Other Health Impairment and Autism</td>
</tr>
</tbody>
</table>

Table 2: Demographics of Sensory Texture Study Participants. In this sensory study, it was unique that, out of the four participants, three were female. Autism is found to be more diagnosed more often in males than in females therefore, having a majority of female participants contrasts greatly from the usual testing demographics for this diagnosis. Additionally, it should be noted that all participants are within two years age difference and three out of four have other diagnoses in addition to Autism.
or duller, depending on the angle of the texture. The sensory board used in this study can be found in Figure 43.

Figure 43: Sensory Board with Labeled Textures. This sensory board was utilized during the Sensory study and was created taking into account the different types of sensory input children with Autism use for stimming. The Furry texture was chosen as a soft and calming texture while the Rainbow Fish was soft, contained sparkles for visual sensory and could be associated with a popular children’s book of the same name. The Ribbed texture was chosen since it was rigid and could produce auditory input by moving across the ribbed surface. The Iridescent Bumps texture was chosen due to the contrast of its sheer fabric and hard bumps which, when moved, can be a visual stim by become brighter or duller.

For the time in which the participants were given to interact with the sensory board, data was taken on which texture is being interacted with, the type of interaction used as well as the number of interactions of each type. Additionally, any comments or behaviors outside the previously defined interactions during this time were documented. This data was taken for five
weeks, during each speech session that the participant has normally scheduled. An example of the data sheets used during this study are below in Figure 44.
Figure 44: Sensory Data Sheet for J and S. This data sheet was designed to focus on which textures the participants interacted with and how they interacted with them. It was encouraged that, during each session, any interactions that did not fit into the given categories be noted and explained, as well as any comments on the textures. If the students did not comment on the textures, the Speech-Language Pathologist provided a verbal prompt asking about texture preference and recorded the response given.
6.0 Results and Discussion

6.1 Trial Visit Observations

During the Full Prototype section of this trial, I was given the opportunity to come to the elementary school and observe the participant’s Speech session. This was possible through prior approval from the administration of the school, since they were already very familiar with the trial and its progress as well as the fact that I would not be interacting with the students. From this, I visited the school at 10:45am for a 30-minute speech therapy session at 11am with a student, called E1 in this study. I then left the school at 11:10am, after a brief conversation with the Speech-Language Pathologist (SLP) and Student-Pathologist (Student SLP), who was finishing her Master’s degree in the field at a local University. The two sessions which I came to observe were on September 21st and October 19th, 2017. A summary of my observations for both sessions are below.

6.1.1 Initial Visit

Upon arriving to the speech room for the session, it was clear that E1 was incredibly social. In the room, there was the main SLP, Student SLP, E1’s aide and myself. Since I was a new person in the room, the student repeatedly tried to engage with me and say hi. From this, the student SLP, who was administering the therapy, directed his attention back to the session. During this session, she reviewed twelve core words and concepts and asked questions to the student based on pictures of family members. During this time, the experienced SLP was giving feedback when needed and taking data for the session.
To begin the session, the tablets were setup with E1’s tablet in front of him on a slant board and the full prototype on a folding table stand in front of the student SLP. E1’s tablet was an iPad in a hard-shell case equipped with the Words for Life application and a corresponding keyguard. Once the tablets were setup, E1 was given the opportunity to interact with the texture on the full prototype by placing this in front of him with the texture facing towards him on the table stand. During this time the student simply picked up the tablet and turned it around so that the screen was facing him, and he could operate it. The full prototype tablet was then moved away from him back into the position in front of the student SLP.

During the core word review portion of the session, the student was told a word and was then asked to select the same word on his device. During this time, the student only needed verbal and gestural prompts except for one word. When selecting this word, the student SLP utilized the Open Window cursor to redirect the student’s attention to the 2x2 grid of icons inside the cursor. From this redirection, E1 selected the correct word. Additionally, in the cases where he selected the correct word and was praised accordingly, the student repeated the word quite a few times before moving on to the next request. During the picture section, the student only required verbal and gestural prompts, especially since he was describing the pictures, yielding the opportunity for multiple correct responses.

During this session, apart from the full prototype and use of the cursors, I did notice a great overarching level of respect both for the student and his device. The full prototype was used mostly by the student SLP to model selecting words and going through different folders present in the AAC application. However, during the picture section of the session, the SLPs needed to use E1’s AAC device, which they referred to as a talker, to see if his sister was added as one of his customized words he could use. Before checking this, they asked him if they could
use his talker to check. Initially, the student responded with the “No” icon on his device. The professionals respected this request and asked again to confirm the response when he then offered a verbal “Yes” at which point the professionals thanked him for letting them use his device and proceeded to search for the desired icon to determine if this icon needed to be added in the future. Overall, this session went smoothly, outside of the initial distraction from a new person being in the room, and provided a unique opportunity to observe a session during the first section of the trial.

6.1.2 Final Visit

Upon arriving to the second session, the reaction to my presence in the room was minimal as compared to that of the initial visit. During this session, the student SLP focused on an activity reviewing core words and, for each correct response, the student is given a block to stack. The purpose of this exercise was to confirm knowledge of core words while combining this into an incentive-driven play activity.

During this activity, the first use of the cursor took place after the verbal and gestural prompts were not enough direction to yield the correct answer after two incorrect responses from E1. When using the cursor, the student SLP held the Open Window cursor on the student’s device and he successfully selected the correct icon after approximately five seconds of processing time.

After the student had successfully identified a few words, he became visibly frustrated with the activity, where he kept selecting the icon combination “I want” in reference to the block rather than selecting the icon for the target word “like”. After this occurrence, the student was
overwhelmed and began attempting to hit his head on the tablet, which resulted in a 30 second break from the lesson. Once E1 finished his break, the same cursor was used for two words and one two-word phrase with varying levels of effectiveness. In the case of the word “like”, which was attempted prior to the break, E1 selected the correct word within approximately five seconds of using the cursor. In the case of the following word, “off”, the student took approximately one minute to select the correct word. For the two-word phrase, “block off”, he took approximately two minutes to select the correct combination with the cursor as well as a verbal prompt of “Over here”. Prior to selecting this phrase, the student was told that would be his last activity of the session. However, once he selected this phrase, he was asked to select another word, but the student was not compliant, and the session was ended.

Overall, this session was a bit more difficult than the one I witnessed during my first visit. In addition to the difference in behavior as compared to the last session, this session allowed me to learn more about the way in which these therapy sessions would approach creating a phrase as opposed to a simple selection of a word. When prompting for a phrase, a great change in pitch and rhythm was present for different combinations of words. Additionally, during the phrase selection, the use of folders was much more pronounced as compared to simply using folders to access a single icon.

6.2 Results: Full Prototype Use

From the data collected in the full prototype section of this trial, several observations and trends were noticed and documented below. For first few sessions of the trial, setup and preferences were the focus. For the texture, it was decided ahead of time to utilize the “Furry”
texture in the tablet case since offering the student the options of different textures and the act of switching out the texture plates may take too much time in the confines of a 30-minute speech session. Therefore, the texture was setup for the student and observations were taken based on the interactions with that texture solely. However, although the student was given the opportunity to interact with the texture in the beginning of each session, he did not show a large amount of interest in the texture after the first two sessions. It is important to note that this student does not have an Autism diagnosis and is 12 years old, making him older than the anticipated audience for this feature when referring to individuals without an Autism diagnosis.

When selecting the cursor from the four provided during the first session with E1, the SLP attempted to use each one and see if he could indicate his preference. However, upon trying each cursor, it was clear that, due to the student’s age and, therefore, hand size, he could not use the Single Pane, Window, Sunken Window or Window-Plate combination since each of these featured partitions around single icons. He was able to use the Open Window cursor since it only had partitions around a 2x2 icon section. Additionally, the fact that the application being used, Words for Life, has one of the smallest displays in both icon size and spacing, caused the space for each icon to be decreased from the original design using the Sonoflex Lite application. However, in the case of the student’s personal device, he does have a compatible keyguard for the Words for Life application, therefore making him able to utilize the partitions around the small icons when presented on a large-scale format.

With respect to the cursor use during the sessions, it was found that, since the student was used to using an AAC application prior, he, at times, did not need an elevated level of prompting outside of the verbal and gestural prompts given. Since the sessions utilized the Least-to-Most prompting technique, it was desired to provide the student with many opportunities to respond
correctly as independently as possible. Therefore, the cursor was only used on the occasions that
the student was not able to select the desired response without more involved prompting
techniques. From the data recorded, a graphical representation of the use of the cursor per
session can be found below in Figure 45, with use divided into two categories, Yes and No.
During one session, on the initial observation date, it states in the data sheets that the student did
not utilize the cursor however, in my observation notes this is not the case. Therefore, this date is
categorized under the “Yes” category, meaning that the student did use the cursor for additional
prompting on this date. Overall, the student utilized the cursor for additional prompting during
37.5% of the sessions.

In addition to cursor interaction, the behavior of the participating student, with respect to
compliance during the session, was noted in the data sheets as necessary. In total, the student was
noted to be noncompliant for three of the 14 sessions studied, accounting for 21.4% of the
sessions used in this trial. This data can be view graphically in Figure 45 as well, noting which
instances the student was not compliant for the majority of the session. This behavior was found
to have a large impact on the data collected and the overall success of the sessions.
Figure 45: Graphical Representations of Full Prototype Study Data. A) Cursor Use per Session. This graph shows whether the participant needed additional prompting outside of verbal and gestural prompts used. If the participant did need additional prompting through use of the cursor, the session would be placed in the “Yes” category. It was found that the participant needed additional prompting during 35.7% of the sessions. B) Compliance per Session. This graph shows whether the participant was compliant for the therapy session, as noted by the Speech-Language Pathologist in the comment section of the data sheet. If the participant was compliant for therapy, the session would be placed in the “Yes” category. It was found that the participant was not compliant for 21.4% of the sessions. During sessions 6 through 11, as shown in gray, three sessions where the student was not compliant correlated with three sessions where the cursor was not used, causing speculation that the student did not participate, therefore did not utilize prompting.
6.3 Results: Sensory Texture Study

For the sensory texture study, I was not able to observe the sessions due to scheduling, therefore I am not able to provide my observations of the sessions from an outside perspective. However, the data taken from each student’s interaction with the sensory board provided insight into their individual behaviors as well as common trends in interactions and texture preferences amongst the group. Below are detailed accounts of the individual student interactions as well as some trends found for students J and S, who were involved in more than one session with the sensory board. A picture of the Sensory Board, labeled with the texture names, is shown in Figure 43 previously.

Student J participated in the most sessions with the sensory board. The three sessions she participated in were a mix of group and individual sessions, with the first one being a 2:1 group session with student S, the second being an individual session and the third being a 2:1 group session with students not involved in this study. During each session, J was given a minute in the beginning to interact with the sensory board. A graph of J’s overall texture interactions is available below in Figure 46, with her interactions categorized by texture and date of session. Additionally, J’s overall interactions graphed by type of interaction is shown as Figure 47.
Figure 46: J’s Overall Texture Interactions. This graph shows the textures that student J interacted with during the three sessions she participated in. It is clear that the J interacted most with the Furry texture, especially on the October 11th session. The iridescent bumps had the most consistent interest, with interactions during all three sessions J attended.
In the first session, J stroked two textures, the Iridescent Bumps and the Ribbed. Of these, J interacted with the Iridescent Bumps three times and the Ribbed twice. When asked which one her favorite was, she selected the Iridescent Bumps. During the second session, J interacted with all four textures provided. Of the four, she interacted with the Furry texture the most, with 15 interactions with that texture during the session. One of these interactions with the furry texture consisted of the student putting her face to the fur. Additionally, during the time allotted, J commented unprompted about the Rainbow Fish Texture stating, “This is as soft as my hair!”.

For the third session, J interacted with all textures except the ribbed texture, with her interacting the most with the Furry texture, but the number of interactions with this texture (3) being far less than the previous session (15).
Student S participated in two sessions, the first which was a 2:1 group session with student J and the second which was individual. This change from group to individual sessions was made due to the needs of student S varying from those of the rest of the group. Given the data from these sessions, a graph of S’s overall texture interactions is available below in Figure 48, with her interactions categorized by texture and date of session. Additionally, S’s overall interactions graphed by type of interaction is shown in Figure 49.

![S's Overall Texture Interactions](image)

**Figure 48: S’s Overall Texture Interactions.** This graph shows the textures that student S interacted with during the two sessions she participated in. Similar to J, it is found that S interacted most with the Furry texture, particularly in the October 17th session. During this session, S regulated herself using the sensory board and interacted with the textures frequently, especially the Furry texture. It is also notable that S did interact with all the textures provided during each session.
During session 1, S interacted with all four textures offered, but interacted the most with Furry, with 6 interactions and Rainbow Fish, with 2 interactions. Included in the interactions with the Furry texture, S rubbed her face on the fur twice. When she was asked which texture was her favorite, she stated that she liked the Furry and Rainbow Fish texture the best. During the second session, we gained insight into how textures could be effectively used for self-regulation during a communication activity in an educational setting. Student S entered the room very dysregulated and used the sensory board to regulate herself successfully to continue with the therapy session and complete her work for the day. During the time of self-regulation, S
interacted with the textures in a variety of ways. Although stroking was the most common type of interaction at 13 instances, S interacted with the textures using each type of listed interaction type as well as another type by rubbing her face on the Furry texture. She also interacted with the Furry texture the most during this session with 26 interactions. In addition to general interactions with the textures, S also made a connection between her classwork and the sensory stimulus she was receiving by pulling the fur off the sensory board and placing it on the bunny rabbit picture on her worksheet.

In the cases of students E2 and M, each student participated in one session with the sensory board. E2 participated in a 2:1 group session and interacted with each texture, using the same quantity and type of interactions. He stroked each of the textures twice and commented unprompted that, “They’re all soft except this one.” in reference to the Iridescent Bumps. M participated in a 4:1 group session and interacted only with the Furry texture, stroking it twice. During these interactions, he verbally stimmed by saying “Ahhhhh” and commented unprompted about the Furry texture asking, “Is that a puppy?” and “Is it skin?”.

6.4 Discussion of Results

From the full prototype testing, the environmental and human factors included could have an impact on the data collected during the sessions. Since E1 was not compliant for 21.4% of the sessions in this trial and the student SLP was conducting the sessions, difficult behavior and need for direction during the session could contribute to differences in the data.

Even though these challenges were present, the use of the cursor for prompting after the initial verbal and gestural prompts were shown to be effective. When used, the cursor
successfully redirected the student’s attention to a specific area of the device and gave the student less icons to choose from to make the selection easier and quicker. Although this wasn’t the intention, the use of the cursor for prompting in the trial situation did require human interaction to hold the cursor onto the student’s personal device. However, if the device in use had a ferrous grid, the SLP would not have to hold the cursor or interact outside of the prompts which are already utilized.

In the case of the texture plate and cursor selection, many factors relating to the student impacted this process. For the cursor selection, hand size had a great impact on which cursors could be used. Due to the fact that E1 is a 12 year old boy, his hand size was comparable to that of an adult woman. This factor eliminated 3 of the 4 choices in cursors since the smaller icons on Word for Life made the cursors with partitions around each icon difficult to use for his hand size. As for the texture plate, the initial selection of the texture and the decision to keep the same texture were based from the limited time in the session, the effort it took to exchange the textures and, further, the level of interest that the student showing in the texture during the first week of sessions. E1’s diminishing interest after the second session confirmed this decision to maintain the same texture. Although E1 did not show a great deal of interest in the texture, the other students, who are on the Autism spectrum and participated in the sensory study, provided valuable feedback for how others may interact with and utilize the textures.

For this sensory study, trends were present amongst the group of students and comments, both prompted and unprompted, about their experience with the sensory board were plentiful. During these sessions, all students were able to comment on the textures in general, with some cases where they responded to prompted questions about texture preferences. In other instances, comments from the students were comparing the textures to known items such as hair, rugs, and
puppies. Additionally, all students commented unprompted except for S, who ended up using the sensory board for the intended purpose of self-regulation with great success.

Overall, the trends present amongst the students in the sensory study were relating to the most popular texture and interaction type. The most popular texture in the study was the Furry texture, with 55 total interactions with this texture from the four participating students. Also, the most popular type of interaction was stroking, with 60 total interactions of this type. Graphs of the total interactions by texture, Figure 50, and by type, Figure 51, can be found below.

![Total Interactions by Texture](image)

**Figure 50: Total Interactions by Texture.** This graph displays the overall trends shown by the four participants in terms of the textures they interacted with. For all participants, the Furry texture was interacted with the most, with 55 total interactions. The trends in participants J and S’s texture interactions were described previously in Figures 46 and 48 respectively. Participant E2 interacted with each texture equally during his session, showing no preference between the four textures and Participant M only interacted with the Furry texture during his session.
Figure 51: Total Interactions by Type. This graph displays the overall trends shown by the four participants in terms of interaction type. For all participants, the Stroking interaction type was utilized the most, with 60 total interactions. The trends in participants J and S’s interactions by type were described in Figures 47 and 49 respectively. Participants E2 and M both solely interacted with the textures by stroking during their sessions.
7.0 Conclusions and Future Work

7.1 Overview of Process: Successes and Opportunities for Future Work

Through the creation and testing of this assistive tablet case, much was learned about the area of Autism access technology, the specific problems that individuals with Autism face and the many ways in which technology can used make their lives easier. In the context of data and conclusions, the various successes, difficulties, and overall behaviors of the participants in this study can provide the Autism research community with powerful insights into new methods of prompting and integrated self-regulation tools. This study also provided many areas for future work to solidify these insights and validate new hypotheses.

The full prototype study provided a very realistic perspective on the use of new assistive devices and technology in an educational setting. Specifically, learning how students may approach using a new AAC application and learning vocabulary was extremely valuable in understanding how they may interact with their own device. Additionally, the compliance of the student for the sessions was both hindering in the interest of collecting data and helpful in gaining an overall understanding of unpredictability in the learning process and working with children. From this information, it is clear that in the future, having a larger sample size in both participants and sessions as well as continued documentation of compliance during these sessions would be beneficial for more plentiful and diverse data sets from which to draw conclusions. These new participants and expanded number of sessions could assist in testing which factors would impact effective cursor use and interest in the textures presented.

In the case of effective cursor use, one of the main successes of this study was that the Open Window cursor was shown to be effective as an elevated method of prompting. This cursor
was used, with much success, to redirect the student, to isolate the field of view to the icons inside the cursor area and to assist in making correct selection. Although this method was only used when elevated prompting was necessary, when it was used, it had a positive effect on the icon selection process. Since the participant was familiar with AAC but was learning a different application when this study was conducted, including younger children who are not familiar with AAC in future work would test this method of prompting further. If children are just beginning to learn how to operate their device and have not developed as far in their communicative skills, they may require more involved prompting to select the correct response, therefore providing more opportunities to test the cursor prompting method. Additionally, these younger children would most likely have smaller hands than the participant of this study, allowing for testing of the other three current cursor designs as well as other shapes and sizes depending on the AAC application in use.

In the texture portion of this full prototype study, it was noted that the participant did not show much interest in the texture after the first two sessions. This behavior suggested that maturity and diagnosis may impact the interest, or lack thereof, that individuals show in the texture. For example, the participant in this case was a 12-year-old boy with multiple disabilities which do not include Autism and he was not very interested in the texture. Rather, he wanted to focus on using the tablet by turning it over to use the screen when given the opportunity to interact with the texture. In the case of the sensory study, the four younger participants who all had an Autism diagnosis all used the time allotted to interact with the textures offered. Certainly, a broader study of different demographics interacting with the same textures is needed to verify any differences in reactions and interest based on the different ages and diagnoses of the participants.
Within the confines of the sensory study performed, the main success was the ability of one of the participants to utilize the sensory board for its hypothesized use, to self-regulate enough to continue participation in the classroom. During this time of self-regulation, the student clearly showed preference to a specific texture. This behavior suggests that, if a preferred texture were available during an educational activity and the child began to get dysregulated, the texture, potentially coupled with a short break, could be used to avoid a meltdown and continue progressing with the lesson.

With respect to the overall trends found in both preferences in texture and interaction type for participants, this effect was obvious in the data, with a strong preference for all participants of the Furry texture and the stroking interaction type. These trends provide insight into which textures may be most popular if this tablet case was to be produced and the potential relation between the popularity of the Furry texture coupled with Stroking. Also, there was another interaction type, which was not listed, that was done by two of the four participants. This interaction was rubbing the texture on their face and was only seen when interacting with the Furry texture. This interaction may not be relevant in the context of a texture plate on a tablet, simply because of the additional features on the plate. However, it is worth noting that students may attempt to interact with the textures in this way. These trends could be validated even further in the case of a future experiment with a greater sample size and known variety in sensory behaviors. In the current study, the participants’ sensory-seeking or sensory-avoiding tendencies were unknown prior to their participation. Therefore, there is a minute possibility that all four participants react to tactile sensory stimulus in a similar manner. In the case of sensory-avoiding individuals, they would prefer more soft textures, like the Furry texture and calming interaction types, such as stroking. The fact that all participants favored this texture and
interaction type could be trends to explore. To determine if this trend is true for children who are sensory-seeking as well as sensory-avoiding, the children involved in a future study would have this behavior evaluated prior to their participation. It is also possible that more children with Autism identify with sensory-avoiding versus sensory-seeking tendencies, which would validate the trends of this study and could be evaluated in this future experiment.

It is clear that in this sensory study, all participants were actively interested and engaged with the textures and the opportunity to interact with them through exploratory play. None of the participants had difficulty with compliance and each one offered comments on the textures they were interacting with, most without any prompting. The comments offered, indicating preference and comparison to known objects, suggest that the students enjoyed interacting with the different textures and were prone to socialization when discussing this enjoyable activity. Additionally, one student connected the texture she was interacting with to a picture on her classwork, potentially motivating her to complete her work once the interaction was completed.

7.2 Extended Testing and Research for Future Development

Upon completion of this project, there are many more steps to be completed and criteria to be explored prior to developing this device for market introduction. An effective next step to test this concept further would be to create a series of full-prototypes using the 3D modeled overall design, as seen in Section 4.2. This series would include a refined method of creating a ferrous grid, ideally integrated into a built-in screen protector.

These new prototypes would allow for a variety of testing methods, specifically to evaluate the physical properties, ease of installation and usability. To test the physical properties
of the tablet case, tests would be performed to determine how shock absorbent the case is when dropped, how high the device could be dropped from without damage to the hard shell or device inside as well as how resistant the exterior shell is to punctures from sharp objects, such as teeth in the case of oral stimming. Further, the clasp mechanism will be tested during the installation and removal process to ensure that an adult is able to open the tablet case when needed and that switching out texture plates would not be a tedious or time-consuming task. Finally, to test usability, the focus would be placed on how the features integrated into the texture plate interact with one another. The goal would be to confirm that one feature does not hinder the use of the others, in turn potentially decreasing the usability of all features in this assembly. In addition to the testing of the tablet case, the cursors will also be tested and modified to mitigate the risk of a choking hazard due to the small magnets used.

After this preliminary testing is performed, another trial would be initiated, ideally with children on the spectrum in early intervention, who are beginning to learn AAC. The ideal testing candidates would also have motor skill difficulties to some extent. This trial would ideally explore the areas of teaching children how to use the tablet with and without the cursors as well as the effectiveness of using the cursors as a motor skill assistance rather than solely a prompting tool. This testing would also evaluate the quantifiable motion aspect of moving the cursor and determine if the magnetic forces present impact the efficiency of navigating the tablet screen.

From this trial, as well as advice from potential customers, any necessary modifications would be made to the model and additional funding would be pursued to create a new series of prototypes. To do this, reaching out to connections in the Autism community as well as attending events such as conferences and trade shows would be necessary to gain enough publicity for the
product. Given this new trial, as well as the previous one conducted in this study, there will be plenty of data to validate the design changes and need for this device for users. Once funding is secured, a new series of prototypes would be created and given to potential customers to provide feedback on using this device in real-world situations. From this feedback, the design will be modified again to address any issues, and, from this revision, the product would ideally be introduced to market.

7.3 Future of Prompting for Children with Autism

Although the initial focus of this project was simply determining how to make communication easier for children with Autism and specific coupled conditions, advancements in prompting techniques were made, specifically in learning how to utilize a new AAC application. Prior to testing this cursor system as a method of prompting, there was not a method of prompting studied which changed the appearance of the tablet screen and did not involve human interaction. This factor of human interaction may seem trivial to many, however, to children on the Autism spectrum, any amount of unnecessary sensory input could interfere with their therapy session and, further, impact their academic progress.

This concept has the potential, with necessary modifications, to provide a more independent alternative to physical assistance through hand-over-hand or hand-under-hand prompting. More research into and prototyping of cursor designs to provide varying levels of physical support could allow for more independent communication overall, not just within the confines of a classroom. Some examples of this physical support could include, but are not limited to, support of the wrist and/or hand as well as an additional area on the tablet case to rest
the hand when not selecting icons. If these supports are proven effective, these cursors may replace the need for a keyguard and allow for more versatility if the tablet is used for other applications. Additionally, the attachment of the cursor to the tablet case would prevent any accidental loss or choking hazard.

Overall, the idea of utilizing techniques with little to no external sensory input in the classroom may allow for students to be more focused on the task at hand and more motivated to complete their work to receive a tangible reward. In the case of praise, verbal praise is often given to the child when they are effective in answering questions or completing an assignment. However, this external sensory stimulus may not feel like rewards to children with Autism, but rather hinder their progress further. However, if the student is given a routine and timed reward based on their interests, this may be more effective in rewarding their good behavior. If user-controlled sensory input was a focus in the education of children on the Autism, including in the area of prompting, communication through AAC devices could be achieved with less effort from both the professional and the student.
8.0 References


Pereira, Anna, Tevis Miller, Yi Min Huang, Dan Odell, and David Rempel. 2013. "Holding a tablet computer with one hand: Effect of tablet design features on biomechanics and subjective usability among users with small hands." Ergonomics 56 (9): 1363-1375.


9.0 Appendix

9.1 Completed Data Sheets from Full Prototype Study
9.2 Completed Data Sheets from Sensory Texture Study
9.3 Texture Sampled from Sensory Texture Study

Furry

Ribbed
Rainbow Fish

Iridescent Bumps