Supporting Communication for Nonverbal Children with Autism

Anusha Vataparambu, Suzanne Dazo, Pranav Sharma
University of Nebraska at Omaha
Omaha, NE
avataparambu,sdazo,psharma@unomaha.edu

ABSTRACT
Autism spectrum disorders affect many children, and it has grown to the point where assistive technologies designed specifically for ASDs are needed. ASDs can hinder the development of social and communication skills, and many children on the spectrum are nonverbal. Our project aims to assist in the development of social and communication skills of nonverbal children through the use of a smart toy. In designing this toy, a contextual inquiry tool place involving therapist interviews and a competitor analysis of existing apps for children with ASDs. The resulting design guidelines drove an iterative ideation phase which led to our final toy prototype. We propose how to evaluate this prototype and conclude with work for the future.

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H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

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autism support; communication; toy design; design process

INTRODUCTION
The number of children being born with Autism Spectrum Disorders (ASD) has grown to the point where many children will require assistance to learn how to communicate and interact with others. Autistic children have difficulties initiating conversation, ending conversations and be a part of a social group and learn the interests of others. They require someone to assist them through direct instructions to help them cope social challenges [4]. Technology can be used to help children with ASD's develop their behavioural and social skills and enhance their individuality without depending on others [8]. Autism Spectrum Disorders take place along an entire spectrum, so many children have different needs and skills when interacting with technology. The purpose of our project is to better enable communication for children with ASDs. While many apps may focus on increasing or using vocabulary, they do not incorporate the social aspect of a language. Communication is a social interaction, and our project aims to capture that by involving both parents and therapists in the use of our technology. This is not only from the child to the caretaker, but also sharing information between therapists and parents as well. The involvement and influence of parents and therapists is critical to the design of technology for children with ASDs [13]. Lower functioning children need the most care and assistance in development, and our technology will focus on these non-verbal children and building up their speaking skills and vocabulary acquisition.

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BACKGROUND
Children with autism spectrum disorder (ASD) exhibit pervasive deficits in social communication and demonstrate restricted and repetitive interests and attention[9]. As a child develops, acquisition of speech and language typically progresses with little or no explicit effort from parents, family, or doctors. Developmental disorders, such as Autism Spectrum Disorder (ASD), can significantly disrupt the natural development of social behaviors, such as spoken communication[6].

Cognitive abilities vary widely even among individuals diagnosed with the same type of disability such as autism or cerebral palsy. Each individual has a unique set of abilities, and an effective technological tool must match the individual's needs in order to augment his or her abilities[2]. Novel interactive technologies are often a source for hope for children with complex communication needs. In particular, there is possibility that they will encourage children to communicate or express themselves in ways that were not previously afforded to them, or not quite as convenient[8]. For children, novelty is necessary in order to have rich experiences that can lead to growth. At the same time, it needs to occur in such a way that it does not overwhelm them and cause anxiety[7]. A lot of stress has been given on creating technologies that implement the interaction style of direct manipulation. As referenced in [7], most software for children nowadays attempts to follow the ideas behind direct manipulation. The one idea that is often not in children and adults' software alike is that of making actions rapid, reversible, and incremental.[7] It is very important to develop a technology that gives feedback instantly. Children are likely to lose interest in the activity if there is not quick response.Children should be given feedback about what stage is their request/progress is. [10] Many of the similarities people with ASD share manifest inwardly through their interaction with the world or out- wardly through their behavior[11]. The advantage of speech output is that it provides a more natural interaction.[13]

Related Work

Smart toys combine the best of two worlds - traditional toys and the power of computers and electronic chips. Experts predict that almost every toy will be powered by interactive technology in the very near future[3]. Moreover, humanoid robots are quite expensive and have not reached consumer market yet; they are developed in highly specialized laboratories and cannot be used at large[1]. Modern toys are interactive, motivate play, and can be used to aid detection and analysis of play behavior[5]. The impairments associated with autism pervade a range of domains including reciprocal social interaction abilities and communication skills.[12] One goal of child's play is to help increase the awareness and understanding of a child's development by automatically providing quantitative measures of toddler-object interactions, annotations of data, and a way to view rich forms of this play data[14]. As referenced in [7], many researchers have explored the use of tangible user interfaces in theit technology. Tangible setups enable users to interact with technology by manipulating physical items, instead of manipulating items on a screen. There is evidence that tangible approaches may increase motivation, facilitate social engagement, and even make some tasks more manageable.

We worked on similar terms to make our prototype like a physical item that could be easily operated by children of any age. Since, tangible prototypes have been said to be more engaging and this satisfies our very first design implication to create something that could be interesting and engaging at the same time. However, we do aim to produce a prototype that is more accessible through lower costs and allowing for it to be present in the home and handled by a child more easily.

CONTEXTUAL INQUIRY

To understand who our different stakeholders may be, the needs of each of these stakeholders, and unique design requirements specifically for working with ASDs, a contextual inquiry was conducted. During this phase semi-structured interviews will be conducted with the intended stakeholders/target audience to gather inputs for designing the system.The interviews will be conducted in the users working environment since it would help us to understand the users interactions with the existing technology and direct observation of the user activities.

Interviews

Data was collected from interviews with speech-language pathologists, a competitor analysis of existing technology, and an analysis of training materials used by parents in working with their autistic children. Two interviews were done face to face and the other one was a telephonic interview. Our interview questions were about their experience working with autistic children, the characteristics of autistic children, what use and challenges are there using technology in therapy and the successes and challenges of therapy itself. The conversations were recorded alongside notes taken during the interview. After each interview, the interviewer wrote a quick debriefing statement to share with the other project members. Additionally, pictures were taken of any technology shown during the interviews for reference in the competitor analysis.

Recruiting participants was done through emails. Contact was made with the department heads of various speech pathology centers throughout Omaha who then forwarded the study information in department-wide emails. Additionally, participants were collected through snowball sampling of other interviewees.

Our first interviewee was a 22 year old graduate student in the Speech - Language Pathology program at UNO. She had in-home therapy experience before getting admitted to graduate school at UNO. She also is a certified Applied Behavior Analysis (A.B.A) therapist.

Our second interview was a 26 year old, speech pathologist, who has 2 years of experience working with autistic children. As a part autism diagnostic clinic, she works with 3 children for 3 hours a week to see if they meet criteria for autism. She provides individual therapy and also works with 7 families in a parent training program.

The last interviewee is a 37 year old, and a speech pathologist for 17 years. She currently works at UNMC but has prior experience working with children in preschool and in the home. She is involved with project imPACT[9], in which therapists train parents in teaching strategies for autistic children.

After all of the data was collected, we transcribed the interviews for which there were just audio recordings. Work activity notes were taken from these recordings and used to generate an affinity diagram. This data was compiled and used to form meaningful clusters. As soon as clusters started to turn into big affinity groups, we were again able to categorize them further into sub-affinity groups like characteristics of the child, child technology, overall goals and their subgoals, therapy techniques, communication, challenges faced, parents role in therapy and how a usual therapy session looks like etc.

The justification for conducting interviews was because we got to observe our users in their work environment. It was easy for users to show us and physically interact with the technology they use during the therapy sessions. In having a semi-structured interview format, we could easily ask follow-up questions. For example, we asked about how to determine what a child's interests are and what to do to motivate a child, which wasn't an original question in the set of interview questions. The interviews generated thoughtful and detailed information from a wide variety of people. Our interviewees ranged from students who have always used technology in therapy to those with decades of experience who saw the change in attitudes about technology in therapy.

Competitor/Training Material Analysis

During the interviews, we asked participants what technology they had used for therapy. We took pictures and wrote down lists of the technology that was useful to them. During interviews, we also asked about the challenges of existing technology and situations where the technology was especially effective. We also asked participants about the training materials that they had available.

The initial applications that we looked into are a few smart apps like TouchChat, in which tapping or pressing the buttons on the screen makes the system speak out the words, phrases or sentences that have been pressed. The person unable to use natural speech can express or communicate to others using this app. Another app was SoundingBoard which is pretty customizable for specific users and help the kids with limited speech to express their needs, emotions etc. We had also looked into project imPACT, which the therapists at UNMC used as a way to train parents as well as provide therapy for children. We looked at [9], the guide for parents about how to interact with their child and therapists teach parents various interaction and teaching techniques. Instead of focusing only on the child, the program focuses on the parents of autistic children.

From this information, we did a further in-depth exploration of these materials. We gathered information on screenshots, the intended audience (age group, level of communication, was this intended for children with autism?), the typical use of the system, and the pros/cons in usability of the system. For the training materials, we also took notes on what information was conveyed in this material, who it was meant for (therapists, parents, or other) and some of the techniques and suggestions provided in the materials. Information from this analysis is outlined in the appendix. Originally, we wanted to have in-session observations, but due to time constraints, privacy concerns, and the safety of the child (preventing distractions) this was not possible. The competitor analysis and analysis of training materials is an appropriate proxy for this information. We can also receive varied information from reviews and interviews that we may not have from sitting in during a single session, and a single session may not cover the breadth of technologies explored from this competitor analysis.

Results

From our contextual inquiry, we identified three stakeholders in the design of our system. These stakeholders are the child, the parent, and an outside caretaker such as a therapist. With these stakeholders in mind, we converted our affinity diagram and work activity notes into design requirements. We report on both the functional and nonfunctional requirements of our system below:

Functional Requirements

- Switching the modes
  - As a user(Parent/Therapist/Child) I should to be able to have different modes available for varied users so that I can distinguish each of the profiles based on the preferences.
- Creating specific tasks depending on their needs
  - As a Parent/Therapist I should be able to create custom tasks for the child so that he/she improve his social interaction skills.
  - As a parent/therapist I should be able to set a time limit for each task that I assign to the child.
- Adding new content
  - As a parent/therapist, (possibly all users, but at the very least the parent and therapist user group) I should be able to add new content (such as vocabulary words) to the technology based on the child's growth and interests.
  - As a parent/therapist, I should be able to hide or show content to prevent unnecessary distractions for the child.
- Audio playback of selections.
  - As a child, I should be able to hear the way that words are pronounced when I select them in the interface.
- Logging child's activity
  - As a user (parent/therapist) I should have access to what my child does within the system to track progress, areas of interest, and areas of improvement for the child.

Non-Functional Requirements

- As a child, I need exaggerated responses to easily imitate/mimic and learn from.
- As a child, images should be easy to understand for me, which may mean being icons, photographs, or both.
- As a therapist/parent, I should be able to quickly change the settings (like if I am changing them during a therapy session with the child)
- As a child, where I can interact with the system should be easy to understand, or easy to teach to me. I should not have multi-step tasks, if possible.
- As a parent/therapist I need the technology to be robust and safe even from accidental droppings.
- As a child I need the technology to recover from being hit rapidly due to my frustration and mood swings.
- As a parent/therapist/child,I need quick response on choosing an option.
- As a parent/therapist, I need a technology which utilizes less space so that it provides high performance.
- As a child, I need a clear and quick indication of the effect of my actions.
- As a therapist, I should be able to instruct many parents and teachers how to use this technology easily
- As a parent, I should be able to instruct my child in how to use this system in every stage of its use.

Design Implications

Our design implications have been formed based on the problems that we heard about during the contextual interviews with the speech therapists.The therapists are well informed with the kinds of problems parents face when when dealing with their children. We transcribed these problems from audio recordings of our interview and converted them to our notes. We learned about these problems and tried to address these problems by building a set of functions that our prototype will have. We also read published material on these problems that strengthened our idea to form the following design implications:

- A common autistic characteristic is that they might not know how to use touchscreen technology, so the final design should have exaggerated responses and be easy to teach from the parent's perspective. We can't expect a child to just pick it up and know how to use it.
- A child doesn't have as good of fine motor skills, so the technology should account for errors like hitting the screen repeatedly and rapidly [13].
- Because motivation is a huge factor for if a child uses a technology, we should work towards a child's interests to get them to enjoy using the technology in the first place.
- Also because motivation can change quickly, our technology should be able to be used in bursts. If there are sensors, the child may move out of them, and nothing should be completely time-sensitive in a way that the child is locked out during a distraction.
- Children are not static. As they learn more, the vocabulary they use will become more complex. The technology should accommodate this. Not only should it grow "with" the child, but it should take into account the child's zone of proximal development and allow the for the child to grow into new vocabulary and language.
- Therapists establish communication between a child and a parent. Therapist also find out the motivations and tell it to parents. Having a way for the therapist and parent to be "on the same page" as to how the child is behaving and what their interests are will be important to maintaining consistency with the child, which is necessary to the learning process.

We also considered some of the design implications when attempting to complete tasks with our system.

- Stimulus can be really overwhelming, so the technology should not be so engaging that it completely distracts the child from completing the desired task.
  - Because a child might only pick a sound/image because they like it and not for communication, it is important to be able to enable/disable distractions within the technology
- The representation of an object is important. A child might not know what a drawing/icon means, so a picture of the object may work better.
  - On the other hand, a child may not be able to generalize, and may think that a picture refers to ONLY that object (only one toy car, instead of any toy car) Thus, this should be able to change depending on how the child understands things, and may need to mix-and-match depending on the child's current level of understanding.
- Parents play a big role in what therapists teach to the child, but also parents might be uninformed about what therapy entails or what's the best technique, so it should be customizable to the parent's wishes, but also be informative to what possible impacts those changes will have.

Finally, we also considered the impact of the environment and how the device should be designed around that.

- An environment can have a lot of distractions, so the design should be usable in a way that it can be put down and picked up again right where it left off.
- Because the device may be thrown around a lot during tantrums or if the child becomes excited, the device needs to be sturdy enough to be used in unexpected ways, and should be able to withstand the full force of a child's throw or hit.

DESIGN IDEATION AND PROTOTYPING

Design Goals

Technology for children with autism has a wide range due to the nature of the disorder. However, our competitor analysis demonstrated that most technology present are apps that may be too far beyond the child's abilities or too distracting. This in turn leads to parents not trusting technology or therapists focusing instead on low-tech alternatives that better teach their children. In developing a design for nonverbal children, our design space is narrowed to becoming more focused on education. Higher functioning children or children who have moved on to being nonverbal may need communication aids, but the primary goal for nonverbal children is in teaching them the basics. We explore teaching these basic skills in both social skills/behaviors and with communication.

For social skills, there are many areas a nonverbal child can learn from. From our contextual inquiry, this could be play skills such as turn-taking or sharing. This could also be social skills such as maintaining eye contact, establishing routines, understanding facial expressions, and appropriate and safe physical behavior. For communication skills, higher level children may need help with the nuances of carrying a conversation, but for helping nonverbal children, we are focusing on moving from gestures to vocabulary acquisition to natural language (full sentences) to more empathetic language (speaking for reasons other than asking for something). The major characteristics that could differentiate designs could be physical affordances, as each child will have different motor skills. Additionally, the educational focus (there are many just for nonverbal children) will greatly change how the design looks. We explore this in some of our design alternatives, as some designs emphasize vocabulary acquisition while other designs focus on developing emotional awareness through understanding facial expressions.

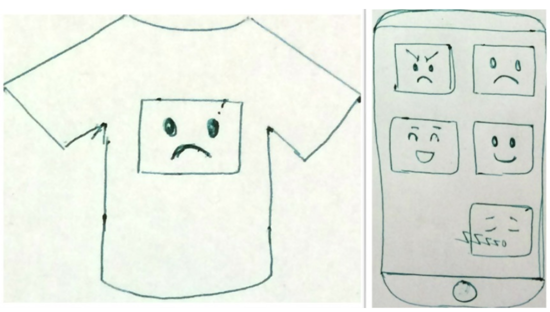
Design Alternatives

The design ideation phase consisted of multiple iterations of synthesis and elimination. Several different types of technologies were considered such as toys, wearables, mobile apps, handheld devices, and intelligent play spaces. Through this ideation we narrowed down the designs to three alternatives.

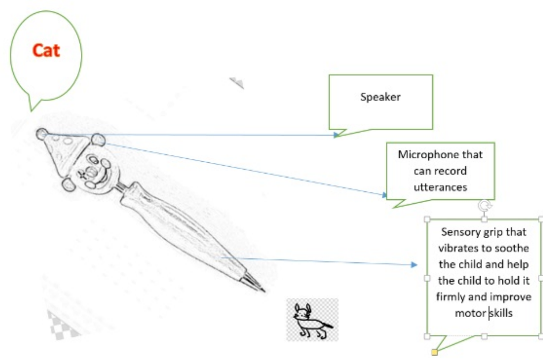
(a) Sensors are embedded internally into an existing toy

(b) Keeps the child engaged by talking about objects in the environment

Figure 1: Initial toy design that led to our final prototype



(a) Emotion T-Shirt Design



(b) Pen Design

Figure 2: Initial designs which were considered but not prototyped

The three alternatives, a wearable, and a smart pen. A description of these designs and the rationale for choosing these designs are included below.

Initial Design 1: Smart Teddy Bear

The first design alternative is a device that augments a toy to help teach children along the autism spectrum how to communicate verbally and appropriate physical behaviors.

This design alternative was developed with a focus on the autistic child stakeholder over a caretaker. A child's interests is their main motivation for learning and for verbalizing. Therapy and parenting guides emphasize the need to follow the child's lead[9], and this toy aims to adapt to the child's interests by being the focus of whatever that interest is. By being able to change and become different toys, this device aims to maintain the child's interests and continue to be a focus of attention where other alternatives may become boring. This includes both changing the outer appearance of the toy and selecting different voices to represent the character. Even the functionality of being environmentally aware allows for the toy to have conversations or prompt the child with things that are immediately relevant to him. This also limits distractions, which is another challenge for teaching children with autism.

The final feature, which is responsiveness to touch, is in response to the need for children to gain the social awareness to not be a harm to others. Understanding cause and effect is a challenge, and this responsiveness allows for the child to learn and practice those concepts.

Another aspect is the need for therapists and parents to be on the same page about the child's behavior and to be able to guide the therapy. Because if this, the toy will store the child's interactions and settings with it locally, which can be accessed or modified by the caretaker at the time. This allows for some consistency of settings (It may be confusing for the child if the toy's voice changed depending on who it was with) and consistency of goals and tasks(conversation sets) that everyone can agree are appropriate.

Many design alternatives for this toy have been considered. A base with the embedded electronics that has removable outer coverings is easiest for the caretaker to set up, but may not cover the range of shapes and sizes of toys that a child has interest in. It also would not be able to be used with a toy the child already has an interest in (unless that toy were to be gutted and become the outer "skin" for the toy, which could be somewhat devastating for the child). An embedded system is usable in a variety of toys (to an extent), but becomes more time consuming and difficult to prepare for the child. Since the child is the focus of this design, we have chosen an embedded system to illustrate (Figure 1b).

Initial Design 2: Emotion Shirt

Autistic children have difficulty in understanding facial expressions. The communication is not alone just the words spoken out but also includes the gestures, body language and facial expressions. The idea is to make children understand initially what each facial expression is and then practice it along with storytelling. Story telling has always captured children's attention and they enjoy it. We want to use storytelling as the activity that engages them. Since, there are less chances of children getting bored with them. It is very difficult to keep an autistic child interested for long in a activity. There could be environmental factors that could distract the child.This idea was brought up to develop the skill of understanding emotions using facial expressions combined with the an activity that children love to engage in.

The Emotion Shirt (Figure **??**) is a shirt with a screen on a on the front of it. The screen has a processor at the back of it that is wirelessly connected with a mobile phone app that has microphone attached to the processor that collects audio from the the caretaker,extract and make the sense of the tone of what caretaker speaks about.It generates the appropriate emotion face as per the context of the story being told.

This technology can be used to help children practice with a set of stories. As the caretaker tells the stories and a face expression changes after making the sense of the caretaker's tone from the story and it then appears on the screen as per the context being talked about. The caretaker observes and makes the observation in the system that keeps the track of the emotions at with the child is getting better and on what emotion does the caretaker need to work on with the child. This system is used by caretaker to tell stories to the child and the screen displays faces to match the tone and emotion of the story.

The caretaker is the one who handles and operates the technology. The Emotion Shirt app has the stories that can be read to the child and the LED screen processor grabs the context and the tone of the story that is being told to the child and the appropriate emotion is displayed on the screen.

Initial Design 3: Pen

The major goals(thoughts that led to the design development) that are considered while constructing this design idea are to design a technology that improves the verbal and motor skills in the children with autism along with analysing his mood changes with respect to time and record his utterances while using the product. The second goal was to design a technology which is capable of tracking the child's activities and progress. The rationale behind this is that it would be helpful for future reference and to keep track of the child's development.

Designing a device which can be used by the child alone once trained even without supervision of the therapist or parent would help the child to incorporate individuality and be independent. A pen is very easy to carry around and is not just confined to a therapy room or specific environment which would help the child to enhance their social skills and communicate with others outside a therapy session.

To design a technology not dependent on other technologies, we considered finding an alternative to our original idea which was an app for a portable device. A limitation of an app for drawing would be that a stylus can be used only on a smart screen to track the activities. Thus, we shifted our design to a pen due to the fact that it is environmentally independent and can be used anywhere (that has paper) (Figure **??**).

Needs of multiple stakeholders drove to this design idea like the therapist wants a technology that is less distracting and easy to teach and learn as there are many mobile/tablet applications for children with autism now-a-days whereas there are some parents that do not want their children to use them without supervision as they are quite distracting and difficult to use.

Therefore developing a single purpose device would help them to learn new thing by drawing it themselves and listening to the audio playback through a speaker that is embedded within the device would help them understand what it is and repeat it. Drawing also makes child to express their views, interests and once he/she draws a picture the technology would be able to analyse his emotions at that particular moment and speaks out how the child is feeling towards a particular task.

Final Prototype

Although the pen was useful as a way to support verbal communication and the shirt offered a way to teach social behaviors to a child, the design idea for the toy successfully captured more of our design goals than the other two alternatives. For this reason, it was selected to develop further into a final prototype for evaluation.

To accomplish these two primary goals, our prototype is a toy that talks and that the child can interact with (Figure 3). The toy can collect sensor data such as microphone recordings and touch data. A Makey Makey was used to collect data from sensors made with conductive thread and convert it to key presses. The key presses are interpreted using a LiveCode application and stored as interaction data within the application.

This data is then reported to the user (parent/therapist) in an application resembling one that would appear on a smartphone. There are multiple features available in this evaluation prototype(Figure 4). There is a controller mode that allows a user to select which prompts the toy will give, which responses the toy will give (if the child does respond, to simulate the end of a conversation), and the ability to enter data about the interaction with the child (Figure 4c). Although the data was originally intended to be generated automatically, a therapist or parent may be better suited to understand what a child is trying to say and record that more accurately. The conversations available can be changed in the settings, which is also where the parent can listen to the current voice options available.

Finally, there are two reports available: an utterance report and a touch report. The utterance report(Figure 4b) will present information on the child's response rate and most commonly used words to track vocabulary acquisition. The touch report

(Figure 4a) allows the user to view information on the child's behavior with the toy which includes what body parts were pressed and if there were any undesirable physical interactions with the bear (such as holding its face for a long period of time).

EVALUATION

Our project is to develop a technology to assist nonverbal children who have autism and their caretakers. The first goal of our project was to assist nonverbal children in building up their communication skills. This includes both improving behaviors/social interactions and vocabulary acquisition. Another goal of our project arose from our affinity diagrams. Parents and therapists often had challenges in knowing what the child was doing, especially since children with autism tend to prefer to play alone instead of with others. Thus, our secondary goal was to support these caretakers by reporting on a child's behavior and interactions with our technology.

The following are our evaluation goals that we are looking to answer in the evaluation phase:

- Determine if the toy has the potential to capture the attention of the child, either on its own or with some sort of prompting.
- Determine unexpected use cases of the toy by the child and any usability issues with the physical toy.
- Determine which parts of the data reported (for both the touch reports and the conversation reports) are easy to understand and accurately interpreted by a caretaker in understanding the childâĂŹs behavior.
- Determine if the layout and workflow of the controls for the toy makes it easy for a caretaker to prompt the child, generate a response, and input data about the interaction
- Determine if the caretaker can easily access and change the settings of the toy.

We plan to conduct evaluation study with children group and child-parent group and ask them to perform a certain task and make observations about it. With children there is no specific task but majorly the aim to observe children is during a free play. We plan to conduct post study interviews and a questionnaire to know more about the experience and the usability issues that would be observed and reported from the two groups.

Usability test with Children and Caretakers

Two groups of participants will be used in the usability test of the system. Group one will comprise of caregivers that could be either a parent/a therapist. In group two, we will have children of at least age three who play with toys and those who make short verbalizations, not more that 2 or 3 words at a time. Prior to consent, the researchers will provide the caregiver with basic information about the toy, but not so much that it will impact the upcoming usability tests. The caretaker will be told about the purpose of the toy, how the data is collected from the toy, and then the researcher will show the caretaker the home page of the app. The researcher will explain that this app controls what the toy says and also reports on the interactions the child has with the toy. After the consent process is complete, the usability tests will begin. The order of the tests are done so that the child will interact with the toy at the beginning of the experiment. This will allow for the maximum amount of attention for the child so boredom from waiting is minimized. Once the child-only tests are complete, a free-play will occur where the caregiver will be asked to use the app to interact with the child. This will last for 10 minutes or until the child loses interest, whichever is first. The final phase of the usability test will only include the caregiver. The caregiver will be given predefined scenarios to complete as the researcher observes and take notes. The caregiver will be asked to perform a think-aloud on their interactions with the system. The overall usability test for both user groups should take 40 minutes. Once the usability test is complete, a questionnaire containing basic demographic questions, a system usability scale, and other questions specific to the interface will be given to the user. The user will have 20 minutes to complete the questionnaire and are free to ask the researcher any clarification questions while answering the questions.

Recruitment Criteria and Strategies

The goal of recruitment is to make sure that participants selected match the work roles/personas. Thus, we will recruit participants from each persona category. Those categories are: A nonverbal child with autism who makes short verbalizations, A parent of the autistic child and a speech-therapist. Although we would like to have 3-5 participants, the use of the toy and the use of the controlling app are drastically different enough that a wider pool of users are needed to fully evaluate both parts. We will look for people who work around us (colleagues) or use announcements and emailing in the professional organization around our campus and match one of the characteristics of our personas. Such announcements include:

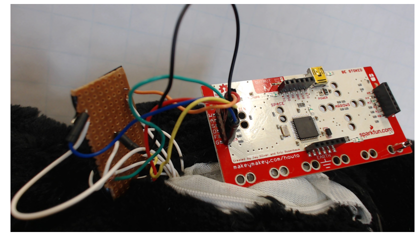
- Making announcements through emails to the heads of Autism groups or special schools that are meant for children with conditions like ASD.The heads of the institutes can make futher anouncement to the various people that are part of the group/institute.

- Making announcements in the speech therapist program at UNO, because a lot of children with autism visit UNO's north campus. We can get to meet the children whose parents would like them to be a part of this study.

Additionally, as there may not be a large number of users available, snowball sampling will be used to collect more participants from those within the network of current participants. Once a participant has agreed to be a part of our study, we will keep in touch with them and mail or call them in advance to remind them about their appointment and make sure that they do not forget to show up. If changes need to be made to an appointment we will make sure that no time is wasted rescheduling and there are no delays in the evaluation schedule.

(a) Touch sensors embedded on our prototypes

(b) Sensors made from wire and conductive thread



(c) A MakeyMakey converts the touch to a key press

Figure 3: The final prototype is a stuffed animal (a) that uses conductive wire (b) to send touch data through a MakeyMakey (c)

Scenario/Tasks

The order of the tests are done so that the child will interact with the toy at the beginning of the experiment. This will allow for the maximum amount of attention for the child so boredom from waiting is minimized. Once the child-only tests are complete, a free-play will occur where the caregiver will be asked to use the app to interact with the child. This will last for 10 minutes or until the child loses interest, whichever is first. Data from this phase will be observational data, such as detecting if the child looks at the toy, touches, the toy, or approaches the toy. This would include the frequency and duration of these events. The free play scenario will continue this with the addition of having interaction notes from the caretaker. Although a cognitive walkthrough would be useful in a free-play scenario, it would most likely be a distraction to the child. The cognitive walkthrough data will be collected instead from the caregiver-only scenarios in order to capture some of what was missing from the free-play scenario.

The final phase of the usability test will only include the caregiver. The caregiver will be given predefined scenarios to complete as the researcher observes and take notes. The caregiver will be asked to perform a think-aloud on their interactions with the system. The overall usability test for both user groups should take 40 minutes. Once the usability test is complete, a questionnaire containing basic demographic questions, a system usability scale, and other questions specific to the interface will be given to the user. The user will have 20 minutes to complete the questionnaire and are free to ask the researcher any clarification questions while answering the questions.

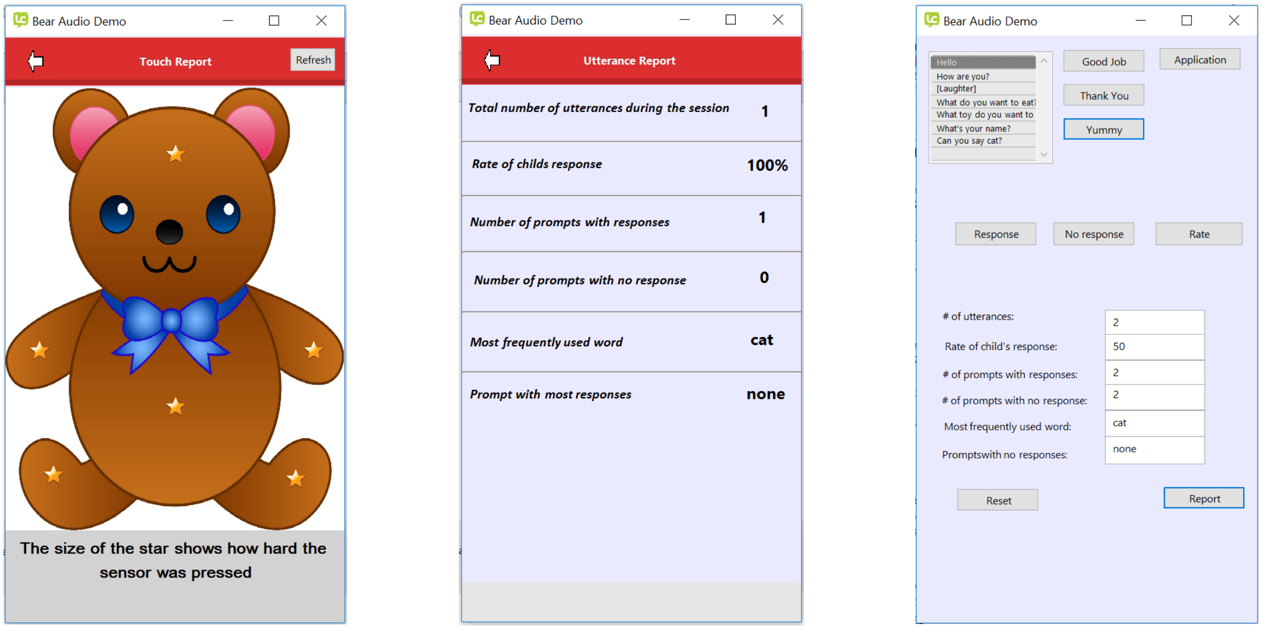
A controlled environment would be best for such an evaluation because details of data are perishable and it is best capture data concurrently and as it happens and is all fresh. A therapy room, especially one at Roskens hall, UNO would be most appropriate. It would be familiar enough to the participant to remove unnecessary distractions, but it can also be modified to our research needs to serve as a proxy for a true lab setting. All the data and observation that have to be made during the study can be handled and converted to notes with the help of all who are conducting the evaluation study.

We plan to conduct following tasks:

1. Being presented with the toy when it is the only thing in the room. [Child]
2. Scenario 1 with the addition of prompting conversations. [Child]
3. Controlling the bear (with a researcher pretending to be a child. This is to make sure the scenario is the same for all participants). [Caretaker]
4. Controlling the bear in a free-play scenario with the child for 10 minutes.[Caretaker & Child]
5. Creating a new voice profile appropriate to a new environment. [Caretaker]
6. Loading a voice profile appropriate for returning to an environment. [Caretaker]
7. Interpreting the generated utterance report(first time user) and calculating the time taken for performing that specific task in a given amount of time. [Caretaker]
8. Interpreting the generated touch report (first time user) and calculating the time taken for performing that specific task in a given amount of time. [Caretaker]

CONCLUSION

In this paper we designed a prototype which helps nonverbal autistic children in improving their communication and behavioral skills through the development of a toy that acts as both a conversational agent and a sensor that can report on a



(a) Touch Report (b) Utterance Report (c) Utterance Report

Figure 4: Screenshots of the reports (a), (b) generated from interacting with the toy. And how the toy would be controlled (c)

child's behaviors to his or her caretaker. By conducting semi-structured interviews with therapists in their own environment, we were able to collect data in a more realistic way. We have considered many smart applications that are being widely used by both caregivers and autistic children but considering the drawbacks with the existing technology led us to design a smart toy as our final prototype. The unique contribution we have presented here is a toy that is not as distracting as many dynamic display devices available today. It allows children to interact in a lower-risk setting as opposed to the complex interactions with people. It also allows for parents to understand how a child is interacting with the toy, and can serve as a proxy between the parent and the child when the parent controls the conversation through the toy. This addresses both of our goals: to improve social skills as well as encourage the development of conversation skills.

Lessons Learned

Overall, collecting interview data was the greatest challenge, and for next time we would like to have more observational data instead of using training materials and technology as a proxy for this information. Everyone came into this project with different ideas of what it means to be autistic, the problems that we would solve, and the best technology for the job. All of those previous assumptions have greatly changed after conducting this contextual inquiry, and we hope to move forward with a clearer idea of the problem space (which is also much bigger than we initially imagined!)

Our group learned the extent to which the contextual inquiry impacted the design process. We considered the flaws in our own design based on these inquiries and made major changes through several iterations of design ideation and critique. Satisfying all of our goals and adapting our designs as drastically as we have were a major challenge, and if we did this again our group would like to evaluate more designs and evaluate those designs with our stakeholders

Limitations of the Study

There are several limitations to the study with notable limitations occurring in the design, prototyping, and evaluation phases of the work. We present these limitations for each of these phases of the project in the following section.

The primary challenge for children with autism is the fine line of engaging the child. If it is too engaging, the child will become so focused on the technology itself that it will be at the exclusion of interacting with others. If it is not engaging enough, the child will not interact with the technology in the first place. It should be able to be used consistently for learning gains, but it also should be able to be used in short bursts as the childâĂŹs attention may not last long enough for a lengthy session with the technology. The interface could make this easier by not locking the child out of the system during these changes in attitude.

The system should also grow with the child, which means that the caretaker/therapist will need to be updating the system a lot. Making clear the childâĂŹs detected interests and quantifying their current progress with tasks will best help the caretaker with adapting the tasks. Although there need to be separate user modes between the child and caretaker, in order to address the requirement that caretakers/therapists be on the same page about the child, some information and reports should be shared. The interface could identify when there are new reports and information available for users (like for the parent after a therapy session). This also means there needs to be a way for the data to be persistent if there are many caretakers for a single child.

A tradeoff that may be present is between ease of learning or setup for the caretaker and ease of teaching to the child. A complex system that has strict routine may be best in some situations, but it loses flexibility in new environments and may be harder for the caretaker to set up.

In the end, the toy could not be made as a standalone toy. The internal core of the toy is connected through a usb to a laptop. The laptop powers our toy and is the processing unit for our toy, too. We could not make our toy free from external wires because of lack of resources and time. The prototype requires a ground wire that keeps hanging from the bear. We attempted to address this with the creation of a wristband, but wearables are an issue especially for children with ASDs, and other alternatives will need to be considered. Additionally, the application cannot be deployed on a smartphone due to lack of power supply. The final prototype could be used only under the supervision of a parent or a therapist (no automatic detection of objects and actions). Also, there are only 6 sensors on the toy due to the limitations of the Makey Makey. If the child does not touch one of these sensors or happens to miss the sensor, data would not be recorded. There are signifiers of where the toy can be touched (and in presenting this prototype to adults, they immediately interact with the toy correctly), but we cannot assume that a child wil lbe have the same way.

One limitation of the evaluation is that the child may not even notice the toy in the room. If the child does not feel safe in the controlled environment then there is little chance the child would interact with the toy as they would normally. The challenge of a free-play scenario is that the child needs to feel safe and open to the idea of playing with a new toy. Although we have made attempts to make our toy interesting, it does not guarantee that it will be motivating enough for a child to come up and interact with it even after prompts are made. Additionally, the results of our evaluation, like many other studies that research children with ASDs, cannot make the claim that what works for the few children involved will work for every child. Every child is unique and, understandably, broad claims are not an expected outcome of these evaluations.

Future Work / Open Questions

As noted in the limitations of our prototype, one area of future work is to overcome these limitations and attempt to make our prototype wireless. This could be done with a smaller embedded device for prototyping such as an Arduino or Raspberry pi. Although we have not had the opportunity to carry out our evaluation study, the next steps would be to gain IRB approval and proceed with the evaluation of our prototype. Some questions that remain rely on the outcomes of the evaluation. Although we hypothesize that our results would be positive and that we could capture the child's interests, how can we redesign our toy in the event of a negative our neutral result? Returning to our initial interview participants for feedback on the toy could also be of use to us to help improve our prototype and answer these questions.

REFERENCES

1. Emilia Barakova, Gilles van Wanrooij, Ruben van Limpt, and Marnick Menting. 2007. Using an emergent system concept in designging interactive games for autistic children. In *Proceedings of the 6th international conference on Interaction design and children*. ACM, 73–76.
2. Melissa Dawe. 2006. Desperately seeking simplicity: how young adults with cognitive disabilities and their families adopt assistive technologies. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. ACM, 1143–1152.
3. Herman D'Hooge, Linda Dalton, Helen Shwe, Debra Lieberman, and Claire O'Malley. 2000. Smart toys: brave new world?. In *CHI'00 Extended Abstracts on Human Factors in Computing Systems*. ACM, 247–248.
4. Lizbeth Escobedo, David H Nguyen, LouAnne Boyd, Sen Hirano, Alejandro Rangel, Daniel Garcia-Rosas, Monica Tentori, and Gillian Hayes. 2012. MOSOCO: a mobile assistive tool to support children with autism practicing social skills in real-life situations. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2589–2598.
5. Manohar Ganesan, Neil W Russell, Rahul Rajan, Nathan Welch, Tracy L Westeyn, and Gregory D Abowd. 2010. Grip sensing in smart toys: a formative design method for user categorization. In *CHI'10 Extended Abstracts on Human Factors in Computing Systems*. ACM, 3745–3750.
6. Joshua Hailpern, Karrie Karahalios, and James Halle. 2009. Creating a spoken impact: encouraging vocalization through audio visual feedback in children with ASD. In *Proceedings of the SIGCHI conference on human factors in computing systems*. ACM, 453–462.
7. Juan Pablo Hourcade. 2015. *Child-Computer Interaction*. CreateSpace Independent Publishing.
8. Juan Pablo Hourcade, Franca Garzotto, Agata Rozga, Monica E Tentori, Panos Markopoulos, Narcis Pares, Judith Good, Helen Pain, and Meryl Alper. 2014. Supporting children with complex communication needs. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems*. ACM, 119–122.
9. Brooke Ingersoll and Anna Dvortcsak. 2009. *Teaching Social Communication to Children with Autism: A Practitioner's Guide to Parent Training and A Manual for Parents*. Guilford Press.
10. Kaska Porayska-Pomsta, Christopher Frauenberger, Helen Pain, Gnanathusharan Rajendran, Tim Smith, Rachel Menzies, Mary Ellen Foster, Alyssa Alcorn, Sam Wass, S Bernadini, and others. 2012. Developing technology for autism: an interdisciplinary approach. *Personal and Ubiquitous Computing* 16, 2 (2012), 117–127.

11. Cynthia Putnam and Lorna Chong. 2008. Software and technologies designed for people with autism: what do users want?. In *Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility*. ACM, 3–10.

12. Ben Robins, Kerstin Dautenhahn, and Janek Dubowski. 2006. Does appearance matter in the interaction of children with autism with a humanoid robot? *Interaction Studies* 7, 3 (2006), 509–542.

13. Harini Sampath, Ravi Agarwal, and Bipin Indurkhya. 2013. Assistive technology for children with autism-lessons for interaction design. In *Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction*. ACM, 325–333.

14. Tracy L Westeyn, Julie A Kientz, Thad E Starner, and Gregory D Abowd. 2008. Designing toys with automatic play characterization for supporting the assessment of a child's development. In *Proceedings of the 7th international conference on Interaction design and children*. ACM, 89–92.