Unfold—An interactive experience on mixed reality platform to solve communication problems faced by children with ASD in the age group of 4-7 years.

Akanksha Vishwakarma
av5785@rit.edu

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Akanksha Vishwakarma


School of Design | College of Art and Design

Rochester Institute of Technology
Rochester, NY, USA

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Thesis Committee Members

**Stan Rickel**  
Graduate Director  
Industrial Design, College of Art and Design  
Rochester Institute of Technology

**Mindy Magyar**  
Chief Thesis Advisor  
Associate Professor  
Industrial Design, College of Art and Design  
Rochester Institute of Technology

**Dr. Cha Ron Sattler-Leblanc**  
Associate Thesis Advisor  
Senior Director  
Academic Support Center  
Rochester Institute of Technology
Abstract

Improving communication with a child with ASD has become an indispensable need in order to make the life smooth for the special child. Research has shown that communication gets driven by mood dynamics, non-verbal interactions, gestural communication and expressions. With the growth in technology, mixed reality and eye tracking are playing a major role in imparting experiences and making us learn about an environment without having to physically be in them. This research work explores how mixed reality can take a child with ASD through an experience that could help them open up and communicate well with others both with and without ASD. A series of training involved aims at an interaction and understanding gestures of others followed by initial training with child himself and animated creature through interaction. This overall experience integrates interactive play and human gestures in the way it happens in the real world. This will train and help enhance their willingness to share, interact and communicate with others besides training the motor skills. The resulting interactive environment addresses communication problem by introduction of a communicative and adaptive medium between a child with ASD and others.

Keywords:
Mixed Reality, Eye Tracking, Autism Spectrum Disorder (ASD), Asperger’s Syndrome (AS), Theory of Mind Skills.

Note:
In 2013, Asperger’s Syndrome was reclassified under ASD and now called as ‘ASD’ as revised by Diagnostic and Statistical Manual of Mental Disorders (DSM) [43]. This paper includes references from paper and resources which were published before 2013. Thus, an older term ‘Asperger’s Syndrome’ has been used at the places where it is referenced from resources older than year 2013. All the other research findings by me were drafted as per the new terminology called ASD.
1. Introduction

Autism Spectrum Disorder (ASD) is a condition which stays lifelong with a group of neural and its developmental disabilities characterized by abnormalities in social interaction, communication and restrictive and repetitive behaviors [1]. There are three main types of ASD, Autistic Disorder, Asperger’s Disorder and Atypical Autism. Asperger’s Disorder and Atypical Autism are milder forms of Autistic Disorder [2]. Asperger’s Disorder affects development capabilities especially in areas like communication and interaction with others [3] and causes language problems such as delayed responses or very little to no speech. Social deficits are evident, and attempts made in social contexts are often clumsy and inappropriate ([4][5]). Whilst verbal expression can be fluent, the content of conversations may be narrow and reflect circumscribed interests and the child may continue a conversation with little regard for the interest of the listener. The child may be motivated to form friendships but is unlikely to possess the skills to succeed ([6][7]). Children tend to get isolated and are more comfortable doing repetitive activities or tasks alone [8]. They also struggle with significant relationships and behavioral challenges and in most cases, have serious social implications on adulthood [9].

Communication is a vital element for any individual to socialize and grow. A successful communicator can comprehend and interpret the dialogue exchanged. Conversations need some interpretation, whether it is understanding gestures, facial expressions or even the meaning behind the words (think of how different tones and expressions can make “That’s fine!” show grievance, compassion or even content). A good communication involves understanding of conversational rules, which is followed by waiting and listening while someone else speaks and then following up with a comment or a question that connects back to what the speaker just said.

Children’s ability to communicate varies depending upon their intellectual and social development. Children with ASD are absorbed in their own world and avoid interacting with others. They face challenges in developing language skills and understanding what others say to them. Besides, they face challenges in translating hand gestures, eye contact and facial expressions. While most of the children with ASD have little to no problem in pronunciation of words, majority have difficulty using language effectively while interacting. They struggle during interaction when body language and vocal tones become part of communication. Thus,
there are several aspects of this problem with children with ASD which call out for effective solutions using latest developments in technology.

Studies show that most people with ASD show an affinity with technology and a positive attitude towards computers [10]. This is because software is intelligent and has an ability to offer a predictable and structured environment that can accommodate their need for organizational support and their preference for routine and repetitive behaviors [11]. There are several advantages on using technology on ASD [12]. The symptom associated in people with ASD can also cause practical difficulties for care providers [13]. Technology has the potential to provide support that are suitable for a wide variety of abilities [14]. Technological interventions allow its use at different speeds and locations, and never lose patience with the frequent repetition that many people with ASD desire [15] besides promoting their cognitive and social skills [16]. Technology is being used increasingly on a variety context, both as assistive technologies and as tools for helping us to understand user’s motivation [17]. Recent research on therapeutic technology is aimed to improve eye contact, determine facial expressions and other behaviors that impact social interaction. In fact, children with ASD usually have difficulty to recognize

Figure 2. Most people with ASD show an affinity with technology and a positive attitude towards computers

facial expressions and to understand associated emotions, to imitate or use emotional expressions, to understand and control their own emotions, or to interpret emotions or empathy with others [18]. Technologies, like augmented reality (AR), have the ability to catch the children’s imagination and to promote their attention, because they can experiment artificial, safe and fascinating environments. In 1994, [19] showed a spectrum where extremes were the known real environment and at the opposite end, the virtual environment, complemented with varying degrees of involvement of real and virtual elements. As stated by [20], the AR has grown exponentially because it allows improving users’ understanding, knowledge and interaction with the real world.

These recent advancements in mixed reality allow it to be applied to solve this problem of communication. An interactive play designed within a mixed reality environment can free
children from behavioral consciousness. Clubbed with eye tracking technology, such a play can track where the participating child is looking and reward positive eye interactions, thus encouraging children to use their eyes during communication. Resulting experience can be intuitive and provoke curiosity enabling children to respond and also take initiative, all while being playful and fun, so the children stay engaged and focused. Such a medium is capable of involving children with their surroundings without stimulating negative emotions.

The problems of heightened sensitivity and overstimulation because of noises, lights, tastes and textures can also be targeted by including interaction with other people, with or without ASD, in this controlled environment. Researches shows social engagement and interaction can also improve motor development, one of the major hurdles for successful communication. Besides, such experiences could help imbibing cognitive learning into children.

2. Supporting Research

Children and adults with ASD have intelligence factor within normal range but their vulnerable cognitive, social and emotional abilities hinder their development of mood handling abilities as explained in Cognitive Behavior Therapy for Children and Adults with Asperger's Syndrome by Tony Attwood. The term “Asperger’s syndrome” was first introduced by Lorna Wing in 1981, who used it to describe children with an intellectual capacity within the normal range but with distinct profile of abilities consistent with findings of ASD (e.g., [21], [22], [23], [23]). Asperger syndrome (AS) is characterized as a disorder primarily involving socio-emotional difficulties [21]. Recent research on Asperger’s syndrome, the diagnostic criteria in DSM IV-TR (APA, 2000) and Attwood’s extensive clinical experience, all agree with this profile of abilities that includes following characteristics:

A qualitative impairment in social interaction:
- Failure to develop friendships that are appropriate to the child's developmental level.
- Impaired use of nonverbal behavior such as eye gaze, facial expression and body language to regulate a social interaction.
- Lack of social and emotional reciprocity and empathy

A qualitative impairment in subtle communication skills:
- Impaired speech but difficulties with conversation skills and a tendency to be pedantic, to have an unusual prosody and to make literal interpretations.

Restrictive interests:
- The development of special interests that are unusual in their intensity and focus - Preference for routine and consistency.

Motor clumsiness, a hypersensitivity to specific auditory and tactile experiences, is another disorder which might be present in a child with ASD. Besides, organizational management, time management and explaining thoughts and feelings using speech are few other areas which get affected in individuals with ASD [21].
Cognitive Behavior Therapy for Children with Asperger’s by Tony Attwood shares that when one considers the diagnostic criteria and profile of abilities of children and adults with Asperger's syndrome, one would expect it to have significant effects on the person's adaptive functioning, especially in a social context, and that such individuals would be vulnerable to the development of a secondary mood disorder. The current research study shows that around 65% of children with ASD also have an affective disorder that includes a range of anxiety disorders [25] and depression. Furthermore, the extensive research on Theory of Mind Skills confirms that individuals with ASD have considerable difficulty identifying and conceptualizing the thoughts and feelings of other people and themselves [26]. The interpersonal and inner world of emotions appears to be uncharted territory for people with ASD.

While communicating with a child with autism reciprocity, mindfulness, emotional openness and motivation are few essential things which need to be considered. Kamini Lakhani demonstrates this in a video where a mom guides her child through a process of applying butter on bread and frying them. The teenager calmly observes his mother and is ready to take up his role and responsibility in the interaction. There is an unspoken understanding between the parent and the child. A feedback loop is in place. There is anticipation and fun involved in this process.

2.1. **Difficulties faced by guardians of children with ASD**

Guardians of autistic children face challenges in locating and making sense of relevant resources [27] and are often uncertain about what support services are available [28]. Emotional support networks for parents of children with disabilities tend to differ from traditional family support networks [29]; these parents often turn to other parents with children with similar disabilities, along with professionals and written sources [30]. These alternative support networks are more difficult to maintain and require additional support when both parents have jobs outside the
In their everyday lives, children with AS experience difficulties with social reasoning and friendships, theory of mind, empathy and the pragmatic aspects of language. They are also more likely to have a specific learning disability and heightened sensory awareness, which can result in significant levels of stress likely to contribute to anxiety. Due to these deficits, the children face struggles in navigating their day-to-day world and it may be, as suggested by Kim et al. (2000), that interventions aimed at reducing anxiety for children with AS may also reduce aggression and thereby enhance functioning and improve relationships with family, peers and teachers. Strategies initially developed for children with autism have been used with some success within AS population [31].
The aim of the solution described in this paper is to work with children with AS, teach them effective strategies to manage feelings and broaden their emotional and behavioral traits. The solution is designed specifically for improving communication abilities of children with AS which would in turn make interactions easier for their guardians.

2.2. Augmented Reality and ASD

Among children with ASD, a neurodevelopmental condition that affects their ability to interact with others can also substantially impact them in their adult lives. At early age, we pretend and play with children by using a stick as a wand or by making tents with bed sheets or imagining a large cardboard box to be a castle which is more than just for fun. It is an important activity which teaches children social and emotional skills and builds their self-esteem.

Zhen Bai, a Ph.D. candidate in Graphics & Interaction Group at Cambridge’s Computer Laboratory, designed an augmented reality (AR) system to help children to be more imaginative in pretend play. In this system, children see themselves on a computer screen as they would in a mirror. She then hands the children simple physical objects like foam blocks which appear on the screen as car, train or airplane. The system detects the movement when child moves the blocks and mimics the activity on the screen. Her paper reports about her observations on this experiment which confirm that the AR system could be an engaging platform for children with ASD [32].

Through her experiments, Bai found that children with Autism work well with computers. Most of the children, who participated in her experiment, use them daily. Bai reached out to parents after conducting her experiment to collect information about change in children’s behavior. Eighty percent of the parents reported that their children were more engaged in the AR setting and some of them also reported that the children tried different activities even afterwards.
2.2.1 Existing AR Games

There are some examples of available games with AR but there are very few applications that train children on social skills in an emotional context even though these have been able to facilitate the acts of socialization.

For example, they could provide feedback to the children’s pronunciation, as happens in visiBabble [33], a system that processes infant voice in real-time. This system replies to the infant's syllable-like pronunciations with animations and records the acoustic-phonetic analysis, reinforcing the production of syllabic utterances that are later associated with language and cognitive development. Similarly, the VocSyl [34] is a software package that utilizes a suite of audio visualizations representing a myriad of audio features in abstract representations. These visualizations aim to provide children a medium of communication and allows them to practice speech-language skills. These interactive interfaces can provide visual support more appealing to children with AS, making the the application more enjoyable. [35] presents prototype systems that aim at challenges faced in designing of large group displays, mobile personal devices, and personal recording technologies. There were other similar projects developed which aimed at development and practice of social skills for children with ASD. For instance, multi-touch displays have been developed to conduct studies with children with autism to enhance their social skills [32]. Shared Interfaces to Develop Effective Social Skills [33] is another tool designed to help small children in group work skills using a four-player cooperative computer game that runs on tabletop technology. Both of these aim at creating a greater engagement for the children with autism in social activities and provide them with an opportunity to learn new forms of social expression. Another method used to engage and encourage socialization is storytelling in a way that promotes the practice of suitable social skills, such as the StoryTable [34].

Several mobile applications have also been developed for inviting and supporting socialization, such as [35], a mobile outdoor game for small groups of children aged 7-10, that was designed with the aim of encouraging social interaction between the players and to promote physical activity. Another project was [36], a mobile technology that empowers children to collaboratively read and create stories. But, none of these solutions have been used to support the socialization of children with autism. Regarding that, [37] is an Android application, designed with both individual and group features in mind, enlarging social skills of children with autism, and empowering synchronized group interactions and shared experience. It uses the smartphone’s camera to augment a real-life social situation with visual support - mimicking the Social Compass curriculum that augments social stories with paper-based visual supports. With AR, it is possible to create more attractive and interactive interfaces that can be manipulated by hand, without using conventional peripherals such as the keyboard and the mouse [38]. This characteristic of AR offers greater interaction between the child and the object, raising their interest and their curiosity, providing greater adherence to the task/activity [39].
2.2.2 Eye Tracking

Eye tracking is a technology that lets you control your device with use of your eyes as you naturally would. An equipped device is able to track user’s eyes and ‘knows’ what a user is looking at. This enables user to interact with other displays e.g. computers using their eyes [40].

2.2.2.1. Immersive and Natural [41]

This technology guides the natural eye movement to make environment more immersive and turns interaction as natural if it is happening in the real world.

Natural Targeting- To pick up, aim or throw an object, users will now only need to look in a direction or at an object rather than physically motion their forehead towards the object.

“This interaction is natural, intuitive and seamless because it so closely mimics real-life interaction.”

Eye Contact – This fundamental non-verbal communication is critical to our interaction with others in the real world. Bringing the same principle to character interaction in a VR film or game makes users even more deeply immersed [41]. Characters are then able to come to life and interact with, or ignore users based on eye contact.

Immersive Graphics and Sound – To create emotive reactions from users it is critical to know where their attention is focused. For example, to create a scary or surprising environment, sounds and characters may appear from where users are not currently looking. In contrast, users can also be calmed when graphical objects are presented in areas that are expected and feel natural to the user.

Figure 6. Current solutions in market to help solve communication issues in children with ASD
The goal of this technology is to humanize technology - with Tobii eye tracking, it’s more about the ‘reality’ than the ‘virtual’. You can create truly immersive and natural movie experiences with eye tracking enabled VR headsets in ways such as:

Personalized Movies- 'Choose your own adventure'
Content that unfolds and ends differently based on where the user’s eyes are focused throughout the storyline. Thus, creating entirely unique experiences while building in repeat-use value for consumers.

Heightened Emotions- When things suddenly appear in the corner of our eyes, we react. Be it with shock, fear, hesitation or suspicion, our emotions are instantly stirred. Eye tracking in VR has the unique ability to tap into our basic human emotions in a way that will pull the user deeper into the VR experience

Merging mixed reality with eye tracking will add more realism in an immersive environment. This will in turn help children with AS without getting bothered much about specialized activity or training. They will be making use of their eyes and will be able to move around to accomplish task. This will impart an instinct and reflex to make use of their eyes and will also teach them on how eye plays an important role when it comes to communication.

2.3 Interviews

For finding out the user’s preferences for mixed reality platforms, I started with a paper-based survey with the parents and therapists of children with ASD. Four parents and three therapists participated in this survey. Parents were given a form with two questions. The first questions were, which platform would they prefer for interactive learning. They were provided with three options: a tablet, a smartphone and a mixed reality head mount. In the second question, they were asked to give reasons for their choice. All the responses were recorded and analyzed. Three out of seven participants preferred using a smartphone or tablet as the communication device. The reasons provided by them were: ease of use (the touch screen), portability, cost and interest of the child:

*I think my son can manage a touch screen. If it is a smart phone or tablet, I can carry it wherever I go.*

*It would be great if the communication medium can be on laptop. My daughter is very interested in her dad’s laptop. She watches with interest what is being displayed on the screen*

The remaining four participants selected a mixed reality platform out of curiosity to observe their kids performing on mixed reality as their kids were well acquainted with the use of tablet and phones. They also shared the information that when their kids are left with tablet or smartphone, they spend hours figuring out new stuff that they didn’t do before. They tend to learn on their own and are quite good with computers too.
Kelly, she is merely 5 years old, but I always find her doing something new on an iPad. When stuck, she asks me for help. But I am the only one she reaches out too. I think, given such new platform, it would be interesting to see her growing and sharing with other students too.

My son Brandon is 7 years old, he already knows about VR environment. He hardly talks to anyone outside, but he is comfortable with both of us. “Mom, I wanna show you something I found today”. I think, exposing him to such medium would allow him to mingle with others too. I wish to see him sharing things with others too.

From the above responses, it can be concluded that guardians equally prefer tablet and mixed reality head mount and I chose to build my first prototype for mixed reality environment as it was shown to be successful [32]. AR has also grown exponentially because it allows improving the user's’ understanding, knowledge and interaction with the real world.

The growth in the use and availability of smart devices, combined with the decrease in their costs, as well as increase in their processing capability, storage and interaction with the user, makes them a suitable tool for families, caregivers and children. Also, the era of mixed reality is a true fact with the introduction of new equipment’s, like HTC Vive and Microsoft Hololens. These devices can be used in educational support and, when combined with eye tracking, can generate playful and interactive environment. At the same time, these technological platforms are now more accepted, prevalent and discreet which makes them more socially acceptable than before. Thus, my design considers the features of these technological platforms to create new tool, which is immersive and enjoyable, to work towards development of social skills in children with ASD.

2.4 Environment

How should an interactive environment be like? What colors and themes should I be using to make sure that children participate and at the same time, how my designed environment is not stimulating other sensory issues among the children with ASD.

To being with, I started exploring the real-time environments in schools and therapy centers. I didn’t want my environment to be felt as if it is aided with elements specifically meant for children with ASD. But I envision my design to be used by others who do not have ASD so that they could also participate with children who have ASD. Attaining this seamless balance was challenging but necessary as it will encourage every child and their associated guardians to be the part of the experience without thinking whether it is suitable for them or not. I started researching several environments and came across Montessori educational system [42].

2.4.1 Montessori educational system

While researching several environments, I came across Montessori educational system. The salient features of this system are described below:
2.4.1.1 Montessori Materials Are Appealingly Designed

Children perform their tasks in a way that it makes them feel as they are simply playing games with their friends, but they are learning progressively in the process, through concepts of increasing complexity.

2.4.1.2. Ingenious

Montessori learning materials are ingeniously designed to allow children to work independently with very little introduction or help. The students are empowered to come into the environment, choose their own work, use it appropriately, and put it away without help.
2.4.1.3. Invite Activity

Dr. Maria Montessori, who developed this education system, believed that moving and learning should go simultaneously. Children must participate with their entire body and use all their senses in the process of learning. They need stages built into the learning process for looking, listening, smelling, touching, tasting, and moving her body.

Montessori materials are designed in such a way that they are drawn to explore with your senses. For example, you would want to pick up the sound cylinders and shake them. They consist of 2 matched sets of wooden cylinders containing varying substances that create different levels of sounds when shaken.

2.4.1.4. “Grow” with the Child

Montessori materials are designed to follow the students throughout their education; they are like familiar faces greeting them in their new classrooms as they advance.
2.4.1.5. Invite Discovery

Teaching children the answers steals their chance to make exciting discoveries on their own—whether the child is a baby wondering “Can I reach that rattle?,” a preschooler contemplating “Why did this tower of cubes fall down?,” an elementary school student pondering “When you divide fractions, why do you invert and multiply?,” or a high school student puzzling “How does city council operate?”

For students of every age, the Montessori environment offers the tools to discover the answers to their own questions. The teacher is their trusted ally and the learning materials are their tools for discovery, growth, and development. The teacher stays with the students for the entire span of their multi-age grouping, usually 2 or 3 years, nurturing each child’s development over that extended span of time.

The design and flow of a Montessori classroom offers a learning environment that considers all kinds of choices. There are spaces suitable for group activity, areas where a child can settle in alone, parts of the room are open and spacious, allowing a child to choose the zone they are comfortable with, etc. Each of these spaces are characterized by set of tasks to be taken up by either a group of children or a child alone. There are no customary rows of school desks; children are free to work tables or on the floor, they can roll out mats on to work on and define their own work space. Walls of a Montessori classroom are not covered with vibrant colored pictures,
instead they use soft colored pictures which could be from museums or created by the children themselves.

These features of Montessori align with my ground research work and what I was looking forward to implementing in my design. After exploring this education system, I got direction for implementation of interactive environment design.

2.4.1.6. Fun Environments themes for children

I performed a small interview with five children: I asked them where they would want to go, what would they want to do that they have never done before. Three out of five children talked about their fascination to cosmic world. They talked about hubble space, black holes, rockets which prompted me to use cosmos as theme for my initial prototypes.

When I asked about their favorite characters, they excitingly talked about fictional super heroes.

![Image of children and a cosmic scene](image12.jpg)

Figure 12. Fantasy World: Children like to see and feel things they can’t do it in reality

Children seemed to like doing things which they don’t get to do, see, or touch. The environment involving futuristic tech, spatial, cosmic events and reactive components in animations got them excited. A story must build around a theme which a child finds interesting and activities
involving interaction with such elements could be encouraging and engaging elements for children.

I envision my environment to be customizable that can have oceanic, cosmic, city or jungle theme which can be selected by children or their guardians depending upon the child’s interest. But to begin with, I implemented a cosmic theme for this interactive design.
Final Environmental Design Features

Considering these factors and supporting research, I envision my designed environment to have both mixed reality and eye tracking features which could effectively solve three challenging areas: eye contact, initiating and participating in conversation, and motor clumsiness.

![Diagram of Final Design Features](image-url)

**Figure 15. Final Design Features**
3. **Ideations**

After collecting all the research data from research papers, interviews and exploring Montessori education methodology, I started throwing my ideas on paper to give visual directions. My intention was to capture gestural and verbal aspect of interactions primarily.

![Primary Solution Design Direction](image16)

*Figure 16. Primary Solution Design Direction*

![Bridging the gap between different personality traits](image17)

*Figure 17. Bridging the gap between different personality traits*
Below are sketches which are visual directions for my design:

Figure 18. Concept Allow child to play with an actual board game training on cognitive skills guided by an augmented bot communicating with the child.

Figure 19. Concept Eye Tracking to select instrument and create music.
Figure 20. Concept: Grows with a Child Assistive Creature that can be configured to soothe a child for their different needs.

Figure 30. Concept Co-operative Games: Allow child to select an avatar and play using it in an environment with other children to achieve common goal.
Figure 31. Concept Co-operative Games: Allow child to select an avatar and play using it in an environment with other children to achieve common goal.

Figure 32. Concept Conversation Prompts: Augmented Character prompts a situation where progress in the game can be made by conversing with the character.
Figure 33. Concept Educational Themes: Allow guardian to select a subject as per the liking of a child around an activity which they like to do.

Figure 34. Eye Tracking Concept Embracing child’s natural behavior, Interactive games around repetitive physical toys, like that of fidget to engage them. This also develops reflex and understanding of eye communication.
Figure 35. Concept Induce physical activity: Coupling AR with physical objects/toys that encourages children to move around and play.

Figure 36. Concept Spatial Understanding: Child interacts with augmented celestial bodies. This helps them developing intuitiveness to deal with hurdles and decision making.
Figure 37. Concept Activity inducing physical activity through curiosity: Child gets curious around the activity and they do physical activity to find answers to their curiosity.

Figure 38. Concept Learning about nature: Flower buds grows as a child move along the guided line. Such activities induce calmness and helps them focus.
Ideations around texture and feel

Figure 39. Exploring different materials and textures to which helps calming children with ASD

Figure 40. Exploration of sensorial forms and textures which can be used as interactive toys in AR environments
After brainstorming the various concepts of mixed reality where a child sees through mixed reality glasses, interacts with the objects which furthers the game by being a part of the game (tangible) or by being an assistive feature (digital). These assistive factors are designed to train a child through playful activities that slowly engages child besides making them comfortable, first with themselves and eventually with other children with or without ASD.

The final concept of this study is envisioned to be an immersive environment created using mixed reality glasses and tangible objects which can communicate with each other to effectively train a child on communication.

This complete set up involves:
1. Tracking System: Launches and creates 360-degree virtual environment. They have ability to communicate with a wearable that child is carrying and a tracker (a physical toy for a child).
2. Pair of Glasses: For a child to put on their eyes through which they enter fantasy world.
3. Tracker (Physical Toys): To give sensorial feedback to the system upon interaction with a child. Along with tracking a child’s motion, it is capable of recoding additional feedback from a child’s hold or touch. Feedback such as tightness of hold, heart rate, body temperature, duration of contact, duration of activity etc can be reported back to the system. These feedbacks could be helpful for guardians to determine the level of engagement in a child and customize the environment as per their child’s need.
4. Classroom Space: Any room that can accommodate the projection size of 15x15 foot radius is enough space for any activity to take place.

Figure 40 (a). Final Concept: Immersive Training Environment for Children
Features of the concept

1. Communication oriented immersive trainings.
2. Eye tracking activities: Develops reflux of making an eye contact in children and helps them overcome their tendency to avoid eye contact. It includes trainings in which a child interacts with components in the interface just by focusing on objects. The system detects the focus in human eye lens and sends signals to give feedback.
3. Allows child to communicate with others without facing them. This helps them interact with others in collaborative sessions without getting them overwhelmed.
4. Includes both individual and collaborative sessions.
5. Supports both ideal state and motor engaging activity sessions.
6. Guardians can customize the training to suit their child needs.
7. Grows with a child: AI powered digital assistant learns the child’s profile as per their responses and preferences in the session and assists them accordingly.
8. Physical sensory toys can be coupled to give elevated experience to children.
9. Data collected from such tracking sessions are processed to give information about child’s activity during the session.
10. Role Playing Activity Sessions: Allows child to learn about others emotional responses without being in actual situation. This elevates level of confidence to take initiative in conversation when they are in public.
11. Accessible, and is not limited to use only for children with ASD.
12. Themed sessions to relief from stress and anxiety which keeps children calm.
13. Learning through play and mindful activities instead of making it feel like a training for a child with different abilities.
14. Rewarding sessions: Sessions centered around training on good behavior helps the children basic etiquettes of behavioral communication.
4. Initial Prototypes and Testing

I developed several prototypes and conducted my preliminary test using wire frames. Even though wire frames are not suitable for testing with children, they could still be used for testing with guardians of the children with ASD. These parents and therapists are well aware of their children's capabilities and their feedbacks are very valuable to any research in this area.

Storyboard

Figure 41. Showing how mixed reality session trains a child on expressing and communicating with themselves which eventually makes them comfortable to play and interact with other children.

For this project, I consulted with the mother of a seven-year-old boy who seemed quite shy and has attended a school for children with Autism. He had minor fine motor control difficulties. He had a general interest in gadgets. He knew about virtual reality but had not used any VR device.
before. The mother works as a cashier at departmental store and had reasonable exposure to technology. She uses smartphone and laptop for communication and browsing. I took her through wireframes able to understand most of its functionalities and provided her with the feedback where she felt the design fell short of abilities to explain interaction through its visual design. The feedbacks were recorded.

![Wireframes](image-url)

Figure 42. Wireframes
ENIRONMENTAL PLAY

This is cosmic theme background.
Character randomly hides behind different cosmic elements. A child has to walk around and find the character. This is similar to activity of peek-a-boo in real world.

MIRROR PLAY

The background theme elements are now dim so as not to confused a child with other interactive elements.

Emotion Visuals
Looking at it selects it, blinking deselects it.

Character
Through this interaction, a child will be able to assign themselves with different emotion emotions and will learn on how each of these emotions are shown up through his facial expression.

GROUP PLAY

Co-op activities where children can decide and participate with each other.

Activity Tabs
A child will be able to select an activity which would direct the child in the space where he will be interacting with other children who selected the same activity.

GROUP PLAY

Group interactions
This is third stage in the environment, where a child will be interacting with each other in role playing activities.

Figure 43. Wireframes
The shortcomings of the design were noted and fixed. I took these feedbacks and implemented them in my first prototype of design which I wanted to test with children. The interactions that were not clearly understood by children were modified in final design.

![User Testing](image)

Figure 44. User Testing

Few studies have been conducted, outcomes have been positive. While conducting tests, it is often not possible to capture or even to hypothesize some of the findings in a quantitative medium. As a part of the evaluation, I asked parents to describe any changes in their child either
positive or negative, that they felt could be attributed to participation in the test. Many parents reported that child wanted to return to an app and its environment.

The test session setup involves a child, a guardian and a prototype on an ipad. The child played the incarnate section of the app. In this section, a character stands in the middle surrounded by some avatar icons and the child needs to assign one of the avatars to the character by dragging it to the character. This puts visuals on the character which then acquires the characteristics of the assigned avatar. Now, the interaction happens between the child and the character. During this session, an accompanying therapist felt that the presence of multiple animating items on the screen distracted the child from understanding desired flow. Consequently, I changed the design in such a way that rest of the object remained idle and kept animations restricted to the character alone. Now, I took the child through screens. In each trial, the guardian asked the child, “Which of the items are communicating with you?” If the child responded by touching the character in the display, this was considered independent response (IR). If the child did not respond on his own, and guardian had to prompt with the word, “Touch the picture here”. When the child responded to this prompt, it was considered a guided response (GR). If the child did not respond even after the prompt and the guardian had to hold the child’s hand and touched the picture. This considered dependent response (DR).

4.1. Outcomes

After taking the child through these trials, it was found that in the first session most children could only provide dependent responses. As the session progressed, the need for dependence dropped and most children started responding to the guidance prompted by their teacher. Further, the need for guidance also got reduced and the children started progressing on their own.

After 2-3 trails, a good visual balance was achieved, and design layouts were intuitive enough for the children to communicate with the character in the play on their own.

Figure 45 (a). Graph showing the response of a child, initially there was more dependency on guardian to help a child progress. But a child’s involvement grew better with improved version of prototypes.
5. Final Design

I chose to name my interactive mixed reality environment “Unfold” suggesting it would get the participating children to open up. Paper and pencil are basic tools that we introduce children to the world of written communication and expression. Origami is another activity which every child goes through at an early age of 3-5 years. Paper planes are one of those early age craft which children make and are well acquainted about its folds. Thus, I used an image of paper plane which will start unfolding as soon it receives child’s eye focus (or gaze).

As concluded from the interview section above, I am proceeding with cosmic theme to design the interface for interactive environment.
To train children on how to use eye tracking feature of an app, couple of interactions have been incorporated in the app to guide them on using their eyes.

The paper plane hangs in the middle. As soon as it receives the focus of children’s eye, it starts unfolding.

Training child to use their eyes through such interactions helps them stay focused. When they look at plane, app detects the eye movement and starts to track it. It starts to unfold, which motivates children to use eye more.
The game plays involve such trainings that helps children grow comfortable with expressions, facial and verbal communication. The game play starts merely with an eye interaction, that onboards a child in the game play. After this, an assistive character ‘Bob- The Meercat’ is introduced.

![Figure 50. Assistive character starts to interact with a child](image)

Eye tracking coupled with AI is able to guide a child just by tracking the child’s eye movement. These activities can be customized as per the child’s wishes.

![Figure 51. Assistive character starts to interact with a child](image)

![Figure 52. After a child enters a name, the slow transition is made into interactive world](image)
To get along, Bob, an assistive character plays peek-a-boo with a child.

5.1. Different Stages of Training

My interactive design has three stages for a child to go through that could translate and make a child understand about the facial emotional responses besides training them on motor skills.

5.1.1. Mirror Play

In this stage, the child will be watching himself in a mirror. He will be assigning different emotions and will observe the change in his own face. This will allow a child to see himself and explore how he can show emotions using his facial expression. This has a feature for a child to take avatars. When I
interviewed children, they talked about famous superheroes, cartoon characters etc. Thus, I have also added some comic character from fictional world allowing children to look at themselves being one.

With this, the child will be able to see himself acquiring different emotions. They will be able to see how their face looks and how facial expressions are encapsulating any emotions. This experience will take them through clear understanding of expression of different emotions.

5.1.2 Incarnate

Bob, The Meerkat, an assistive character who is introduced at the start of the environment, will come and swing by sometimes to talk to children. Children will be able to interact with it with the use of their eyes. Bob will react to child's gaze and the reaction will be in accordance with the scenario.

One such scenario is included in the second stage of the game. In this scenario, the child assigns a different form to Bob with the help of eye tracking.

For this, the child first looks at Bob, then he looks at mood/character icon. The one receiving the gaze of the child gets assigned to Bob. Now, Bob takes that form and starts interacting with the child as that character. This teaches the child about acquiring different roles in different conversation. Children will be able to learn about others' personalities and their reactions when they interact with them.

5.1.3 Co-operative Play

This is the third and final stage of interactive environment. Here, the child will be able to interact with other children. These children also become part of this interactive environment through a mixed reality glass. During this interaction, they participate and communicate with each other to perform cooperative tasks in role playing activities.
Figure 55. A child is now playing with another child, without seeing them. They interact in an immersive environment where they have to help each other to reach a common goal.
6. **Summary**

My supporting research on communication issues faced by children with AS and their guardians helped me resort to solving challenges that children with AS face, as listed below:
- Making eye-contact
- Initiating and Participating in conversations
- Learning Motor skills

The experiments and games existing around Augmented reality have helped me in selecting the functioning/functional methodology for my design solution, where it turned out successful. They also introduced the parameter of cognitive learning.

Another sprouting technology, eye-tracking, which is currently being developed for VR systems, is a lucrative addition to interactive environment which will prompt children to use their eyes and will train these children to use them instinctively and reflexively.

Exploration of Montessori educational system gave me the inspiration to build intuitive features along with consideration for aesthetics and space for my final design.

7. **Future Work**

The fully developed mixed reality environment has potential to get clubbed with other features.

Customizable Environments

The future advancement of this interactive environment involves customizable environments where guardians can select environment as per child’s interest. They can add and customize task like that of creating music, chasing a butterfly or even playing cooperative game with other children.

Motion Tracking

A connected app can be developed to integrate the motion tracking information. This will be reported to guardians informing them about the activity of their children in an environment. The resultant output can be analyzed and accordingly the environment can be customized to suit child’s need for improvement. For example, the app can show reports like:

“Amy finished 7 out of 10 tasks today. She walked 0.3miles during her activity. She performed better than before”

Integration with other physical toys

MoonPads, created by Mariana Pinheiro who is a RIT alumna from Industrial Design, a collection of sensory tiles that guides children with developmental disabilities through games and activities, can be augmented as environmental elements where child can land upon to finish assigned tasks.
8. Conclusions

The difficulty in communication with child with autism is not solely because child with autism do have communication problems. It is also because there is sad perspective associated with autism. This perception needs to be modulated to understand that autism demands altogether different language for communication. It takes time to learn, children with autism are already good at it. We need to learn this trait of communication.

“There’s public awareness campaigns about autism, and I would just caution people that many of these messages are ones of woe and despair—how difficult it is to raise children with autism, and I’ve raised two children with autism. There are some difficulties there, but there are some wonderful talents and gifts these individuals have as well. So, it’s not something that we want to eliminate, it’s something we want to understand and help society work more favorably with.”
- (Abowd, Gregory)

This statement by Gregory Abowd inspired me to pick my design solution. I envision my product to help children with AS specifically. But at the same time, I don’t want my product to be marketed as something specifically for children with AS, rather it would be an immersive environment for children to interact learn and grow.

In one of the conversations with Ms. Patricia Moore, who is recognized as one the most socially conscious designer, manifests this approach in one for her suggestions in which she said:

“We should always look forward to design for all.”

This inspired me to study and observe my users well, but at the same time, I made sure that my users not confined only to children with AS. This helped me conceptualizing my design around children.

Reference


[29] Kerr & McIntosh, 2000; Tsibidaki & Tsamparli, 2007


