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# Supporting Individuals with Autistic Spectrum Disorder with Various Technologies: A Review

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***Abstract---*** *Autism Spectrum Disorder (ASD) is a complex disorder that has become quite common in the recent years. Various researches have shed light on the importance of disorder's early detection and a much needed support children with ASD needs. The study assesses technologies as support tools for individuals with Autistic Spectrum Disorder. Real life situations often create anxiety and panic attacks in individuals with ASD as the disorder prevents them from acting and reacting normally. Technologies help create controlled environments, acting as an intervention to support people with ASD in therapies. The paper is divided into the types of technologies developed as support tools: mixed reality applications, dedicated applications and robots. Each is further classified by the difficulties that are cantered on namely communication and interaction skills, social learning and imitation skills and other conditions. Most of the studies show that technology is a useful tool in supporting people with ASD. However, understanding that autism is a spectrum disorder and symptoms vary from one individual to another is essential and the need for personalized support tools as opposed to generalized tools is necessary. In the above mentioned way, there is an opportunity for such children to express themselves.*

***Keywords---*** *ASD, Mixed Reality Applications, Dedicated Applications, Robots.*

## I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex disorder of brain development. It takes its roots in early stage of brain development of an individual. The obvious signs of the disorders emerge between 2 and 3 years of age and lasts throughout a person's life. There is no one type of autism and the cause of autism were not definite until recently where many researches are being pursued. ASD is an expanding health problem. Matter of fact, studies estimated that 1 out of 68 had autism in the year 2014 and the rate is increasing year by year. Studies of cause and early diagnosis are a necessity [5]. Crowd sourcing is predicted to accelerate discoveries of cause [1]. So far, research stated that the number of rare gene changes by itself causes autism. In most cases, the cause is autism risk genes and environmental factors influencing early brain development. The non-genetic factors increase the risk of ASD usually before and during the birth of the child. Some factors might be advanced parental age at time of conception, maternal illness during pregnancy, certain difficulties during birth like periods of oxygen deprivation and others. Autism is called a spectrum disorder because the individuals with ASD exhibit a wide range of symptoms.

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The symptoms can be broadly categorized into 1) Communication and interaction behaviour.

Social interaction and imitation behaviour and 3) others. Some specific symptoms that can be observed are,

- Difficulty in communicating and understanding the figurative language spoken.
- Poor interaction skills and difficulty in holding consistent conversations which is the result of poor communication.
- Inconsistent eye contact and therefore the individuals tend to look and listen to people less.
- Using words that are odd yet hold special meaning to the people affected and known to only those familiar with the individuals way of communication.
- Talking length about one's favourite subject without realizing or taking into consideration if others are listening.
- Some individuals may be sensitive to light, noise, clothing and temperature.
- Difficulty in interpreting emotion and conveying emotions.
- Some individuals exhibit intellectual disability while some may excel

A set of essential behaviors need to be identified for diagnosis and systems like DISCO are adopted [2]. No standard treatment for individuals with ASD is found. However, behaviour and communication therapies, skills training and medicines help control the symptoms.

Recently, technologies have paved in as support tools that offer great assistance in helping individual with autism as well as help the caregivers understand the disorder better. With the introduction of electronic smart devices like tablets and mobiles, there has been a weighty effect on individuals with ASD. Individuals are given a medium to interact, express and learn thus break out of an isolated life they endure otherwise [3][15]. Real life situations that the individuals generally encounter causes anxiety and panic attacks. The disorder prevents an individual from acting and reacting normally. Technologies provide a controlled environment and act as support tools for therapy and many more.

Nuria Aresti-Bartolome et al [4] studied technologies as support tools and broadly categorized them as

1) Virtual Reality applications
2) Dedicated applications
3) Tele-health systems
4) Robots

The above becomes a base-point for literature review. In the review, discussions would be regarding in the following section: firstly, the mixed reality applications and the difficulties it centers on. Secondly, the dedicated applications and the area it focuses on. Next, a discussion on the studies of robots would be done. Lastly, an assessment on the entire study is done and conclusions are drawn.

## II. VIRTUAL REALITY/AUGMENTED REALITY/MIXED REALITY APPLICATIONS

Senses have played a major role in helping human beings perceive the world around. In other words, one experiences reality through one's sensory inputs and the interpreting ability of human brain.

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A Sensory input is thus an important term. If made-up information is fed as sensory input, then in reality one perceives will also change in response. Therefore, providing an imaginary reality, a setting to imitate reality is virtual reality which would make the headlines in technological advancements like Facebook's Oculus Rift, Sony's Project Morpheus and the Samsung Gear VR.

On the other hand, there is an augmented reality which also works in creating realities by combining digital information with user's environment. In VR, a completely new and artificial environment is created but in AR, existing environment is topped with new information.

Mixed reality or hybrid reality mixes real and virtual worlds to produce new environments that are a hybrid of AR and VR.

Technology has been used in therapies for some time now but mixed reality is a recent addition. The technologies help individuals with ASD develop skills necessary to lead an independent life through a controlled environment that can be later encouraged to try in the real world. Existing applications like Avaz encourages communication through pictures and text, Visual Routine allows creation of text based and image based schedules, Go Talk NOW is an alternative communication app that has various uses for different levels of users and many more. However, not many personalized apps to help the autistic children are available.

Mixed reality also enables the caregivers, parents, doctors and researchers have a better insight on how autistic children are challenged by difficulties like sensory overload and aversion to stimuli [1]. Recently National Autism Society wanted to common people to have a glimpse of what is autistic and a simulation for remaking a video of a boy who is adversely overwhelmed by sensory overload like flickering lights is done. The simulation of the 360-degree video is what many called truly terrifying but an insight like never before.

The inability to recognize emotions and respond appropriately is a great hindrance that impairs an individual with ASD from acting normally in any social setting. Bekele et al [6] have explored how individuals with autism respond to facial expressions in a virtual reality environment. A VR based facial emotional expression presentation system was designed to monitor the eye gaze and physiological signals related to emotion recognition. 10 adolescents with ASD and 10 typical adolescents were analyzed with the system and the variations of gaze and physiological patterns were recorded. Results state that the adolescents with ASD looked 11.32% ($p<0.05$) more towards the forehead area and 12.1%

($p<0.05$) less to the mouth area than the normal subjects and also looked 5.58% less to the eye area and 1.89% less to the nose area. The statistics give a better understanding of how individuals perceive motions and can be used for development of VR system that would act as an intervention.

Another important skill that ASD individuals struggle with is adaptive skills that keep them from being independent. Joshua Wade et al [7] have proposed a driving intervention through virtual reality in the form of gaze contingent adaptive virtual reality simulator. A study comprised of 20 adolescents with ASD and results of the individual's behavior on purely performance and performance with the help of the VR were taken. The gaze contingent VR was clearly beneficial.

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There have been many VR specialized real world and simulated driving system for purposes that are not related to ASD. Results have shown that drivers from all backgrounds display inattention while driving. To minimize inattention, there have been gaze contingent systems to assist driver awareness in real world driving environment. The system consists of 1) audio feedback alerts of objects that the driver may not have noticed 2) two cameras that obtain several features of environment and driver like head nodding and yawning 3) warning mechanism based on vibro-tactile features. ASD individuals recognized hazards less often than normal people did and also find multitasking problematic. Thus, the VR mentioned above was modified to have embedded rules specifically towards ASD intervention, provides feedback to improve driving outcomes and integrate with host of sensors to create a dynamic closed loop interaction would prove beneficial.

Virtual reality applications have given desirable results when used as therapeutic tools. Virtual reality creates safe environments for individuals to comfortably interact and thus improve one's social skills. It also helps understand autism better through the study of how individuals react and respond to external stimuli generated from the VR and also stresses on the necessity for personalized apps to help individuals with ASD.

## III. DEDICATED APPLICATIONS

Advancement in technical field has been vast over the past decade and computers, tablets and mobile phones have taken over the world. The above mentioned are what one calls as dedicated applications. Mobile applications are handy and portable. Individuals with autism can use the application as a medium of intervention to better interpret the situation around and also communicate better.

There is not much awareness on the neural basis in the disorder and take help of technologies to either compensate externally for a said difficulty or achieve the same function through other means. Language and social communication is a major difficulty faced by individuals with ASD and Harini Sampath et al [11] proposed an alternate means to communicate. The paper has designed an alternative and augmented communication where pictures are used instead of language since studies have proved autism children are great visual thinkers. The proposed solution aids in both expressive and receptive communication where device converts language to pictures and vice versa completing the communication loop.

Receptive Communication:

Caregiver Text messaging device Wireless channel Hand-held device Child Expressive Communication

Child Handheld device Speech Caregiver.

Thus, it is a personalized tool for effective communication.

A course of instructions delivered through a computer is generally what is called a Computer based Training system (CBT) and Karanya Sitdishanguan et al [8] have proposed to act as an intervention to assist individuals with ASD. The paper states the reliability of CBT based on the ease of use and learning efficiency and have proposed based on various interaction styles 2 systems 1) Window Icon Menu Pointing device (WIMP) and 2) Tangible User Interface (TUI). WIMP based CBT is comprised of standard computer mouse or touch screen whereas TUI is generally of a tabletop setting and Elementary skill is used for assessment.

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The results demonstrate that TUI is easier to use with its rich multi modular interface and thus increase fast learning. The WIMP based CBT abstraction of icons and metaphors are not comprehensible by users.

Many believe one problematic symptom that restricts ASD individuals from normal social interaction is the inability to recognize emotions. S.A. Cassidy et al [9] proposed an assistive technology where text is converted to emotionally expressive speech. The app is called Xpressive Talk where a near video realistic avatar is generated and it utters inputted text in a large variety of emotional tones.

A study was conducted with 40 adolescents and adults who were asked to recognize emotions on 20 videos of a female actor speaking four neural sentences each in different emotional tones; happy, sad, angry, afraid and neutral. The result shows confusion matrices for participants' emotion inferences in the typical control and ASC groups in each condition respectively. Both groups appear to provide more correct than incorrect emotion inferences for both the real and XpressiveTalk conditions. People with ASC appear to be less accurate overall than others. Participants in both groups also appear to be less accurate when inferring happy and angry from XpressiveTalk compared to the real face. The above clearly shows that technologies are promising intervention tools to improve emotion processing and attention skills in adults with ASD.

Touch screen technologies have become popular over the years and Muhamad Fairus Kamaruzaman et al [10] have used the technology to create an assistive technology that assists parents, instructors and teachers to train children with ASD and aims to provide colorful, animated and creative learning of basic numeracy and calculation. TALNA expanded as touch screen assistive learning numeracy apps provides learning and discovering name of each number, practice writing on tracing dots and learning to count and solve addition arithmetic problems.

Dedicated applications utilize the current trending technologies like mobile and touch screen to act as an assistive technology for individuals with autism. Again, the stress on personalized applications is depicted by various researches. Dedicated applications are beneficial as either a trail to compensate a symptom like inability to recognize emotions externally or finding other means to solve the difficulty is done.

## IV. ROBOTS TO SUPPORT ASD

Robots are machines programmed to mimic human actions but more efficiently. Thus when one talks about robots helping individuals with ASD, one is actually talking about engaging individuals with feature very similar to a human which is far less complicated and more comfortable for the child. The factor mentioned here reduces the anxiety in children who generally find any social interaction threatening. Such robots are a learning experience for a child and instills spontaneity in one's otherwise controlled lifestyle. Robots are used for diagnosis and therapies to treat ASD nowadays. Robots tune their social skills and subsequently observe the reactions and form some kind of scale that can later can be compared and evaluated in therapies.

Milo is a popular humanoid that assists teachers and parents dealing with kids with ASD. Milo teaches children emotions, expressions and appropriate social behavior.

To shed light on the educational objectives that the professionals work with Claire A.G.J Huijnen et al [14] identified corresponding robots.

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Four focus group were taken with professional from nine organizations worked to create an overview. There were 74 objectives in nice different domains out of which the three domains predominated and were identified to be majorly related to robots; 1) Social interaction 2) Play 3) Communication. Other domain like self-care, independent skills, preschool skills, emotional well-being and functioning in daily reality were unaddressed.

Pedro Ponce et al [12] proposed the use of signal detection and fuzzy signal detection for improving social interaction of a semi-autonomous robots and humans in therapies. In terms of fuzzy logic, real world signal takes a value in the range between unequivocal presence and unequivocal absence and when the above is combined with signal detection, fuzzy signal detection is derived. The above could be integrated into validation process for assistive robots [13]. SDT treats observers as both sensors and decision maker which help evaluate social robots with human psychology tools and thus improve human interaction. The obtained results can be further used for efficient design of social robots.

| Author | Clinical Group | Area | Method | Results |
|---|---|---|---|---|
| Maude M David et al | none | Diagnosis of ASD | Crowd Sourcing | Building sandbox of coupled data can be efficiently translated into approaches in therapy. |
| Sarah J. Carrington et al | Sample 1- 82 children, Sample 2-78 children and Sample 3- 190 individuals. | Diagnosis for ASD | Listing essential behaviors for diagnosis of ASD using DISCO | Social communication, items measuring sensory behaviors majorly discriminate ASD with others. |
| Chandler DL | None | General | A review | Technology is beneficial in diagnosis and treatment of therapies. |
| Nuria Aresti-Bartolome et al | None | General | A review | Broadly, technologies classified as 1) Virtual Reality 2) Dedicated Applications 3) Tele-health Systems and 4) Robots. The above form great supportive tools for both children with ASD and their caregivers. |
| Caitlin E. Dugger | None | Early intervention to diagnose ASD | Applied Behavior Analysis (ABA) training, naturalistic Behavioral program and Family Involvement. | Early intervention shows significant improvements in different parts of Communication with ASD. Reduction of symptoms and sometimes even prevention of ASD is possible. |
| Bekele E et al | 10 adolescents with ASD and 10 typical adolescents | Response to facial expressions | Virtual reality -presented the facial emotional expressions and collected the synchronized eye gaze and physiological data | Contempt and disgust as well as fear and surprise were difficult to discriminate. Extreme and low levels of emotions were hard to be detected. Adolescents in the ASD group paid less attention to the eye area |
| Joshua Wade et al | 20 adolescents | Adaptive skills: Driving | Virtual reality | Provides embedded rules specifically towards ASD intervention, provide feedbacks to improve driving outcomes and integrate with host of sensors to create a dynamic closed loop interaction. |
| Karanya Sitdishanguan et al | 12 LFA children | General | Elementary skill teaching via WIMP and TUI CBT | Taking advantage of predictable environments provided by computer to be used in teaching. TUI has better ease of use than WIMP does. |
| Cassidy SA et al | 40 adolescents and adults | Recognition of emotions | Dedicated hand held application | Synthesized neutral and sad faces are recognized more accurately than the real face as they have better signal clarity. Synthesized happy and angry faces were found hard to recognize more so than others |
| Muhamad Fairus Kamaruzamana et al | None | Learning numeracy | TaLNA | Assist learning of numeracy and calculation in touch screen app proves to beneficial. |
| Harini Sampath et al | 4 children with reading difficulties | expressive and receptive communication | Converting texts to picture and vice versa. | Proved beneficial in assisting learning. |
| Pedro Ponce et al | None | Social interaction between robots and humans. | Signal detection and fuzzy signal detection. | A powerful tool for evaluating the correct response of robots to human interaction and thus be used for further research and design. |
| Claire A. G. J. Huijnen et al | None | 9 different domains | Mapping robots to corresponding domains. | Social interaction, Play and Communication were some major domains that were easy to map. The robots are supportive in learning and therapy. |

## V. MACHINE LEARNING METHODS

Machine learning is one of the new and upcoming methods used to detect and classify various neurological disorders. They are increasingly effective in finding hidden connection between various features that may not be visible to human intelligence. Machine learning is type of artificial intelligence that objectivises to learn new features from the data that is used to train the "model" and predict new or unknown data. It is of two types, Supervised and Unsupervised learning.

In supervised learning, the machine learning model is trained with some human interference. An example would be training the model to classify patients from control subjects, where the mode is first "taught" to differentiate between them using training data. In unsupervised learning, the model is left to make its own assumptions about the data., thus learning any unknown connections or hidden variables in the process. Both methods are equally robust in its own way and are deployed with much success in its own fields.

In this study, different supervised machine learning models were trained upon the ABIDE dataset aka Autism Brain Imaging Data Exchange. It is a consortium of International Neuroimaging Data sharing Initiative, containing open source data measured from the brain images of 539 patients suffering from ASD and 573 control subjects. The accuracy scores obtained from the various methods used to predict the patients are tabulated below.

| Id | Machine learning method | Accuracy (%) |
|---|---|---|
| 1 | Logistic Regression | 54.90 |
| 2 | Decision Trees | 51.36 |
| 3 | Linear Discriminant Analysis | 55.67 |
| 4 | Quadratic Discriminant Analysis | 55.37 |
| 5 | Random Forest Classifier | 56.36 |
| 6 | K Neighbours Classifier | 50.90 |
| 7 | Naïve Bayes | 57.72 |

As the above table shows, naively using a machine learning to classify the data provides a decent metric to draw conclusions. Using advanced methods such as Deep Learning may prove to better as done in works such as [17] [18].

## VI. CONCLUSION AND FUTURE WORK

The conclusion drawn after careful study and writing of the review is that technology serves as a support tool for people with ASD and their caregivers.

A hypothesis predicted states that individuals with ASD are drawn to technology because of the predictability and thus help inculcate targeted behaviours. The major symptoms are difficulty in social interaction and communication and also a hindrance for an individual from living an independent life. Many adaptive skills like driving are also proven to be of great difficulty.

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Technologies act as an intervention and assist learning and are also widely used for diagnosis and in therapy. They are majorly divided as mixed reality application, dedicated applications and robots. Mixed reality applications work on creating safe environments and encourage interaction of the individual in a setting very similar to reality. The above-mentioned application improves comfort and instils the necessary skills. Dedicated applications on the other hand use the trending technology like mobile to create assistive applications that are easy to be held and handled by individuals. Lastly, robots and humanoids are used to mimic human feature and encourages individuals with ASD to interact and build better relationships. The applications also teach emotion recognition and social skills. They also store the result of the interaction that is further used in assessment. A Clear understanding that autism is a spectrum disorder and one generalized application will not be a solution to aid. Therefore, more research on personalized tools is needed.

Having said that, future work has been contemplated on creating a framework for personalized dedicated application that helps in improving the social interaction skill of a child with ASD. In particular, it will help the child in recognizing emotions around them. Study has revealed that children with ASD tend to notice the mouth and not the eyes while a person is talking to them. Using the above base-point, the general idea of the framework will be to take audio clips of voices speaking different emotions as reference and help label emotions displayed by the person speaking to the child with which, the social interaction skill would improve in the future.

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