ANALYSIS AND IMPROVEMENT IN ASD THERAPIES USING ROBOTICS

A Final Year Project Report

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ABSTRACT

Autism is a neurodevelopment disorder affecting 7.5 million people around the world. 1 in 42 boys have autism and there is no cure for this. Child suffering from autism challenges with social skills, repetitive behaviors, speech and nonverbal communication. Several therapies are done to minimize the effects of autism and make children more social and less anxious.

Our idea is to use combination of different biomedical and other sensors to get data from autistic children and study their behavior. NAO is used as a therapy robot which performs different actions and child's behavior is noted. We used EEG, EMG and Kinect to get insights about the behavior of autistic children.

We performed two interventions i.e. Joint Attention and Imitation on different children with different severity level of autism and it was noted that there were some improvements in their behavior. They become more familiarized and comfortable with the robot and their social skills were enhanced.

PREFACE

This report looks into the details of Autism Spectrum Disorder. It has been discussed in depth including its definition, types, symptoms and therapies. The main focus has been on the robotic therapy for autistic children and its effectiveness when combined with different biomedical and advanced sensors.

Our motivation has been to do as much as possible in our capacity to improve the quality of life of these children so that they are not left behind and can learn efficiently. This project enabled us to observe these children and understand the diversity of people around us. We became a regular part of their school routine and it gave us pleasure and strength that these children started seeing us and NAO as part of their families. We were exposed to the human emotions and feelings which we had not experienced before.

This project was the best part of our academic life and all the children we interacted with during the course of your sessions will remain forever in our memories.

We are glad that we were able to influence their lives in a good way and got to spend a great time with them. We hope that we see and meet them again when they are grown up and living their lives to the fullest. We wish them best of luck in their lives and may they ever keep shining and smiling.

ACKNOWLEDGMENT

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Thank you everyone again who is mentioned here and all other people who helped us directly and indirectly to make this project a success.

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ABBREVIATIONS

ABA	Applied Behavior Analysis
ASD	Autism Spectrum Disorder
EDSM	Early Denver Start Model
AS	Asperger Syndrome
EMG	Electromyography
CBT	Cognitive Behavioral Therapy
EEG	Electroencephalography

CHAPTER 1: INTRODUCTION

Problem Statement

Devise a system of fully Automated therapy sessions for Autistic children when they play football with two Nao robots gathering specific inputs from latest sensors like MYO band, EEG headset and Kinect to gather real time data and integrate it to extract useful information to increase their skill set

Motivation

We grew up idealizing geniuses like Charles Darwin, Albert Einstein, Bill Gates, Steve Jobs, Sir Isaac Newton, Henry Cavendish and admiring their works in maths science and technology who provided a basis for most of the knowledge we've gathered in our lifetimes but the fact that all of these had ASD often goes unnoticed. [1].

For science enthusiasts like ourselves, we want an Einstein from every household to take these works ahead so that man can make home in Mars. But with 1 in 68 children's talent going to waste because their Autism isn't getting the treatment it deserves, the dream for Mars seems unlikely. [2].

The realization that with the right therapy, their other talents can be unleashed for mankind to take us forward as a whole is a big incentive on its own.

Because all children with Autism have problems with social interactions but they are extremely good at technology, robots create that bridge where humanoids having a human like face yet are animated -not real so ASD children are more engaged with them. For ASD children. Robots are predictable, less intimidating, repetitive and won't get annoyed and frustrated at them or bash them when they don't perform well which is necessary for therapy of Autistic.

We believe that Robots are a key to the future of diagnosis and therapies in illnesses like Autism in which the threat is due to social interaction making them disengage even from family. Maintaining eye contact and interaction with them is not at all like that with a human therapist.

We wanted to contribute our part for the greater good and not only help the ones in need but put more genius at work for humanity's progress by providing a helping hand with ASD children.

Objectives

1. To develop an automated system for the autism interventions
2. To increase the social and cognitive skills of autistic children through our robotic therapy
3. To integrate EEG, EMG and Kinect sensors to work together which has not been done before i.e. these sensors have not been used together in autism earlier.
4. To develop an Applied Behavior Analysis therapy through NAO robot
5. Real-time processing and analysis of the behavior and emotional state of the autistic children by combining the data from EMG and EEG to deduce meaningful results

Autism Spectrum Disorder (ASD)

According to Autism Speaks, "Autism, or autism spectrum disorder, refers to conditions characterized by challenges with social skills, repetitive behaviors, speech and nonverbal communication, as well as by unique strengths and differences. It is caused by different combinations of genetic and environmental influences". [10]

1. ASD Statistics

1 in 68 American children have ASD. It is found that males are affected by autism five times more than females. Approximately, 1 in 48 boys and 1 in 252 girls have autism in USA. [2] Autism prevalence in the world is shown in fig. 1 below. [3]

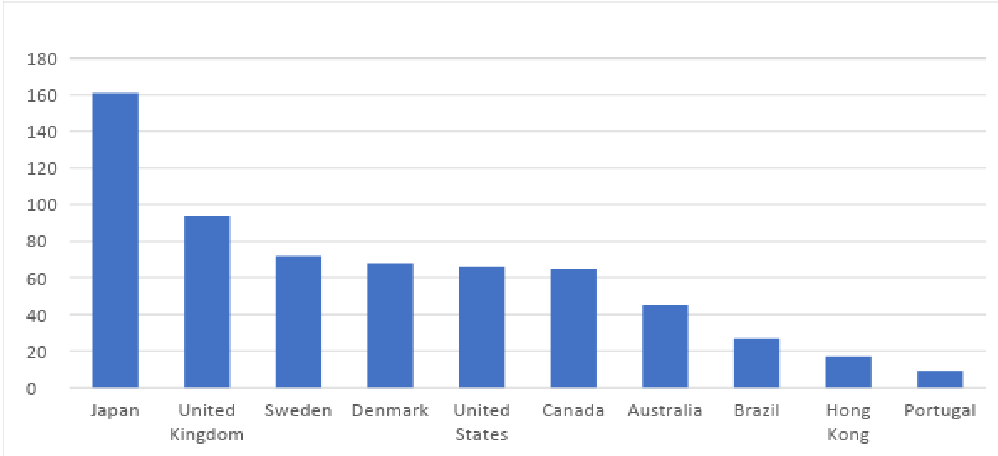


Figure 1. ASD prevalence in different countries as of 2017 (per 10,000 children)

2. Autism in Pakistan

345,600 individuals are reported to have autism in the country but this problem is highly underreported. Thus, the actual figure is significantly great. Facilities for treating autism are lacking in Pakistan. This means more than 300,000 people lack elementary skill and they can't secure a traditional employment. [4]

Types of ASD

There are three different types of ASD.

1. Asperger Syndrome (AS)

Individuals with Asperger syndrome commonly have some slighter symptoms of autistic disorder. They have social problems and abnormal behaviors and interests. They do not have trouble with language or intellectual disability.

2. Autistic Disorder

It is also called 'classic' autism. Individuals with autistic disorder commonly have important language delays, social problems and difficulty in communication, and abnormal attitude and interests. They also suffer from intellectual disability.

3. Pervasive Development Disorder (PDD-NOS)

It is also called ‘atypical’ autism. Individuals who possess some of the symptoms of autistic disorder or AS may be identified with PDD-NOS. The symptoms cause only social problems and communication difficulties. [5]

Therapies used in ASD

Following are the therapies used for autistic child.

1. Parent Education and Training

Parent training can be beneficial as they know the strengths and weaknesses of the child. In this way, they can teach their child to cope with difficult aspects of his life. It is a very focused treatment done by the parents for their child with love and support for him. They train him for dealing with various social and cultural issues

2. Social Skills Training and Speech-Language Therapy

Therapists use training and therapy for individuals with autism. Autistic children lack strong communication skill but they should at least know how to express their feelings. Therapists usually use visuals to teach social skills. Group therapy is also a part which can help the child how to interact with his/her colleague. Speech-Language and communication therapy can also help the child in dealing with different scenarios in life.

3. Cognitive Behavior Therapy (CBT)

CBT is used to help children with ASD to improve their emotions, impulse control, fear and depression. CBT is different from other therapies because it deals with cognitive abilities rather than social skills. This therapy teaches how to react with a person in case of depression, anger, outburst, etc. This therapy can be designed for separately for each patient thus, it is results in more effectiveness

4. Applied Behavioral Analysis (ABA)

Hundreds of therapists have used ABA for treatment of ASD since 1960. A lot of literature is also available about this therapy which makes it the most effective and successful therapy. ABA includes cognition and speech-language therapy. There are three steps that are followed in ABA.

Step 1: Subject the patient to ABA therapy which includes verbal to physical stimuli.

Step 2: Reaction of patient towards the therapy which can both be positive or no response.

Step 3: The results depend on behavior. If there is a positive response then the therapy is fine but it results no response then considerable changes must be done.

ABA therapy is highly structured and curriculum is divided into small parts, each part is removed as the child learns it. As the child masters the skill, he/she gets an award. ABA therapy works on step by step learning. Therapy includes sports and other interesting features. As the child learns a skill or progresses, the results are noted by direct observation but if the results are not satisfactory or are negative then changes are made.

5. Sensory Integration/Occupational Therapy

A lot of children with ASD have issues with their motor skills and senses. Sensory integration can help in improvement of their senses. This can reduce clumsiness and other problems in the child. Moreover, when the senses are working correctly, the child will start talking, communication which will result in improvement in social skills.

6. Medication

Medication doesn’t directly improve children with ASD but it can reduce the symptoms that occur like depression, clumsiness, hypertension etc.

7. **Early Start Denver Model (ESDM) Therapy**

This therapy is based on principle of ABA. This therapy works on step by step learning but with discrete trials.

8. **TEACCH**

Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH) method is not an actual therapy but a tool that assists ASD individuals understand their surroundings. It also helps autistic child how to organize and structure.

In our project, we are using ABA therapy. The reasons for choosing this therapy are given below.

Why ABA?

ABA is the most effective therapy for autism. A lot of work has been done in this regard and it is most preferred by therapists around the world. Dawson, G. et al applied ESDM therapy and community intervention on a group of 48 children ranging from 1.5 years to 3 years of age. Children who received ESDM showed more improvement in IQ and adaptive behavior as compared to community intervention. [6]. Lovaas O. applied intensive ABA therapy on 19 children for 40 hours a week in a duration of 2 years. 9 in 19 children performed better in school with minimum support while 1 in 40 children in control group had significant improvement. [7]. Landa. R. J., and Kalb, L.G applied ABA on 48 children above 2 years for 6 months and they got significant improvement in IQ, social skills and reduction in severity level of autism. [8]. Cohen, H., Amerine Dickens, M. and Smith, T. analyzed 21 children who got ABA therapy for 35-40 hours/week and 21 children who were in control group. After 3 years 17/21 children who got ABA therapy were fully included in regular education with no or limited support while only 1/21 children was included in regular education from control group. Children who got ABA had better IQ and social skills than control group children. [9].

Robots in autistic therapies

There are multiple robots which have been developed and utilized in Autism Spectrum Disorder curing. Few of them are given in Table I, which are famous along with their specifications. Among all, NAO is more famous and its being utilized in different applications along with Autism Spectrum Disorder.

Table 1: Commonly Used Robots in Autism Spectrum Disorder Therapies

Robot Name	NAO	iRobi	Robotics OP2
Height (cm)	53	32	45.45
Weight (kg)	4.3	7	3.0
DOF	25		20
CPU	Intel Atom @ 1.6GHz	Celeron @733 MHz	Intel Atom N2600 @ 1.6 GHz (dual core)
CPU additional accessory		256 MB, HDD 40 GB	4 GB DDR3, 32 GB mSATA
Operation Time	90 minutes (LIPO battery)	180 minutes (LIPO battery)	30 minutes (LIPO battery)
Built in OS	NAOqi 2.0 (Linux based)		Any Linux or Windows release (32 bit only)
Compatible OS	Windows, MAC and Linux		Linux and Windows (32 bit)
Programming Languages	C++, Java, MATLAB, Urbi, C, .Net, Python		
Sensors	Two HD cameras, four microphones, sonar rangefinder, two infrared emitters and receivers, inertial board, nine tactile sensors, eight pressure sensors	Camera, Microphone, 7 Ultrasonic sensors, Inertial unit, 12 IR sensors, Floor detection sensor, 2 stereo speakers, stereo Mac, 7 inch Touch screen, 6 Tactile sensors	Serial communication, 2 USB ports, 3 axis-gyro, 3 axis-accelerometer, 2 microphones
Connectivity	Wifi, Ethernet	Wireless LAN installed for internet connection (101.11 b/g)	Ethernet, mini HDMI
Cost (US)	7996	4598	9600

CHAPTER 2: LITERATURE REVIEW

We are using three main sensors/devices in our project i.e. Myo Armband (EMG+IMU), Emotiv EPOC EEG Headset and Kinect. The literature review for each of these is given below.

Myo Armband in Autism

Myo Armband is a wearable gesture control device that provides interface between humans and computers like other input devices i.e. microphone, mouse, webcam etc. but it feels much more realistic. It was released mainly for the purpose of non-contact communication thus creating a virtual environment on mobiles, PCs, tablets etc. It works using electromyography (EMG) as its main working principle to study the electrical activity that goes on in the muscle when it requires movement either to change its position, move on joint axis or neither in isometric contractions.

In 2016, scientist found them trying to analyze MYO band's working. They tried to find a visual representation of physical gestures to do the job of mouse and keyboard. They conducted an activity-based study encouraging a group of people to play a game first using the keyboard then the MYO band. They found out that when playing Need for Speed and Oculus Rift the people where more excited and even had better performance. In 2016, Ganiev et al. in this research paper about Myo band said that the forearm muscles where usually the MYO was worn is homogenous with the calf muscles on the leg. [11].

In 2016, scientists delved deeper into exploring the EMG signals from the muscles of legs focusing on walking as an activity. Taking the Biceps and Rectus Femoris into account, it was found out that in ASD and TD children RF muscle showed drastic differences and that this could be a vital criterion for setting the rehabilitation plan. [12]. Similar work was done for Tibialis Anterior (TA) and Gastrocnemius (GAS) muscles during walking. GAS was found to show significant differences when a group of 18 children was analyzed having 8 suffering with Autism. [13].

In another study the subject TD and ASD were exposed to a stimulus and it was observed that their motor neurons behaved very differently showing greater anxiety and startle in ASD children. [14].

Kinect in Autism

For children with ASD playing XBOX is a part of their education in Steuart Weller Elementary School in Virginia. [15]. Students with autism need a kinesthetic approach to encourage them to move around and engage their whole body gives them a complete experience than most of the other strategies out there. ASD hinders one's interaction with others and Kinect allows them to do just that. The console works with motion sensor instead of the controllers so players have to use their bodies and share space. It's like going inside a virtual reality and dealing with the scenarios created. Teachers at this school began using Kinect 2012 and say it's both a resource of recreational use and motivational tool. They observe that before such therapies they went from writing two sentences to a paragraph and used a less negative approach to deal with a problem would talk through the teachers at times [15]. While there still isn't much research on the Kinect as a therapy aid for ASD, use of the device is gaining recognition. Instead of articulating, direct instructions where the frustration increasing because they cannot perform the task they are being commanded, the game automatically show them what they are supposed to do and what is the gaming infrastructure thus minimizing the instructions. This way they were found to easily pick up the task they were supposed to do in the first place. No one claims that the Kinect is a miracle cure, but with the positive result so far, therapists and teachers say that it is a virtual raft ride forward in ASD therapy.

In 2016, works to indulge autistic children with Kinect was done in Karachi, Pakistan. They set up a vision-based system to let a child play with a toy car when it is being controlled by the child himself further exploring the theory that such kids were indeed more comfortable with the toys instead of human therapists. The aim was to teach them laws of interaction as well as sense of direction. It was found out that they were easily indulging in the activities and their concentration was held. For this reason, we are encouraged to explore Kinect and autism together. [16].

In other work, the aim was to look at, amid a joint attention (JA) elicitation errand, how Autistic children (ASD) and kids with ordinary improvement (TD) carry on and investigate their 4 dimensional (which means spatial 3D + time) while communicating with a human or with a bot. The researchers constructed a framework that utilized a Nao robot and a recognition framework in light of a RGB-D sensor (Kinect) to catch social engagement signs. A JA acceptance analysis was performed in which kids with ASD (N = 16) and coordinated TD kids (N = 16) had a 3-min communication with the robot or with a specialist. Nao instigated JA by looking; by looking and pointing; and by looking, pointing and vocalizing at pictures. The two gatherings of youngsters performed well with the specialist. Be that as it may, with Nao, the two gatherings had bring down JA scores, and the youngsters with ASD had an essentially bring down score than the TD kids. The scientists concluded that multimodal Joint Attention enlistment was more effective. The 3D spatial world look investigation indicated less precision. The storage compartment position in ASD demonstrated less dependability in the 4 measurements contrasted with TD controls. [17].

EEG in Autism

Before going into the details of use of EEG in Autism, we will first look at the work done in EEG in general and what functionalities it has.

The basis of human body mechanism lies in the fact that each cell either Nerve cells (neurons) or red and white (erythrocytes or leukocytes) or Neuroglial cells or Muscle cells (myocytes) or Bone cells or Skin cells communicates with each other to develop all the skills known to the human body. This communication is done in the form of impulses which results in the way we interact.

These impulses are made possible due to the electrical conductance. . Thanks to the cells' working in accordance with fundamental laws of physics of electrical conductivity that EEG or Electroencephalography enables us to observe what goes inside of the head. EEG sensors do so by attaching electrodes dipped in an electrolytic solution to scalp and detecting minute electrical activity and observing it's patterns for recognition.

Since the last hundred years, man has worked on developing eeg from the scratch to specifying the number of electrodes used, to new and improved statistical methods and their employment and to establishing standards.

A lot of work has been done in this prospect to shape the human EEG research landscape.

The earliest work was done as early as in 1957 by William Dement and Nathaniel Klietman who found themselves face to face problems like impossible use of paper for record keeping. They started from the observations of dreaming on EEG and established that in a rapid eye movement part of sleep was when the most dreams occur and provided a basis of all future EEG work. [18]. In the 1998 critical work was done to frame wavelength syns and to correlate the abstract to the physical. Brain activity is made possible when the signals are transmitted in a range of wavelengths. As it goes from delta to Gamma i.e frequency it's speed increases to transmit signals. One main measure would be wavelength but by no means is it the only one. Going by the wavelength, we are given information as to how fast it is, i.e. frequency of transmission, similarly, amplitude (synchronized, or desynchronized) gives a measure of intensity. [19].

The author, Walpgang found out that if the amplitude of the wavelength varied, the memory had a better chance at sticking and the subject person will be more likely to remember things. He established this for upper alpha wavelength i.e 10-13Hz. In contrast to this, he found out that theta waves i.e. 4-7Hz that were in sync corresponded to efficiency in storing new experiences in memories. [19].

The author found out that this behavior was due to different wavelengths targeting different parts of the brain. the theta wave targeted that of storage and coordination while the alpha to that of semantic memory.

In the year 2006, Wolfgang again got to work on alpha waves and found out their sync and desync had a lot to do with control over thoughts/ actions and losing of control/consciousness. it is termed as event related synchronization/ event related desynchronization. [20].

After dreaming patterns and its effect on EEG signals, in 2013 meditation held researcher Cahn's interest. it was observed that frequency was subdued but increased alpha and theta band power. The differences might be due to the variance from person to person and the type of meditation. his work also combined the results from other medical scans with EEG like PET and fMRI scans. [21].

International 10-20 EEG nodes placement is shown in figure 2 below.

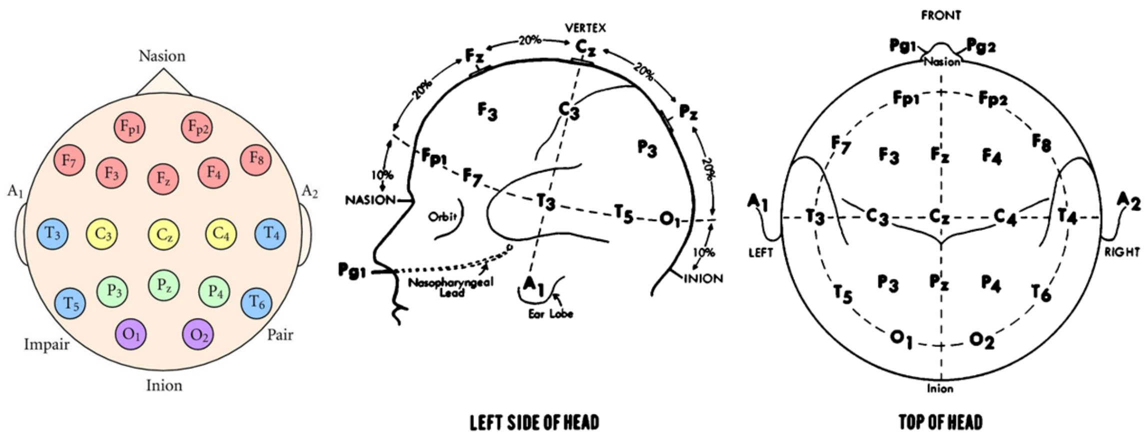


Figure 2. 10-20 system of EEG nodes placement

The brain wave spectrum is divided into four types depending upon its wavelength:

•Delta 0.5 Hz to 3 Hz

•Theta 3 Hz to 8 Hz

•Alpha 8 Hz to 12 Hz

•Beta 12 Hz to 30 Hz

•Gamma 25 Hz to 100 Hz

Now we will take a look at the use of **EEG in autism**.

Autism, EEG and Brain Electromagnetics research has been carried out in immense detail. The aim here is to identify the difference between working and relaxing state EEG mind signals when comparing a TD and an ASD child.

In 2003, the requirement was to analyze ASD sensitivity towards pitch of a generated sound. The work featured correlation b/t pitch signals of ASD and TD + response latency + confidence rating system. The Procedure was production of different frequency sets in order to check of differentiating power of ASD child to pitch analysis. The features were ROC curve + perpendicular distance of curves + area under curves. [22].

Seiji's aim was to check flicker response of Adult using Fourier transform using Alpha band EEG extraction. It featured spectra comparison, amplitude and phase, and phase differences then utilization of discrete time Fourier Transform. [23]. In 2007, researchers wanted to detect and compare different background EEG signals of ASD and TD using different techniques. They used FFT, STFT, STFT-band width etc. Features of this work were parameter p associated with FFT, STFT, STFT-band Width. [24]. In year 2008, it was showed that beta band is more useful for ASD detection among TD. Beta band discriminative was found out to be 84.2 %. This work featured coherence value measure of degree of coupling between two signals. Used STFT for frequency analysis. [25].

In 2010, Surdiman and friends tried to extract EEG signals via performing visual activities for TD and ASD child. They used Visual Evoked Potential Method for the study of alpha band. They featured the set parameters for min value, max value, mean, standard deviation. After their study they claimed that the alpha value is high in ASD as compare to TD child. And ASD often need glasses to improve visual response. for the purpose of their research they incorporated use of signal processing toolbox of MATLAB. [26]. The same year, researchers tried to check the scanning power of ASD child when they see the faces of people. The methodology was that the ASD child will be shown different faces with emotion and then EEG signals were recorded. Wahab and Marini used Mel-Frequency Cepstral Coefficient (MFCC), delta, delta-delta, and energy features. And MLP model for categorization. [27]. In the same year, authors aimed to check ASD with motor movements. Two motor movement examples like imitating a finger tapping and clinching a hand along with motor movement of eyes open and close were taken. And by using Gaussian mixture model for feature extraction and MLP model. [28].

Ali et al. showed that alpha band (96.4 % discriminative analysis) is more reliable and useful for detection of ASD among TD in relaxed eyes open condition. They experimented with more activities in Gamma band temporal lobe of mind. They established a coherence value measure of degree of coupling between two signals. Used STFT for frequency analysis. [29]. In the same year, a study aimed to detect ASD among down syndrome using EEG and FFT analysis. Down syndrome is a genetic disorder with one extra chromosome in the DNA. Visual Evoke Potential (VEP) technique was used to check alpha band values to find that ASD with high values and down syndrome with low. [26].

Bose et al. aim was to use EEG as a bio-mark for ASD using modified multiscale entropy. Featuring modified multiscale entropy vector. Classifier was KNN and SVM and efficiency was found to be - 100 % + 70% to 90%. [30]. David et al. identified the behavior of ASD (when interacting with robot) using GMM and Bayes classifier for overhead camera. [31]

Features were avoiding the robot, interaction with the bot or playing bubbles, staying still, near parent behavior, against the wall, or without any of these.

The next year, researchers wanted to detect ASD child via showing him / her emotional videos (faces) and then capturing EEG signals of ASD as well. Preparation of data was done using short time Fourier transform Gaussian Mixture model to extract features MLP model (Machine learning). [32]. Uvais et al. aim was to detect ASD using Eye opened and eye closed motor imitation. It used ASD EEG in eye closed / open TDOA MLP classification resulting in 90% accuracy. [33]. Jamal et al worked to measure functional brain connectivity of ASD and TD during perception of fearful, happy, and natural faces using the techniques LDA and SVM (Machine Learning). He features modularity, transitivity, characteristic path length, global efficiency, radius and diameter. [34].

In 2016, the aim was to record EEG signals of ASD child with forced short sleep. This was done to observe power of different signals. As a result, they were able to detect how the EEG response of a TD child in short sleep mode. [35]. Jing Fan detected engagement level, emotional states, and mental workload using virtual reality-based driving simulator. In order to do that, EEG signals were compared using KNN and SVM, Bayes Network MLP. It was found that engagement + workload gave 80% accuracy while emotional states gave 75 %. [36].

Laxmi Raja’s aim was to use Neural nets feedforward and feed backward to identify ASD from EEG signals. It incorporated auto-regression and burg method. A survey was done to categorize the child as either TD or ASD. EEG results were based on patterns and comparison recognition. Comparison based features were absolute power, relative power, coherence, Mu wave suppression. While pattern recognition features: features vector to classification algorithms. [37].

Interventions Literature Review

1. Intervention for Joint Attention Improvement

The formal definition of joint attention is:

"Joint attention or shared attention is the shared focus of two individuals on an object. It is achieved when one individual alerts another to an object by means of eye-gazing, pointing or other verbal or non-verbal indications. An individual gaze at another individual, points to an object and then returns their gaze to the individual" [38]

Children being affected by autism spectrum disorder have problems related to joint attention transferring. Joint attention transferring is mandatory to keep yourself aware and to understand what is going on around your social circle. Usually autistic children have lack of joint attention and hence it's a bio marker [41] for indication of autism spectrum disorder due to which they are not able to completely familiarize their self that what's going on around them and what to do in response. Galvanic Skin Conductance base analysis is presented by [50] and used it as an indicator for ASD. [42] presented an intervention for joint attention improvement. Their setup consists of a room comprising three LCD monitors at two different walls of room and a NAO humanoid robot in front of child, fig. 1. There will be different pictures which will be presenting on these LCD monitors and NAO robot will be pointing towards those LCD monitors. Child's head direction is being tracked with the help of a cap using an IR-array mounted on it along with camera to estimate tilt in head's direction. Effective hit count, duration of hit count

, latency of first hit, and percentage hit are parameters used. At last, Robot is used to give reward depending upon the calculation of these parameters. [43] presented the work which is an upgradation of [42]. Only a closed loop feedback system has been introduced for making whole system adaptive. In Human Robot Interaction (HRI), joint attention is too much important. Using visual feedbacks, interaction can be improved. [51] designed different modules for the recording of initial responses of ASD child and then highly concentrate on joint attention or eye contact maintenance during the whole therapy. Joint attention shifting, and estimation is highly based on gaze analysis. Gaze analysis of autistic and typically developed kids will be completely different and it can be modeled with the help of Variable-order Markov Model (VMM) [52] Robots can be used to improve the gaze / eye contact among children with High Functioning Autism (HFA) [53]. [53] made a game which consists of verbal communication and then ask for eye contact from child. The shifting of gaze and duration of eye contact are measured as parameters.

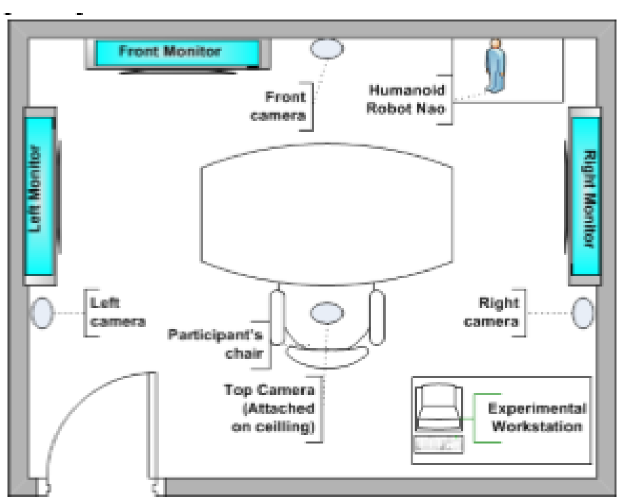


Figure 3 Joint Attention Improvement

There are multiple parameters which have been utilized in joint attention-based intervention studies, few important parameters in Joint attention interventions are mentioned in table II.

Table 2: Joint Attention Measurement Parameter

Parameter Name	Reference	Description	Sensor
Max look	[42], [53]	Max duration of child looking at robot	Front & overhead cameras
Effective hit (Gaze shift to target)	[42]	Did child shift gaze to target?	Overhead camera
Pointing to target	[42]	Robot is pointing to target screen	Camera in pointing direction
Audio clip with pointing	[42]	Robot is pointing to target via speaking	Camera in pointing direction
Duration of hit count	[42]	Duration of looking at target	Overhead camera
Latency of first hit	[42]	After how long child see at pointing direction	Time estimation using system clock.
Percentage of hit	[42]	How many times child see towards target?	Calculation based
Frequency of looking	[51], [53]	How many times per minute child looks at robot?	Manually evaluated by psychologist
Duration of each occurance of interaction	[51]	After how long same interaction is repeated?	Manually evaluated by psychologist
Percentage of eye gaze duration	[53]	How much time, during session, child was looking at robot?	Calculation based

2. Intervention for verbal communication skills improvements

Verbal communication skills are also important because it gives us freedom to speak and clearly convey our message to other people but children with Autism Spectrum Disorder lack this. Robots can also be used to increase the verbal communication of ASD child via obeying orders. [54] has designed a robot which is programmed using tag-based word recognition in a sentence and then performs actions accordingly, figure 4.

Figure 4 Verbal Communication Improvement

There are multiple parameters which have been utilized in verbal communication-based interventions, few important parameters in these interventions are mentioned in table III.

Table 3: Verbal Communication Interventions' Parameter

Parameter Name	Reference	Description	Sensor
Speaking (Word recognition)	[54]	Person spoke and word recognized	Word recognition engine
Not speaking (No word recognition)	[54]	Person did not speak and no word recognized	Word recognition engine

3. Interventions for non-verbal communication skills improvements

Many of autistic children also suffers from non-verbal communicational issues. They even do not understand common daily life gestures. Non-verbal communications are also important for those children who cannot speak naturally and its mandatory to teach such children non-verbal communications so that they can easily live and can properly interact with people as well. Non-verbal communication usually includes gestures. There are different gesture-based therapies and their aim is to make autistic child to communicate via non-verbal communication (gestures). There are different gestures which are taught to autistic child with the help of robots. This thing also falls in the category of imitation behaviors as well. Application of non-verbal communication is too much broader. [55] tested this non-verbal communication on an industrial robot where they studied stop, come on, higher, carry on, slow down, and no idea. Degree of the engagement of child is also important. Sometimes, actions speak louder than words. ASD child's engagement is also affected by the actions being performed by people residing around them [56], Figure. 5.

Figure 5 Engagement Detection of ASD Child [56]

Figure 6 Non-verbal communcation (gesture) testing

[57] presented an interesting factor and stated that ASD people do not have eye blink interpersonal synchronicity in them. Usually non ASD people have eye blink interpersonal synchronicity means their eye blinks are completely synchronized with the pause of speaker while having conversation but in case of ASD people, this synchronicity does not exit. There are multiple parameters which have been utilized in nonverbal communication-based interventions, few important parameters in these interventions are mentioned in table IV.

Table 4: Non-verbal Communication Interventions' Parameters/Gestures

Gesture / Parameter Name	Reference	Description	Sensor
Wave one hand	[55]	Initial signal to robot	Gesture recognition via image processing
Come here	[55]	Calling robot to come closer	-do-
Come closer	[55]	Calling robot to come closer	-do-
This one	[55]	Pointing to any thing	-do-
Carry on	[55]	Telling robot to continue job	-do-
Stop	[55]	Telling robot to stop	-do-
Slow down	[55]	Telling robot to reduce speed	-do-
Come here	[55]	Giving direction to robot to move towards desired position	-do-
No	[55]	Negation to robot	-do-

Gaze	[56]	Gaze direction	Interaction recognition via image processing and machine learning
Actions	[56]	Actions on objects (Toys) and partner (parents or Therapists)	-do-
Eye blink synchronization	[57]	Eye action on pause action of speaker	Clustering and Linear regration
Eye blink frequency	[57]	Eye blink rate	-do-

4. Interventions for imitative behaviors

Imitative behaviors are also important. Child suffering from ASD also face issues in imitation. They do not properly complete few physical movements due to lack of interest and not getting proper guidance. Robots can be used in such situation, where child has to imitate the behavior shown by the robot and then robot evaluates the performance of the child. Usually these imitations are based upon gestures [47], [58], figure 7 and figure 8. ASD children are also prone to repeat few movement again and again, called stereotyped movements. These stereotyped movements are used as bio-marker for the detection of ASD. [59] given a way to detect and record such stereotyped movements using Kinect sensor, fig. 9. [60] used human pose estimation and skeletonizing algorithms to detect arm flipping behavior in ASD child.

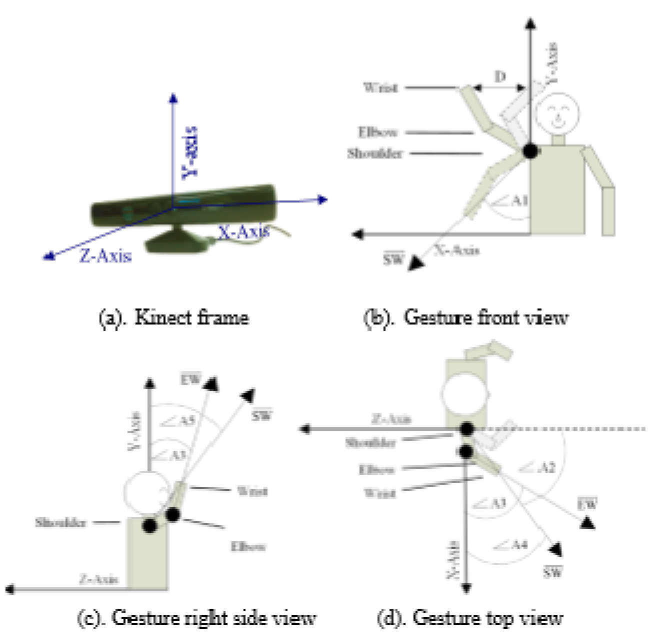


Figure 7 Imitative behavior recording [47]

Figure 8 Imitative behaviors [58]

Figure 9 Stereotyped movements recording using Kinect [59]

5. Interventions based on physical play therapy

Robots are even able to physical play with ASD child which will ultimately increase his / her social interaction skill. [61] presented a physical play game where two levels are involved: touch my body and dance with me. Interaction area around robot was divided into three regions and results are as under, which indicates that which participant remains in which area and for how much duration? [62] also introduced physical play therapy for ASD children using soccer playing game. social interaction, joint attention, turn taking, communication and eye contact factors analysis has been presented. Robots can also be used to teach ASD child about body parts of human being. [63] performed this task using

KASPAR robot where they were teaching child about different body parts and then evaluating using touching to robot and then filling the drawing.

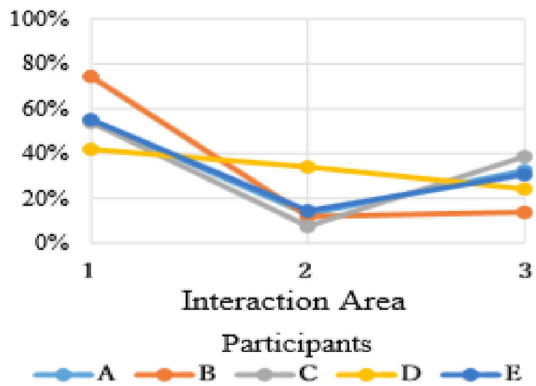


Figure 10 Participant interaction with NAO robot. [61].

There are multiple parameters which have been utilized in physical playing-based interventions, few important parameters in these interventions are mentioned in table VI.

Table 5: Physical Play Interventions' Parameters

Parameter Name	Reference	Description	Sensor
Interaction distance	[61]	Distance between robot and child	NAO robot
Touching	[61]	Did child touch the robot or not?	NAO touch sensors
Time of Interaction	[61]	How long child physically interacted with child?	NAO touch sensor along time calculation.
Motion synchronicity	[61]	How well child followed the robot?	Video analysis.
Joint attention	[62]	Did child shift his / her joint attention?	-do-
Eye contact	[62]	How long child maintained eye contact with NAO robot?	NAO robot.
Touching body parts	[63]	How well child know that which part is being asked to touch?	KASPAR robot touch sensors.

6. Interventions based on facial expressions

Our faces speak a lot about our personality. There are different related parameters which can be used to estimate our mood while doing any physical task. When autistic child is interacted with humanoid robot, he / she will be having some expressions which will be telling us about the adaptability of ASD child while interacting with robot. [64] used this approach while considering sadness, happy, fear, anger, and neutral moods, figure 11. Depending upon these modes, we can make robot's behaviors more and more adaptive and hence can ensure valuable human-robot interaction. When robots are interacted with autistic children, they have an impact on them. This impact can be measured via different techniques e.g., we can use their facial expressions [64], mood estimation, either they like, dislike or engaged with robot [65] etc. [66] divided the face in to eight different parts, figure 12 and performed a comparison between ASD and TD child under different facial expressions / emotions and stated that ADS child's response remains slightly less than TD child's response. [67] has designed an Affected Robot-Assisted Activity (ARAA) using wearable EMG device for real time facial expression recognition. NAO humanoid robot was used in this study and behaviors were changeable by therapist after getting information related to facial expressions of child, figure 11. In their previous work, [68], they have measured the smile and facial behaviors of child using same equipment.

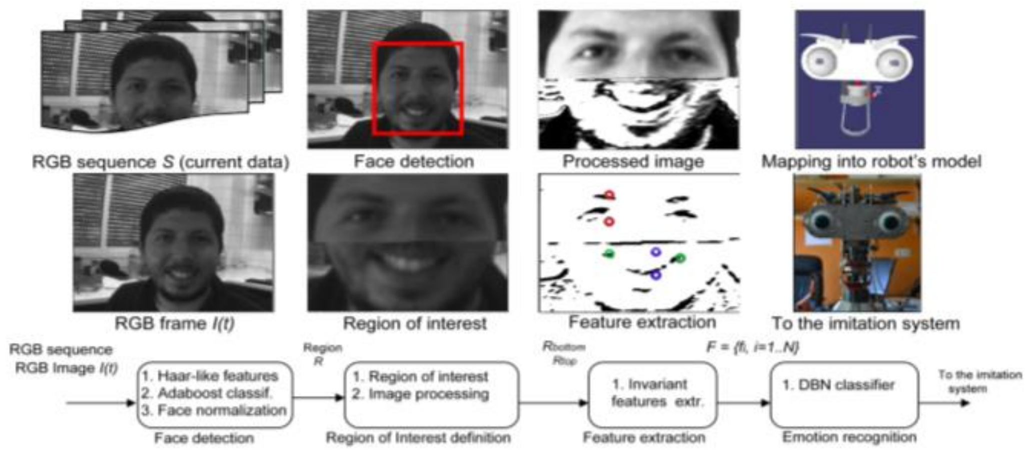


Figure 11 Facial expression capturing in [64]

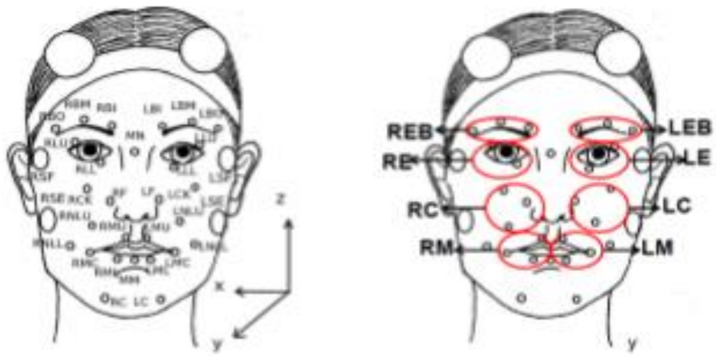


Figure 12 Facial division in 66

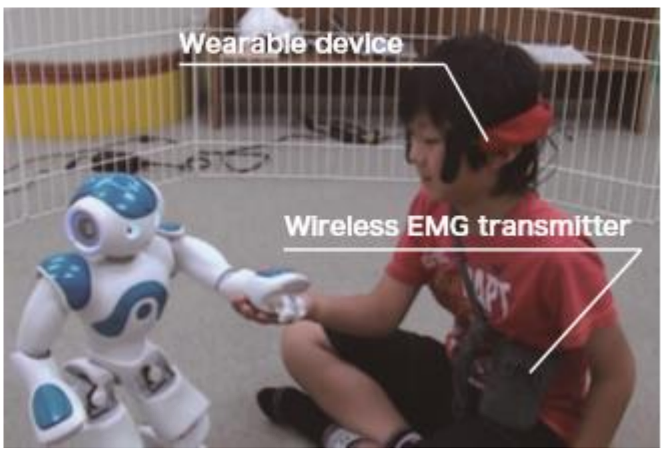


Figure 13 Facial expression using wearable device and robot's behavior [67]

Sometimes emotion based catagorization, of ASD and typically developed (TD) children, leads towards wrong categorization of children. [30] proved that there is no major differences between TD and ASD children emotions except emotions related to state of fear. Sometimes it also happens that ASD child even does not recognize the emotions. In such cases, we have different robots that can teach this thing to ASD child e.g., ZENO robot. [70] presented a game based emotions learning for ASD child. In this study, child has to present few emotions to robot using rackets, which will be shown by the robot previously, and then upon correct presentation of emotions, he / she will be rewarded accordingly, figure 14. They taught fear, happiness, sadness, surprise and anger emotions.

Parameter Name	Reference	Description	Sensor
EB	[64]	stands for Eye Brows	Camera & Dynamic Bayesian Network
Ch	[64]	stands for cheeks	-do-
LE	[64]	stands for Lower Eyelids	-do-
LC	[64]	stands for Lips Corners	-do-
CB	[64]	stands for Chin Boss	-do-
MF	[64]	stands for Mouth's Form	-do-
MA	[64]	stands for Mouth's Aperture	-do-
REB	[64]	Right Eye Brow	Activation of region based on movement of region.
LEB	[66]	Left Eye Brow	-do-
RE	[66]	Right Eye	-do-
LE	[66]	Left Eye	-do-
RC	[66]	Right Cheek	-do-
LC	[66]	Left Cheek	-do-
RM	[66]	Right Mouth side	-do-
LM	[66]	Left Mouth side	-do-
Smile measure	[68]	Checking that whether child smiled or not?	EMG wearable sensor and Artificial Neural Network.
Tactile interaction	[70]	Either child is touching robot or not?	ZECA humanoid robot
Successful & unsuccessful attempts	[70]	How many attempts were successful and how many were not?	Image recognition based using ZECA cameras.

Figure 14 Rackets used by child to answer robot

There are multiple parameters which have been utilized in facial expression-based interventions, few important parameters in these interventions are mentioned in table VI.

Table 6 Facial Expression Based Interventions' Parameters

7. Interventions based on games

Games based interventions have also been developed by different people for improvement of their responses to events being occurred around them. Few people introduced concept of virtual reality [71] in games as well which is used to evaluate problem handling accuracy of Autistic child, and increasing adaptive behaviors skills, figure 15. Computers, laptops, tablets and even mobile phones are utilized in these types of interventions along with different robots and auxiliary hardware just to give award to Autistic child according to his/her performance. [72] developed a serious game for Autistic child where they interfaced a Tangible User Interface (TUI), matrix like structure, with Graphical User Interface (GUI) in computer. Child was given a task to draw a pattern on TUI given in figure, initially provided on paper and then later on via computer GUI. There are multiple parameters which have been utilized in game-based interventions, few important parameters in these interventions are mentioned in table VII.

Parameter Name	Reference	Description	Sensor
Recording of EEG head signals during driving in virtual reality	[71]	How well child is driving?	14-channel Emotiv EPOC neuroheadset
Therapist rating during driving situation along with time stamp	[71]	Evaluation from therapist side	PCA, KNN, and SVM algorithms
Social interaction	[72]	Number of initiated social interaction between participants	Video based analysis
Playing alone time	[72]	Time for which the participant was playing alone	-do-
Collaborative playing	[72]	Time for which the participant was playing with other participants	-do-
Engagement in other activities	[33]	Time not spending in playing game	-do-
Performance	[33]	Number of minimum levels completed successfully	Counted by code in game

Table 7: Game Based Interventions' Parameters

Figure 15 Virtual Reality based games for ASD child

8. Interventions based on video scenes perceiving

Visual perception is an important aspect of human nature. Different people perceive different scenes in different ways. ASD child has lack of visual perception as well due to which he / she face lack of joint attention transferring and in extreme cases, he / she will be simply unaware of what is going on around him / her? People have designed different video showing based therapies, and then noticing the expressions and feeling of ASD children [73]. [74] used a video for testing smelling power of ASD and presented this fact as bio-marker for ASD detection and proved that ASD child is less able to correctly identify the odor of fruits and flowers as compare to TD child, fig. 16. Firstly, a video was presented to child, comprising of any fruit or flower, then he / she has to sniff the smell being given to him / her by fragrance get and then he / she has to answer the question, via seeing picture, that which smell he / she felt? Human Robot Interaction (HRI) has a related concept called uncanny valley. Whenever robots are designed, it might possible the they will be rejected by users, a concept to whom word uncanny valley describes. [75] has used WABIAN-2R robot and executed different gaits with emotions and then ask from different people to rate the gait and recognize emotions of robot. It was found that ASD people were more sensible towards emotions of robot as compare to non-ASD people.

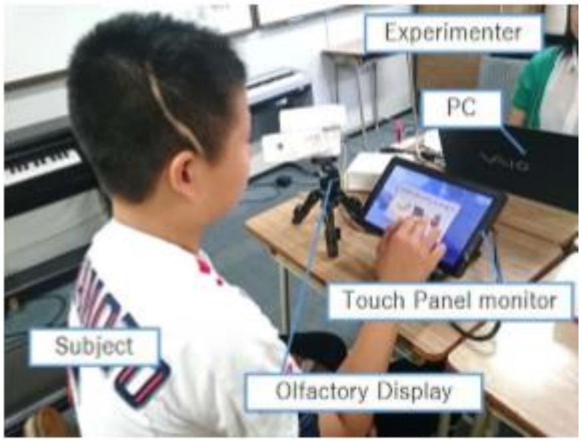


Figure 16 Smelling ability of ASD child [74]

There are multiple parameters which have been utilized in interventions based on video scenes perception, few important parameters in these interventions are mentioned in table VIII.

Table 8: Video Analysis Interventions' Parameters

Parameter Name	Reference	Description	Sensor
Navigation	[73]	Are users viewing the entire video? What segments of the video do students select to view, and why? How many times do users view any given video segment? and what video applications are more attractive or engaging?	Manually evaluated
Knowledge acquisition	[73]	How do users perform with the assistance of video materials? is there any relation among users' viewing patterns and the level of the acquired knowledge?	-do-
Attitudes	[73]	How do users perceive video-based instruction? is there any significant shift in their attitudes during a video-based instruction?	-do-
Average correct answer ratio	[74]	Number of correct answer ratio	Calculation based
Percentage of emotion recognition	[75]	Percentage of emotion recognition along with gait by ASD and TD people	Manually calculated.

9. Interventions based on EEG signal analysis of ASD children

There are multiple number of interventions for ASD child that can be integrated with EEG signals of different body parts of ASD child. Though we can integrate these EEG signals in these interventions, but we require some sort of pre-processing for removing artefacts. [76] developed a technique to remove eye blink and muscular artefacts from EEG signals of ASD child, fig.17. [77] reported an abnormal brain activity in ASD child while eye opening and closing compared with TD child using EEG.

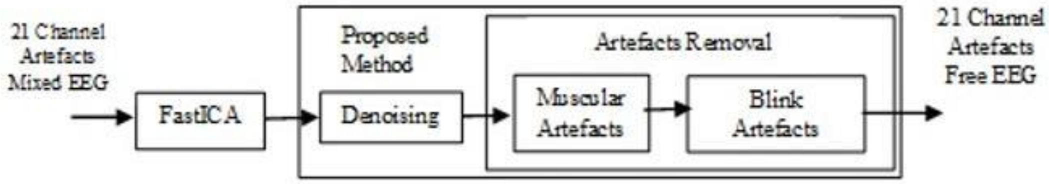


Figure 17 Artifact removal from EEG signals of ASD child. [76].

CHAPTER 3: METHODOLOGY

In this project, we are using intervention-based therapy which consists of different levels to analyze the behavior of a child. In each level, we are using different devices and sensors to receive feedback from child and process it to get meaningful insight of the his behavior and state.

Devices and Sensors

Following are some of the devices used in our project:

1. Emotiv EPOC EEG Headset
2. Myoband
3. Kinect for Windows
4. Firefly MV 0.3 MP Camera
5. NAO Robot

1. Emotiv EPOC EEG Headset

Brain activity of a person can be recorded by different sensors like MRI, fMRI, fNIRS and EEG.

MRI uses strong magnetic field to generate detailed image of brain, soft tissues, bones etc. It is done by MRI scanner which is a long tube containing very powerful magnets.

On the other hand, fMRI is the indirect method of measurement of brain activity. It detects changes in blood flow in the brain by using magnets to measure paramagnetic properties of hemoglobin [77]. The active parts of brain require more oxygen so by analyzing the changes in hemoglobin the functioning status of that part of brain can be determined [78]. It is a new technology which is still in developing stages.

fNIRS uses infrared to analyze hemodynamic response of brain and work on the principle that biological chromophores have different absorption properties [77]. It is portable but it has low reliability and accuracy.

EEG is a direct method to record activity in brain non-invasively. It uses several electrodes to measure electrical impulses in brain which are produced due to neurons [79]. It gives real-time measurements with easy setup and working. It is highly reliable and can be done by compact device.

Based on the comparison given above, we decided that EEG is the most convenient option for us to use in this project because of its high accuracy, reliability and compact-size.

Now, the next step was to choose an EEG device which will be used in this project. We wanted something portable and wireless which would not intimidate the child. Therefore, we selected Emotiv EPOC EEG Headset which is an award-winning research grade EEG [80]. It is a wireless device which uses Bluetooth to connect with computer and it has 14-channels to record EEG data. It also has in-built inertial sensors which can be used to determine the tilt and movement of head.

Figure 18 Emotive EPOC EEG Headset

Figure 19 A child wearing Emotiv

2. Myoband

EMG signals are used to measure the muscle activity of a child when he is doing different activities. To record EMG signals, we are using Myoband which is a wireless, wearable gesture control device. It contains 8 medical-grade surface EMG sensors along with 9-axis IMU which contains 3-axis accelerometer, 3-axis magnetometer and 3-axis gyroscope [81].

It was selected because it is widely-known commercial device which connects wirelessly to a computer via Bluetooth. It can be worn on leg or arm and gives raw EMG data through each of 9 EMG sensors and also the IMU graphs. It can also detect different gestures.

Figure 20 Myo Armband

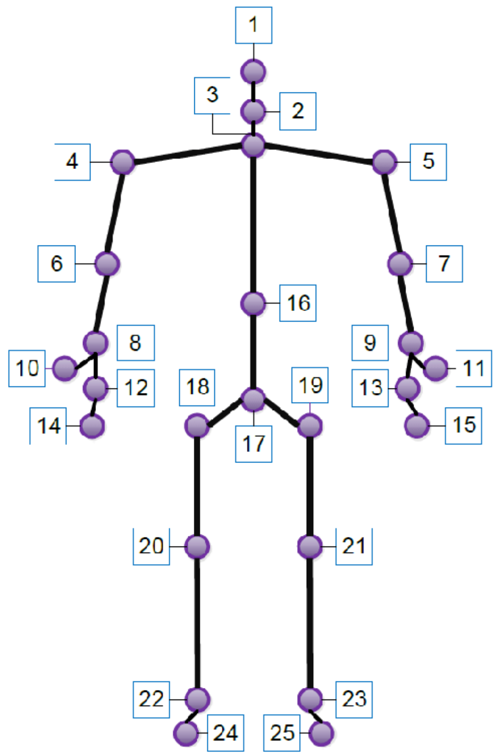
It will be used measure the movement of leg of a child while playing football with NAO robot. Also, it will record the muscle activity and reflexes of a child which will be helpful in comparison of TD child with ASD child.

3. Kinect for Windows

Kinect is a motion-sensing device manufactured for Xbox. It uses RGB camera, infrared depth sensor to record color and depth image/video, respectively. It is used in our project for skeletal tracking and posture recognition. We are using Kinect for Xbox One which is then connected to computer through Kinect for Windows Adapter.

Figure 21 Kinect for Xbox One

It can identify 25-joints and can track upto 6 people. The identified joints are shown below:



1. Head	6. ElbowLeft	11. ThumbRight
2. Neck	7. ElbowRight	12. HandLeft
3. SpineShoulder	8. WristLeft	13. HandRight
4. ShoulderLeft	9. WristRight	14. HandTipLeft
5. ShoulderRight	10. ThumbLeft	15. HandTipRight

16. SpineMid	21. KneeRight
17. SpineBase	22. AnkleLeft
18. HipLeft	23. AnkleRight
19. HipRight	24. FootLeft
20. KneeLeft	25. FootRight

Figure 22 Joints identified by Kinect V2

4. Logitech C270 Camera

Our robotic therapy consists of a child playing football with NAO robot. So, to track the location of a child, robot and ball, we are using an overhead camera which will be mounted on the roof. We will use this to find the poses of the objects also the acceleration and velocity of the ball once it is kicked by a child.

For this purpose, we are using Logitech C270 webcam which gives wider angle to cover broader perspective and it is a most commonly used camera for industrial and non-industrial application.

Figure 23 Logitech C270 Webcam

5. NAO Robot

NAO Robot is a humanoid robot developed by Softbank Robotics. It is the main component of our project as it plays a major role in robotic therapy. In our level-based therapy, NAO robot will play football with a child and our different sensors will measure the response of a child to these stimulation and activities.

Different robots are used in therapy for autism but NAO robot proves to be most successful of them all because of its customizability, 25 degrees of freedom and flexibility to perform different task.

Figure 24 NAO Robot

Now that we have elaborate the main devices in our project, we will now look into how these devices will be connected and how we use different softwares to obtain data from them.

Softwares

To interface and integrate the above-mentioned sensors to the computer and among each other, we will use several different softwares which are mentioned below:

1. MATLAB 2016a
2. Research SDK for Emotiv EEG

3. MyoConnect and MyoDiagnostics
4. Kinect for Windows SDK v2.0

1. MATLAB 2016a

MATLAB will serve as a main platform where all the sensors will be integrated. We will obtain EEG and IMU data from Myoband through MATLAB. It will also be used for skeletal tracking from Kinect.

The details of connection of Myoband and Kinect with MATLAB are given below:

b. Connection of Myoband with MATLAB

To receive data from Myoband in MATLAB we are using Myo SDK MATLAB MEX Wrapper [82]. It requires Myo SDK and Myo Connect as pre-requisites.

After installing this library, we can use its GUI to obtain real-time data from 8 EMG sensors and 9-axis IMU of Myoband. The screenshot of the GUI is shown below. The data can also be stored in form of arrays which can be accessed later.

For gesture recognition, the gestures are first stored in the calibration profile of MyoBand through Myo Connect app and once the stored gesture is recognized, it is displayed in the GUI on MATLAB.

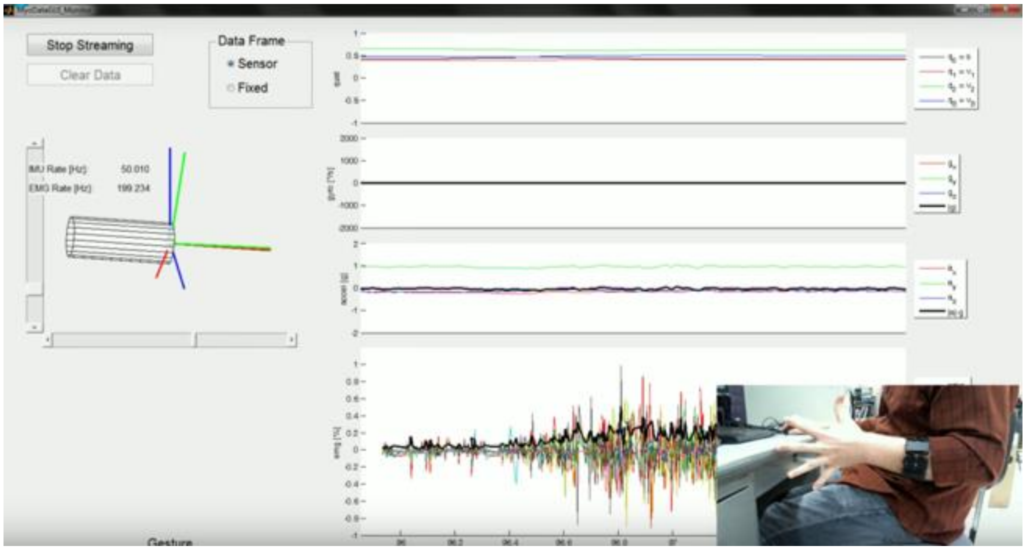


Figure 25 EMG and IMU Data Obtained from Myo Band in MATLAB

c. Connection of Kinect with MATLAB

Kinect for Xbox One is connected to PC through Kinect for Windows Adapter. It's data stream for color and depth video is then accessed via MATLAB. It requires Kinect for Windows SDK v2.0 and Image Acquisition Toolbox Support Package for Kinect For Windows Sensor [83].

The skeletal tracking is shown as below:

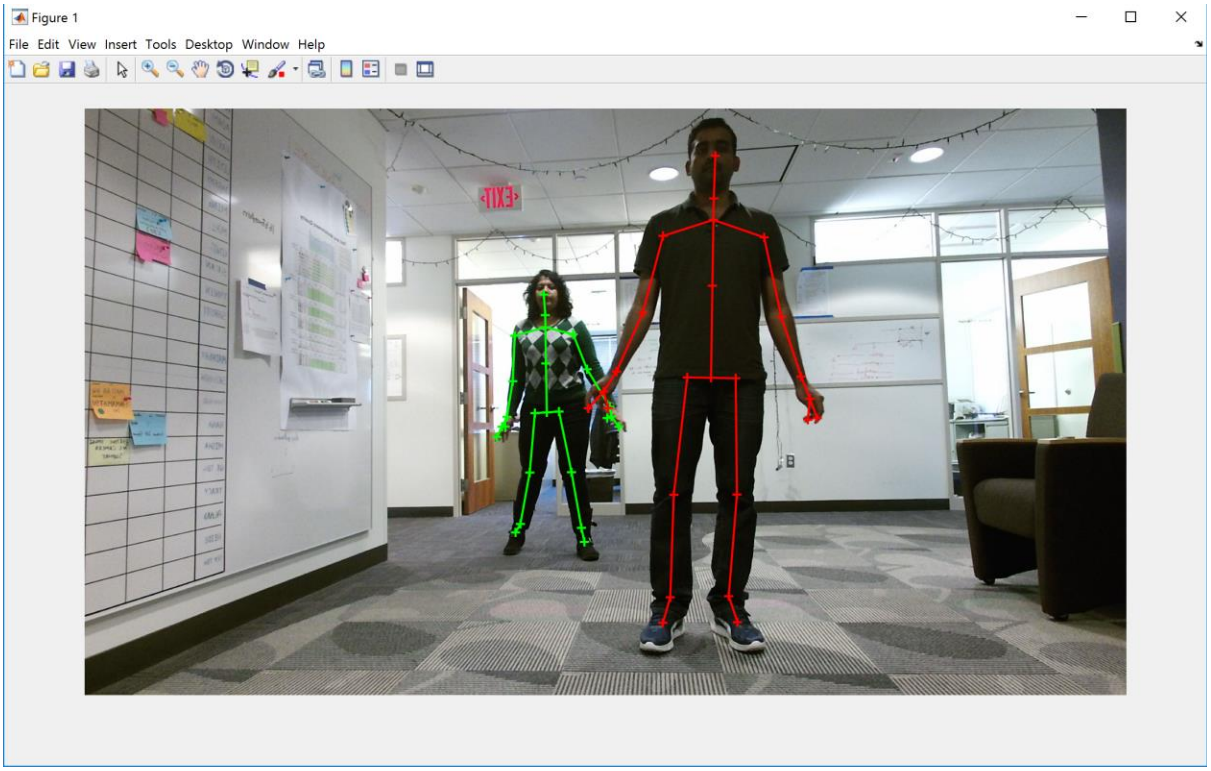


Figure 26 Sketal Tracking through Kinect in MATLAB

2. Research SDK for Emotiv EEG

Emotiv EPOC EEG headset gives us data in several forms which we can use according to our application. Research SDK is used to extract the data from it and then process it to obtain desired results. Emotiv headset gives us following data.

a. Facial Expressions

It can detect seven facial expressions which are:

1. Look Right/Left	2. Blink	3. Left Wink	4. Smile
5. Right Wink	6. Raise brows	7. Clench Teeth	

They are displayed as shown below:

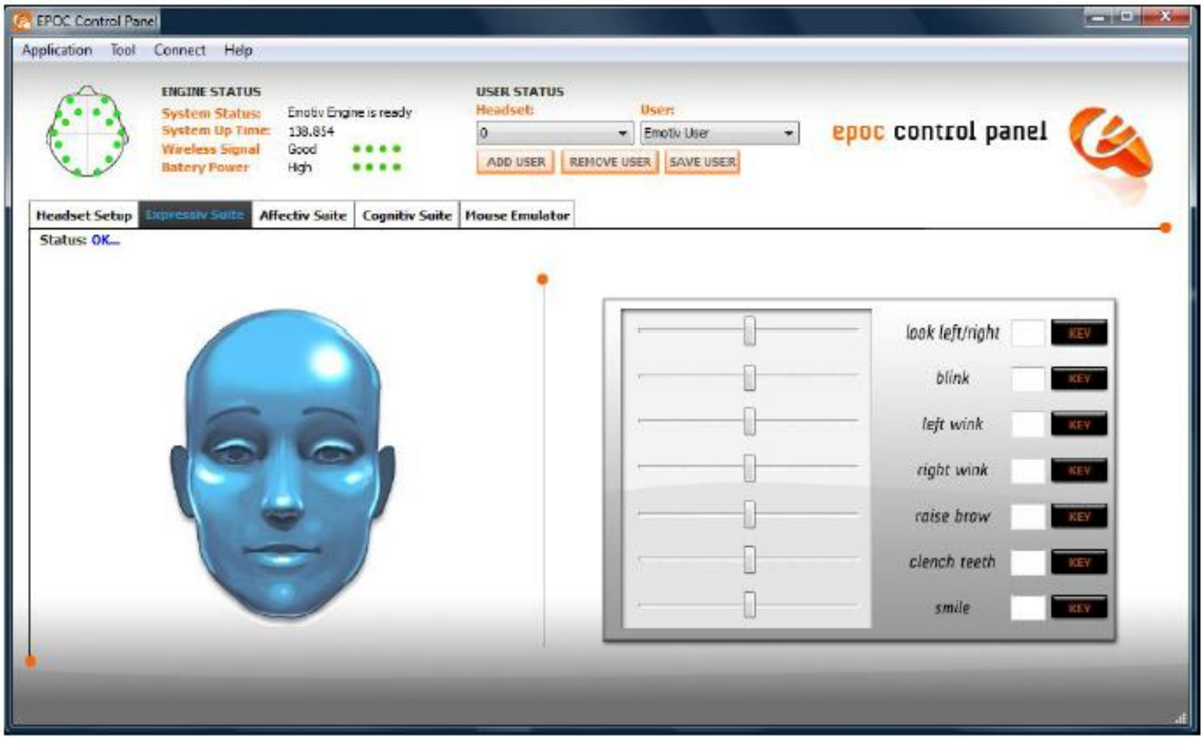


Figure 27 Facial expression recognition through Emotiv EEG

b. Performance Metrics

Through SDK, we can get data of several emotions experienced by a child. They include:

1. Interest	2. Engagement	3. Stress
4. Relaxation	5. Excitement	6. Long-term Excitement

The data about these emotions and states is collected real-time and displayed in the GUI as below.

Figure 28 Emotional states detection through EEG

By analysing these curves, we can determine that how is the child feeling to a certain stimulus or activity.

d. Head-movement tracking

EEG headset is equipped with 9-axis IMU sensor containing 3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer. It can be used to track the movement of head of a child which will give meaningful insight about his interest that whether he is nodding, or looking straight into the robot etc.

Emulator suite in EEG Research SDK tells us this information.

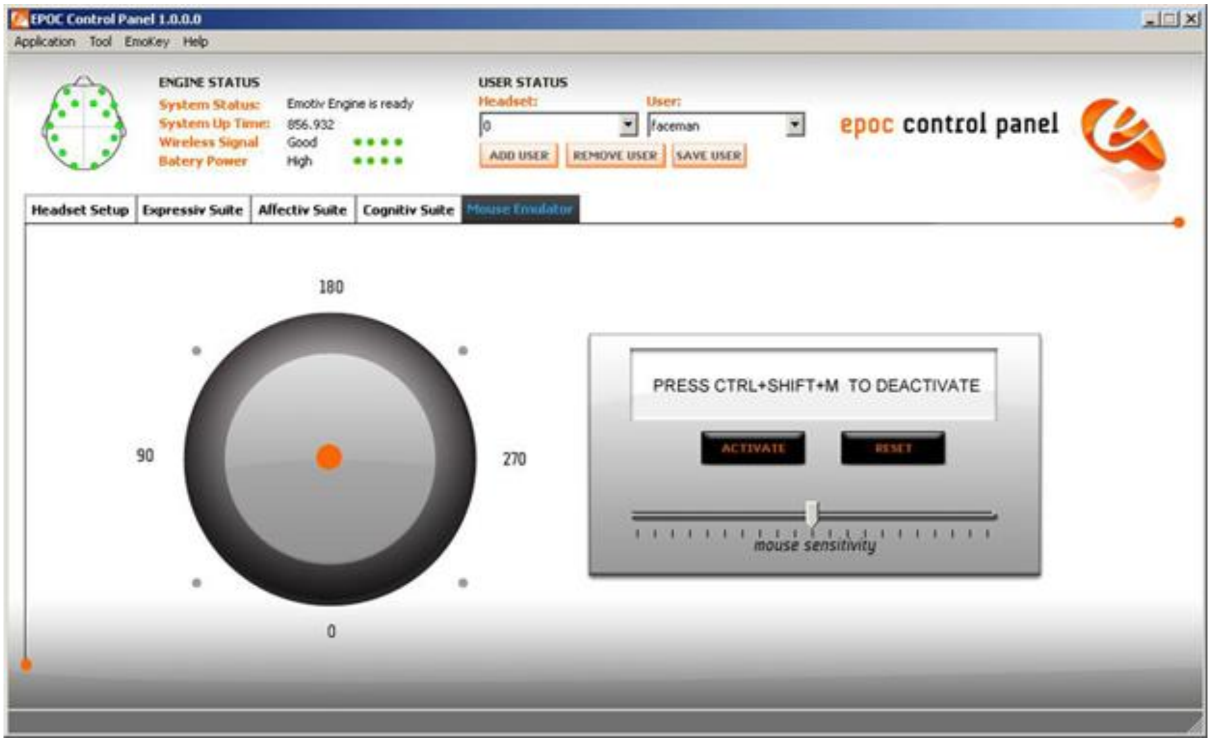


Figure 29 Head movement tracking through EEG headset

Interventions for Applied Behavior Therapy

Our therapy was based on two interventions i.e. Intervention 1 and Intervention 2. Their details are given below:

1. **Intervention 1: Joint Attention**

Joint attention is cognitive and social skill. It is achieved when one individual alerts the subject by means of eye-gazing, pointing or other verbal or non-verbal indications. It plays a critical role in social and language development.

In this intervention, two robots and one child are involved. Robots performs four different actions; blinks eyes, rainbow colors of eyes, says hello/hi, stands up and waves hand. These actions are performed alternatively by each robot. Child have to make eye contact with the robots when it performs an action. If a child turns towards the robot at the right time when it performs action, it means that the child is reacting correctly.

Brain state of the child is checked before and after the invention with the help of EPOC EEG headset and the angle of turn of child or joint attention is taken with the help Kinect V2. The success rate of the intervention is calculated after the intervention,

2. **Intervention 2: Imitation**

Imitation is an advanced behavior and a form of social learning which an individual observes and replicates the behavior of another. In this intervention, the robot performs action and the child tries to replicate it. This intervention involves two robots and one child. One robot stands up and move forward and backwards and the child tries to copy it while the other robot stands up and raises hands. Each robot gets active when a child keeps an eye contact for 4 seconds. If the child imitates the robot, it means the child is reacting correctly.

The brain state of the child is observed with the help of EPOC EEG headset before and after the intervention. To check if the child is performing the correct action, Kinect v2 is used. It tells us about whether the child is moving forward or backward or weather the hands are raised or down. The success rate is calculate in post processing.

Mathematical Modelling

Our project is research-focused with more emphasis on integration of sensors and devising new algorithms using machine learning and fuzzy logic to get meaningful results. However, there are some calculations we would be doing in our project. We would need to find the velocity, acceleration and the force by which the ball is kicked. We will do it through video processing by overhead camera. The following procedure will be adopted.

3. **Calculating velocity of a ball**

Let’s suppose that the ball is with child and he kick it towards the robot. The ball travels with a certain velocity and acceleration. The positions of the ball is recorded at different intervals, say t1, t2, t3, t4.

The arrangement is shown in the figure below:

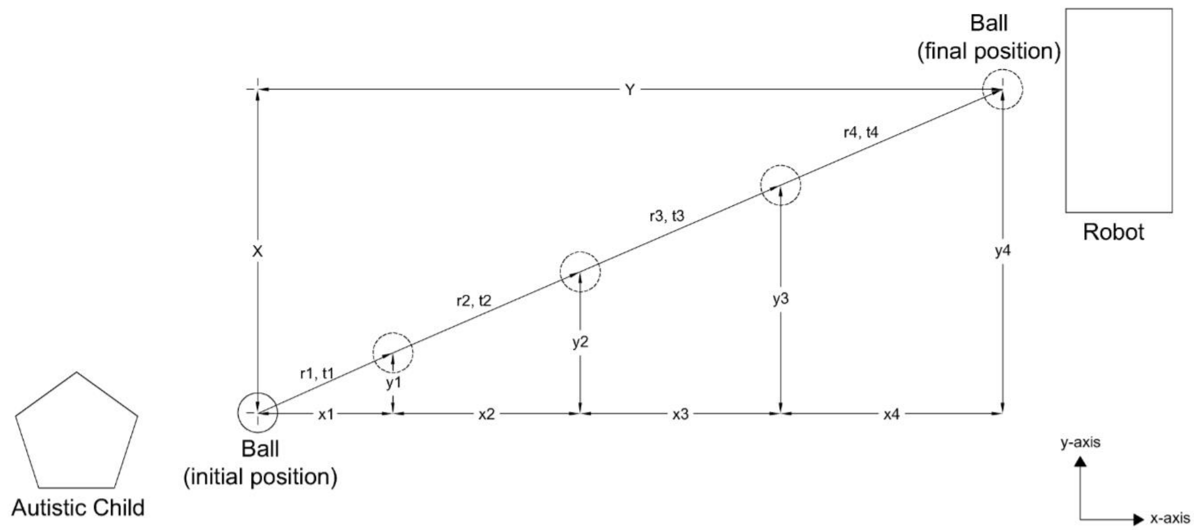


Figure 30 The movement of the ball as the child kicks it towards the robot

We know that the frame rate of the camera which we are using is 60 fps.

Therefore, for average velocity,

$$Distance_{total} = r_{total} = \sqrt{X^2+Y^2}$$

$$Time_{total} = t_{total} = \frac{No. of\ Frames}{Frame\ Rate}$$

$$Velocity_{avg} = v_{avg} = \frac{r_{total}}{t_{total}}$$

For instantaneous velocity,

$$Distance = r_i = \sqrt{{x_i}^2+{y_i}^2}$$

$$Time = t_i = \frac{No. of\ Frames}{Frame\ Rate}$$

$$Velocity_{ins} = v_{ins} = \frac{r_i}{t}$$

4. Calculating acceleration

Acceleration can be calculated as the change in velocity over time. We will need initial and final velocity of the ball. We will calculate it as below:

$$Initial\ velocity = v_i = \frac{r1}{t1}$$

$$Final\ velocity = v_f = \frac{r4}{t4}$$

$$Acceleration = a = \frac{vf - vi}{t}$$

5. Calculating force of kick

To calculate the force with which the child has hit the ball, we will have to determine the acceleration of the ball before kicking and after kicking. From this change we will be able to calculate the force.

Let’s take a look at the figure given below:

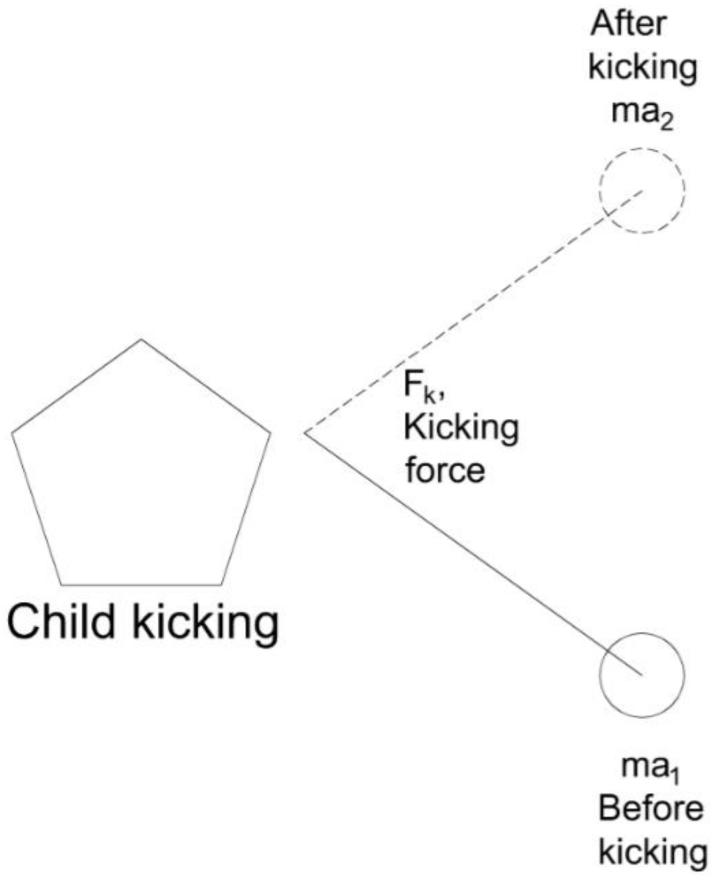


Figure 31 The force experienced by ball before and after kicking

The ball is moving towards the child with a force F_1 equal to ma_1, then the kid kicks the ball with force F_k and it starting moving with a force F_2 equals to ma_2.

The kicking force can be determined as below:

$$Mass\ of\ ball\ =\ m$$

$$Force\ before\ kicking\ =\ F_1\ = ma_1$$

$$Force\ after\ kicking\ =\ F_2\ = ma_2$$

$$Kicking\ force\ =\ F_k =\ ma_2 -\ ma_1\ =\ m\ (a_2 - a_1)$$

Please note that the kicking force will be only calculated and have meaning when the child has actually kicked. We will know this from the kicking gesture recognition data from Myoband. Otherwise, if he has not kicked then the ball will simply be reflected by hitting him. In this regard, the force obtained will be useless.

Hardware Architecture:

Kinect, Myo Band and Overhead camera are integrated through MATLAB on computer. Emotiv EEG is connected to computer through its SDK. This arrangement is shown below:

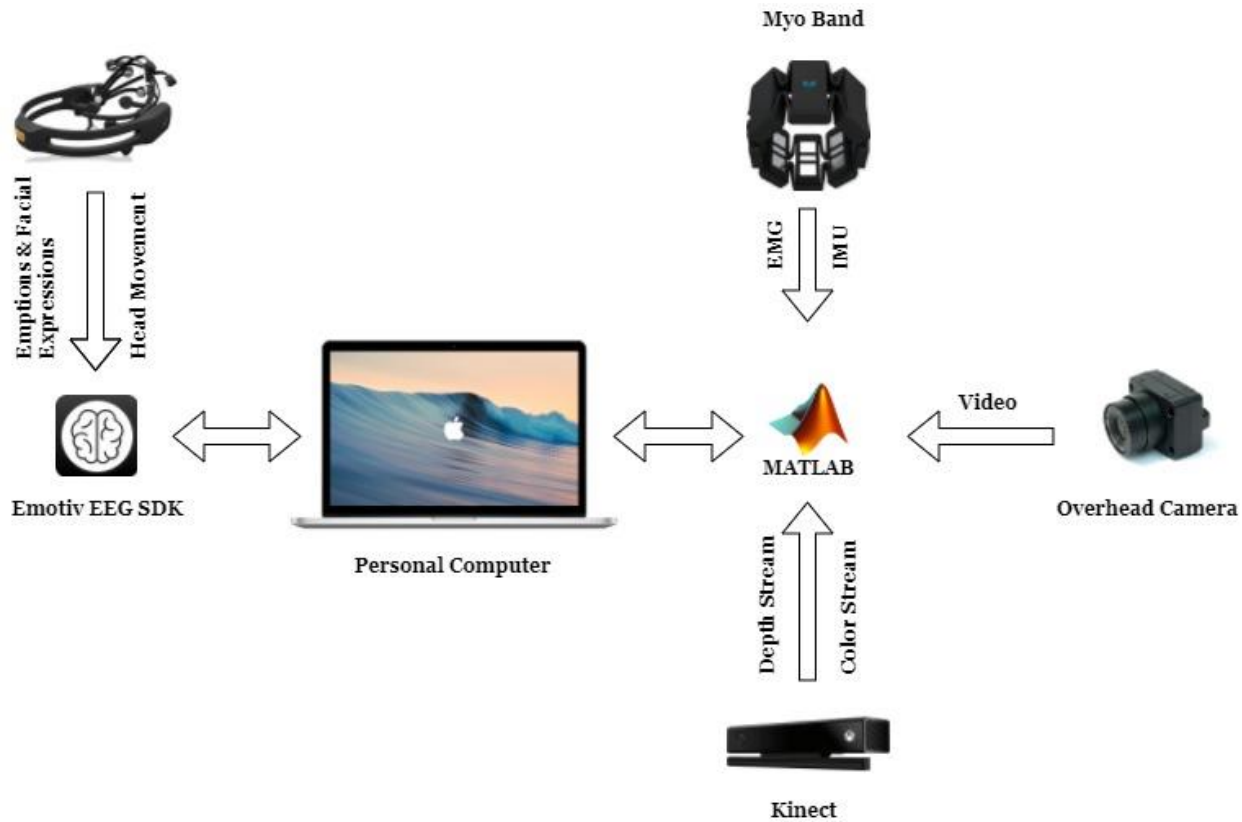


Figure 32 Hardware Architecture

Project Architecture:

The project consists of several blocks. During intervention we are dealing with three parameter which are: Posture recognition from Kinect, Ball dynamics and Actions/Eye contact from NAO robot which is giving us joint attention data.

We are getting brain activity from EEG headset before and after the intervention to note the interest/engagement of the child. Lastly, we are post-processing all this data to classify in interested or non-interested groups, and also validation of joint attention by stitching the data from NAO and Kinect.

The project architecture is shown below:

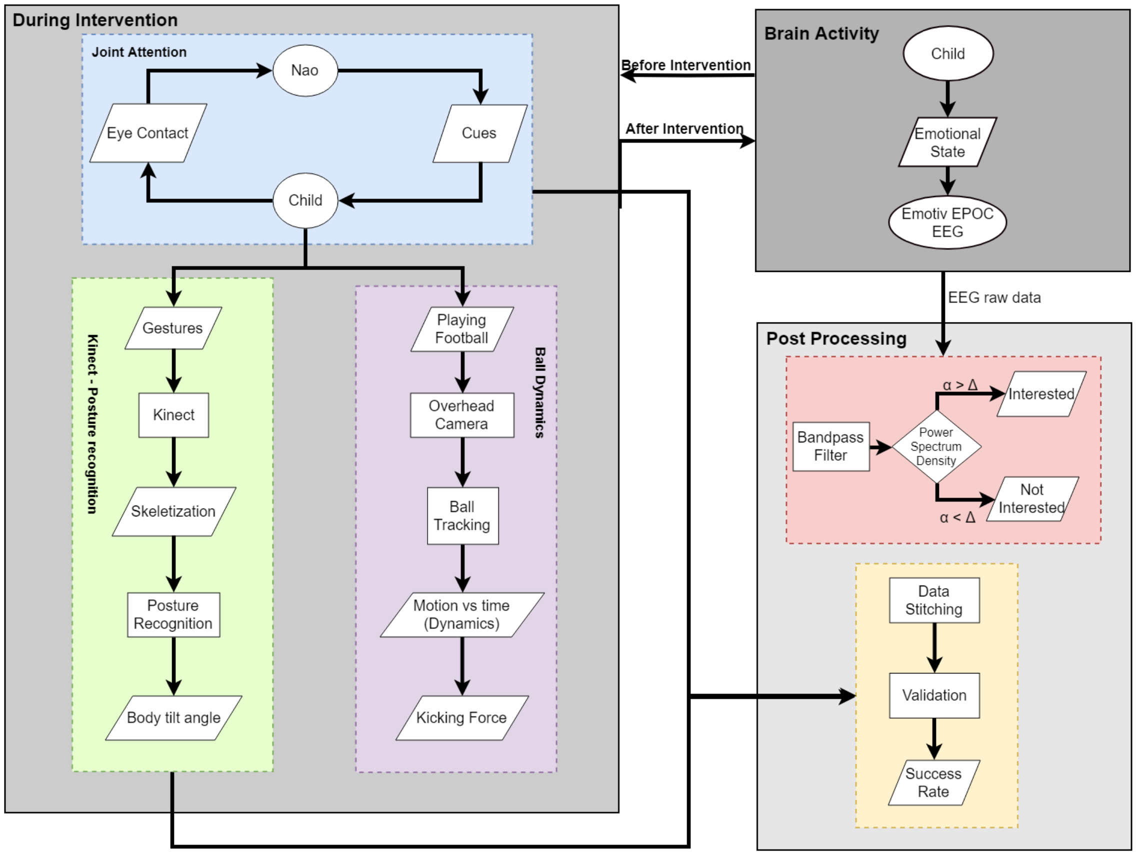


Figure 33 Project Architecture

Problems faced and their solutions

During the course of this, we faced a lot of issues and we resolved them accordingly. Some of the issues are mentioned below along with the method adopted to solve them.

Issue faced	**Resolution**
Weak connections of Emotiv EEG nodes on children	Tested on a 9-year old child fit-aided by a cap
Cannot export data from EEG software	Looked for a software which could do that
Use fNIRS to identify emotions	Highly unreliable and had to work from

	scratch so decided not to go for fNIRS
Find SDK	Searched on forums, websites, torrents etc.
Delay due to SDK unavailability in lab	Stringent follow-up with equipment distributors
Noise and unreliability of sEMG sensors of lab	Shifted to Myo Band
Needed separate accelerometer and gyroscope	All included in Myo Band
MyoMex library not working in MATLAB	Changed registry settings and deleted previous version of MATLAB which resolved the issue
Myo Band is made to work only on arm and detects hand gestures only	Hacked Myo Band to work on legs and made calibration profile to identify leg gestures
Kinect V2 does not connect with MATLAB	Change MATLAB version from 2013 to 2016 which has toolbox for Kinect V2
Less online support available for Kinect V2	Posted on different forums to ask for help
Issue in skeletal tracking. Low fps.	Use color stream overlay instead of doing it from depth stream
Mismatched joint connections in skeletal tracking	Took help from Sir Vaqas and also posted on Mathworks
Force calculation of kicking. Should we use strain gauge?	If we use strain gauge so we will not be able to determine that either it is the kick's force or the force with which the ball is hitting the foot. So use overhead camera instead and fall force and acceleration through image processing

Choose overhead camera	DSLR? Go Pro? or Point Grey Firefly MV? Which model to choose.
DSLR does not connect with MATLAB	Do not use DSLR
Point Grey Firefly MV requires special card	NI card is required. RISE lab's laptop has it available. So we will use RISE lab's laptop for everything.
Kinect joint matching	Manually examined the arrays using hit and trial
Kinect algorithm for angle calculation	White background 3D experimental calculations
Kinect error in the program when no body	Change the conditions for the body present
Kinect not working for multiple people	Proper assigning of values to the body struct
Kinect Values in multiple message box	--
Myo Band gestures not on leg ; resyncing issue	Changing the unlock gesture
Changing the unlock gesture	Hardcoded hand gestures only
Unlock gesture not working	Trying for syncing gesture instead

We conducted our therapy sessions in Autism Resource Center E-11 Islamabad. Introducing Autistic children to new things is hard. Be it people, toys, gadgets or environment, it's a tedious and time taking process.

We started off with attending the target kids' therapy sessions and had multiple sittings with their particular therapists to understand each individual better.

The next step was to gradually familiarize them with the EEG headset, the Myo band and the robot by introducing their images flashcards in their ABA therapy sessions.

Gradually they were introduced to the sensors and the robot. Firstly, without a stimulus and gradually transitioning to the intervention.

The interventions also were started gradually. By firstly performing the activities in front of the child and then the therapist helped them and the goal of unsupervised independent activity was reached.

CHAPTER 4: RESULTS AND DISCUSSION

The following table shows the initial data set of the children which were a part of the therapy.

Table 9: Details of the children

Name	**Age**	**Communication**	**Severity Level**
Ammar	15	Verbal	Severe
Hussain	5	Verbal	Mild
Rehan	7	Non-Verbal	Severe
Aazan	7	Verbal	Mild
Shayan	4	Non-Verbal	Moderate
Abbass	9	Non-Verbal	Severe
Haniya	7	Non-Verbal	Moderate
Arham	3.5	Non-Verbal	Mild
Raniya	8	Non-Verbal	Severe
Ali	4	Non-Verbal	Moderate
Mustafa	7	Non-Verbal	Moderate
Average Age	**6.9**		

Initially, 11 students were observed for the effect of the therapy. It consisted of 9 boys and 2 girls whose details are given in the table above.

Three children (Raniya, Haniya and Shayan) were dropped out from the dataset because of health issues, non-availability and non-consent from parents. Out of remaining eight children, only three were verbal and the other were non-verbal. In terms of severity level of autism, three were severe, two were moderate and three were mild cases.

The interventions were divided into two categories, i.e. 1 and 2. For each intervention there were 7 sessions to be organized for each child which means that total 14 sessions were conducted for each child during the period of one and half month.

For each session, the posture angle of the child from Kinect was noted. It tells the tilt in the posture of the child to show that which robot was the child looking at. The action cues were given by robot and the eye contact was measured from its camera. The eye contact was further verified by the posture angle which validated that the child is tilted towards the same robot which he is looking at.

The success rate for each session was measured as below:

$$Success\ Rate = \frac{No.of\ readings\ validated\ from\ Kinect}{Total\ no.of\ readings} \times\ 100$$

The plots of success rate in each session for each child are given below:

Results

6. Ali

a. Intervention 1:

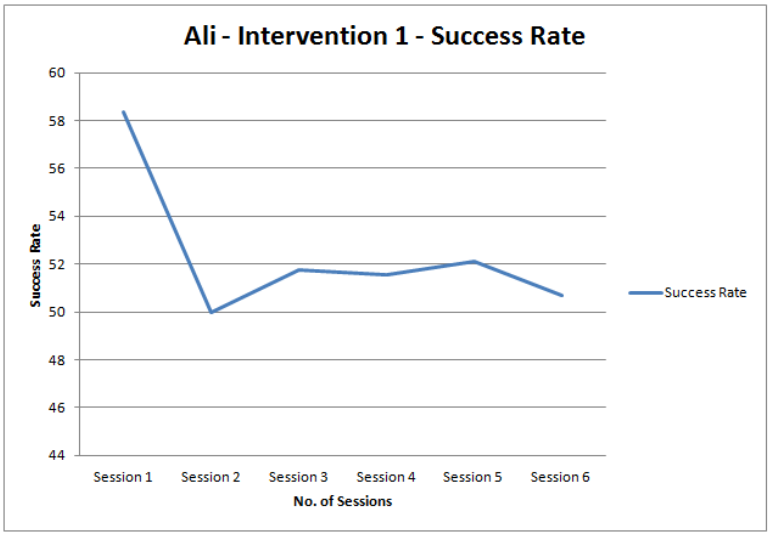


Figure 34 Ali – Intervention 1 – Success Rate

b. Intervention 2:

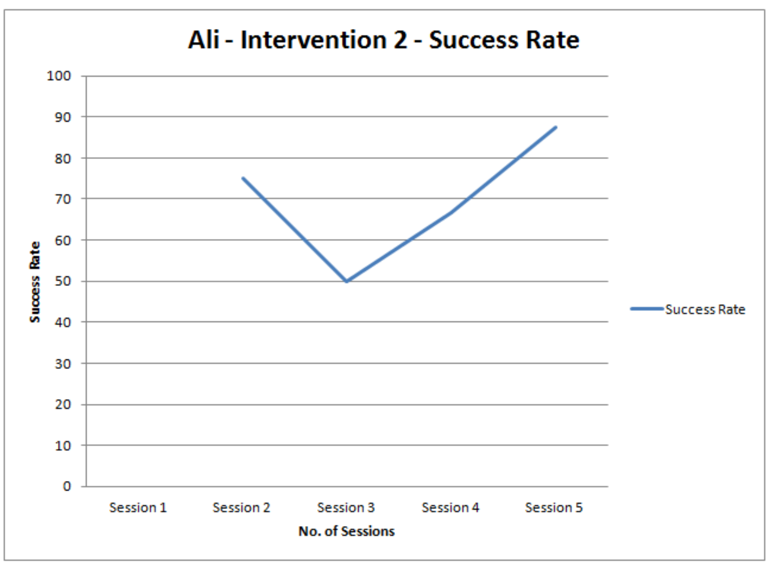


Figure 35 Ali – Intervention 2 – Success Rate

2. Hussain

a. Intervention 1:

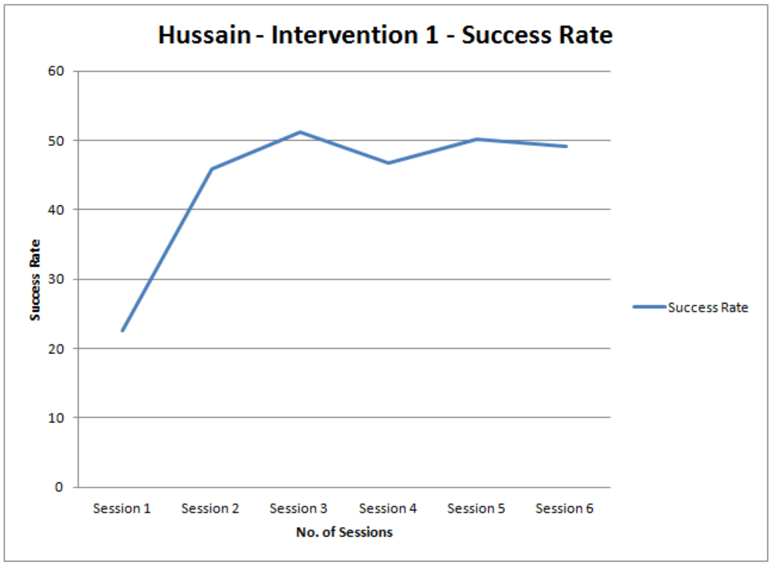
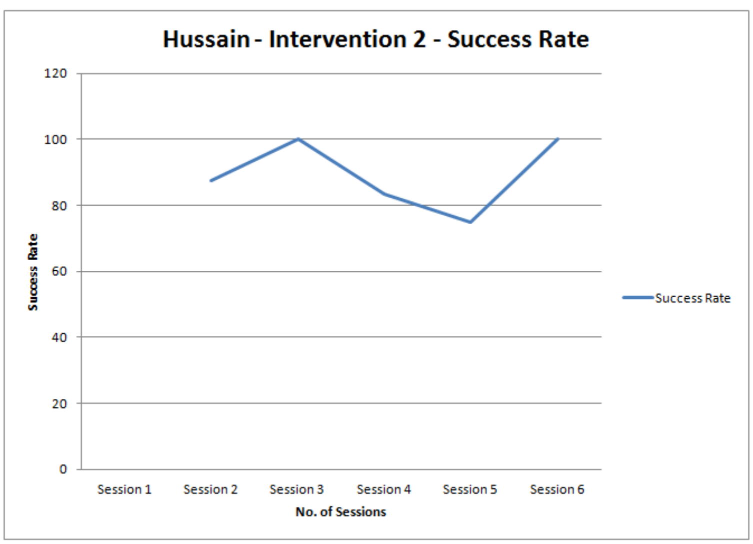


Figure 36 Hussain – Intervention 1 – Success Rate

b. Intervention 2:



3. Aazaan

a. Intervention 1:

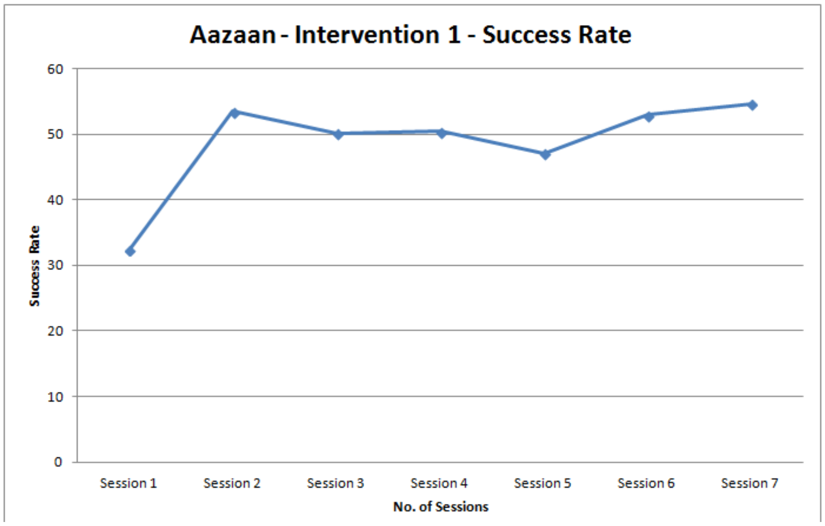


Figure 37 Aazaan – Intervention 1 – Success Rate

b. Intervention 2:

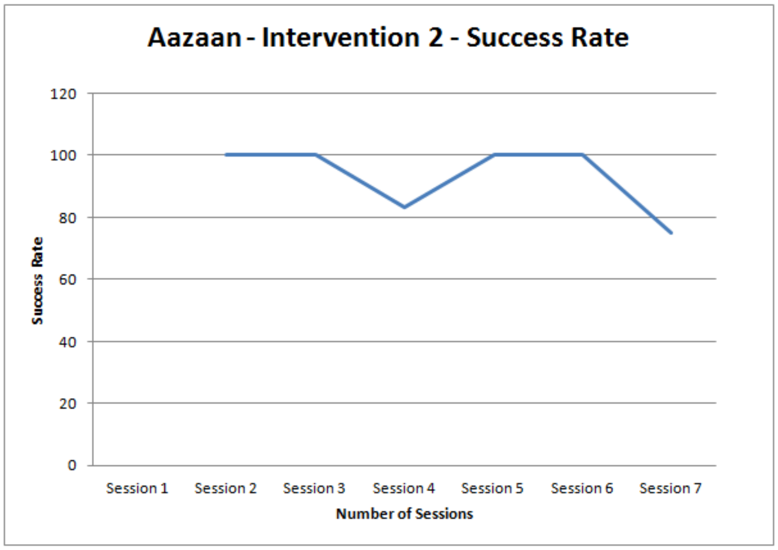


Figure 38 Aazaan – Intervention 2 – Success Rate

4. Mustafa

a. Intervention 1:

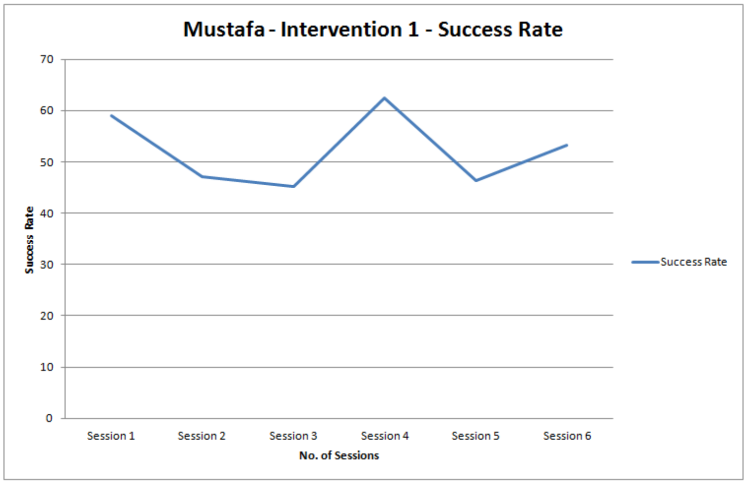


Figure 39 Mustafa – Intervention 1 – Success Rate

b. Intervention 2:

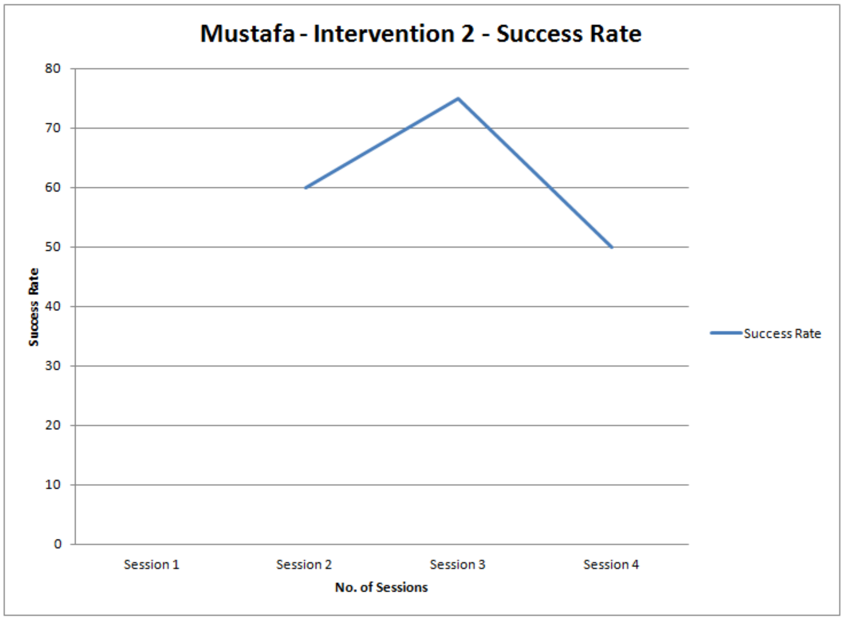


Figure 40 Mustafa – Intervention 2 – Success Rate

5. Abbas

a. Intervention 1:

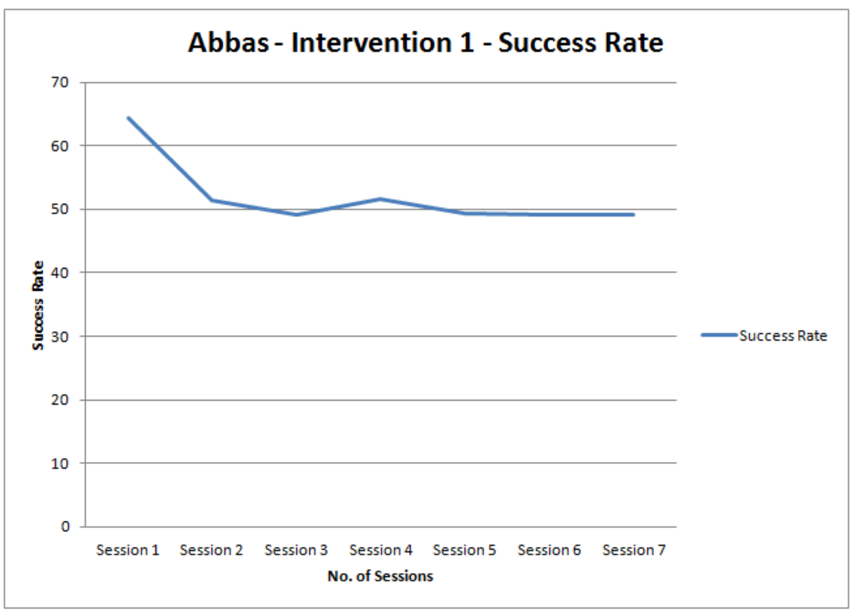


Figure 41 Abbas – Intervention 1 – Success Rate

b. Intervention 2:

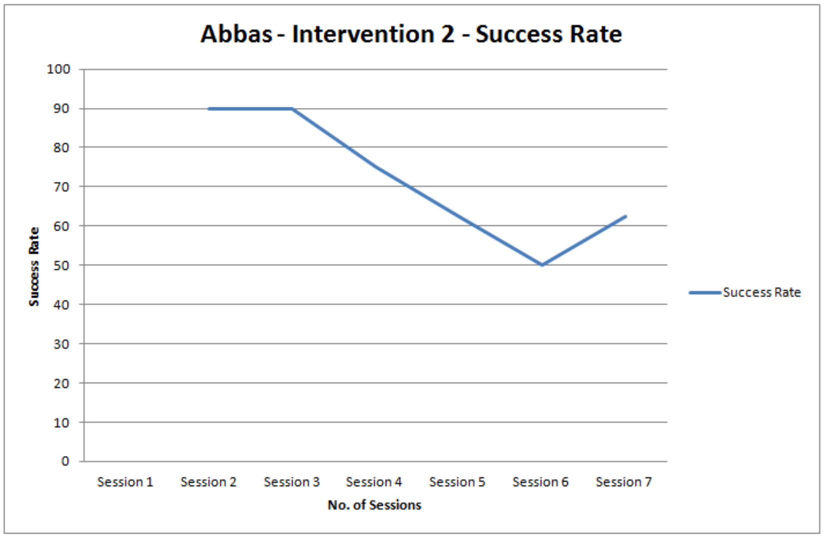


Figure 42 Abbas – Intervention 2 – Success Rate

6. Arham

a. Intervention 1:

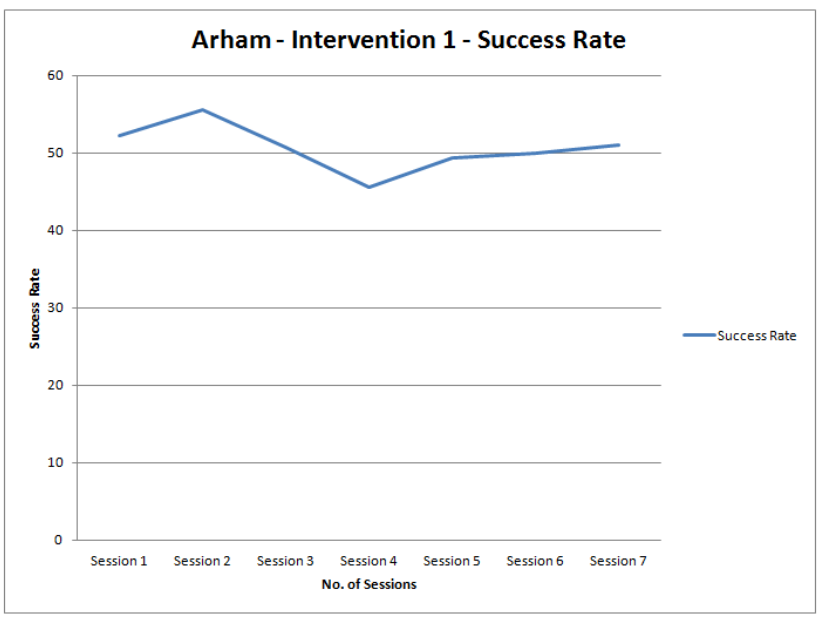


Figure 43 Arham – Intervention 1 – Success Rate

b. Intervention 2:

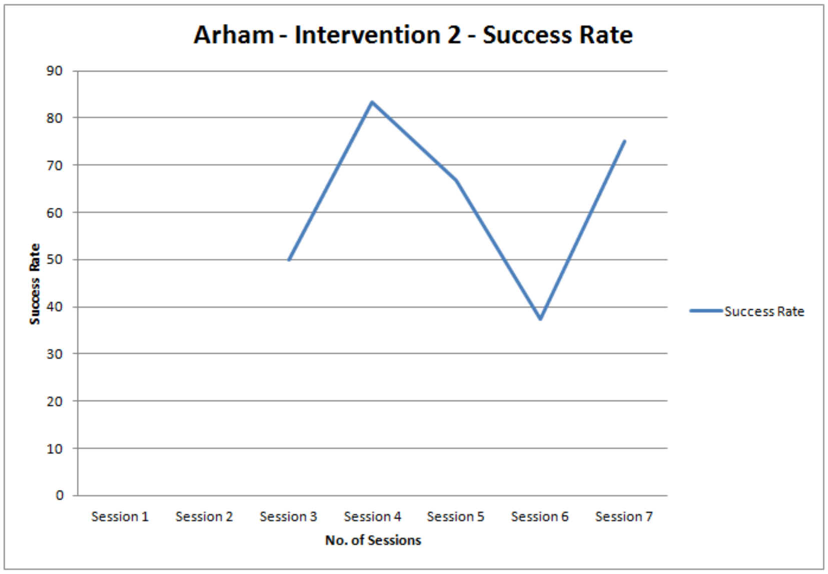


Figure 44 Arham – Intervention 2 – Success Rate

7. Rehan

a. Intervention 1:

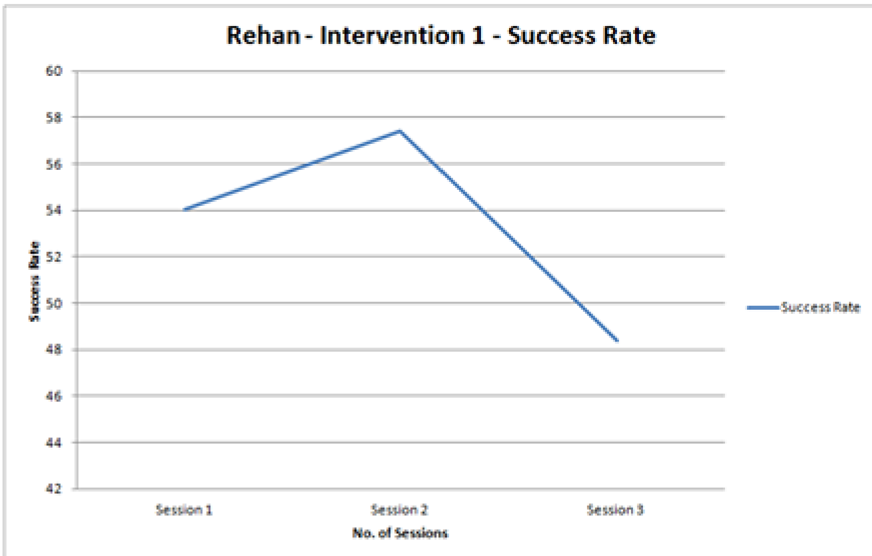


Figure 45 Rehan – Intervention 1 – Success Rate

b. Intervention 2:

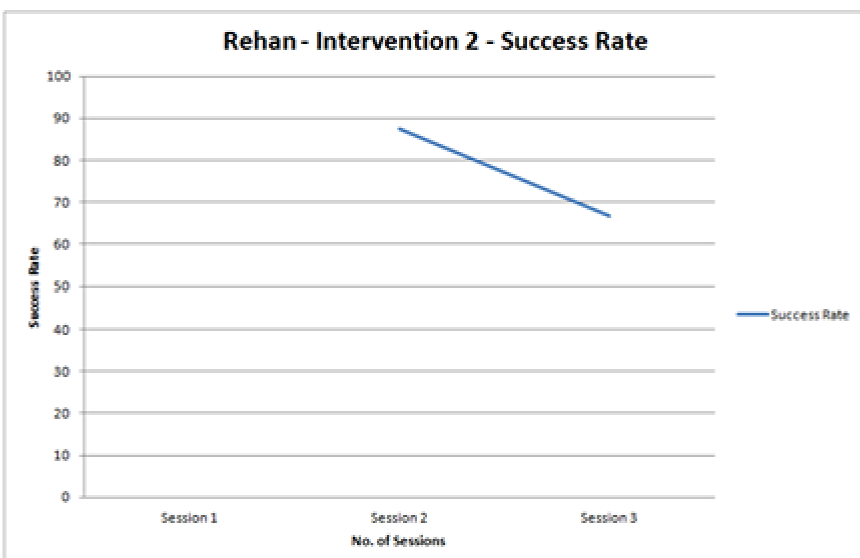


Figure 46 Rehan – Intervention 2 – Success Rate

8. Ammar

a. Intervention 1:

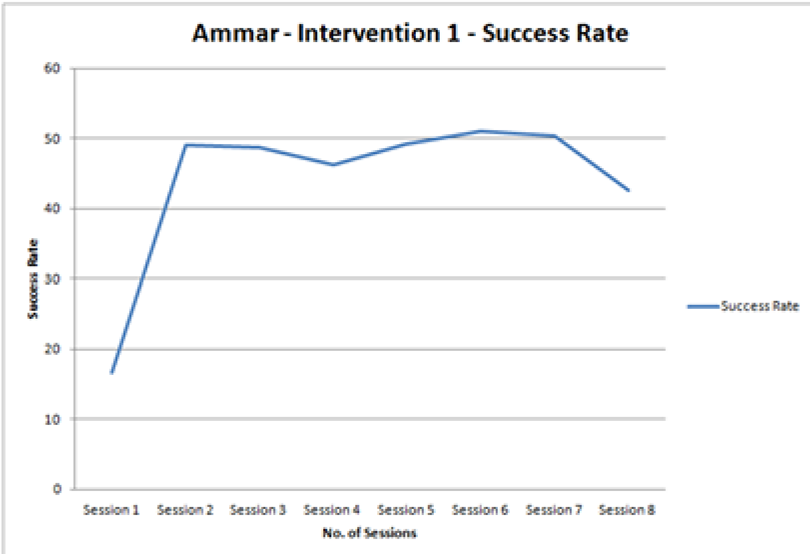


Figure 47 Ammar – Intervention 1 – Success Rate

b. Intervention 2:

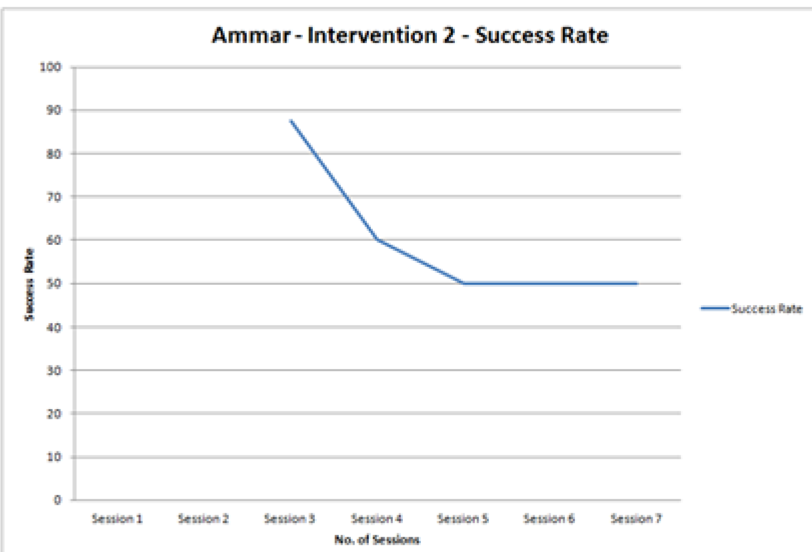


Figure 48 Ammar – Intervention 2 – Success Rate

The results of all the children in tabular form are given below

Table 10: Final results of the children

NAME	INTERVENTION	INITIAL READING	FINAL READING	AVERAGE	%AGE CHANGE
AMMAR	**1**	16.7	42.6	44.2	**155.4**
	2	87.5	50.0	59.5	**-42.9**
ABBAS	**1**	64.3	49.0	52.0	**-23.7**
	2	90.0	62.5	71.7	**-30.6**
ALI	**1**	58.4	50.7	52.4	**-13.2**
	2	75.0	87.5	69.8	**16.7**
ARHAM	**1**	52.2	51.0	50.6	**-2.2**
	2	50.0	75.0	62.5	**50.0**
HUSSAIN	**1**	22.6	49.1	44.3	**117.4**
	2	87.5	100.0	89.16666667	**14.3**
MUSTAFA	**1**	59.0	53.3	52.2	**-9.7**
	2	60.0	50.0	61.7	**-16.7**
AAZAAN	**1**	32.4	54.6	48.7	**68.6**
	2	100.0	75.0	93.1	**-25.0**

Discussion

After the sessions were completed, one more child (Rehan) was dropped from the data set because of insufficient no. of sessions of conducted of him. That leaves us with data set for seven children from which following observations were noted.

On the basis of first session and last session in intervention 1, only three children (Hussain, Aazaan and Ammar) showed improvement. Average improvement was 113 %. Remaining four children showed negative improvement which means that they regressed. But the reason behind this could be that in first sessions there was a shadow with children who was assisting them in activities so this resulted in higher success rate in first session as compared to the last session.

If we look at the results of intervention 2 then similar trends can be observed there as well. Three children (Hussain, Ali and Aazaan) showed improvement while rest of the children regressed. Average improvement was 27%.

The children which showed improvement had mostly mild or moderate severity level of autism so it means that there is higher tendency in mild cases to improve their joint attention and imitation. If the number of sessions were greater than significant improvement in all children may have been noted.

Some children like Abbas and Arham regressed according to the data because they had very short attention span so they lost interest in the therapy after some time because they already knew what was going to happen.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

Conclusion

This robotic therapy was a first stepping stone of its kind in the field of autism. If we talk in terms of interest level of children for robotic therapy, then we observed they were interested and surprised by the robot to a great extent. We started by introducing them to the robots and made them familiar with their 'friends'. In first one and half month, all of the children got comfortable with the robot and didn't use to get scared of its rapid moments and sound. It was a huge success.

However, when actual interventions were started then it was observed in the end by looking at the data and almost half of the children showed improvement while the other half did not. There can be many reasons for that behavior. The inclusion of shadow in the initial sessions may have affected the performance of the children. The other reason may be that most of the children were in moderate to severe range of autism and it requires significant amount of time to observe tangible improvement in them.

Nevertheless, this project opened up new doors in this field and if more work in done on this project then we can have tangible results in the form of improvement in social skills of children.

Recommendation:

The introduction of technology into Autism is on the rise. With every passing day man's job is made easier thanks to automation and robotics. The current setup is one of its kind and that is why it is so novel. This unique combination of sensors and Nao provides us with unique data acquisition. This data can further be enhanced/polished in the following ways:

1. **Improvement in Kinect:**

Kinect identifies the joints in the body and gives us real time information of the body posture. This information is used to see whether the child is following through the instruction he's being given. Such readings give us a measure of accuracy of motor coordination, processing time and understanding of the task at hand. Kinect's readings were observed to be improved by a number of factors. For example, better lightings, one skeleton at a time etc. These factors should be set to ideal readings in a 'control environment' so that all these variables can be made constant in all the sessions for better comparison and deductions.

2. **Improvement in Myo Band:**

The usage of Myo Band on the leg can be made possible with the head start that we have. This unique placement in the body can not only be used for this project but also create numerous other applications. Speaking for this case in particular, Myo Band can be used to understand the kick dynamics of the autistic child. This can lead to another more complex intervention for those children who have mastered the planned intervention 1 and 2. This intervention can enable them to play soccer with each other and the Nao robots. Thanks to Myo band which can give real time kick dynamics, we will judge their motor activity in a fully automated set up with minimal supervision.

3. Improvement in EEG:

We can use more child friendly alternates to the EPOC Emotive EEG headset. This will not only put the child at ease but will also ultimately positively affect our findings. The Signal processing can also be automated using machine learning which can give us real time information inside the head of the child during the activity.

4. Improvement in Nao Robots:

Autistic children rely hard on reinforcements. These are any motivation that encourages them to keep doing the work that they were doing. For therapy and teaching purposes this reinforcement is often encouraging words or simply high fives. Such reinforcements can be incorporated in the Programming of the bot. Not only this should be real time but this will also engage the interest of the child in a better way so that this interaction can be as humane and as natural as possible. This real time feedback from a robot will also boost their morale.

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Geraldine Dawson, Sally Rogers, Jeffrey Munson, Milani Smith, Jamie Winter, Jessica Greenson, Amy Donaldson, Jennifer Varley
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