A Rehabilitation Therapy for Autism Spectrum Disorder Using Virtual Reality

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Abstract. Virtual reality (VR) is a technology that simulates 3D image or environment which allows user to interact with a real or virtual environment. Using VR we can artificially create sensory experience such as sight, touch, hearing, and smell. The immersive environment can be like the real world in order to create a lifelike experience. It can be created using head mounted display, Projection, Monitors, Haptic devices, etc. Its applications widen its wings to various fields such as Education, Medicine, Military, Aerospace, etc. Autism Spectrum Disorder is a neuro-developmental disorder that highly affects normal people's peace of mind. The symptoms include lack of attention, interaction, social behaviors and so on. To overcome these, we propose a virtual environment based therapy to enhance the social skills, emotions and attention of the Autism child. The virtual environment includes various levels. First level focuses on attention grasping using color lights and sounds. Second Level focuses on increasing social interactions touching a ball, throwing it and bursting same color balloons, etc. Third Level focuses on decision making. The proposed virtual reality therapy produces positive results over repetition and it also notices at what stage the autism kids become panic, frustrated and enthusiastic.

Keywords: Virtual Reality · Virtual environment (VE)
Rehabilitation therapy · Autism Spectrum Disorder · Social interaction

1 Introduction

1.1 Virtual Reality

Virtual Reality (VR) is to immerse a user within a computer generated, virtual environment that should be visually identical to the real one. The basic concept is to receive the sensory input from the outside world and use the visual and auditory cues to give a feeling of reality to the virtual world. VR has its applications in a large spectrum of fields such as Military, Education, Healthcare, Entertainment, Fashion, Construction, Business and the arts. Virtual reality applications are Augmented Reality, Virtual Worlds and Kinect. For making more realism and increase Human Computer Interaction, AI plays a major role. It is also used to design good haptic interfaces. An insightful study of typical VR systems is done. All components of VR application such

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as input, output and software and interrelations between the components are thoroughly examined. VR has its own hardware issues such as motion sickness, vomiting, etc. It has its own advantage also. Generally, any of the concept can make understandable by pictorial representation or animation or with real time examples video. Like that VR has the prominent role in Education field for better understanding of the concepts. This is the key factor for us to include this in our proposed work. Additionally, human factors and their implication on the design issues of Virtual Environment (VE) are also included.

1.2 Autism Spectrum Disorder (ASD)

Autism Spectrum Disorder [13] is a neuro-developmental disorder. ASD ranges as a spectrum of symptoms. So, it is named as Autism Spectrum Disorder (ASD). Asperger Syndrome comes under this umbrella. This disorder has its own spectrum of deficiencies. Autism affected children lacks in attention, social communication, emotions and interactions. ASD has various set of conventional therapies. Repeated use of therapies leads to a good result. Repeated training by man power leads to tiredness and frighten. So, the proposed work planned to implement all the conventional therapies into virtual environments.

There are two types of conventional therapies. They are discrete trial teaching and stimulus-response reward technique. Discrete trial teaching is a method that breaks down tasks into smaller components called trials, and stimulus-response - reward techniques that use physical objects to teach basic skills such as attention management, compliance, and imitation. However, most children with autism find task repetition boring and frustrating, and the objects used don't appeal to them. Consequently, children with autism often spend a lot of time off-task and have difficulty in sustaining their selective attention. Caretakers use a variety of strategies to help such children stay on task and have a more positive experience, such as annotating text on top of physical objects, using verbal and physical prompts, and offering rewards.

These therapeutic interventions cannot be made common for autism treatment, because of its spectrum nature. It means it varies with each individual affected by autism. Autism is characterized by deficits in social interaction and communication, and unusual and repetitive behavior. Cognitive abilities in people with autism vary between those with average to above average intelligence, and others who function within the moderate to profoundly mentally retarded range. Mostly, autism manifests at birth or within the first two-and-a-half years of life. Many autistic children are perfectly normal in appearance, but spend their time engaged in puzzling and disturbing behaviors that are different from those of typically developing children. They may show little or no interest in people including their parents, and pursue repetitive activities with no apparent purpose. The prevalence of autism is estimated as 1 to 2 per 1000 children, and close to 6 per 1000 children. According to the Centers for Disease Control and Prevention (CDC) around 1 in 68 children has been identified with some form of ASD in 2012 than in 2002 (1 in 150).

Many conventional therapies produce better results over a long period of time. To overcome this delay, a promising technology virtual reality technology has been introduced. In Virtual Reality same conventional therapies has been converted to

virtual environments and make the autistic child to focus, interact and react over the environment as in the real world. This technology doesn't make the child distress. With high end processing units, we can have very smooth virtual environments.

This paper is organized as follows: Sect. 2 focuses on the related work. Section 3 focuses on Methodology of the proposed Work. Section 4 deals with outcome of the proposed work and Sect. 5 concludes with the Work.

2 Related Works

Cordeil et al. [1] made a comparative analysis on CAVE and HMD for immersive Collaboration in network connectivity. After few analyses, they have identified that participants using HMD where faster than CAVE. Affordances for collaborative data analysis using both HMD and CAVE are the same. Thus concluded that in near future latest HMD will be used by massive users. For analysis they have used 3D network visualization because of its abstract nature. They have analyzed the impact of VR platform on task performance, collaboration and user experience.

Spatio-Temporal Based Learning Method [8] used for learning and reasoning the interactions among the objects. Through Learning, we can gain the experience of how to achieve the goals in gaming environment.

Mindful Meditation (MM) [4] leads to heavy psychophysical effects. In real time, the study has been done as during and after the MM, unable to predict the psychophysical effects. So it has been implemented using VR. It leads to positive results. The existing findings on MM only interpret the hypo metabolic state of mind and physiological parameters. So it does not produce the correct results. VR considers ecological factors, Parasympathetic nervous activity and sympathetic activity.

Realism [5] of virtual surfaces can be evaluated using haptic models constructed from data recorded during interactions with real surfaces. This model has 3 components. They are surface friction, tapping transients, texture vibrations. Following a perceptual discrepancy paradigm, intensity of surface property such as slipperiness, hardness can be avoided.

ClinicaVR [2], is a VE classroom tool for accessing attention and inhibition in children and adolescents. It aims at investigating certain validity and reliability aspects of tool, examine the relationship between performance in the virtual test and the attendant sense of presence and cyber sickness experienced by participants and assess potential effects of gender and age on performance in the test. Results of this tool support both concurrent and construct validity as well as temporal stability. Genders will not lead to performance degradation, but age does. This tool did not cause much cyber sickness.

Treatment for Online Gaming Addiction [6] can be done by improving the functional connectivity of the cortico-striatal-limbic circuit by simulating the limbic system using virtual reality therapy (VRT). After treatment, Young's Internet Addiction Scale (YIAS) scores were reduced. Connectivity to posterior cingulated cortex and bilateral temporal lobe gets increased. From results VRT seems to reduce the severity of online gaming addiction.

FACE [15] is an interactive life like facial display developed in android platform that helps the children with autism to learn, identify, interpret, and use emotional information and extend these skills in a socially appropriate, flexible, and adaptive context. Therapist will help the student to interact with FACE. The treatment scheme is based on a series of therapist-guided sessions in which a patient communicates with FACE through an interactive console. If the student is not interested, the image will fade off. The architecture of the facial automaton consists of an anthropomorphic head and a facial tracking and expression recognition device. This module will track the actions of the autism child and detects the face expression. From this they can easily identify the deficiencies. FACE is an application which has face like appearance which is able to express and modulate the basic emotions in a repeatable and flexible way, to quantitatively analyze the emotional reactions of individuals through optical analysis of facial expression, to track a human face over time, and to automatically store all data. FACE's control can be performed by an external supervisor or by an algorithm which implements a predefined design. The skeletal structure has been constructed using CAD/CAM. Soft tissues of the head were fabricated from materials used for facial reconstruction in the world of animatronics and archeology.

Virtual Dolphinarium [11] has been developed for potential autism intervention. Instead of having Dolphin Assisted Autism therapy they provide IDM- Enabled Autism Therapy. As Dolphin is an endangered species Dolphin Assisted Therapy is not advisable. To overcome these virtual dolphins were made and same Dolphin assisted therapy was made by the therapists. In Dolphin assisted therapy the children are to spend their initial times in pool activities to encounter the real dolphins. All these activities are enriched through Virtual dolphin interaction program. It allows children with autism to act as dolphin trainers at the poolside and to learn nonverbal communication through hand gestures with the virtual dolphins. Immersive visualization and gesture-based interaction are implemented to engage children with autism within an immersive room equipped with a curved screen spanning a 320° and a high-end five-panel projection system. It will promote learning skills and positive behavior.

CAVE Automated Virtual Environment (CAVE) is the virtual environment widely used in various research implementations. A workflow has been designed [3] that facilitates annotation operation such as creation, review and modification. Using this CAVE environment, the above said workflow has been implemented and obtained good results in task performance and an experience. This data annotation is used in immersive VR application to support data analysis.

The Virtual Reality Social Cognition Training (VR-SCT) [14] intervention was developed to increase social skills, social cognition and social functioning in providing effective treatments for adults with HFA. Primarily, this pilot study investigated the feasibility of a 10-session VR-SCT intervention in adults with High Functioning Autism (HFA). A secondary aim was to quantify social change over time using social performance and skill measures, and a functional questionnaire.

Bekele et al. [10] proposed a facial emotion expression recognition system. It monitors eye gaze and physiological signals related to emotions. Using these data, we can able to know how the autism affected adolescents respond to the facial expressions. The facial expressions of 10 adolescents were taken and processed with the eye gaze and physiological signals to identify the type of facial expression.

Wang and Sourina [12] proposed a novel method for multi-fractal analysis of EEG signals named generalized Higuchi fractal dimension spectrum (GHFDS) and applied in mental arithmetic task recognition from EEG signals. Electroencephalography (EEG) is used to monitor the brain's functioning and using neuro feedback technique we can train back the brain through audio or video or tactile cues. This multi fractal analysis technique produces improved result in both single channel and multi-channel subject dependent algorithms.

3 Methodology

Usually, ASD evolves from the age group of 18 months to adults. Many technologies are providing various solutions to the adults suffering from Autism. If we provide solutions to the age group starting from 2 years then it will be useful to the society. But providing solution to children than adults is a tedious process. We have proposed the work considering the age group starting from 2 years. The proposed framework deals with development of Virtual Environment that treats the autistic children. Figure 1 depicts the virtual scene. An autistic child is left in the Virtual room. Make the child to interact with the virtual environment by sequence of activities. First is grasping attention. This is enriched by sounds, highlighting colors and so on. This may or not make the child attentive. If not, the autism kids will be noticed their emotions that what type of expression is the child expressing. If panic, change the environment to make the kid cool. If not train them in the same environment till reaches the standard score of normal child. After making attention, make them to socially interact with the environment. Interaction means performing the tasks included in the environment. Also make the kid to travel along the path with friends. This will increase the social interactions. By repeated tasks the autistic kid can able to interact with strangers in the real world. After interactions, certain tasks are given to test their decision-making skill,

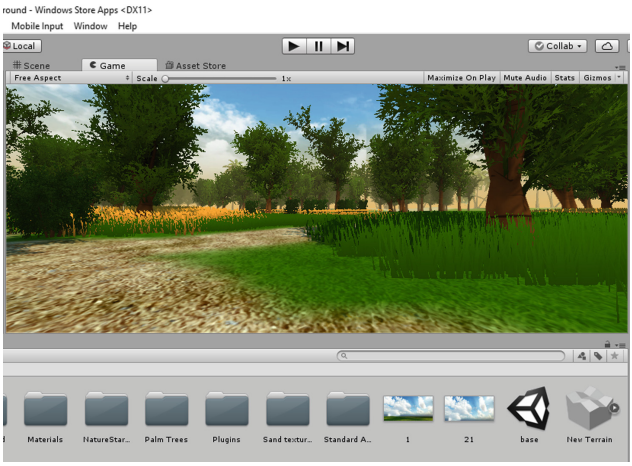

Fig. 1. Proposed model of virtual scene

concentration, and reasoning skill. The entire system is encircled with Cameras, Tracking System, Gesture recording system, and Audio-Visual Recording System. Expressions have been tracked and identified the mood of the child using Luxand Face SDK. Later on gestures were tracked and find out whether they are interested to interact with the environment are not. These data are stored in higher end database. Cameras are used to track the entire body actions of the child. The Visual tracking system is used to grasp their emotions or expressions from faces through eye ball tracking and eye gaze movement tracking. All these recorded data will be processed until it meets the standard score. Figure 2 depicts the flow of virtual training.

After the treatment, the performance of the Autism child is monitored. Also, their emotions, expressions, social interaction and interest towards the environment are monitored using Survey Questionnaire and analyzed with the standard Likert Scale range. Table 1 depicts the IQ range and its significance. The total score of each child is likely to fall in the specific range as in Likert scale after this therapy. These results will

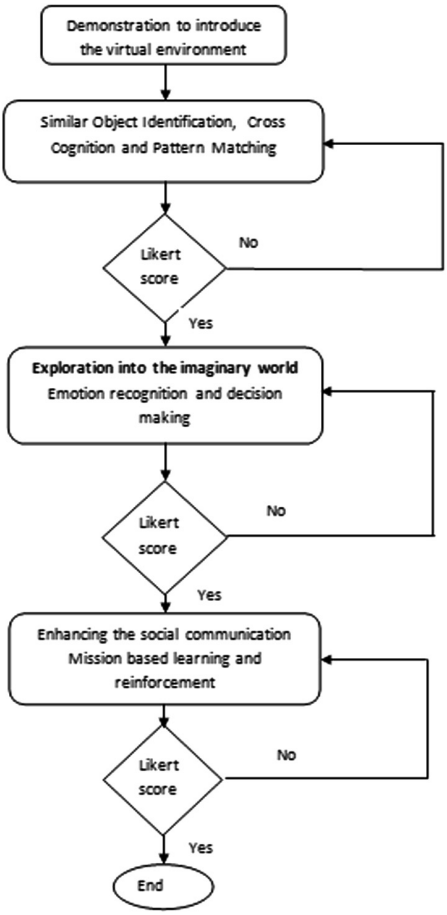

Fig. 2. Flow of virtual training

Table 1. IQ levels and its significance

S. no	IQ level	Significance	Population (%)
1	Below 70	Problem in IQ	4
2	90 to 110	Average	95
3	Above 130	Intellectual giftedness	1

be compared with the standard IQ, BQ and Likert Scale of a normal child to prove the results. Iterate process till it reaches the target (i.e., IQ - 100). To reach the target, the interactive module can be re-designed into an interesting and creative mode. To achieve smoothness of this interactive module 3D rendering can be increased.

4 Outcome of the Proposed Work

Conventional autism therapies are achieved by repetition. But it will be enhanced by therapist. Each Child must be monitored by a single therapist. Some of these therapies include hectic devices to control the autism kids. Even with VR, we can go with devices. But the only reason we omit devices is the distressing nature to the child. To overcome this, we have come up with the proposed model. In the above proposed model, the results were obtained and compared with the standard scale. Repetition of therapy will be made until it reaches the specific standard range. VR treatments highly produce positive results by increasing the IQ, BQ and Social Skills. The Verbal and Non-Verbal Emotion Recognition is achieved by the standard scales. The new Advanced Clinical Solutions for WAIS-IV and WMS-IV Social Perception Subtest [21] was utilized to measure social perception abilities. This measure yields four scaled scores derived from various tasks. First, the SP-Affect Naming assessed the ability to match photographs of faces and people interacting to basic words of emotions. First level of our game is assessed using this SP-Affect Naming and its specific scale falls under 0 to 60. Second, SP-Prosody is a similar assessment but with auditory stimuli. Second level of game is assessed using SP-Prosody. The range of Likert scale for this falls under 0 to 30. These two subtests combine into the third Social Perception Total Score (SP-Total). Fourth, the SP-Pairs score reflects a combination of abilities in deciphering non-literal language, such as sarcasm, and the intention of the speaker. Two measures assessed Theory on Mind (ToM), or the abilityto generate inferences about the thoughts and feelings of others. Our last level of game is measured using the above-mentioned metric and the results are analyzed for the specific range to be 17 to 80.

Participants are asked to interact with the virtual environment and their emotions, social interactions and attention has been noticed. Responses were recorded, compared with the standard scores. If not achieved the standard specific range, then repetition of same treatment takes place. The scoring criteria are based on the 6-point Likert scale method. Participants describing higher levels of intentional and mental states of the stimuli are awarded higher scores with the raw score range of 0–30. The results of the above proposed work will range in the scale given below in Table 2.

Table 2. Metrics for analysis

S. no	Measure	Specific range (Likert scale-6 pt)
1.	ACS-SP	65–110
2.	Ekman60	0–60
3.	Theory on mind – eyes	0–36
4.	Triangles	0–30

The target is to train and treat 4% of population to reach the above-mentioned scores. The proposed methodology not only improvises the social skills and attention but also induces positive behavior among the autism children. Table 3 depicts the result of autism kids that undergone training in virtual environment. 5 kids were taken into consideration for the initial stage of the proposed work and made them to interact with the virtual environment. Level 1 is attention grasping and Level 2 is increasing social interactions. Based on the Theory on Mind metrics, the standard range for a normal child falls between 0–36. Without repetition we have obtained the below positive results. By repetition over a time, it will produce good results and leads to progress to other levels.

Pretest results are obtained from conventional therapies such as occupational therapy and speech therapy. The post test results are obtained after the proposed VR training. From the Table 3 the scores have been improved among the autism kid. Results can also be improved by increasing the impressiveness of the virtual environment through high rendering and having tactile haptics feedback.

Table 3. Result analysis

Child	Severity	Age	Level 1		Level 2	
			Pre test	Post test	Pre test	Post test
Kid 1	Average	4	4	7	6	7
Kid 2	Mild	5	6	10	7	10
Kid 3	Average	4	4	6	6	8
Kid 4	Average	6	4	7	6	7
Kid 5	High	4	2	7	4	7

5 Conclusion

The therapy using VR is highly admissible and responsive even if it is expensive. It produces a very high percentage of positive results. Autistic children normally expects the smooth environment, our proposed model provides such smooth environment with high rendering. Our proposed therapy addresses lack of attention, social interaction and emotional value. As per our study VR based therapy over a time period of repetition will produce better results. Future scope of research is to purely immerse the child in virtual environment and addressing other deficiencies.

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