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Virtual Reality as a Promising Tool for Autism Intervention

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ABSTRACT

This paper explores how Virtual Reality (VR) systems have been used as a rehabilitation tool for disabled population. Reviews were done in applications of virtual reality in patients with neurological disorders, visual impairment, psychiatric problems, children with physical disability and neurodevelopment disorders. This article mainly focused on the current status and use of virtual reality for children with autism. Literature was reviewed and the important findings are discussed in this paper. The virtual reality systems & designs, interventions method, treatment intensity and its effectiveness in target population were analyzed. The following skills emotion recognition, contextual processing, social attribution & executive function of analogical reasoning, navigation performance, safety skills, social interaction, motor & cognitive skills, conversational understanding were found to be improved in children with autism spectrum disorder by using VR. The paper also detailed the studies done in India using virtual reality in the disability field, mainly in autistic population.

KEYWORDS: *Virtual Reality, Autism Spectrum Disorder, Rehabilitation tool, Disability*

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INTRODUCTION

Virtual reality (VR) is a promising technology which has applications in wide range of aspects. A systematic literature review was done in this paper to determine the uses of VR in the field of rehabilitation especially in children with autism. This work also investigated the status of VR technology in the rehabilitation of individuals with autism in Indian scenario.

Virtual reality has been defined as an "interactive, immersive experience generated by a computer" (Pimentel & Teixeira, 1993).Human-computer interactivity is attained through multiple sensory channels which allow people to explore Virtual Environments (VE) through sight, sound, touch and sometimes even smell (Wang & Reid, 2011).In terms of human experience VR is a mediated environment which creates the sensation in a user of being present in a physical surrounding (Seipel, 1993).

Virtual reality is about generating "acceptable "reproductions of real things or environments for training, entertainment or design purposes. It uses computers to generate 3D environments in which one can navigate and interact. Navigation implies the capability to move around and explore the features of a 3D scene, such as walking through a forest. And interaction means the capacity to select and manipulate things in the scene, for example, grabbing and examining a flower found in the forest. In other words, VR fully immerses the user in a three-dimensional, computer-generated world and depending on the system used; the amount of immersion in the virtual world can be any place from barely being capable to affect virtual objects to feeling every part of the virtual world. The target of anyone involved in the field of VR is to create an environment that is indistinguishable from the real world. It requires real-time graphics, a stereoscopic display, used to produce the illusion of 3D and a tracking system to obtain head and hands motion. Head-Mounted Displays and Stereoscopic glasses are commonly used technologies (Gutierrez, F, & Thalmann, 2008).

There are different types of VR systems. A major difference between these VR systems is the mode with which they interface to the user. Some of the common modes used in VR systems includes; Window on World Systems/Desktop VR, Video Mapping, Immersive Systems, Telepresence and Mixed Reality (Isdale, 1993).

Clinical Applications of VR

Virtual reality technology has broad range of applications in the field of rehabilitation. VR has proven its applications in patients with neurological disorders, visual impairment, psychiatric problems and children with physical disability and neurodevelopmental disorders.

Benefits of VR for children with disabilities:

In recent years, VR tools have originated as an assessment and treatment methods in rehabilitation of disabled population. The properties of VR, especially its malleability,

make it a flexible medium for the creation of customized applications to satisfy the requirements of disabled children. Depending on the treatment goal of program the VE characteristics can be modified to incorporate or exclude certain categories of stimuli. This adaptability helps to encourage an optimal interaction for these children. VR can be considered as an assistive technology, due to its countless potential to reduce the effects of disability in these populations. VR technology also offers children with disabilities, larger access to many experiences and can enhance various skills (Mccomas, Pivik, & Laflamme, 1998).

A variety of unique attributes of VR technology are the rationale for using it in rehabilitation field. These distinctive attributes include the opportunity for experimental and active learning which inspires and motivates the patient. Additionally there is the capability to objectively measure patient's behavior in challenging environments. The stimulus delivery and its measurement can be controlled experimentally. VEs provide the chance for repeated learning in different trials and provide the capacity to increase the task complexity gradually while fading the help offered by therapist. The stimulus delivery in VE is automated in nature which helps the therapist to provide physical support according to patients need without detracting task complexity (Weiss, Kizony, Feintuch, & Katz, 2006).

Applications in neurorehabilitation:
Virtual Reality applications in the rehabilitation of neurologically impaired population are expanding at a fast pace and a huge variety of platforms and programs have been developed. Its application is evident in patients with stroke and traumatic brain injury(Weiss, Kizony, Feintuch, & Katz, 2006).The results of the VR technology study for physical rehabilitation in patients with chronic frozen shoulder and post-traumatic brain injury suggested that effective VR-based rehabilitation could be used as a supplement or alternative to conventional therapy (McComas, et al., 2003).

In stroke patients, VR can be used as a more comprehensive and controlled evaluation tool of prospective memory than other standard memory tests (Brooks, Rose, Potter, Attree, Jayawardena, & Morling, 2002). For individuals with unilateral spatial neglect due to right hemisphere stroke,non- immersive interactive VEs are an effective medium for teaching the safe road crossing task (Naveh, Katz, & Weiss, 2000).

Applications in psychiatry:
Patients with psychiatric illness were also benefitted by using VR technology. In schizophrenia patients, social skills training using VR role-playing were compared with traditional role –playing. It was found that VR may be a helpful supplement to traditional social skill training because of the improvement noticed in terms of conversational skills and assertiveness (Kyung-MinPark, et al., 2011).

A study result using a application of VR integrated program showed improvements in schizophrenia patient's social dysfunction behaviors like negative symptoms, anxiety, discomfort and avoidance and thus it can be used as an adjunct technique for their social skill intervention(Calafell, Maldonado, & Sabate, 2014) .

Applications in visual impairment:
Applications of VR in visually impaired people are also emerging. An application called Virtual Reality Simulator which is capable of making an auditory representation of VE was developed for visually impaired people. It helps in rendering the virtual world completely through hearing (Torres-Gil, Gonzalez, & Gonzalez Mora, 2010).

Applications in neurodevelopmental disorders:
Aguirre et al (2019) carried out a project by creating a VR game, which places intellectually disabled students to become very confident when they are faced with a stressful scenario in their everyday lives. The VR environment make a safe space in which they can develop their social abilities and increase their situational awareness, hence they can train themselves to be more relaxed when they face stressful situations in the true world (Aguirre, et al., 2019).

Studies were conducted using technology based games such as Wheelchair Net and Social MatchUP. The contribution of Wheelchair Net, a technology based training program in the education of physical disability children was studied by giving a chance to practice driving in virtual motorized wheelchairs in a computer-generated world safely. The study results showed achievement in driving skills of participants as indexed in true reality (Inman, Loge, Cram, & Peterson, 2011). Social MatchUP, is a multiplayer VR game for children with neurodevelopmental disorders which enhances their social and communication skill, and it can also be used as a learning tool. It is a simple concentration-like game, run on smartphones (Loiacono, Trabucchi, Messina, Matarazzo, Garzotto, & Beccaluva, 2018).Vona et.al (2020) did a case study by means of the Social Matchup application for people with neurodevelopmental disorders to develop their speech-based conversational capability. The participants were 24 persons in 2 groups, one group of participants playing a game in Social MatchUP and the other group playing a game that is similar as in the application but in the real world. Their results point out that the game experience in Social MatchUP was usable and enjoyable, and boosted top conversational abilities with respect to its corresponding item in the physical setting (Vona, Silleresi, Beccaluva, & Garzotto, 2020).

There is paucity of **Indian studies** on use of VR for rehabilitation. Reviewed studies are summarized as follows,

In a study by Doctor et.al (2019) was found that VR training to be therapeutic in improving psychosocial factors of spinal cord injury patients. Their reduction in stress, anxiety and increased calmness were reported in post intervention (Doctor, Gadgerao, Udpikar, Shyam, & Sancheti, 2019).A systematic review was done by Ravi et.al (2017) to provide updated evidence-based guidelines for VR rehabilitation of patients with cerebral palsy in their sensory and functional motor skills. They concluded that VR rehabilitation is a promising intervention for improving balance and motor skills of patients with cerebral palsy (Ravi, Kumar, & Singhi, 2017). A study was done by Sharan et.al (2012) to find out the effectiveness of VR based training in the rehabilitation of children with cerebral palsy. There were 14 participants in the study group and 15 subjects in the control group. Outcome measures used in the study were Manual Ability Classification System, Pediatric Balance Scale,child satisfaction, level of participation, motivation and cooperation. While comparing with the control group, the results of study group were reported to be improved

significantly in all the outcome measures except in Manual Ability Classification System (Sharan, Ajeesh, Rameshkumar, Mathankumar, Paulina, & Manjula, 2012).

Muneer et.al (2015) explored the use of VR-based games to improve the motor, communication, cognitive and social/emotional skills in children with developmental disabilities. Their result reveals significant progress in motor, cognitive and social/emotional skills (Muneer, Saxena, & Karanth, 2015).

Based on the reviews done above, areas for which VR has been successfully used in the rehabilitation field is summarized in the following Table.

Table 1

SL NO	AUTHORS	YEAR	AREAS FOR WHICH VR HAS BEEN USED	SUBJECT / POPULATION STUDIED
1	Brooks, Rose, Potter, Attree, Jayawardena, & Morling.	2002	Prospective memory assessment	Stroke
2	Naveh, Katz, & Weiss	2000	Safe road crossing task	Unilateral spatial neglect
3	Kyung-MinPark, et al	2011	Social skills	Schizophrenia
4	Calafell, Maldonado, & Sabate	2014	Social skills	Schizophrenia
5	Torres-Gil, Gonzalez, & Gonzalez Mora	2010	Environment recognition, auditory rendering	Visual impairment
6	Inman, Loge, Cram, & Peterson,	2011	Driving skills	Physical disability
7	Aguirre, et al	2019	Social skills and situational awareness	Intellectual disability
8	Loiacono, Trabucchi, Messina, Matarazzo, Garzotto, & Beccaluva	2018	Social and communication skill	Neurodevelopmental Disorders
9	Vona, Silleresi, Beccaluva, & Garzotto	2020	Conversational ability	Neurodevelopmental Disorders
10	Doctor, Gadgerao, Udpikar, Shyam, & Sancheti	2019	Psychosocial factors	Spinal cord injury
11	Ravi, Kumar, & Singhi	2017	Balance and motor skills	Cerebral palsy
12	Deepak, P S, R, M, Jospin.	2012	Balance skills	Cerebral palsy
13	Muneer, Saxena, & Karanth	2015	Motor, cognitive and social/emotional skills	Developmental disabilities

Table 1: Successful use of VR in the rehabilitation field

Application of VR in Autism

This article has a robust literature review regarding the present status and use of VR for autism spectrum disorder. Autistic individuals have impairments in social and communication skills, lack of imagination or abstract thought and the presence of stereotyped, repetitive behaviors. Considering the balance between flexibility and control of the treatment program in autistics, VR systems play an excellent role in treatment outcome. Several skills from motor, cognitive, social and emotional domains were investigated in these studies. Autistic individuals improved their learning and transferred to new skills in considerably less time through VR systems.

A detailed literature review was done on the uses of VR in autism and is summarized in the table below.

Table 2

Source	Participant characteristics	Description of treatment	Description of results
Yang et al(2017)	Sample size: 17young adults Gender: 2 females, 15 males Mean age: 22.50 years Diagnosis- : High functioning Autism	Design: Within subjects VR System: Windows computer Webcam and a headphone with built-in microphone. Intervention: Virtual Reality Social Cognitive Training (VR-SCT). Treatment intensity: 2x 1 hour session per week for 5-weeks	VR-SCT significantly improved emotion recognition in terms of the ACS-SP scaled scores and in theory of mind from pretreatment to post treatment.
Wang et al(2010)	Sample size: 4 children with autism Gender: 3 boys, 1 girl Age range : 5-10 years Diagnosis: Autism spectrum disorder	Design: single subject design with nonconcurrent multiple baselines across subjects VR System: laptop computer with tracking web cam Intervention: Virtual Reality-Cognitive Rehabilitation (VR-CR). Treatment intensity: baseline phase: 4 to 6 weeks Treatment phase: 3 discrete sessions x 10 minutes	Improvements in contextual processing ability from baseline to treatment for each child, with average increases from 15% to 46%. All children maintained a high level of performance at the two-week follow-up assessment.

Sait et al (2019)	Sample size: 9 children Gender: not specified Age range : 4-12 years old Diagnosis: Autism spectrum disorder	Design: within subject study VR system: AutiVE, VR glasses, interfaces from website and unity scenes Intervention: VRinto the educational system(school scene and classroom scene)based on applied behavior analysis Treatment intensity: 2sessions	VR system helps the autistic child's to enrich the ability to adjust in a new environment. 8 children were satisfied and accept the VR headset. 5 of them remembered the scene presented. Few words were repeated by the children.
Didehbani et al(2016)	Sample size: 30 children Gender: 26 males,4 females Age range : 7-16 years Diagnosis: Autism spectrum disorder	Design: within subjects VR System: Second Life™ version 2.1, three-dimensional virtual world software (Linden Lab, 2003). Microsoft Windows XP or newer, graphics cards of ATI Radeon 8500 or better and 1.5 GHz 86 CPU using a 24-inch monitor with a resolution of 1920 x 1200. Intervention: Virtual Reality Social Cognition Training Treatment intensity: 10x 1 hour sessions across 5 weeks	Significant improvements were noticed on emotion recognition, social attribution, attention and executive function of analogical reasoning.
Saiano et al(2015)	Sample size: 7 adults Gender: allmale Age range : 19-44 years Diagnosis: Autism spectrum disorder	Design: within subjects VR System: video projector, displaying a VR environment on a 2 m × 2 m screen, Markerless motion capture device (Microsoft Kinect) Flexible Action and Articulated Skeleton Toolkit (FAAST) Intervention: integrated approach based on VE and natural interfaces (Street crossing) Treatment intensity: 10x45 minutes sessions(1session/week)	Over sessions, 6 out of 7 significantly improved their navigation performance, but did not reduce the errors made in street crossing. Both parents and caregivers stated a significant progress in the subject's street crossing ability. Interaction with VEs effective in facilitating the acquisition of safety skills in autism
Self et al(2007)	Sample size: 8 children Gender : 6 boys 2 girls Age range: 6 to 12 years Diagnosis : Autism spectrum disorder	Design: between groups (randomly assigned to 2 groups) VR System: laptop computer with a CPU, 3DSMax6.0 software, a separate 19-in Ultra Sharp Dell flat panel monitor ,a Scent Palate Intervention: comparing benefits of using VR to benefits of an integrated/visual treatment model on safety skills. Treatment intensity: 2x30 minutes for 5 week for each phase	Both groups improved in their learning and transfer of safety skills. The VR group, however, learned these skills in considerably less time.
Yuan et al(2018)	Sample size: 72 children Gender: 64 boys, 8 girls Mean age: 106.3 months	Design: within subjects VR System: four-side Cave Automatic Virtual Environment (CAVE),goggles Intervention: VR enabled training program. Six learning scenarios were designed, including a relaxation scenario, four training scenarios and one consolidation scenario. Treatment intensity: The one-hour training session would end with a debriefing session.	Children from training group scored higher on emotion expression, regulation, social interaction and adaptation after the training than before the training. There was a statistically significant interaction between group and time on affective expressions and on social reciprocity.
Karanth et al(2015)	Sample size: 5 children Gender: 4 boys, 1 girl. Age range: 4-8 years Diagnosis : 4 boys with Autism Spectrum Disorder and 1 girl with Learning Disability	Design: within subjects VR System: Xbox360(developed by Microsoft, consists of a console with a 240 GB hard drive and a controller) and Kinect (motion-sensing device created by Microsoft) Intervention: VR Games Treatment intensity: 4 and 6 sessions (20-30 minutes) over a span of one month.	Pre and post intervention scores revealed that the children made significant progress, not only in certain motor skills but also in skills from the cognitive and social/emotional domains. None of the children regressed in any of the skills monitored from the different domains.
Rosenfield et al(2019)	Sample size:	Design: within subjects	Through the repetition and

	2children Gender : 1boy, 1 girl . Mean age: 6 .5 years Diagnosis: Autism Spectrum Disorder	VR System: Oculus Rift SDK,Oculus Rift VR headset,VE comprises five primary software modules: Staging script, vision processing script, voice processing script, data archive script, and character animations. Intervention: VR-based assistive technology which integrates gaze tracking and voice processing Treatment intensity: 15 nonconsecutive minutes	analysis of these virtual interactions, users improved social and conversational understanding. The study was a positive experience for the users, and minimal training was required to use the VR headset. The users quickly discovered the immersive nature and malleability of the system, while also interacting socially in the physical world.

Table 2: Use of VR in autism

VR Studies in India on Autistic Population

Review of literature reveals few Indian studies on VR in ASD.

A virtual environment based therapy was proposed by Manju et.al, (2018) to enhance the social skills, emotional skills and attention of the children with autism. The virtual environment included 3 levels, first level focused on increasing attention, second level focused on improving social interaction and third level focused on enhancing decision making. The proposed therapy produced positive results on repetition and it also noticed at what stage these children became panic, frustrated and enthusiastic (Manju, Padmavathi, & Tamilselvi, 2018). VR based joint attention task platform was developed by Jyoti et.al (2020) which was augmented with hierarchical prompt protocol such as using eye cue, head turn, finger pointing, and sparkling cues. The participants included in the study were 20 pairs of age-matched autism spectrum disorder and typically developing children and the study results indicates the potential of the system to identify their deficits in joint attention skills. The study group showed difficulty in following eye cue, the ability to follow finger pointing was the best, and some could pick up merely the sparkling cue. All typically developing participants were able to follow eye cue without requiring other cues (Jyoti & Lahiri, 2020).

A physiology-sensitive VR-based social communication system (which is equipped with anxiety-sensitive feature) was developed by Kuriakose et.al (2017) to improve autism children's performance in a social task. The equipment can objectively identify and quantify one's anxiety level by monitoring physiological biomarkers thus helps to offer tasks of varying challenge levels in an individualized way thereby helping to encourage improved social communication-related performance. This can help to recognize elements of social interaction which is anxiety-provoking for them. Thus in future this system may help to build up a comprehensive social ability learning platform that can improve quality of life of persons with autism (Kuriakose & Lahiri, 2017).The effect of using collaborative VEs during intervention programs for children with autism was studied by Yogeswara et.al (2013). There were 10 subjects in both the experimental and control group. The two tasks given in the study were emotion recognition and theory of mind. In emotional recognition task the subjects were asked to respond only for happy faces when both the neutral and happy faces are presenting. And in the theory of mind task participants were asked to make two judgements; reality judgment and a think judgment. Studies were done during the pre and post intervention stage and compared responses with and without collaborative VEs. Results imply that the presentation of emotional expressiveness as part of VE helped autistic children to communicate without fear and thus recognize others emotions (Yogeswara, Kumar, Santosh, & Anand, 2013).

A study was proposedby Shree et.al (2020) which contributes the children affected with autism to develop managing their safety awareness on fire by recognizing the environment that is about to cause a fire disaster and help them to make exit from the situation. They generated a model environment to create awareness towards the safety on fire by finishing the tasks given through stages and to observe them to examine their task performances and formulate the participants to energetically immerse into virtual experiences. Thus this system helped children with autism to learn about fire cautions, how to react and get away from a fire accident (Shree & Selvarani, 2020).

The literature review of Indian studies on persons with autism indicates that VR can be used in various domains such as to identify deficits in joint attention, intervene on social communication, safety and following social rules.

Conclusion

VR technology has abilities and its benefits in the rehabilitation field mainly in autism are evident from the reviews done in this paper. From the review of Indian studies in autism, it is clear that most of the studies were happened in IIT rather than in a rehabilitation setup. However those study results also revealed positive outcomes in children with autism. Thus in future more studies should occur in India in the field of autism rehabilitation using VR. VR has a huge potential to become a promising tool for autism intervention.

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