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# Impact of Virtual Reality, Augmented Reality and Mixed Reality Technologies in Supporting Life with Disabilities - A Review

K.Pradeep[1], K.Prakasan[2]

[1]*Department of Production Engineering, PSG College of Technology, Coimbatore, India.*
[2]*Department of Production Engineering, PSG College of Technology, Coimbatore, India.*

*Email: [1]kpp.psgtech@gmail.com, [2]kpr.prod@psgtech.ac.in*

***Abstract— Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) is seeing a pharaonic rise due to the developments in computer, graphics, and sensor technologies. Industry 4.0 is acting as a catalyst for the growth of these technologies. This review paper is prepared by percipiencing research papers and medical reports published in the last 25 years where Virtual Reality and Mixed Reality technologies are used to bring solace into the life of disabled individuals. Outcomes of different research are compared and critically analyzed.***

***Keywords—virtual reality, mixed reality, augmented reality, disability***

## 1. INTRODUCTION

Virtual Reality technology has been in vogue since the mid-20th Century. Morton Leonard Heilig invented Sensoroma in 1962, which is considered as the first Virtual Reality hardware ever made [1]. He made this device to enable users to be part of the movie that he has made. Since then, VR technology has grown multiple folds in terms of applications and users. The technology is finding applications in multiple domains such as training [2, 3 and 4], healthcare [5, 6 and 7], data visualization [8, 9 and 10], video games [11,12 and 13], education [14,15,16 and 17] and tourism [18, 19, 20 and 21]. The reason for the widespread acceptance of the technology is attributed to the sharp fall in the price to performance ratio of computers [22, 23], graphic cards [24] and sensors [25]. In the past decade, Virtual Reality technology has been finding its way to the consumer market due to the digitalization of day-to-day activities [26 and 27]. Artificial Intelligence [28], Cloud Computing [29] and 5G technologies are enabling technology firms to scale up their Virtual Reality applications and increase their profit margins. VR technology hit a stagnation point in the late 90's due to the high cost of sensors and graphic technology. Such limitations led to the rise of Augmented Reality in the early 21st century. This technology does not require any additional device other than the smart mobile devices that most people have and use these days. AR technology is intended for the consumer market, which is not willing to invest a lot of capital into VR technology that is still growing into the consumer market. Interest around this technology came to a halt when researchers and developers realised that it provides lesser immersion when compared to Virtual Reality technology. Both Virtual Reality and Augmented Reality are still popular in various domains. Shortcoming of Virtual Reality and Augmented Reality got overshadowed by Mixed Reality which picked the best apples out of both its predecessors. This technology enables the user to experience a very high

level of immersion by rendering a virtual environment on top of real objects which the users can interact with [30].

In healthcare, VR, AR and MR technologies are used for patient rehabilitation [31, 32 and 33], pre-surgery training [34, 35 and 36] and as a possible treatment for trauma [37, 38 and 39]. In this paper we have explored, compared and analysed the outcomes of these technologies in aiding rehabilitation and treatment of various disabilities. According to the World Health Organisation (WHO), over 15% of the human population has some form of disability [40]. WHO defines disability as the inability of an individual to carry out certain tasks or activities. Every individual will exhibit one or more types of disability during their lifetime. Disabilities are very prevalent in the elderly population. In a study conducted by the WHO, it is predicted that the world will have a large percentage of its population over the age 60 years or above by the year 2050 [41]. And thus any interventions that are designed should be suitable for the elderly population as well.

The International Classification of Functioning, Disability and Health (ICF). framework is assisting researchers and healthcare workers to understand qualitative and quantitative data with respect to disability [42]. This framework also helps to determine the kind of intervention a disabled individual will require. According to ICF, there is a relationship between the ability of an individual to carry out tasks or activities, environment in which the individual works or lives, individuals ability to participate in social activities, individuals personal character, body functions, structure and health condition.

The United Nations (UN) too have intervened to support the disabled individuals. The UN 2030 Agenda from which the Sustainable Development Goals (SDG) are derived from have goals and targets set to improve the quality of life of the disabled individuals. The Goal 3 and Goal 10 of the SDG are framed to improve the health and livelihood of the marginalized populations, especially the disabled communities [43, 44 and 45].

## 2. METHOD

The objective of preparing this review paper is to share our interpretations and insights into various methods adopted by researchers in developing interventions for the disabled individuals using Virtual Reality, Augmented Reality and Mixed Reality. We have also compared and discussed the results of papers reviewed to facilitate proper selection of methodology, devices, and participants for future studies.

In this paper, we have explored, compared, and analyzed the outcomes of VR, AR and MR based interventions in rehabilitation and treatment of disabilities. We have considered motor, visual, and cognitive disabilities for this review. These three disabilities are plaguing the majority of individuals. Nine papers published in Scientific Report (4 papers), Eye (1 paper) and Virtual Reality (4 papers) are reviewed in this paper. The average age of participants in the paper selected is twenty five years (Mean Age, M = 25) and total number of participants is 450 (average count per study, n = 17.31). Classifications are not done based on genders. It is assumed that the Assistive Technologies will benefit individuals of all genders equally. We have also enumerated and discussed various hardware and software used for these studies.

## 3. DISCUSSION

We have compared the VR, AR and MR technology based interventions to the conventional interventions. We have reviewed the papers by comparing the studies based on whether the VR/AR/MR applications are created by using only the computer generated environment or a blend of computer generated visuals and real life entities. The qualitative comparison is done by considering various VR,AR and MR parameters like immersion, error, effectiveness of intervention to name a few. Details of the same are summarised in Table I and Table II.

TABLE I. COMPARING RESULTS OF RESEARCH WHERE RECREATION OF REAL WORLD IN THE VIRTUAL ENVIRONMENT

| **Authors** | **Target Function** | **Participant Information** | **Results compared to Traditional Training** |
|---|---|---|---|
| Anglin *et al* [46] | Viscomotor | n = 24<br>M = 23.9 | Immersion ↔<br>Sickness ↔<br>Target error ↔<br>Reaction time ↔<br>Movement time ↔<br>Cognitive response ↑ |
| Rebecca *et al* [47] | Vision | n = 44<br>M = 24 | Capacity of visual working memory ↑<br>Visual processing speed ↑ |
| Nesaratnam *et al* [48] | Vision | n = 3<br>M = 47.33 | Cost of testing ↑<br>Lancaster red-green score ↔<br>Hess screen score ↔<br>Lees screen score ↔ |
| Alain *et al* [49] | Vision | n = 63 | Auditory perception ↔ |
| Chris *et al* [50] | Motor | n = 48<br>M = 23.9 | Task completion time ↑<br>Users perception ↓ |

↔ No Change, ↓ Decreased, ↑ Increased, n = Number of participants and M = Mean Age of the Participants

TABLE II. COMPARING RESULTS OF RESEARCH WHERE CUSTOM MADE VIRTUAL ENVIRONMENT

| **Authors** | **Target Function** | **Participant Information** | **Results compared to Traditional Training** |
|---|---|---|---|
| Yannick *et al* [51] | Vision | n = 60<br>M = 25.1 | Accuracy in men ↑<br>Visual awareness ↑<br>Rod and Frame test ↑ |
| Woong Choi *et al* [52] | Viscomotor | n = 17<br>M = 20.12 | Tracking accuracy (Frontal and Sagittal Plane) ↑<br>Errors (Frontal and Sagittal Plane) ↓ |

| | | | |
|---|---|---|---|
| Girolamo et al [53] | Vestibular system | n = 105 | Vestibular ocular reflex ↑<br>Vestibulo spinal reflex ↑ |
| Sha *et al* [54] | Motor | n = 30 | Task completion time ↔<br>Effectivity of training ↑ |
| Line *et al* [55] | Cognitive and Viscomotor | n = 22<br>M = 23 | Score of copy and recall ↔ |

↔ No Change, ↓ Decreased, ↑ Increased, n = Number of participants and M = Mean Age of the Participants

After reviewing several research papers and reports by WHO, it is observed that 75% of the research is done to benefit the individuals with movement disability (*Table III*). This could be due to the large proportion of the population facing movement disability when compared to other disabilities. This could also be attributed to the fact that ageing and other age related illness causes some form of movement disability. Most papers concluded that the interventions were on the positive side, despite not conducting clinical trials. Authors did indicate the need for such trials and some authors even planned to conduct them after they published their initial findings.

TABLE III. DISTRIBUTION OF STUDIES BASED ON THE TYPE OF DISABILITY

| S.No. | Technology | Targeted Disability | Number of Papers |
|---|---|---|---|
| 1. | Virtual Reality | Movement Disability | 16 |
| | | Cognitive Disability | 03 |
| | | Vision Disability | 03 |
| | | Hearing Disability | 01 |
| 2. | Mixed Reality | Movement Disability | 02 |
| | | Cognitive Disability | 01 |

TABLE IV. SUMMARY OF KEY FINDINGS FROM THE STUDY CONDUCTED BY NASRIN ET AL [55]

| S.No. | Recommended Framework of Intervention |
|---|---|
| 1. | Games based interventions must be user friendly and entertaining. |
| 2. | Participants prefer to engage in the rehabilitation programme along with their family members. |

| | |
|---|---|
| 3. | As participants are not familiar with new technologies, special consideration must be given while designing interventions around them. |
| 4. | As most of the daily activities performed by any individual heavily rely on hands, interventions must be designed to enhance upper limb motor functions. |

From the papers reviewed, it is understood that there is little to no consideration given to the needs of a disabled individual. Interventions were designed around the problem and not the user who is facing the problem (not human centric). WHO's framework is not adopted either. This limits the capabilities of the disabled individual.

The potential of Mixed Reality technology is not explored by researchers while designing interventions around disability (table 2). Although this technology has been there for a while, only a few researchers used it in their work. It is our opinion that the use of Mixed Reality will be more effective and relevant, for studies that involve disabled individuals. This is from the fact that the Mixed Reality technology provided the highest level of immersion when compared to Virtual Reality (and Augmented Reality).

Hardware used in the studies are either commercially available in the market or designed and built for the purpose of the study. And most of these hardware are intended for gaming but repurposed for research. In this study, nineteen commercial and four custom build hardware were used. All the custom built hardware used will require large space to operate and hence is not feasible for intervention at home environment. Enumeration of the devices used is in Table V.

Most researchers have utilized Oculus Rift for their studies. Thus, it is safe to assume that the device is standardised for conducting experiments and designing interventions for the disabled individuals.

There are a lot of interventions designed by doctors who are treating patients with diseases that cause disabilities. Vast majority of the papers reviewed are from NeuroScience

HARDWARE AND SOFTWARE USED IN VARIOUS STUDIES

| S.No. | Parameter / Method |
|---|---|
| 1. | **Commercial Hardware used in studies:**<br>Samsung Gear VR<br>Microsoft Kinect<br>Microsoft HoloLens<br>Nintendo Balance Board<br>Nintendo Fitness Plus<br>Bertec Balance Advantage<br>Leap Motion<br>iPad Touch<br>Oculus Rift<br>nVisor SX HMD<br>Optitrack<br>VICON Nexus Motion Capture System<br>Magnetic Tracker<br>EMG Biofeedback System |

| | |
|---|---|
| | Phantom Omni<br>EEG Sensors<br>ArmeoSpring<br>Braccio di Ferro<br>Force Dimension Delta-6 Robot<br>Intersense IS 1200 Optical Tracking System |
| 2. | **Software used in the studies:**<br>Unity<br>Blender |

## 4. CONCLUSIONS

Although this paper focuses extensively on Virtual Reality and Mixed Reality, it is worth noting that Augmented Reality could provide low cost solutions. The advantages of the technology are not capitalized yet by the research community. Most interventions use VR which is followed by MR and AR. Augmented Reality which lies between the VR and MR must be studied for its feasibility in designing interventions around disability. The technology could add value to cognitive studies and rehabilitation research [56]. Further studies must be conducted to understand the relationship between the accuracy of the virtual environment and level of immersion on the effectiveness of interventions. Based on our analysis, we recommend pursuing VR and MR based solutions for effective treatment and reduced treatment time. Moving towards AR is recommended only when cost of investment is a factor of concern. In continuation of our assessments in this paper, we have decided to build both VR and MR based solutions for the disabled individuals. Outcomes of our studies will be published shortly. VR,AR and MR have the ability to change the lives of the disabled individuals.

We hope that the data presented in this paper helps researchers in their studies and improve the quality, usability and affordability and effectiveness of the interventions that are designed around disability.

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