The emerging role of virtual reality training in rehabilitation

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Abstract

Virtual reality (VR) uses computer-generated simulations to create a virtual environment for users which appears, sounds, and feels like real-life objects and events. The use of VR in rehabilitation is relatively new and has demonstrated to be an effective tool in achieving desired clinical outcomes by active engagement of participants. Over the past few years, the use of VR in rehabilitation has rapidly increased because of its advantages over traditional rehabilitation techniques. These include better patient adherence to the rehabilitation protocols with high levels of engagement and motivation. This review summarises the available evidence on the role of VR in rehabilitation, its effects, and scope across different clinical conditions and outcomes. We also describe the current status of VR utilization in rehabilitation settings across Pakistan and highlight the need for further research.

Keywords: Virtual reality, exergaming, augmented reality, narrative review, neurorehabilitation, advances.

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Introduction

Virtual reality (VR) uses a computer-generated simulated three-dimensional environment to provide a virtual world to the user with seemingly real images and sounds. It provides an interactive environment where participants can visualize, communicate and manipulate with computer-generated illusions, ultimately enhancing their learning for different outcomes.[1] In the past two decades, the use of VR in rehabilitation has increased among healthcare professionals to provide maximum support and quality care to the community.

Types of virtual reality

There are three primary types of virtual reality simulation.

1. **Immersive virtual reality** provides a fully immersive experience of the virtual or non-physical world to the participant involving equipment such as VR glasses, a head-mounted display, headphones, gloves, and possibly a treadmill. This type of VR provides the most realistic simulation environment to the participant who feels a part of the virtual world. This is most commonly used for gaming and entertainment.[2]
2. **Semi-immersive virtual reality** is based on interaction with a partial virtual environment using a screen, displaying real images instead of an avatar in the virtual environment. While it immerses the participants into a different reality, it also allows them to stay connected with their actual surroundings outside the virtual world. Compared to immersive VR, it has fewer side effects such as cybersickness (dizziness and vomiting) and therefore, it is the most commonly used type of VR in rehabilitation practice.[2]
3. **Non-immersive virtual reality** is based on traditional illustrations with a computer-generated environment with no immersion into the virtual world. Body and gadgets are separate, and the user stays fully connected with their physical environment. Non-immersive VR systems make use of equipment such as digital screens, game consoles, keyboards, mouse and controllers.[2]

Use of virtual reality in rehabilitation

VR has been widely used in healthcare, including medical training, patient treatment, telemedicine, disease awareness programmes, and medical marketing. The use of VR is now increasingly common among rehabilitation professionals because of its several advantages over traditional rehabilitation techniques. These include but are not limited to assessment in a more naturalistic environment, safe evaluation of potentially dangerous situations, dual-task assessment, consistency in assessments, better outcome measurements and training protocols, high patient motivation, engagement, and participation.[3] VR also helps overcome the challenges associated with physical, supervised, and person-specific training, which can be expensive, physically exhausting for professionals, time-consuming, and does not meet certain repetition (therapy dose) requirements such as in neurological deficits for neuro-plasticity. In contrast, VR provides easy access to home-based activities, promotes independent and active participation of patients, thereby increasing the repetitions and adherence to the rehabilitation programmes.[3]

Howard (2017) reported that VR rehabilitation programmes

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are more effective than conventional rehabilitation programmes for the improvement in physical outcomes.[4] They proposed three mechanisms for these better outcomes; increased excitement, increased physical fidelity, and cognitive fidelity. Physical fidelity refers to the degree to which a virtual environment appears and sounds real, while cognitive fidelity refers to how a simulator involves the user in cognitive activities used in the real world.[4]

VR is widely used in various fields of rehabilitation and has shown promising effects in health outcomes.

Neurological rehabilitation

VR has been successfully used in different neurological conditions like brain and spinal cord injury, cerebral palsy, Parkinson's disease, attention deficit hyperactivity disorder, dyslexia, multiple sclerosis, and focal epilepsy. VR programmes mainly target motor control, posture, balance, movement disorders, strength and endurance in these conditions and it has shown more potential for improvement than the traditional rehabilitation interventions.[5]

Musculoskeletal rehabilitation

VR has also been used in various musculoskeletal conditions such as osteoarthritis, rheumatoid arthritis, post total knee arthroplasty, chronic low back pain, cervical pain, adhesive capsulitis, and fibromyalgia. The primary outcomes in these conditions are endurance, strength, and functional impairments. A systematic review reported significant positive effects of VR in chronic neck pain, shoulder impingement syndrome, rheumatoid arthritis, knee osteoarthritis, ankle sprains, and cruciate ligament reconstruction; however, the evidence on effects of VR in fibromyalgia, back pain, and knee arthroplasty was inconclusive.[6]

Cardiopulmonary rehabilitation

VR has shown significant improvements in cardiovascular conditions such as coronary artery disease, stable heart failure, coronary artery revascularization, valve replacement surgeries, angioplasty, cardiomyopathy, prehypertension and other cardiac pathologies and pulmonary conditions like chronic obstructive pulmonary disease. The use of VR improved endurance, functional performance, pain and ability to walk, energy expenditure, high-density lipoprotein cholesterol, body composition, and quality of life in patients with cardiopulmonary diseases.[7]

Sports rehabilitation

VR has been used as a training tool for athletes and other sports professionals. A VR-based training in sports has several benefits such as supporting athletes to train (cycling, walking, weightlifting, rowing, and running) irrespective of weather situations, geographical variation to compete with other athletes and allowing accurate and replicable control over features of the virtual environment.[8]

Psychosocial rehabilitation

VR based interventions have been successfully utilized for the management of anxiety disorders, depression, psychosis, bipolar disorder, substance disorders, eating disorders, phobias, stress, post-traumatic stress disorder and schizophrenia.[9]

Specific clinical outcomes addressed by virtual reality

The clinical outcomes that the rehabilitation professionals can potentially target through VR in different conditions include but are not limited to motor control, balance, gait, strength, pain control, improved physical endurance, mental well-being, reduced fatigue, and better cognition.

1. **Motor control:** VR provides a specific enriched environment to re-learn motor skills and tasks through repetitive training, task specificity, problem-solving, and experience stimulating neural plasticity in neurological deficits like stroke, brain injury and multiple sclerosis.[10]

2. **Balance:** VR provides multi-sensory feedback through virtual environments and offers audio-visual cues, generating synaptic activities and improving collateral networks within the brain to enhance the patient's balance abilities.11 VR has demonstrated beneficial effects in improving balance in stroke, Parkinson's disease, multiple sclerosis, cerebral palsy, and traumatic brain injury.[12]

3. **Gait and walking abilities:** VR provides a dynamic set of tasks where weight shift, body movements, small steps, reactive balance, and objective progression during the VR experience improve locomotor abilities. VR significantly improved the walking speed, distance covered and the number of steps per day.[12]

4. **Strength:** The exact mechanism of how VR improves muscular strength is unclear. However, VR has a diverse set of applications and can change a simple task to a complex activity based on the user's ability and provides a natural environment for intense activities, ultimately improving strength. In a 2015 study patients with Parkinson's received task-oriented resistance training incorporated in a virtual environment such as heel raise, squats, and stepping resulting in significant improvement in muscle strength and walking ability.[13]

5. **Pain:** The current evidence supports use of VR as a valuable pain distraction intervention with minimal side effects. A systematic review showed that VR experience was an effective non-pharmacological intervention for individuals experiencing pain from burn injuries or acute or chronic medical procedures.[14]

6. **Fatigue:** Fatigue is a debilitating problem for individuals suffering from conditions like stroke, multiple sclerosis, cancer, kidney failure, pulmonary diseases, and autoimmune disorders. A recent systematic review suggested an inverse relationship of VR training with fatigue levels. However, there was limited evidence available, and further studies are needed to make strong inferences.[14]

7. **Cognition:** There is evidence to support VR use for cognitive training in individuals suffering from cognitive impairments. Cognitive training aims to maintain or improve higher mental functions like attention, concentration, memory, and problem-solving skills. Zhao et al. (2020) in a systematic review reported that exergaming is beneficial in improving cognitive function in people with dementia or mild cognitive impairments. The proposed underlying mechanism could the rich environment provided by VR games which stimulates brain functioning.[15]

The use of Virtual reality rehabilitation in Pakistan

Although VR rehabilitation is being used in the USA and Europe for more than 2 decades, it is relatively a newer rehabilitation tool in Pakistan. Only few centers have the VR rehabilitation set-up, and all are in the major cities of Pakistan. However, the research on the use of VR in rehabilitation has increased in the last few years. A literature search in August 2021, revealed 14 published research studies on the use of VR in rehabilitation in Pakistan. The most common VR device used was X-box Kinect 360. Most studies suggested that VR is an effective tool compared to the traditional exercise programmes in terms of goal attainment, motivation, and engagement. All studies demonstrated beneficial effects of VR; however, most studies were either limited to the elderly population or neurological conditions only targeting balance, mobility, and function. In addition, many studies lacked statistical power and used a weak experimental research design. Future studies with larger sample sizes targeting other conditions and outcomes with stronger research designs are needed to make better conclusions about the scope of VR rehabilitation in Pakistan

Conclusion:

The current literature supports the use of VR as an innovative, engaging, and cost-effective tool for rehabilitation professionals. It has been successfully used in many neurological, cardiopulmonary, and musculoskeletal disorders with good outcomes. It has certain advantages over the traditional rehabilitation interventions which should be considered while making a rehabilitation plan. The research and use of VR rehabilitation is increasing in Pakistan and there is a need to improve the quality of research in order to generate high quality evidence.

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