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The Effect of Long-Term Use of Virtual Reality Training on Cognitive Deficits in Post-Traumatic Brain Injury (TBI) Patients – Case Report

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Abstract

Traumatic brain injury (TBI) can result in significant impairments in executive function, memory, and attention, adversely affecting daily functioning and rehabilitation outcomes. Cognitive rehabilitation after TBI is a challenging process often requiring training in daily living skills. While traditional rehabilitation methods benefit TBI patients, modern innovations like virtual reality (VR) offer promising potential for cognitive recovery. This study aimed to investigate the potential benefits of virtual reality-based therapy for improving cognitive function in individuals with traumatic brain injury. A single-case study was conducted involving a 23-year-old male with TBI, recruited from the neurosurgery rehabilitation ward of Saveetha Medical College and Hospitals. Pre- and post-test measurements were taken using the Digit Span Test and the Montreal Cognitive Assessment (MoCA). The patient underwent a 10-week rehabilitation protocol, including VR-based therapy, delivered six times a week for one hour per session. The MoCA score improved from 18 (pre-test) to 27 (post-test). The Digit Span forward test score increased from 4 to 7, and the Digit Span backward test score improved from 2 to 4. These findings indicate significant improvements in cognitive function following the VR-based intervention. This study highlights the potential of virtual reality as a valuable tool for enhancing cognitive recovery in individuals with traumatic brain injury.

***Keywords**: Cognition Rehabilitation, Digit Span Test, MoCA, TBI, Virtual Reality.*

Introduction

Traumatic brain injury (TBI) is a major contributor to cognitive impairments, which can manifest as memory deficits, challenges with concentration, and difficulties in problem-solving and decision-making. [1, 2] Cognitive impairment refers to a reduced ability to perform mental tasks and is often linked to diminished executive functioning. Recovery through cognitive rehabilitation after a TBI is a complex and lengthy process, typically involving training in daily living skills [1, 3, 4]. In India, TBI is a leading cause of illness, disability, mortality, and significant socioeconomic consequences, with an estimated 1.5 to 2 million people sustaining injuries and 1 million fatalities annually [5-7]. The outcome upon discharge and the quality of life in the future are directly correlated with the severity of the brain injury. The proportion of individuals surviving serious brain injuries has increased in recent years as a consequence of advancements in technology, medicine, and intensive care therapy. Still, the survival quality is quite low and inconsistent with the restoration of any meaningful capacity [5, 8]. There have been some successful attempts to enhance attentional processes through the use of pharmaceutical agents to raise cerebral arousal-activation; however, there is little evidence that stimulant medication has a major or long-lasting effect, and this method also exposes the patient to adverse or potentially hazardous side effect [9-11]. The goals of

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traditional rehabilitation therapies are to help TBI patients with their emotional, cognitive, and physical impairments [12]. On the other hand, new and innovative technologies, including virtual reality (VR), provide an engaging method of improving cognitive recuperation. VR is a real-time computer-generated artificial world with distinctive sensory features that can interact with the real time [13-15]. In rehabilitation, VR use could help in repetition, feedback, and motivation. Training that is both dynamic and valid is made possible by the use of 3D interactive virtual reality settings in rehabilitation [16, 17]. A popular neuropsychological test for evaluating memory retention, concentration level, and cognitive flexibility is the Digit Span Test. It tests people's ability to manipulate and store information in the short term by requiring them to remember digit sequences in either forward or reverse order [18]. The Montreal Cognitive Assessment (MoCA) is a tool used to screen for mild cognitive impairments, focusing on areas such as memory, attention, and executive function. Introduced by Nasreddine and colleagues in 2005, it has proven to be more effective than the MMSE in detecting cognitive issues at an early stage. Its effectiveness has been validated in various populations, including patients with Alzheimer’s, stroke, and traumatic brain injury. MoCA's reliability in clinical practice and research has made it a standard for early cognitive screening [19, 20]. This case study investigates the impact of virtual reality training on a patient's cognitive deficiencies following a traumatic brain injury (TBI) utilizing the Oculus operating system.

Case Description

Subject: A 23-year-old male presented after a road traffic accident that occurred on 8th August 2023 at 8:00 PM in Thimmasamudram, involving a collision between a two-wheeler and a truck. Upon arrival, the patient was in critical condition with a Glasgow Coma Scale (GCS) score of E1VTM1. A CT scan revealed a hemorrhagic contusion in the left temporal region, a subdural hemorrhage in the left occipital region, and subarachnoid hemorrhages in the bilateral frontal regions. The patient underwent surgery, which successfully resolved the intracranial hemorrhages. Initially, his condition was complicated by severe lung secretions, unstable vital signs, and a persistently low GCS. Once stabilized, he was referred to the neurosurgery rehabilitation department to begin physiotherapy for further recovery.

Subjective Examination

History of present illness (HPI): The patient came with complaints of cognition problems like memory, difficulty in planning and problem solving, difficulty in speaking with balance and coordination problems, and ataxic gait. Current functional status: patient was less confident and unable to perform multitasking, and cerebral ataxic gait is present, unable to perform memory and task-oriented complex activities. Medical history: no history of diabetes and hypertension. His employment history, financial status, and family circumstances were all unremarkable.

Objective Examination

On Observation*:* The patient was conscious and oriented, Ectomorphic, Abdomino-thoracic pattern of Respiration. While lying supine, the upper and lower limbs on the left side were externally rotated, adducted, and extended. The patient upper extremity is extended, slightly abducted and externally rotated and wrist was grapped around the side of bed and lower extremity in flexion, ankle plantarflexion in sitting. standing was fully supported. No noticeable deformities, muscle wasting, or swelling were observed. The patient's vital signs were stable, and there were no signs of distress.

On Examination*:* Vital signs were

measured before and after each treatment session. Blood pressure ranged from 110 to 170 mmHg systolic and 90 to 110 mmHg diastolic. Body temperature was between 96°F and 98°F, oxygen saturation (SpO_2) varied from 96% to 100%, pulse rate ranged from 70 to 82 beats per minute, and respiratory rate was 16 to 22 breaths per minute.

Investigations

Patient went for CT for brain and thorax region. and in the CT diagnosis, which revealed hemorrhagic contusion in the left temporal region, sub-dural hemorrhage in the left occipital region, and sub-arachnoid hemorrhage in the bilateral frontal region. The CT thorax showed multifocal patchy dense air bronchogram and round glassing noted in the right upper lobe and bilateral lower lobe.

Physical Diagnosis

The power of both the lower limbs was 3/5. The patient's gait pattern was cerebral ataxic with very poor balance and coordination. patient's upper limb strength was 3/5. patient had intentional tremor while doing activities. patient is partially dependent.

Outcome Measures

The initial examination was done using the GCS and RLA, which are standard scales, and initially the patient had a low GCS, which is the score of 5/15; later it went up to 15/15. Similarly, RLA level was IV; later, it increased up to level VII. For evaluating cognition, we used the Montreal Cognitive Assessment (MoCA), in which visuospatial, memory, attention, language, and recall were assessed: visuospatial/executive (3/5), naming (3/3), attention (2/6), language (2/3), abstraction (0/2), delayed recall (2/5), and orientation (5/6).

Digit span scale is an effective tool for assessing memory, attention, and recall. In which we asked some random sequence of no and the patient said in forward order and backward order: digit span forward (4), digit span backward (2)

Materials and Methods

A single case study was conducted in a Rehab Department. The study involved a 23-year-old male patient with cognitive deficits post-Traumatic Brain Injury (TBI). The objective was to assess the effect of VR training using the Oculus operating system on cognitive deficits. The study was assessed pre-test and post-test using Montreal Cognitive Assessment (MoCA) and Digit Span Test. After 48 hours of admission, individuals with history of TBI who had finished the initial clinical evaluation were placed in the program of rehabilitation. The patient underwent an extensive medical evaluation following the acquisition of their signed informed consent, and information on their sociodemographic, educational background, current neurological conditions, radiological findings, and biochemical was documented. Motor, cognitive, and functional outcomes were evaluated. The study conducted ten weeks, consisting of six sessions per week. Each session involved fifty minutes of virtual reality training. Alongside virtual reality, patients underwent standard rehabilitation to address neuromuscular impairments. This routine care encompassed stretching, resistance exercises, progressive gait training, spasticity management, physical therapy to enhance alignment, and locomotion exercises. The virtual reality rehabilitation program was developed using Cognifit Software. This application provides cognitive training exercises in a virtual environment, focusing on enhancing memory, attention, and other executive functions. For detail follow table 1. After the completion of 10 weeks of intervention the patient underwent assessment using Montreal Cognitive Assessment (MoCA) and Digit Span Test. The pretest and posttest values were tabulated and compared for better understanding [21, 22].

Intervention

Over a 10-week period, the patient underwent 60 treatment sessions, with one session per day lasting 50 minutes (Table 1). One session incorporated standard physiotherapy techniques, while the other involved clinical Pilates exercises.

Table 1. Exercises given to the Patient

Types of Exercise	Activities Given to the Patient
Memory Exercises	Patients can engage in memory recall exercises in virtual reality (VR), such as recollecting the locations of the items in a virtual room and resolving puzzles that demand for the recollection of previously taught material.
Attention Training	Patients can practice sustained attention by participating in tasks such as virtual object tracking, which requires them to monitor moving objects or identify differences between things.
Problem-Solving	Virtual reality environments mimic real-world situations like organizing items, making a plan, or figuring out a series of challenges. Patients are able to enhance their decision-making and executive functioning skills as a result.
Spatial Navigation	Patients can engage in spatial memory exercises such as following instructions or traversing virtual mazes to follow the visual clues.

1st Week to 3rd Week: Following the establishment of long-term goals, standard physiotherapy exercises were implemented alongside virtual reality (VR) training. These included bed mobility exercises, muscle strengthening routines, self-assisted range of motion activities, perturbation exercises, mat-based activities, and mobile games designed to enhance attention. Before VR training, the patient was not interested in exercises like peg board activities and other attention activities. The VR training was done by some different types of attention-related games using cognifit software. After 3 weeks of training, MoCA score improved from 18 to 21, digit span forward score increased from 4 to 5, and digit score backward from 2 to 3.

4th Week to 6th Week: Following the improved cognition after 3rd week, patient now have interest in normal exercises like dynamic balance and peg board activities. Fear of falling was also reduced during these activities. In 4th week, we added sitting without any support with other physiotherapy exercises and asked the patient to control and focus to prevent himself from falling. Similarly, in 5th week we added standing without any support with preventive measures of fall and asked the patient to control his own body, and we continued this same protocol for 6th week. After 6th week, MoCA score increased to 24, digit span forward score increased to 6, but digit span backward score remained the same as 3.

7th Week to 10th Week: After 6th week of sitting balance increased; without support, the patient can stand, but the pattern of gait is still the same with support. patient was now interested in attention training and also fearfulness significantly decreased but still there. But after some training, the patient was getting bored and did not want to go with cognitive training protocols. But the patient was interested in VR training. In 7th and 8th weeks since the sitting balance was improved, we aimed for static and dynamic standing balance with VR training. In the 9th and 10th week we started initiating walking balance, but the ataxic type of gait remained. After 10th week, the MoCA scores increased to 27, the digit spans forward score increased to 7, and the digit span backwards score increased to 4.

Results

The results of this study show significant improvements in cognitive function following a 10-week virtual reality (VR) training program for a traumatic brain injury (TBI) patient. Montreal Cognitive Assessment (MoCA) scores increased from 18 (pre-test) to 27 by the 10th week, reflecting enhanced cognitive performance. Digit Span Forward scores improved from 4 to 7, indicating better attention and working memory. Digit Span Backward scores increased from 2 to 4, highlighting gains in executive function and cognitive flexibility (Table 2 and Figure 1). These findings suggest that VR-based therapy, combined with standard physiotherapy, can effectively enhance memory, attention, and overall cognitive abilities in TBI patients.

Table 2. Result Analysis with MOCA, DIGIT SPAN before and after Intervention

Test	pretest	3rd weeks	6th weeks	10th weeks
MoCA Total Score	18	21	24	27
Digit Span Forward	4	5	6	7
Digit Span Backward	2	3	3	4

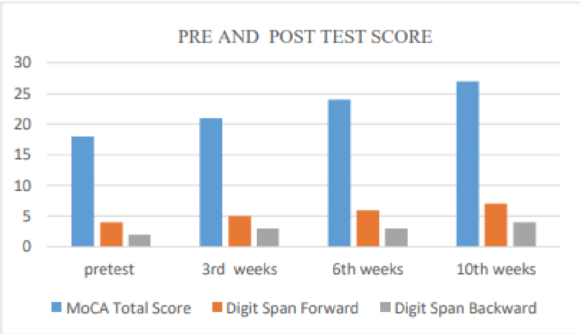

Figure 1. Pre and Post Result

Discussion

This case report explores the impact of virtual reality (VR) on cognitive impairments in a patient with traumatic brain injury (TBI), focusing on areas such as memory, attention, and problem-solving. Similar to the findings by Rosaria et al., which highlighted the benefits of VR cognitive rehabilitation in enhancing visuo-executive functions and coping strategies in severe TBI, our case demonstrates how customised VR interventions can effectively address individual cognitive needs. Like the VRRS system described, our approach utilized tailored virtual exercises targeting specific subdomains, aiming to promote neuroplasticity and active patient participation while potentially alleviating depressive symptoms [23]. Systemic obstacles to providing effective treatment for traumatic brain injury (TBI) in Pakistan's primary and secondary healthcare settings. The study highlighted the significance of established protocols, training, and technological advances to address current deficiencies in TBI management [24]. Larson et al. emphasized the safety and feasibility of VR for cognitive rehabilitation, reporting minimal side effects and notable improvements in attention and cognitive engagement. Similarly, our case shows that the immersive and interactive aspects of VR significantly enhanced the patient’s focus and adherence to therapy. These parallels highlight VR's potential to create a stimulating, controlled environment for addressing cognitive deficits in TBI [25]. De Luca's findings on non-immersive VR also align with our results, particularly in demonstrating improvements in attention processes such as task-switching and sustained focus. While non-immersive VR offers a less intense sensory experience, our case underscores the adaptability of VR-based interventions in meeting patient-specific needs, reinforcing its utility as a practical adjunct to conventional cognitive rehabilitation. Like these studies, our findings support further exploration of VR in clinical settings to validate its long-term efficacy and scalability [26].

Conclusion

A 10-week VR training program combined with conventional physiotherapy significantly enhanced cognitive functions in TBI patients. Notable improvements were observed in MoCA scores as well as Digit Span Forward and Backward tests. These findings suggest that VR training is a promising intervention for TBI rehabilitation, warranting further research to establish evidence-based practices.

Conflict of Interest

Authors declare no conflict of interest.

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