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Improving Cognition and Motor Performances Through Fully Immersive Virtual Reality Using on a Head Mount Device Among Patients with Chronic Stroke

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Abstract: A stroke can negatively affect several areas of cognitive function. There have been several attempts to improve the disability status of patients with chronic stroke (CS). In recent years, technological innovations such as immersive virtual reality (IVR) systems using head-mounted display (HMD) devices have proven actual in ameliorating motor and mental impairments in patients with neurological illnesses, together with CS. The aim of the study is to prove that an IVR game program using an HMD is as effective as traditional virtual reality rehabilitation, which is expensive and has high set-up costs. The study was designed to evaluate the cognitive and motor outcomes after IVR rehabilitation for eight weeks in patients with CS and to compare them with a control group. All patients were randomized to a control group (17 persons) in conventional cognitive rehabilitation and an experimental group using IVR-HMD (17 persons). The IVR-HMD intercession package (3 periods per weak, 100 minutes per episode) includes virtual reality game content to improve consideration, recall, and dealing out speed. Cognitive assessments were performed using the Mini-Mental State Exam (M.M.S.E.) and Symbolic Digit Substitution Test (S.D.S.T.) before rehabilitation therapy and after treatment. Physical work was evaluated employing a gait speed test, 8-foot up-and-go test, and handgrip test. The autonomous t-test or chii-square test was utilized to measure the distinction between the starting point (start of intercession) factors. After a study, there were no significant changes in MMSE scores within either group. However, on the SDST, the IVR-given group displayed a substantial advance compared to the controller group (before: 33.4 ± 9.0, after: 39.6 ± 9.5, $p = 0.02$). The group $*$ time interaction for SDST was also substantial, representing that IVR-based intellectual exercise had a helpful effect on cognitive function. Grip strength (before:22.3 ± 6.1, after: 24.3 ± 5.5, $p = 0.03$), gait speed (before: 1.15 ± 0.32, after: 1.19 ± 0.37, $p = 0.04$), and the 8-foot up-and-go test (before: 6.76 ± 1.46, after: 6.33 ± 1.92, $p = 0.02$) presented important advance in the IVR-treated cluster compared to controller's. The finding suggests that the IVR-HMD treatment had a positive impact on upper limb strength, gait speed, mobility, and cognitive function of chronic stroke patients. These results suggest that IVR gaming programs using HMDs are as effective as traditional VR rehabilitation programs, and may even replace them. Further research in this range is needed to approve its longstanding efficiency and probability.

Keywords: Head-mounted Demonstration, Immersive Virtual Reality, Bodily Rehabilitation, Cerebrovascular Illness

1. Introduction

At present, stroke was the most frequent source of death around the world and the second greatest

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common cause of disabled life for a long time in the world[1]. "Chronic stroke patients" refers to individuals who have experienced a stroke and are in a phase of their recovery that typically extends beyond the acute stage, which is often considered to be several months or more after the initial stroke event. As restorative medicine progresses, mortality rates are diminishing. Keeping patients spurred is one of the issues with today's conventional rehabilitation medicines, as patients regularly see working as repetitive and tedious[2].

Recently, virtual reality (VR) has been considered to rehabilitate stroke patients[3]. A randomized control exploration comparing physical, cognitive, and VR workouts among typical elderly showed noteworthy changes in VR workout as well as in cognitive function, with older grown-ups inclining toward VR exercise to physical workouts[4]. VR may be a computer reenactment environment that is exceptionally comparable to real-world circumstances and scenarios, giving clients a feeling of "being there" physically[5].

The utilization of completely immersive VR (IVR) for cognitive stroke restoration, with a few requiring specialized apparatuses and controllers, has been suggested as a replacement with most of the exertion being thru screen-founded VR[6][7]. There are moreover works that utilize the complete potential of head-mounted devices (HMDs) without console and mouse interaction[8]. The work displayed in this paper is unique in that it could be a completely IVR amusement that utilizes commercially accessible HMDs.

IVR-based cognitive preparation has as of late picked up significance in neurological investigations. A later meta-analytic consideration detailed that semi-immersive VR emphatically impacts cognitive and physical function in individuals with neurological diseases[9][10]. A full IVR cognitive preparation considered for individuals with cognitive impedance appeared with more noteworthy sentiments of security, fulfillment, less uneasiness and weariness, and less inconvenience compared to writing and paper preparation[11]. These focal points of IVR over pen-and-paper cognitive preparation may offer assistance in progress adherence to cognitive preparation and may be a successful mediation for chronic stroke patients[12].

IVR gaming using head-mounted devices (HMDs) can offer many benefits in the rehabilitation of stroke patients. Here's how it compares to rehabilitation using traditional virtual reality devices: VR using HMDs provides a high level of realism. This helps stroke patients to rehabilitate in a more realistic environment. This realism helps stroke patients with the recovery of brain function and the improvement of motor skills. The level and difficulty of the game would be adjusted to focus on what the patient needs, depending on their physical ability and level.

IVR is progressively utilized in health-related areas and intercessions and may be a compelling instrument to delay the progress of degenerative brain and psychiatric diseases[13]. However, existing IVR therapy equipment and programs are expensive, inaccessible, and boring for patients. There was a need to develop a cheaper, more accessible, and less boring treatment. The author believes that IVR games using HMDs can meet this need. However, there have been few studies using these HMD gaming devices in therapy and we felt that a more systematic and scientific study of their effectiveness was needed.

Until now most studies still depend basically upon non-immersive or semi-immersive VR[14], and the paybacks caused by fully immersive VR in stroke restoration have not been completely investigated. In this manner, there is a need to examine the impacts of full IVR mediation on cognitive and physical work in stroke patients. The purpose of this paper is to study cognitive outcomes after rehabilitation training with IVR in chronic stroke victims.

The research questions or hypotheses were as follows: First, is IVR on HMDs effective in the rehabilitation of stroke patients? Second, is it as effective as conservative rehabilitation? Hypothesis: IVR game programs using HMDs will be as effective as conventional virtual reality rehabilitation, which is expensive and has a higher setup cost.

2. Research Methodology

2.1 Participants in the Study

The research investigation used a randomized controlled test plan to investigate the impact of IVR using HMD (IVR-HMD) cognitive training on stroke survivors. The study enrolled 34 community-dwelling stroke survivors as participants. Participants were 19 to 79 years of age, and belonged to the adult population. These participants were haphazardly allocated to either the controls or the virtual reality intervention cluster. Between March 2021 and January 2022, 34 community-dwelling stroke survivors were enlisted. Members were at first screened from a stroke registry database to distinguish candidates and constrain the probability of screening failure. Consideration criteria were as follows.

:(1) involvement of one-sided stroke at least six months and no more than 120 months earlier, (2) inactive extension of movement of the paretic arm, elbow, wrist, thumb, and fingers inside 20° of typical; (3) capacity to communicate as decided by the specialist at baseline testing. Exclusion criteria incorporate (1) injuries within the brainstem/cerebellum which will meddle with the visual perception/cognitive capacities required for motor relearning, (2) the existence of other neurological conditions which will impede engine learning capacities, (3) orthopedic conditions or remedial vision clutters that modify coming to capacity, (4) serious cognitive disability (Montreal Cognitive Evaluation score <20); (5) extreme aphasia; (6) failure to read; (7) congestive heart failure, unsteady cardiac arrhythmia, hypertrophic cardiomyopathy, serious aortic stenosis, angina pectoris, or a history of shortness of breath at rest or amid exercises of day by day living; (8) elderly cognitive impedance, who are inadequate to employ virtual reality glasses 'Oculus Quest' which could be a VR-only game framework.

2.2 Randomization

To avoid selection bias, the study employed a computer-generated fixed-block randomization strategy. This approach ensured that participants were assigned to groups in a way that balanced important factors like age, sex, disease duration, and participating center.

An additional 34 subjects were included at the start, who were haphazardly allotted to either controls (nr = 17) or the VR intercession group (nr = 17). In order to maintain a strategic distance from the predisposition of the determinants, a computer-generated randomization of the fixed blocks strategy was used. to haphazardly allow members to intercession or control groups, making squares stratified by age, sex, disease duration, and taking part centrals. The mean age of members ranged 63.5 ± SD 5.31 years old.

2.3 Ethical Considerations

Ethical approval (reference number 2202-018) was attained from the Institutional Review Boarding of the Dankook School Hospital before the trial begins. No information that could identify individual participants, was collected and the survey was completely anonymous. The voluntary and anonymous nature of the survey and their right to withdraw from the survey before the proposal was explained to participants. Data collection, processing and storage were in accordance with Data Protection Regulations.

2.4 Interventions

The intervention group (EG) received VR-based cognitive training using Oculus VR goggles, specifically the Oculus Quest 2 headset. The VR program included four different activities aimed at improving various cognitive and motor skills. The EG performed up to 24 schedules of IVR-cognitive preparation over two months. There were three schedules at a week, and every IVR preparation schedule went 100 minutes, scattered with coaching on VR preparing and ocular extending works out. The control gathers (CG) got only conventional cognitive rehabilitation utilizing pencil-and-paper strategies. In summary, both groups got the same sum of neurorehabilitation sessions, but only the EG has gotten cognitive preparation utilizing IVR.

Intercessions were performed exclusively, as most of the diversion strategies were accessible on the stage. All recreations were played standing up, and a few were uprooted, which may spur the client to move. The portrayal of the diversion within the intervention program and the information to take after each diversion are as follows. The EG understanding performs work out in a virtual world made of Oculus VR goggles (HMD) with three-dimensional pictures. The essential HMD utilized amid improvement was the Oculus Quest 2. The amusement is outlined to utilize eye-hand coordination, an ability that is regularly impeded after a stroke, making it fundamental for everyday living capacities. The virtual reality program comprises four sorts of exercises: First is “Beat Saber", which is a cadence amusement where you employ lightsabers to slice pieces in time with the music. It can make strides in arm and upper body development and coordination. The second is "Racket: Nx", which is a diversion that combines tennis and squash. It can make strides in hand and arm development and improve body coordination. Third is "Tetris Impact", which is a present-day and outwardly shocking take on the classic Tetris puzzle game. It can offer assistance to make strides in center and spatial cognition aptitudes. The last one is "Greenery", which is an action-adventure diversion where players are involved in the enterprises of a little mouse named Plume. It can upgrade problem-solving capacities and spatial cognition.

2.5 Assessment

Outcome Measures: The purpose of the investigation was to evaluate the efficiency of IVR-HMD interventions in improving frontal mental function (processing, memory, and performance function) by assessing changes from starting point to 8 weeks using neuropsychological assessment.

Each patient has gotten a total neuropsychological assessment before and promptly at the end of the study (i.e., T0 and T1, separately). The Mini-Mentality State Exam (MMSE) has been utilized to survey general cognitive work[15]. The electronic tablet form of the Symbolic Digit Substitution Test (SDST) was utilized to survey frontal lobe functions[16]. Within the SDST, nine sets of numbers and images appeared on the beat one-half tablet show, and subjects were asked to coordinate the comparing numbers and images that appeared on the foot half of the show. During SDST, the shorter the total test time, the better the cognitive performance.

Physical work was evaluated employing a strolling fastness test, portability test, and grip test. The strolling rapidity test was 7.0 m long, counting a 1.6 m speeding up separately, a 4.0 m "favored strolling speed", and a 1.5 m slowing down. To evaluate portability, an 8-foot up-and-go test of 2.44 m was utilized. Hand hold quality (HHQ) of the lesser hand was counted with an advanced manual dynamometer (TKP 5201 Grip-D Tadei, Tokyo, Japan). HHQ was calculated twice and normal esteem has been utilized for factual examination. Sociodemographic factors such as instruction, age, pharmaceutical, and smoking were collected by a prepared analyst.

In summary, the study conducted assessments before and immediately after the intervention (at T0 and T1, respectively). These assessments included various measures of cognitive function and physical abilities, such as MMSE, Symbolic DSTest, walking rapidity test, movement test, and grip strength test.

2.6 Data Investigation

All comparisons have been two-sided evaluations (alpha level = 0.05). All measurable investigations have been analyzed utilizing SPSS Measurements for Windows (IBM), adaptation 25.0, 2017 program bundle (Chicago, Illinois, USA). The Shapiro-Wilk test has been utilized to confirm typical information dispersion. The t-test or chi-square test has been utilized to measure the distinction between the starting intercession factors. An iterative estimation ANOVA demonstration was utilized in order to perform group-to-group comparisons of nonstop factors. Duration was treated as a categorical variable, and the evidence involved clusters, duration, and group-specific intellect as fixed effects. Conclusions regarding the adequacy of VR mediation were based on comparing frontal cognitive work change from baseline to eight weeks, assessed by MMSE, DST between groups.

In summary, this research study used the randomized controlled study design to investigate an impact by IVR using HMD (IVR-HMD) cognitive training on stroke survivors. It compared the outcomes of stroke survivors who received IVR interventions with those who received traditional cognitive rehabilitation, with a focus on cognitive and physical function assessments before and after the intervention.

3. Results and Discussions

3.1 Interpretation of Data

[Table 1] shows the socioeconomics and standard physical and cognitive function of the considered populace. There were no critical contrasts in restrictions between the intercession and control clusters at a starting point. In both the IVR treatment group and the control group, the study enrolled a similar number of participants, with slightly more men in the control group (9 vs. 7). Additionally, the average age, height, and BMI were quite similar between the two groups, indicating that the randomization process successfully balanced these factors. Both groups had similar baseline values for weight, height, and BMI. These values fall within a relatively healthy range, suggesting that the participants had reasonably good overall health. Diastolic blood pressure was slightly higher in the control group. These differences were relatively small and may not be clinically significant. The duration of illness was quite similar in both groups, indicating that the groups were well-matched in terms of how long they had been living with stroke-related impairments.

Baseline measurements of grip strength, gait speed, 8-feet Up and Go, k-MMSE, and Symbolic DST were collected. The baseline values for these variables were reasonably consistent between the two groups, indicating that there were no significant baseline differences that could skew the results.

[Table 2] shows comparing physical and global mental function.

Grip Strength: The IVR treatment group showed a statistically significant increase in grip strength from baseline to post-intervention (before:22.3 S.D. 6.1, after: 24.3 S.D. 5.5, p = 0.03), suggesting that IVR-based mental training had a positive outcome on upper limb strength. On the contrary, the controls have not shown a significant change in grip strength. This indicates that the VR intervention had a specific impact on upper limb strength improvement. Gait Speed: Gait speed increased significantly in the IVR treatment group (before: 1.15 S.D. 0.32, after: 1.19 S.D. 0.37, p = 0.04) but decreased slightly in the controls. The group * time interaction was substantial (p = 0.01), indicative of that the improvement within gait speed was more pronounced in the IVR treatment group. This suggests that VR interventions may enhance walking abilities in stroke survivors. 8-feet Up and Go: The IVR treatment group exhibited a significant reduction in the period engaged to complete the 8-feet Up and Go test (before: 6.76 S.D. 1.46, after: 6.33 S.D. 1.92, p = 0.02), while the control group showed no significant change. Although there was no significant group x-time interaction, this finding suggests that

VR-based interventions may contribute to improved mobility and agility.

Cognitive Function (MMSE and SDST): There were no significant changes in MMSE scores within either group. However, on the SDST, the IVR-treated cluster showed a substantial advance compared to the control cluster (before: 33.4 S.D. 9.0, after: 39.6 S.D. 9.5, p = 0.02). The group x time interaction for SDST was also significant (p = 0.03), indicating that IVR-based mental training had a helpful outcome on cognitive function, specifically on tasks related to symbol-digit substitution.

In summary, the data from [Table 2] suggest that the IVR-HMD treatment had a positive impact on upper limb strength, gait speed, mobility, and cognitive function, particularly in tasks related to symbol-digit substitution. These findings support the hypothesis that immersive virtual reality interventions can be beneficial for stroke survivors in terms of both physical and cognitive rehabilitation. The control group, which received conventional rehabilitation, did not show the same degree of improvement in these areas.

[Table 1] Chosen the Body Estimation, Cognition, and Body Utilitarian Features of the Subject within the Starting Point

Variable quantity	IVR treatment	Control
Nr (men)	34-(7)	34-(9)
AGES (Y old)	62.6 (5.5)	62.7 (5.6)
Height(meters)	1.57 (.09)	1.58 (.08)
Weight(kg)	58.7 (8.9)	60.3 (8.8)
B.M.I. (kgs/m^2)	024.5 (3.1)	024.3 (02.8)
S.B.P. (mgs/Hg)	130.2 (11.5)	129.5 (18.5)
D.B.P. (mg/Hg)	75.4 (10.9)	70.3 (11.6)
Length of illness (Years)	2.3 (1.4)	2.2 (1.5)
Grip strength (kilograms)	22.3 (7.0)	23.1 (5.2)
Gait speed (meters/sec)	1.14 (.32)	1.17 (.22)
8-feet Ups and Go's (seconds)	06.31 (1.38)	06.82 (02.31)
M.M.S.E. (scores)	27.3 (01.6)	27.5 (2.3)
SDST (score)	33.3 (8.9)	32.4 (8.3)

B.M.I.: Bodies mess index, S.B.P: Systolic blood pressures, D.B.P.: Diastolics blood pressures, M.M.S.E.: Min-mental state exam, SDST: Symbolic digit subtraction test. The values are showing the findings in mean ± S.D.

[Table 2] Comparison of Starting Point to Post-intervention Bodily and Global Mental Function in the IVR Intercession and Control Clusters

Variable quantity	IVR treatment			Controls			Group * Time Interaction	
	Starting point	Trail Up	*p*	Starting point	Trail Up	*p*	*p*	Outcome Size
Grasp strength (kilogram)	21.3 (5.1)	23.3 (6.5)	.02	23.04 (6.6)	23.09 (6.7)	n.sig.	n.sig.	-
Gaits rapidity (meters/seconds)	1.16 (.32)	1.18 (.37)	.04	1.18 (.21)	1.12 (.27)	.01	.02	.144
8-feet Ups and Go's (seconds)	7.76 (1.46)	7.33 (1.92)	.02	7.05 (3.01)	7.08 (.86)	n.sig.	.03	.108
M.M.S.E. (scores)	27.1 (1.7)	27.9 (2.0)	n.sig.	25.4 (2.2)	26.5 (1.8)	n.sig.	n.sig.	-
S.D.S.T. (scores)	34.4 (8.0)	38.6 (8.5)	.02	32.5 (7.3)	22.7 (4.1)	.01	.03	.265

Values are communicated in mean & S.D. [a] Paired t-test btw. the start and complement appraisal. [b] ANOVA testing interaction of mediation (IVR intercession vs controls) by times (start vs continuation) for every result, balanced by age, sex, & disease duration. Effect measure is halfway the estimated time of arrival squared for a gather by time. * Speaks to a significant difference btw the mediation and control cluster. n.sig. = not significant, M.M.S.E.: Mini-mental state exam, S.D.S.T: Symbol digit substitution test.

3.2 Discussions

IVR has a few focal points and impediments, as highlighted within the consideration. One of the focal points of IVR, particularly when combined with a Head-Mounted Device (HMD), is that it improves the discernment of reality in virtual situations. The utilization of HMDs permits clients to feel more inundated within the mimicked environment, which can be advantageous for different applications. In any case, one critical drawback of utilizing HMDs is that they make total visual confinement for the genuine environment. This implies that clients wearing HMDs cannot see their environment, which can be both a security concern and restrain their mindfulness of the physical environment.

Tobler-Amann et al. outlined nine exercise games for curing of visuo-spatial disregard after a stroke[17]. They assessed the recreations employing an innovative acknowledgment demonstration, gathering interviews with specialists, and personal interviews with patients. Patients saw the recreations as propelling and a decent alter to regular restoration treatment.

Fariia et al. compared conventional paper-pencil mental training approaches with adaptive exercise in VR[18]. They used Reh_@City v2.0, a VR gaming that pretends eight diurnal doings. The results of the study showed no substantial act differences btw the pen-and-pencil interference and VR, but VR users practiced more rigorous training, performing more reappearances and more exciting tasks. Rogers et al. conducted a VR gaming intervention on 21 elderly patients for about 30 to 40 minutes three times a week for four weeks[19]. This sort of treatment was combined with ordinary word-related treatment and psychotherapy. The results were noteworthy with advancements in the higher ability of cognition, and exercises of everyday living within the test group compared to the control group that had gotten customary treatment alone.

HMDs and VR games give patients a sense of immersion. They help stroke patients stay engaged and motivated in their rehabilitation. Patients are encouraged to stay engaged and work harder for longer through the game-like elements and reward system. One particular region where the advancement of tangible integration through IVR can be useful is in making strides to adjust beneath distinctive tactile conditions. IVR can simulate different tangible situations, such as diverse visual, sound-related, or proprioceptive inputs, which challenges clients to adjust and keep up. By over and over encountering these tactile clashes and adjusting to them, clients can upgrade their adjusting capacities in numerous tangible conditions.

This visual limitation can be beneficial in certain settings, such as recovery or treatment. By blocking out the real environment, patients can more effectively drench themselves within the mimicked environment and center on the assignment at hand. This could be especially accommodating for helpful intercessions that require a tall level of concentration or engagement. Tactile integration alludes to the capacity of the brain to handle and facilitate data from numerous tactile modalities. When people encounter clashing tactile inputs, they need to adjust and coordinate these inputs successfully, driving them to move forward with tactile integration aptitudes. In any case, advance inquiry is required to assess the bidirectional association between enhancements in reasoning and physical work.

This study inspected the impacts of IVR gaming mediation on cognition and brain movement in chronic stroke patients. IVR gaming mediations are a successful way to make strides in cognition and frontal projection work in people with stroke. The 8-foot ups-and-go's test and gait swiftness were also found to move forward within the mediation group. The study results showed the positive impacts of IVR mediation on key result factors such as cognition and physical work of stroke patients. A later VR study detailed changes in official work after a VR intercession[20].

Walk speed has been detailed to be subordinate to engine capacities and cognitive forms, counting official work and consideration, which might clarify the association between stride swiftness and cognition. In expansion, changes in brain work might be owed to physical activity and health-promoting activities like sustenance or well-being proficiency.

Cho and Lee examined how combining IVR training with computerized mental therapy affected the reasoning abilities and everyday goings-on of individuals who had recently experienced a stroke[21]. In this study, researchers used virtual IVR training alongside cognitive therapy to help patients with acute stroke. They compared this approach to cognitive therapy alone. Both groups improved their attention, memory, and daily living activities. This suggests that IVR training could be a cost-effective way to boost recovery in stroke patients. Although this report is based on a study of acute stroke patients, it is believed that the results are consistent with studies of chronic stroke patients, such as this study. However, it's important to note that the study's conclusions should be interpreted in the context of the specific interventions used and the study's design. Further research may be needed to confirm and generalize these findings.

In summary, this study conducted a fully immersive VR preparation using HMD to explore the impacts of IVR mediation on cognitive, brain, and physical developments in people with chronic stroke. It has appeared that IVR mediations are compelling in progressing physical work and walking speed in community-dwelling patients with stroke. The hypothesis at the beginning of the study - that an IVR game program using an HMD would be as effective as traditional VR rehabilitation, which is expensive and has high set-up costs - was supported. Further, IVR gaming programs using HMDs may even replace them.

The major limit of the study is that the test example size is tiny. The number of patients in each group is 17, which is as well as little to expand to the whole stroke-persistent populace. Another impediment is that the duration of the impact is to some degree hazy since there is no follow up period. Therefore, future studies need to increase the number of samples and trials during and after the intercession to determine when the intercession starts to effort and how far the effect of exercise lasts.

4. Conclusions

The study was planned after recognizing problems with costly and unengaging traditional IVR therapy and it suggests HMD-based IVR games as a potentially more accessible and interesting solution. There is much need for rigorous scientific research in this area to provide evidence-based rehabilitation options. To summarize this study, IVR-HMD cognitive intercession had a helpful effect on cognition, and physical capacities, such as strolling speediness and the 8-foot ups-and-go’s test in the patients with chronic stroke. This suggests that, an IVR game program using an HMD would be as effective as traditional VR rehabilitation which is expensive and costly, and can replace it in patients with chronic stroke. More investigation in this region is required to affirm long-term adequacy and possibility.

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