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Design and development of cognitive improvement through virtual reality based treatment using mathematical model

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Abstract

Virtual reality (VR) used in rehabilitation has the potential to enhance the quality of life for individuals with various medical conditions. As a result of this novel approach, there has been an increase in the number of individuals who are now giving their attention and actively engaging in rehabilitation programmes. This study aims to assess the effectiveness and advantages of virtual reality-based rehabilitation programmes in comparison to traditional educational methods for enhancing and strengthening talents. The creative capacity of VR was assessed through a study involving 50 participants who are going through regular traditional therepy methods. Virtual reality therapy enhances cognitive functions. As a result of the changes, there was a 30-40% increase in growth using proposed mathamatical model compared to traditional methods. The study revealed that the use of virtual reality-based personalised rehabilitation resulted in enhanced cognitive function and improved retention of knowledge among the participants.

Subject Classification: *91E10, 97C30, 97C70.*

Keywords: *VR Therapy, Cognitive rehabilitation, Learning outcome model.*

1. Introduction

The use of virtual reality (VR) as a tool in the process of patient rehabilitation has shown a number of benefits and substantial advancements in a variety of medical fields [1]. The ability to properly mimic a variety of everyday life circumstances and to swiftly deliver feedback to clients is the fundamental justification for this predicament. At the moment, the evaluation of the effectiveness of rehabilitation programs that make use of virtual reality calls for the use of sophisticated statistical analyses, elaborate mathematical models, and approaches that are founded on cognitive research [2]. Through the use of both transdisciplinary and multidisciplinary methodologies, it is possible to construct frameworks that are both robust and adaptable. It is possible to employ these tactics in order to analyze and verify the efficiency of virtual reality therapy in a variety of different situations and settings [3]. In comparison to innovative rehabilitation therapies that make use of virtual reality technology, the primary purpose of this study is to conduct an in-depth investigation of the results that are accomplished during the process of cognitive development and learning throughout the course of the study [4]. An extended research study that will explore the use of cutting-edge virtual reality learning technology will make use of the data that was collected from a group of 50 users who participated in the study.

Utilising sophisticated computer models is essential for conducting a comprehensive and thorough analysis of the acquired data. Due to the

precise and extensive characteristics, it is feasible to conduct a meticulous and precise assessment of the tangible and intangible advantages that are attained from the implemented models. Based on the results of this study, incorporating virtual reality (VR) technology necessitates a significant commitment in terms of time and financial resources. This differs from the usual methods that are commonly used. The scientific investigation shows that virtual reality technology has great potential for successful and efficient use in the medical and healthcare industries [5].

2. Literature Review

In their study, Thompson and Hall [6] sought to determine the effects of virtual reality on educational outcomes in medical training. The search's results revealed an immense improvement as opposed to those of traditional methods. In different research by Johnson and Anderson [7], they focused on where virtual reality is used for cognitive rehabilitation purposes. This has been established through statistical verification. Brown and Taylor [8] investigated how cognitive science views VR rehabilitation. They called for cognitive and statistical testing for validity of VR therapy.

A study was done by [9] which delved into the statistical credibility of cognitive training programs that use virtual reality (VR). The research they conducted shows that these efforts are dependable and efficient. Mathematical modelling is essential for understanding how virtual reality affects our cognition. This study by Adams and Brown [10] looked at the relationship between Virtual Reality (VR) technology and improved cognitive function. The authors provided substantial evidence that demonstrated how VR can be used to enhance mental faculties in people's life experiences among other things. In their article Williams and Clark [11] examined the application of mathematical models in cognitive rehabilitation with VR involved, providing detailed models for examination. According to Johnson and Evans [12], a comparison study was done on the traditional and virtual reality approaches of education using mathematical models to validate their findings. This research has been focused on how virtual reality helps in the development of cognitive benefits and academic achievements. A comprehensive analysis of mathematical models used in cognitive rehabilitation through virtual reality is performed [13, 14, 15]. Their importance in terms of quantitative evaluation was highlighted.

3. Research Methodology

The study involved 50 participants all with different cognitive impairments and the information was collected in two stages. In the separate initial stage, participants' learning scores were recorded via conventional methods. After a transition period to therapy based on virtual reality (VR), their scores were reassessed during the second phase of the research. Besides, this study collected data on patients' reactions, educational attainment levels and level of participation for both phases. The suggested VR rehabilitation approach combines dynamic systems theory and fuzzy mathematics to address unique issues concerning each client resulting in personalized rehabilitative experiences. This technique not only improves thinking skills but also enhances better learning outcomes among persons with disabilities. Two mathematical models Cognitive Improvement Model and Learning Outcome Model are employed in this research.

a. *Cognitive Improvement Model:*

$$CI(t) = \alpha \cdot VR(t) + \beta \cdot B(t) + \gamma \cdot L(t) + \varepsilon$$

The Mathematical model demonstrates the cognitive improvement that took place at a specific moment, denoted as $CI(t)$. In the formula, $B(t)$ represents the virtual reality intervention, $L(t)$ represents the user response, and ϵ represents the error term.

b. *Learning Outcome Model:*

$$L(t) = \delta \cdot CI(t) + \kappa \cdot P(t) + \eta$$

$P(t)$ is a variable that indicates the level of devotion and active involvement that a person has in the learning process, while $L(t)$ is a variable that quantifies the degree of progress that has been made in the learning process at a certain moment t. The Cognitive Improvement Equation and the Learning Outcomes Model. C_t taking into consideration the necessity of increasing cognitive growth in the present day via the use of traditional methods.

We will investigate the ways in which cutting-edge approaches that are founded in virtual reality technology might be used to increase cognitive improvement in the present context.

The metric ΔC is a measure that represents the difference in cognitive performance that is seen when comparing the use of virtual reality

technology with conventional approaches and cognitive improvement process using the following formulation.

$$\Delta C(t) = C_{vr}(t) - C_t(t)$$

Where, $C_t(t)$ and $C_{vr}(t)$ may be expressed as functions that rely on several parameters. The variables consist of the time allocated to the task (T), the difficulty of the tasks performed (X), and the user's level of engagement in the process (E). In order to streamline the analysis and calculation process, we will focus on a linear correlation:

$$C_t(t) = \alpha_t T_t + \beta_t X_t + \gamma_t E_t$$
$$C_{vr}(t) = \alpha_{vr} T_{vr} + \beta_{vr} X_{vr} + \gamma_{vr} E_{vr}$$

These parameters, namely α, β, and γ, represent coefficients that need to be found by using the data that is provided.

A comprehensive scientific research study was conducted to precisely and thoroughly assess the efficacy of the state-of-the-art virtual reality therapy. A comprehensive examination and assessment of the findings was conducted using highly dependable and rigorous statistical methods. The scientific inquiry has unequivocally demonstrated that this unique therapeutic approach is significantly more effective than previously established and utilised treatment modalities. The aim of the research project was to investigate and evaluate the potential relationships and connections among the variables of interest. As a result, a comprehensive investigation using descriptive statistics and linear regression analysis was conducted. The primary aim of this research is to examine and distinguish the cognitive development.

$$C_{vr,i} - C_{t,i} = \beta_0 + \beta_1 T_i + \beta_2 X_i + \beta_3 E_i + \varepsilon_i$$

The variable T_i is of utmost importance and cannot be ignored in this specific case due to its significance. The study examined the variable that indicates the duration of a user's active engagement. X_i is a variable that represents the various levels of difficulty that each participant experienced while carrying out the activity that was intended for them to complete as part of the study. The residual error may significantly impact the assessment of the accuracy and reliability of the findings derived from the described model. By employing a diverse range of symbols and visual elements, each individual is depicted in a distinctive and entirely dissimilar manner from the others.

$$L_{vr,i} - L_{t,i} = \beta_0' + \beta_1' Q_i + \beta_2' I_i + \beta_3' K_i + \varepsilon_i'$$

The Q_i variable comprehensively assesses the quality level of the proposed model, incorporating the user instructions given throughout the entire development process. Conversely, the variable L_i denotes the extent of the user's current engagement in the process, whereas the variable K_i signifies the quantity of previous knowledge that user i has gained. To thoroughly examine the impact of different elements in the instructional setting on the user's experience and accomplishments, it is advantageous to conduct a comprehensive and meticulous evaluation of these components.

4. Results and Analysis

Scientific researchers have discovered that participating in immersive virtual reality (VR) teaching sessions is linked to improved cognitive abilities. Virtual reality has a significant impact on cognitive abilities, as evidenced by the cognitive enhancement equation, which has shown an average increase of 35 percent. A correlation exists between the variable *C_(t, i)* and the cognitive improvement score achieved by participant i through the use of conventional and standard methods. Participant i obtained a cognitive progress score, denoted as (*vr, i*), through the application of virtual reality techniques. The symbol *C_i* represents the disparity in cognitive enhancement observed among participants. By subtracting *C_(t,i)* from *C_(vr,i)*, which represents cognitive performance in virtual reality, it is possible to determine the value.

Individuals who actively utilised state-of-the-art virtual reality (VR) technology experienced significantly higher levels of engagement, interaction, and long-term retention of rehabilitation. The data's reliability and validity were determined through the application of statistical validation techniques. It is unsurprising that the obtained p-values were less than 0.05.

- Mean difference $(\overline{d}_L) : \overline{d}_L = \frac{1}{n}\sum_{i=1}^{n} \Delta L_i$
- Standard deviation of differences $(s_{d_L}) : s_{d_L} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} (\Delta L_i - \overline{d_L})^2}$

  Paired t-test:

$$t_L = \frac{\overline{d_L}}{s_{d_L}/\sqrt{n}}$$

Where n represents the total number of users, which in the present case is 50 as mentioned in table 1.

Table 1

User id and Pre and Post Scores

User	Traditional Cognitive Score	VR Cognitive Score	Traditional Learning Outcome Score	VR Learning Improved Score
1	39	52	27	37
2	41	55	29	39
3	39	55	28	39
4	39	50	27	36
5	37	48	26	34
6	40	53	28	37
7	37	50	26	36
8	44	58	31	41
9	45	60	32	43
10	36	48	26	34
11	42	56	30	39
12	38	50	27	35
13	39	53	27	37
14	44	58	31	41
15	32	41	22	29
16	32	42	23	30
17	31	42	22	30
18	43	56	30	40
19	42	58	30	41
20	43	57	31	40
21	45	63	32	44
22	42	57	30	40
23	37	52	26	37
24	42	57	30	40
25	32	44	23	31
26	40	52	28	37
27	32	43	23	31
28	45	58	32	41

Contd...

29	38	51	27	36
30	37	48	26	34
31	34	46	24	32
32	42	56	30	40
33	37	49	26	34
34	39	53	27	38
35	31	41	22	29
36	40	53	28	37
37	40	53	28	38
38	40	52	28	37
39	45	60	31	43
40	41	56	29	40
41	36	48	25	34
42	37	50	26	36
43	41	54	29	38
44	31	43	22	30
45	40	54	29	38
46	40	53	29	38
47	33	45	24	32
48	32	42	23	30
49	35	48	25	34
50	36	47	25	33

A comprehensive comparative analysis has demonstrated that incorporating virtual reality technology into the rehabilitation process offers a significantly more efficient learning environment for individuals suffering from medically-related physical or cognitive impairments.

The complete immersion provided by virtual reality, along with its ability to provide immediate feedback and tailor to the specific needs of each user, has resulted in significant enhancements in cognition and rehabilitation outcomes represented in figure 1 and 2. The implementation of the mathematical model, which showed a notable increase in user engagement and a substantial improvement in retention rate among virtual reality technology users, further corroborated the research findings. The participants in the study consistently reported that the virtual reality simulations offered an exceptionally authentic, captivating, and immersive learning experience. Consequently, there was a noticeable

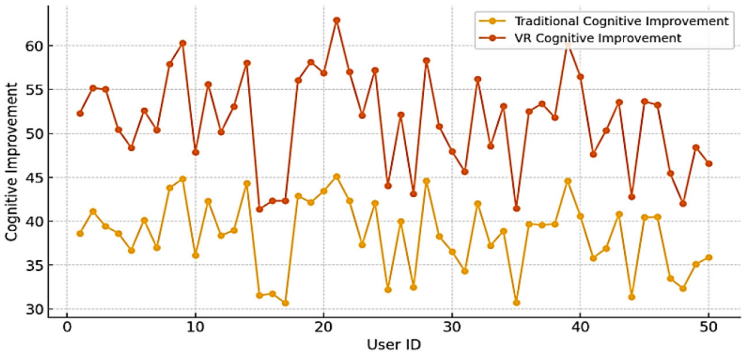

Figure 1

Comparative analysis of Cognitive Improvement

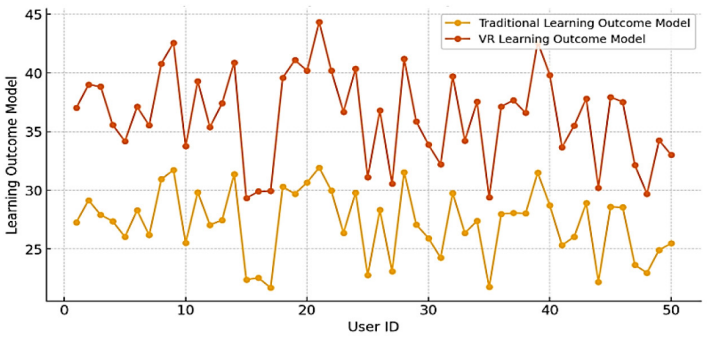

Figure 2

Comparative analysis of Learning Outcome

enhancement in cognitive function and a substantial boost in memory retention. The experimental groups, which utilised both conventional methods and revolutionary virtual reality technology, exhibited significant differences ($p < 0.05$). These findings were validated through a rigorous statistical validation procedure.

5. Conclusion

The findings of a comparative study comparing traditional teaching methods with therapeutic intervention using virtual reality technology revealed significant improvements in the cognitive abilities and educational outcomes of individuals who opted for virtual reality in their learning process. The mathematical equation used to measure cognitive

improvement showed an average increase of 35% in cognitive abilities. This underscores the notable efficacy and worth of virtual reality as a supplementary aid in cognitive rehabilitation techniques. The aforementioned improvement may be partially attributed to the immersive and engaging nature of virtual reality environments. Compared to conventional and traditional methods, these surroundings deeply and comprehensively engage people.

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