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Fully Immersive Virtual Reality Training for Cognitive Functions of Children with Down Syndrome

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ABSTRACT

Background: Children with Down syndrome (DS) have overall cognitive and adaptive functioning impairments. Specific cognitive domains are mainly affected such as attention and visual memory. Immersive technologies such as virtual reality (VR) hold great potential in delivering enjoyable and therapeutic experiences.
Objective: To identify the effect of fully immersive VR technology on cognitive functions of children with DS.
Methods: Thirty boys with DS aged from 7 to 10 years who attended a special school, were selected and assigned into 2 equal groups; the control group practiced their regular activities of school and daily living (received no treatment); and the study group practiced the same activities as control group in addition to 12 VR sessions of 20 minutes over a period of 6 weeks. RehaCom software was used to assess cognitive functions (attention and visual memory) pre and post intervention for all participants.
Results: Both groups were similar at baseline, comparison of post-test values between the control and study groups revealed significant difference for attention (p=0.0001) and visual memory (p=0.0001) in favour of the study group with percentage of improvement (95.67%) and (51.75%) respectively.
Conclusion: Fully immersive VR games can improve the attention and visual memory of children with DS; therefore, it can serve as a valuable intervention for their cognitive rehabilitation.

Keywords: Attention, Cognitive Rehabilitation, Down Syndrome, Technology, Virtual Reality

1. Introduction

Down syndrome (DS) is numerical autosomal chromosomal disorder resulting from the presence of an extra chromosome 21 in all or some somatic cells. The incidence of DS varies in different populations (1 in 319 to 1 in 1000 live births) **[1].** A significant correlation has been noted between IQ and all areas of function; children with DS have impairments in many cognitive domains that influence their level of functioning **[2].**
Cognitive function is a broad term that refers to mental processes involved in the acquisition of knowledge, manipulation of information, and reasoning. This general term is used to describe many different functions such perception, memory, learning, attention, decision making, and language abilities. These cognitive processes influence perception, memory, speech, thinking, decision-making, and problem-solving **[3].** RehaCom is a comprehensive and sophisticated system of software for computer-assisted cognitive evaluation and rehabilitation. It includes specific aspects of cognitive domains as attention, concentration, memory, perception, activities of daily living **[4].**
Virtual reality (VR) is a type of technology that holds great potential in delivering enjoyable and therapeutic experiences. It has been applied in the rehabilitation of many developmental areas **[5]**. it is a computer technology that simulates real-life learning and allows for increased intensity of training while providing augmented three-dimensional and direct sensorial feedback. It is a novel technology that allows users to interact with a computer-generated scenario (a virtual world) making corrections while performing a task. There has been limited research

involving the inclusion of VR gaming systems in neurorehabilitation and there is an identified need for researches to establish the value of VR in the populations with neurological disorders (6).

The fully immersive VR is used by researchers and educators to provide safe access to realistic experiences that may otherwise be logistically difficult, dangerous, or impractical to implement. VR allows complete control over the stimulus and add motivation for practice by including playing in the rehabilitation **[7,8].** It is being used as a therapeutic intervention for restoring coordinated movement patterns as it can activate the cerebral cortex and improve motion function [9]. This study investigate the impact of fully immersive VR technology on the cognitive functions of children with DS. There was limited evidence regarding the use of fully immersive VR, which offers complete sensory engagement. Therefore, this study aimed to examine the impact of fully immersive VR technology on the cognitive functions of children with DS.

2. Material and methods

2.1. Study Design and Setting

A prospective experimental pretest-posttest design was used and the study was conducted during the period of October 2023 and March 2024. Children were recruited from Eltarbia El Fekria school for children with Special Needs and Education in Dokki, Giza and the virtual reality sessions and the assessment were done at Faculty of Physical Therapy, Cairo University in Egypt.

2.2. Ethical Considerations

This study's protocol was reviewed and approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/004334), and it was registered on clinical trials database of registration with a registration number (NCT 05849818) according to the Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans. A written consent form was obtained from the parents of each child for participation before starting the study procedures.

2.3. Subjects

The sample size for this study was calculated using the G*power program 3.1.9 (G power program version 3.1, Heinrich-Heine-University, Düsseldorf, Germany) for two tailed test. Sample size calculation based on t-tests (means: difference between two independent means-two groups), type I error (alpha = 0.05), power (1-βeta = 0.80), and the Effect size d = 1.145 with a total sample size for 26 participants for 2 independent groups comparison for major variable outcomes. Considering a 10% drop out rate, the appropriate minimum sample size for this study will be 30 patients (15 patients in each group as a minimum).

Children with DS were screened, thirty of them were eligible according to the following *inclusion criteria:* children diagnosed with DS, their age range from 7 to 10 years and their IQ range from 63 to 68 (mild intellectual disability), they were able to understand and follow the instructions and can walk independently.

The *exclusion criteria* include significant visual or hearing, mental or psychological problems that interfere with understanding instructions, musculoskeletal problems or fixed deformities in upper or lower limbs or any other serious medical problems.

The sample were assigned into two groups

- **Control Group**: 15 children received regular activities of daily living and school (attended school 3 days/ week) (received no treatment).
- **Study Group**: 15 children practiced the same activities as control group in addition to 12 virtual reality sessions using fully immersive VRapeutic software gaming technology (Viblio and garden do modules) for 20 minutes/session and 2 sessions/week for 6 weeks.

2.4. *Assessment*

Cognitive Functions Assessment

Rehacom computer-assisted cognitive technology was used to assess the cognitive functions (attention and visual memory) of all participants for pre and post-test (at baseline and after 6 weeks), it has 24 progressively harder stages. It provides abroad range of cognitive assessments including attention visual memory and perception.it offers more engaging environment whis is crucial for children with DS. There are eight stages, each has three varying degrees of difficulty ranging from easy (low object similarity) to difficult task (high object similarity), and there are three, six, or nine photos in the matrix **[10]**. At the beginning, the therapist explained the testing procedures to the caregiver and gave the instructions to the child about each assignment. The child sat in front of the screen in a relaxed position and started with the screening module by using an example to ensure that the child understands the task, then complete the targeted domains (attention and visual memory) testing **[10].**

2.5. Interventions

2.5.1. **Virtual reality**

This study used two virtual exercises from VRapeutic's library of therapeutic modules, namely, Viblio™ and GardenDo™. These virtual reality exercises were developed using Unity™ (version 2019.4.40f1 LTS). VRapeutic's system consists of a standalone VR headset—currently the system is compatible with Oculus Quest™ and PICO, and we used the former in this study. The headset is equipped with two handheld controllers, and a laptop, in addition to **an LED** display (108cm/43) to guide the activities during the session.

2.5.2. **The experimental group received 12 sessions 20 minutes (6 weeks) of fully immersive virtual reality plus same activities of control group.**

The virtual reality modules—GardenDo™ and Viblio™—were chosen based on the following criteria. First, they target functional tasks that are challenging enough, yet attainable, compared to traditional exercises which constitute a highly engaging medium for children training. Second, while attempting to complete the exercise, those functional tasks address cognitive functions, such as attention and visual memory. Besides providing an interactive and motivating medium for training, the adopted exercises offer immediate feedback, user friendliness, and a logical flow represented by a built-in progression, from easiest to hardest, inside the virtual environment.

The GardenDo™ game involves a plant watering activity, where the child is instructed to fill a watering can from a tap, and then go water different plant pots. The complexity of the task, the number of pots, and the nature of the environment are all customizable. The game required the child to grasp the controller using the dominant hand. The player is then instructed to walk a few steps within the playing area and lean forward to reach the watering can by flexing the shoulder and extending the elbow of the dominant upper limb. The can is then required to be grasped by pressing on a controller button. The next step is to water several pots in sequence which needs the child to maintain the water flow, being poured in each pot, until the plant blooms. Keeping the water flow necessitates keeping the shoulder still, extend the elbow horizontally and control the trunk position, and then go to the next pot.

The Viblio™ game is a book ordering activity, where the child was asked to arrange a specific number of books on the shelves in sequence. The height of the shelves, the number of shelves, and the number of books are all customizable. The game required the child to grasp the controller by the dominant hand, walk a few steps within the playing area, and then lean forward to reach the books placed on a table or on the ground. Grasping a book necessitates flexing the shoulder and extending the elbow of the dominant upper limb while pressing on a button on the controller. The task is then completed by putting the grasped book on the shelf in sequence, before the child can proceed to take another book.

A therapist who has been trained to use the system, including the VR modules, supervised the VR session. More importantly, the trained therapist made sure to introduce the system to the children and get them familiar with the required movements prior to the onset of VR-based training sessions.

3. Statistical Analysis

Data were screened, for normality assumption test and homogeneity of variance for age, IQ, attention, and visual memory variables. The normality test of data using Shapiro-Wilk test was used, that reflect the data were normally distributed ($P>0.05$) after removal outliers that detected by box and whiskers plots. Additionally, Levene's test for testing the homogeneity of variance revealed that there was no significant difference ($P>0.05$). If the p-value for the Levene test is greater than 0.05, then the normality and variances are not significantly different from each other. If the p-value for the Levene's test is less than 0.05, then there is a significant difference between the variances. All these findings allowed to conduct parametric analysis. The data is normally distributed and parametric analysis is done.

The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). Quantitative data are reported as mean and standard deviation for DS children age, IQ, and cognitive functions variables. Independent t-test used to compare between two groups for DS children age and IQ variables. Mixed design 2 x 2 Multivariate analysis of variance (MANOVA) test was used to compare between the two groups and pre- vs. post-treatment values of the main variable outcomes (attention and visual memory).

Bonferroni test was used to compare between pairwise within and between groups of the tested variables which F was significant from MANOVA test. Effect size calculation by Eta square (η^2) which considered a value of 0.2 represents a small effect size, value of 0.5 represents a medium effect size, and value of 0.8 represents a large effect size. All statistical analyses were significant at level of probability ($P \leq 0.05$).

3.Results

This study conducted to identify the effect of fully immersive virtual reality on cognitive functions of DS (attention and visual memory), a total of 30 children with DS were equally distributed into two groups, they were assessed pre and post treatment.

3.1 Subject Characteristics:

The general demographic data for participated children showed no significant differences (P>0.05) in the mean values of age (P=0.985) and IQ (P=0.788) between control and study groups as shown in table 1.

Table 1. Clinical demographic data for children in both groups.

Items	Groups (Mean ±SD)		*P*-value	*Significance*
	Control group (n=15)	Study group (n=15)		
Age (year)	8.80 ±1.14	8.90 ±0.84	0.985	NS
IQ (%)	63.13 ±2.50	65.80 ±1.97	0.788	NS
Quantitative data are expressed as mean ±standard deviation (SD), P-value: probability value, NS: non-significant.				

3.2 *Attention:*

The results of the multiple pairwise comparison tests for attention within each group (Table 2 and Figure 1) showed that attention Score increased slightly from 3.00 ± 0.00 to 3.67 ± 0.81, with a non-significant mean difference 0.67(95% CI -0.02–1.35), small effect size 0.06, and improvement of 22.33%, (p = 0.056). Minimum Reaction Time Improved from 2680.00 ± 280.15 ms to 4903.60 ± 703.92 ms, reflecting an mean difference 2223.60 (95% CI 1648.78–2798.41), medium effect size 0.51, and 82.97% improvement (p = 0.0001). Maximum Reaction Time Increased from 32,507.13 ± 7,209.11 ms to 37,667.00 ± 6,250.28 ms, with a mean difference 5159.87 (95% CI 1192.92–9126.82), small effect size 0.07, and fair improvement of 15.87% (p = 0.044).
While in the study Group we found that Attention Score increased significantly from 3.00 ± 0.00 to 5.87 ± 1.68, reflecting a mean difference 2.87(95% CI 2.18–3.56), medium effect size 0.69, and 95.67% improvement (p = 0.0001). Minimum Reaction Time: Improved from 2645.73 ± 720.84 ms to 4979.93 ± 743.65 ms, showing an mean difference 2334.13 (95% CI 1759.31–2908.95), medium effect size 0.54, and 88.23% improvement (p = 0.0001) and Maximum Reaction Time: Improved significantly from 32,512.93 ± 14,513.38 ms to 20,453.73 ± 1,172.90 ms, with a mean difference -12059.20 (95% CI 5692.26–18426.14), small effect size 0.21, and 37.09% improvement (p = 0.0001). The improvement percentage for reaction time was calculated according to divided the mean difference value on pre-treatment value multiple 100.
Statistical multiple pairwise comparison tests for children between both groups (Table 2 and Figure 1) indicated that there was significant improvement in favour of study group as following attention Score: The study group's post-treatment score (5.87 ± 1.68) was significantly higher than the control group (3.67 ± 0.81) (p = 0.0001) with medium effect size 0.69 . Minimum Reaction Time: Post-treatment scores were significantly better in the study group (4979.93 ± 743.65 ms) than the control group (4903.60 ± 703.92 ms) (p = 0.001) with medium effect size 0.54 .Maximum Reaction Time: The study group showed significantly faster reaction times (20,453.73 ± 1,172.90 ms) compared to the control group (37,667.00 ± 6,250.28 ms) (p = 0.0001) with medium effect size 0.21.

Table 2. Within and between group comparisons for attention

Variables	Items	Groups (Mean ±SD)		Change	Effect size (η2)	*P*-value[2]
		Control group (n=15)	Study group (n=15)			
Attention	Pre-treatment	3.00 ±0.00	3.00 ±0.00	0.00	0.06	1.00
	Post-treatment	3.67 ±0.81	5.87 ±1.68	2.20	0.69	0.0001*
	MD (Change)	0.67	2.87			
	95% CI	-0.02 – 1.35	2.18 – 3.56			
	Improvement %	22.33%	95.67%			
	Effect size (η2)	0.06	0.69			
	P-value[1]	0.056	0.0001*			
Minimum reaction time (mses)	Pre-treatment	2680.00 ±280.15	2645.73 ±720.84	34.27	0.09	0.136
	Post-treatment	4903.60 ±703.92	4979.93 ±743.65	76.33	0.54	0.001*
	MD (Change)	2223.60	2334.13			
	95% CI	1648.78 – 2798.41	1759.31 – 2908.95			
	Improvement %	82.97%	88.23%			
	Effect size (η2)	0.51	0.54			
	P-value[1]	0.0001*	0.0001*			
Maximum reaction time (mses)	Pre-treatment	32507.13 ±7209.11	32512.93 ±14513.38	5.80	0.07	0.995
	Post-treatment	37667.00 ±6250.28	20453.73 ±1172.90	17213.26	0.21	0.0001*
	MD (Change)	5159.87	-12059.20			
	95% CI	1192.92 – 9126.82	5692.26 – 18426.14			
	Improvement %	15.87%	37.09%			
	Effect size (η2)	0.07	0.21			
	P-value[1]	0.044*	0.0001*			

Data are expressed as mean ±standard deviation; MD: Mean difference; CI: confidence interval; P-value: probability value * Significant (P<0.05); P-value1: Probability value within each group; P-value2: Probability value within among groups

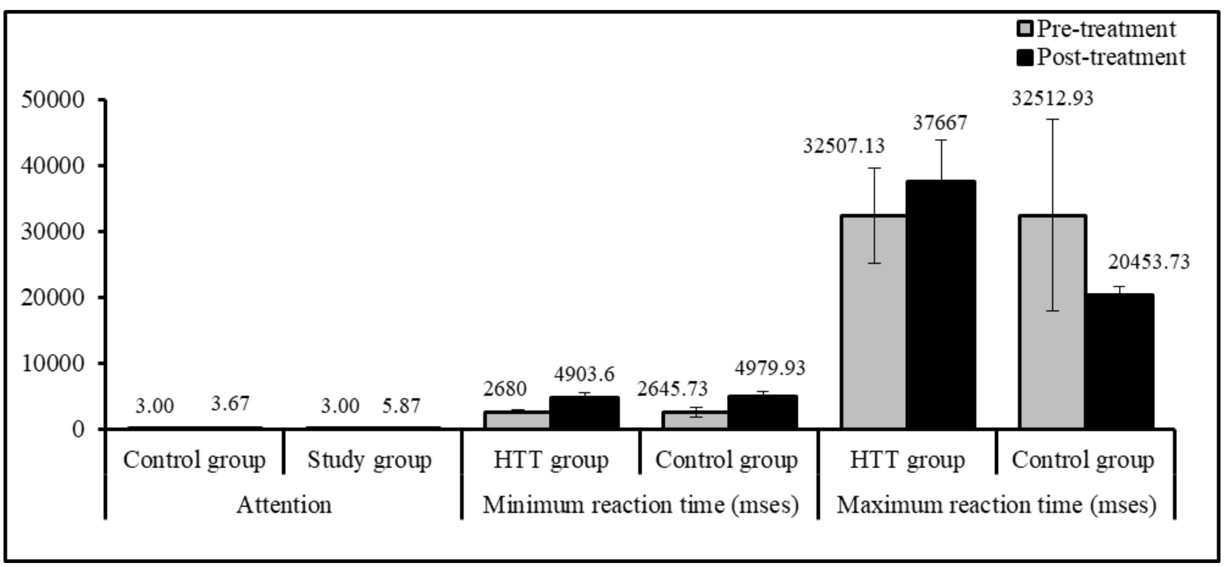

Figure 1. Mean values of attention at pre-and post-treatment in both groups

3.3. Visual Memory:

Statistical multiple pairwise comparison tests for visual memory within each group (Table 3 and Figure 2) showed that In the Control Group we found the following results Minimal improvement in visual memory score from 3.00 ± 0.00 to 3.07 ± 1.03, showing only a mean difference 0.07(95% CI -0.59 – 0.72), no effect size 0.00, and 2.33% increase (p = 0.841). Acquisition Time: Increased from 16.73 ± 2.81 sec to 25.93 ± 3.80 sec, with mean difference 9.20 (95% CI 3.35 – 15.04), small effect size 0.15, and a moderate improvement of 54.99% (p = 0.003).

While in the study Group we found that Significantly improved in visual memory score from 4.00 ± 0.00 to 6.07 ± 1.48, reflecting a mean difference 2.07(95% CI 1.40 – 2.72), medium effect size 0.41, and 51.75% improvement (p = 0.0001).Acquisition Time: Improved significantly from 16.47 ± 8.15 sec to 29.53 ± 12.90 sec, with a mean difference 13.06 (95% CI 7.22 – 18.91), small effect size 0.26, and 79.30% improvement (p = 0.0001).

Statistical multiple pairwise comparison tests for visual of DS children between both groups (Table 3 and Figure 2) we found that the study group improved significantly than control group as following visual memory score at Post-treatment, the study group's score (6.07 ± 1.48) was significantly higher than the control group (3.07 ± 1.03) (p = 0.0001) with small effect size 0.41 .Acquisition Time The study group showed significantly greater improvement (29.53 ± 12.90 sec) compared to the control group (25.93 ± 3.80 sec) (p = 0.001) with small effect size 0.26 .

Table 3. Within and between group comparisons for visual memory

Variables	Items	Groups (Mean ±SD)		Change	Effect size (η^2)	*P*-value²
		Control group (n=15)	Study group (n=15)			
Visual memory	Pre-treatment	3.00 ±0.00	4.00 ±0.00	1.00	0.00	0.703
	Post-treatment	3.07 ±1.03	6.07 ±1.48	3.00	0.41	0.0001*
	MD (Change)	0.07	2.07			
	95% CI	-0.59 – 0.72	1.40 – 2.72			
	Improvement %	2.33%	51.75%			
	Effect size (η^2)	0.00	0.41			
	P-value¹	0.841	0.0001*			
Acquisition time (sec)	Pre-treatment	16.73 ±2.81	16.47 ±8.15	0.26	0.01	0.928
	Post-treatment	25.93 ±3.80	29.53 ±12.90	3.60	0.26	0.001*
	MD (Change)	9.20	13.06			
	95% CI	3.35 – 15.04	7.22 – 18.91			
	Improvement %	54.99%	79.30%			
	Effect size (η^2)	0.15	0.26			
	P-value¹	0.003*	0.0001*			

Data are expressed as mean ±standard deviation; MD: Mean difference; CI: confidence interval; P-value: probability value, * Significant (P<0.05); P-value1: Probability value within each group; P-value2: Probability value within among groups.

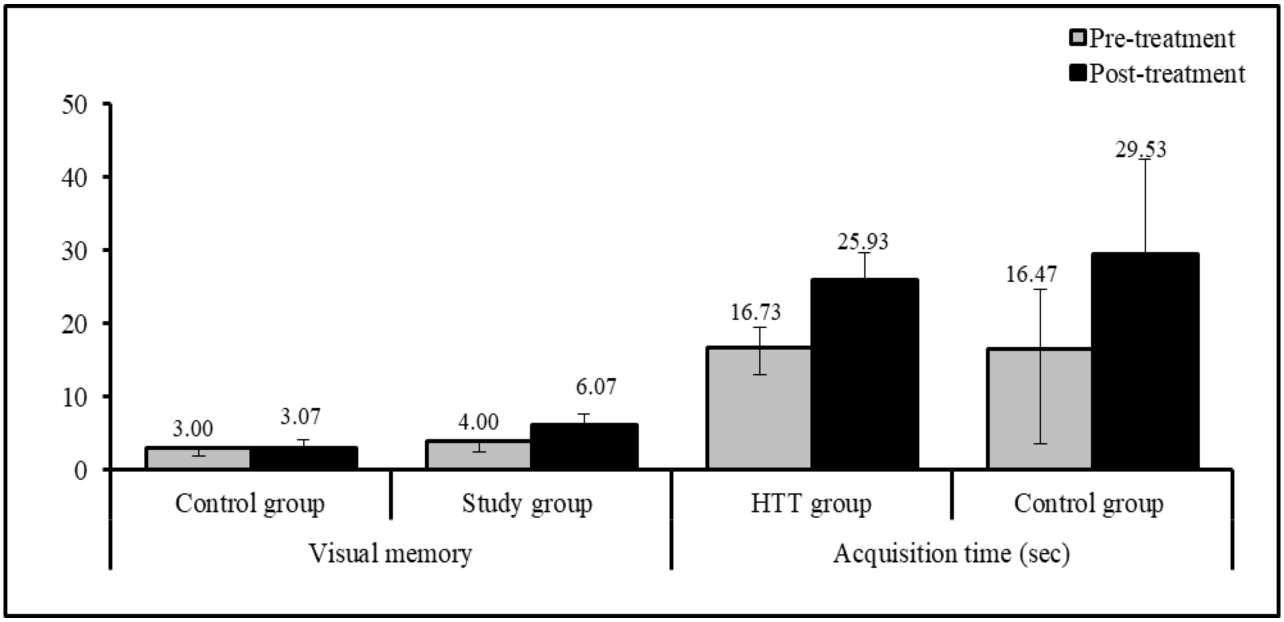

Figure 2. Mean values of visual memory at pre-and post-treatment in both groups

4. Discussion

This study examined the impact of fully immersive virtual reality (VR) therapy on cognitive functions in children with Down syndrome (DS). Significant improvements were observed in attention and visual memory within the study group, confirming the potential of immersive VR to enhance cognitive processes. These findings contribute to a growing body of evidence supporting the transformative role of VR in cognitive rehabilitation.

One of the most notable outcomes of this study was the substantial improvement in attention among the study group, with an increase of 95.67% compared to only 22.33% in the control group. The post-treatment attention scores for the study group were 5.87 ± 1.68, significantly higher than the control group's 3.67 ± 0.81. with mean difference change 2.2, indicating a large effect. Improvements in visual memory were similarly pronounced, with a 51.75% enhancement observed in the study group, while the control group recorded only a 2.33% improvement. Post-treatment visual memory scores were 6.07 ±1.48 for the study group compared to 3.07 ±1.03 for the control group, with mean difference change 1.12 reflecting a large effect. These results highlight the unique capabilities of immersive VR to engage children with DS in meaningful, task-oriented activities that stimulate attention, memory, and motor-cognitive coordination.

Down syndrome affects different systems in the human body, with a negative impact on general development **[11]**. DS causes a reduction in cognitive abilities, with visual-motor skills being particularly affected.

The study also employed RehaCom software as a standardized tool to assess cognitive improvements quantitatively. RehaCom modules provided objective data on sustained attention, visual memory, and reaction times, revealing significant gains among the study group. For example, the visual memory module indicated enhanced recall performance, and reaction time assessments demonstrated faster cognitive processing, corroborating the benefits of immersive therapy. These results supported by **Maggio et al. [12]**, who noted that RehaCom facilitates targeted cognitive rehabilitation by offering structured and measurable strategies that align with individual therapeutic needs the findings validated the use of rehacom to asses and monitoring and measure the cognitive impairment for children with DS. The integration of RehaCom and fully immersive VR allowed this study to combine dynamic, experiential interventions with precise, modular assessments, offering a comprehensive framework for advancing cognitive rehabilitation practices.

The effectiveness of immersive VR therapy in this study aligns with findings from previous research. There are a variety of explanations for why VR could improve motor abilities of children with DS; the multisensory feedback provided by the VR therapy may explain improvements in performance as well as learning, also it could positively affect the brain reorganization/plasticity, motor capacity, visual-perceptual skills, social participation and personal factors **(13)** Besides providing external stimulation, VR has additional potential to stimulate the internal sensorimotor system, possibly linked with better functional outcomes. When a specific task is expressed in a game form, the feedback of VR responds to visual and audio information of the task, informs of the user's errors in movement, and effectively controls the movement. Thus, VR-based training is an intervention approach that is considered superior compared to the traditional interventions, which are passive and repetitive and do not provide sensory feedback on the outcome of performance **(14).**

Michalski et al. [15] reported that fully immersive VR enhances neurocognitive outcomes such as memory retention, executive function, and attentional control. Their meta-analytic study revealed that VR environments create immersive sensory experiences that foster deeper engagement for the sample used (Ds wide age range 6-16 years) Similarly, **Torres-Carrión et al. [16]** emphasized that VR-based gestural interactions significantly improve visual-motor coordination and cognitive abilities in adolescents with DS adolescents aged 12-18 years. Complementing these findings, **Boato et al. [1]** demonstrated that VR games support psychomotor and cognitive development by stimulating spatial organization, balance, and motor planning through engaging visual feedback for balanced gender distribution for DS children and developmental delay with age range 8-14years.
Also, **Standen and Brown [17]** reported that immersive VR enhances focus and engagement in children with intellectual disabilities, a finding consistent with the attention improvements observed in this study. Similarly, **Shalev et al. [18]** demonstrated that VR reduces inattentiveness and hyperactivity, a pattern mirrored in the improvements in sustained attention as measured by RehaCom with sample size of 50 children including 15 DS children. Furthermore, **Park and Lee [19]** emphasized that gamified VR environments increase motivation and task adherence, an essential factor for successful interventions, particularly in children with cognitive disabilities. Additionally, **Garcia et al. [20]** highlighted the role of immersive environments in promoting problem-solving and sustained attention, noting that sensory-rich simulations improve neurocognitive engagement for children with different neurodevelopmental diseases including DS with age range 6-12 years.

Despite these encouraging results, it is important to consider contrasting perspectives. For example, **Turnbull and Phillips [21]** cautioned that short-duration interventions like the six-week program employed in this study might not result in long-term cognitive benefits. Their work underscores the importance of conducting longitudinal studies to evaluate whether the observed improvements are sustained over time. A systematic review by **Tortora et al. (22)** examined VR-based cognitive rehabilitation therapies for older adults with mild cognitive impairment. While the findings suggested that VR interventions could be as effective as conventional cognitive training, the review highlighted the need for more rigorous research to understand the degree of VR's effectiveness and the potential role of immersion in influencing its efficacy. Similarly, **Krinsky-McHale et al. [23]** raised concerns about the accessibility of fully immersive VR for children with severe motor or visual impairments, who may struggle to interact effectively with such systems. A study by **Michalski et al. (24)** explored the feasibility of using VR to improve classroom behavior in individuals with Down syndrome. While the findings were encouraging, the study highlighted potential accessibility challenges, such as the need for tailored VR experiences to accommodate the unique needs of individuals with intellectual disabilities. The authors emphasized the importance of designing VR interventions that are user-friendly and accessible to this population. We didn't find present research with any contradictory results on the effectiveness of VR on cognitive function of children with DS, only some side effects were reported as, **Saredakis et al. [25]** highlighted potential side effects such as cybersickness, a condition characterized by dizziness and discomfort that could limit the applicability of immersive VR. While no such adverse effects were reported in this study, future research must address these potential barriers to ensure the broad adoption of VR technologies.

The theoretical underpinnings of this study are rooted in neuroplasticity and embodied cognition theories. Fully immersive VR employ sensory integration, real-time feedback, and interaction to activate mirror neurons, facilitating cognitive restructuring through repetition and engagement. **Prochnow et al. [9]** emphasized that immersive interventions engage multiple sensory modalities, enhancing neural connectivity and promoting cognitive flexibility. Additionally, **Borgnis et al. [26]** reported that VR environments foster executive functions such as decision-making and memory consolidation by simulating real-world scenarios that require problem-solving and attention management. These theoretical frameworks offer valuable insights into the mechanisms underlying the cognitive improvements observed in this study.
Full immersion is crucial to any type of learning activity that involves any type of body coordination such as medical training for surgery, learning physical therapy exercises, recreational activities (e.g., martial arts, dance, yoga), and manual skills (e.g., repair, combat training). Recent advances in computer graphics, computer vision, motion capture, and computer power have made it possible to build systems that allow us to assess the effectiveness of fully immersive virtual reality **(27).**

Although this study contributes to the growing evidence supporting VR therapy, several limitations warrant consideration. The school from which the sample was collected included only a few numbers of girls, so the sample was limited to boys in order to keep the baseline similarity and avoid the bias of different school activities if the sample was selected from different schools, but this may limits the generalizability of the findings across genders. Additionally, the relatively short intervention period may not fully capture the long-term benefits associated with VR therapy. A study by **Creed et al (28**) found some challenges faced by individuals with disabilities when using augmented and virtual reality systems. The authors identify key barriers like inadequate feedback, limited customization and high cost. Future studies should incorporate larger, more diverse samples and adopt randomized controlled designs to validate and extend these findings. Furthermore, addressing accessibility issues through the development of adaptive VR systems, as suggested by **Krinsky-McHale et al. [3]**, could expand the reach of VR-based interventions to a broader population.

5. Conclusion:

In conclusion, the observed improvements in attention and visual memory after using the fully immersive VR therapy offers a promising framework for cognitive rehabilitation. VR has more impact on cognitive abilities of children with DS than practicing school activities alone. These findings support the value of integrating innovative technologies into therapeutic practices and provide children with DS the opportunities for cognitive, social, and motor development.

6. Conflict of Interest:

The authors declare no conflict of interest.

7. Sources of Funding:

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