Research Article

Received: 2 January 2024 / Accepted: 27 February 2024 / Published: 5 March 2024

Developing Independent Skills Using a Virtual Reality-Based Training Program for Children with Down Syndrome

Sherif Adel Gaber

Associate Professor,
Department of Special Education,
Faculty of Education,
King Faisal University,
Al-Ahsa,
Saudi Arabia

DOI: https://doi.org/10.36941/jesr-2024-0037

Abstract

Children with Down syndrome (DS) have difficulties developing independent skills (IS), which affects their ability to carry out daily tasks and social interaction. To develop these children's skills and enhance their independence, this study aimed to develop the IS of children with moderate DS through a training program based on virtual reality (VR). The study sample consisted of 18 male students with DS at the "Obour Day Care" Center in Al-Ahsa, Kingdom of Saudi Arabia. Their ages ranged from 8–12 years (mean age = 9.45, standard deviation ± 1.47). The study took a quasi-experimental approach, and the research tools were the Independence Skills Scale (ISS) prepared by Badawi (2018) and a training program developed by the researcher. The results showed a statistically significant difference between the mean ranks of the first experimental group (to which the VR program was applied) on the ISS for the pre- and post-measurements in favor of the post-measurement ($z = -2.207$, $p = 0.027$). There was also a statistically significant difference between the mean ranks of the second experimental group (to which the regular program was applied) on the ISS in the pre- and post-measurements in favor of the post-measurement ($z = -2.201$, $p = 0.028$). There was no statistically significant difference between the mean ranks of the control group (which was not exposed to any intervention) on the ISS in the pre- and post-measurements ($z = -0.647$, $p = 0.518$). In addition, there were statistically significant differences between the mean ranks of the three groups on the ISS in the post-measurement ($x2 = 15.284$, $p < 0.001$) in favor of the first experimental group, followed by the second experimental group. Based on the results, it is recommended that a training program based on VR be integrated into various training and educational programs targeting children with moderate DS, in order to enhance their independence and develop their skills.

Keywords: *Virtual reality, Independent skills, Self-care skills, Down syndrome*

1. Introduction

1.1 Down Syndrome

Down syndrome (DS) is the most common live-born genetic disorder and has a distinct medical and psychological profile (Kats et al., 2023; Santoro et al., 2023). Also known as trisomy 21, it is a condition where a baby is born with an extra chromosome number 21. This occurs due to incorrect cell division during egg or sperm formation and leads to delays in mental and physical development and increased health risks. Individuals with DS typically have mild to moderate intellectual disability, growth retardation, and characteristic facial features (Akhtar & Bokhari, 2023; Faragher, 2023; Powell-Hamilton, 2022).

Every year, around 6,000 newborns born in the United States have DS, which indicates that DS affects around one out of every 700 children (Mai et al, 2019). The cause of DS is not fully understood, but advanced maternal age is a known risk factor (MedlinePlus, 2023). The error in cell division likely occurs after conception, and the impact on the individual depends on when this error occurs and which cells are affected. Some individuals with mosaic DS may not be diagnosed until adulthood (Faragher, 2023).

There are three forms of DS. It is not always possible to determine the difference between the types without looking at the chromosomes since their physical characteristics and behaviors are identical:

1. Trisomy 21: 95% of DS cases have trisomy 21. Each cell has three separate copies of chromosome 21.
2. Translocation DS: Around 3% of DS cases have an extra chromosome 21 attached to a different chromosome.
3. Mosaic DS: Around 2% of DS cases in children with mosaic DS have three copies of chromosome 21, while others have two copies. Children with mosaic DS may have fewer features due to the presence of cells with a typical number of chromosomes (Shin et al., 2010).

Children with DS were not included in public schools in the United States until the mid-1970s, when efforts were made to promote their integration into mainstream education (Grigal et al., 2018). Research on DS is of great importance to improve developmental and behavioral functioning and ensure the integration of individuals with DS into society (Sani-Bozkurt, S., 2018).

Children with DS face various health issues, including learning and memory impairments, congenital heart disorders, leukemia, malignancies, and Hirschsprung disease (Rafi & Maricle, 2023). They also often struggle with physical activity and have a higher risk of obesity and dementia, including Alzheimer's disease (Oreskovic et al., 2022). Balance issues also pose safety concerns during regular activities (Guerrero et al., 2023). Additionally, hearing loss is prevalent among children with DS, although the impact on their speech and functioning is not yet fully understood (Porter et al., 2023). Developing life skills such as healthy eating, meal preparation, the ability to provide personal information, and describing symptoms to a doctor are crucial for children with DS and can enhance their independence (Krell et al., 2021).

Due to the negative impact of DS on physical and mental development, children with DS face challenges in acquiring independent skills (IS), particularly self-care skills. Several Arab studies have addressed the development of independence and self-care skills in children with DS. These studies have implemented training programs and demonstrated their effectiveness in enhancing IS such as eating, drinking, dressing, hygiene, and self-care (Al-Dakhil et al., 2023; Badawi, 2018; Hawass, 2019; Mustafa & Ibrahim, 2021; Obaidi & Zaerur, 2020). Despite the diversity of interventions and their effectiveness in developing independence and self-care skills in children with DS, there is a lack of research in the Arab world on the use of virtual reality (VR) for developing such skills.

Virtual Reality

Technology plays a crucial role in daily activities, allowing people to stay connected with family and friends. Technology is also being applied in education, with VR tools being used to cater to students' needs, allowing designers to control the system effectively (Lorenzo et al., 2019).

VR, a futuristic technology, has its roots in the mid-1950s with Sensorama, a machine that played 3D (three-dimensional) movies, and generated odors and vibrations. Over time, technological advancements have led to a progressive evolution in devices and interface design, making VR a significant advancement in the field (Iberdrola, 2024). Jaron Lanier created the term VR in 1987, and his research and engineering contributed a variety of items to the fledgling VR business (Lowood, 2024).

VR is a 3D environment created using computer hardware and software, which allows users to explore and interact with their virtual surroundings. The user may need to wear a device such as a helmet or goggles to interact. Deep immersion in a VR environment allows users to suspend their beliefs and accept the environment as real, even if it is fantastical (Sheldon, 2022). VR can enhance the learning experience by providing a learner-centric environment, which in turn, can enhance student presence and engagement compared to traditional classroom practices (Kim et al., 2020).

VR can be categorized into three types: (1) non-immersive, (2) semi-immersive, and (3) fully immersive. (1) Non-immersive VR is computer-generated, allowing users to control VR activities without direct interaction. It is commonly used in everyday life and relies on a computer or video game console. (2) Semi-immersive VR connects users to their physical surroundings through VR glasses, allowing them to experience a different reality without physical sensation. This type of VR is often used for education or training. (3) Fully immersive VR is the most realistic simulation experience, incorporating technological advancements for a complete virtual tour integrating sound and sight. It is confined to a specific environment and away from the physical surroundings commonly used for gaming and entertainment. The artificial environment is created using VR glasses, body detectors, gloves, and sense detectors, creating a stereoscopic 3D effect for a believable experience (Atria Admissions Team, 2022).

Advantages and disadvantages of VR:

(A) Advantages of VR: (1) A fictional space separated from the real world, created through computer graphics simulation, (2) Immersion: users are physically separated from the real world through VR headsets and headphones, (3) Sensory input: VR headsets track users' location, allowing for realistic movement in the virtual environment, and (4) Interactivity: virtual components allow users to interact with the world, such as by picking items, swinging swords, smashing mugs, and pressing buttons.

(B) Disadvantages of VR: (1) High cost: VR equipment can be expensive, making it less accessible for some, especially small businesses and individuals, (2) Limited content availability: VR content requires special skills and money, limiting the variety of available activities, (3) Health concerns: VR can cause motion sickness, physical discomfort, and damage to eyesight and balance, and (4) Negative effects of isolation and dependence: VR can lead to social isolation and other negative effects if its use is excessive (Banoula, 2023).

The Ontario Institute for Studies in Education (2022) points out the similarities and differences between VR, augmented reality (AR), mixed reality (MR), and 360-degree VR and AR, which are different immersive experiences that use headsets or closed head-mounted displays to transport users to an alternate world. AR enhances users' presence by adding digital objects and overlays, while MR combines VR and AR using holographic lenses. 360-degree VR creates panorama photos or videos using 360-degree cameras, stitching together multiple images. However, 360-degree experiences are not VR in its simplest form, as they are used within a VR headset to create the illusion of an alternate world that does not have real-world visibility.

Several studies have indicated the effectiveness of VR in improving several skills among children with DS, including a study by Gómez et al. (2018), which found that a VR-based intervention improved postural control and motor skills in such children. Mohamed (2019) emphasizes the effectiveness of VR for motor rehabilitation, recommending more well-designed trials. Lopes et al. (2020) demonstrated that VR training enhances sensorimotor functions in DS children and can be combined with other rehabilitation interventions, while Stander et al. (2021) found that VR is effective in improving motor proficiency in DS children, and Michalski et al. (2022) found that exposure to VR improved such children's behavior in the classroom.

By reviewing previous literature, we can see that there is a clear need to develop IS for children with DS, as previous studies have indicated that most of these children suffer from a lack of IS due to the effects of DS on motor and learning abilities. Using VR as a tool to enhance IS development might be a promising solution. However, there are insufficient studies that provide strong and rigorous support for the effectiveness of using VR training programs in the IS development of children with DS. By addressing this research issue, this study can strengthen the evidence base, providing reliable evidence about the effectiveness of VR in IS development in these children.

Therefore, the study aimed to verify the effectiveness of a training program based on VR in the IS development of children with DS. Thus, the research plays an important role in expanding our understanding of how IS are developed in children with DS. This study is also of great importance for guiding the design and development of future training programs based on VR for children with DS. By understanding the effectiveness of this technique and its impact on IS development, the findings can be applied to direct efforts to develop effective and targeted training programs for these children. The results are also applicable to educational institutions, therapeutic centers, and communities of children with DS, and can contribute to improving the daily lives of children with DS and their ability to interact with others and participate in society. Therefore, this study aimed to answer the following four questions:

1. Is there a significant difference in the mean ranks of IS between the pre- and post-measurements for the first experimental group (using the VR program)?
2. Is there a significant difference in the mean ranks of IS between the pre- and post-measurements for the second experimental group (using the regular program)?
3. Is there a significant difference in the mean ranks of IS between the pre- and post-measurements for the control group (no treatment)?
4. Is there a significant difference in the mean ranks of IS among the three study groups in the post-measurement?

2. Methodology

2.1 Approach and Design

This study took a quasi-experimental approach to suit the nature of the study, which aimed to explore the effectiveness of VR (the independent variable) in developing IS (the dependent variable) among a sample of children with moderate DS. Therefore, the study design relied on three experimental groups with equal numbers (each group included six children) and homogeneity. Group 1 was the first experimental group (to which the training program based on VR was applied). Group 2 was the second experimental group (to which the regular program applied at the center was applied). Group 3 was the control group (to which no treatment was applied). The three groups were homogeneous in terms of age, IQ (intelligence quotient), degree of disability, and degree of IS.

2.2 Participants

The study population included all children with middle-grade DS from the "Obour Day Care" Center in Al-Ahsa, Saudi Arabia. In the first semester of the 2023-2024 academic year, according to official statistics issued by the Center, there were 35 children with DS. The basic sample used for this study was 18 children, who were all male (mean age = 9.45, standard deviation ± 1.47) with a mean IQ = 47.89 (standard deviation ± 4.60). These participants were intentionally chosen for ease of access. They were divided into three groups randomly after the researcher obtained scientific research ethics approval from King Faisal University. To implement the program and obtain official approval from their families to include them in the experiment, the focus was on males only due to the nature of the training situation in the Kingdom of Saudi Arabia, where only male teachers and researchers are able to train male children. The following inclusion criteria were applied to the participants:

- Chronological age from 8 to 12 years.
- IQ score from 40 to 54.

- Has DS, but does not have any other accompanying disabilities.
- Lower-than-average lack of IS.

Of the 35 children with DS in the 2023-2024 school year, two children were excluded from this research because they did not meet the conditions, and two others were excluded because their parents refused to participate in the program. The remaining 13 children were excluded because they had severe DS.

Tools

2.3 Independence Skills Scale (ISS) (Prepared by Badawi, 2018)

The ISS was developed by Badawi (2018) using a sample of 30 children with DS in the Kingdom of Saudi Arabia. The scale consists of 38 items, distributed across four dimensions, where the first dimension (eating), consists of nine items, the second dimension (drinking) consists of four items, the third dimension (dressing and undressing) consists of 12 items, and the fourth dimension (personal hygiene and self-care) consists of 13 items. The scale was presented to a group of specialized and experienced arbitrators to ensure the suitability of the items and that they were correctly allocated to their given dimensions. Items that achieved an agreement rate of 75% were accepted for inclusion.

The scale items are scored on a 3-point Likert scale (no = 1, somewhat = 2, yes = 3). The scores for each dimension are separately summed, and then the four dimension scores are summed to calculate the total score for the scale, where a low score indicates that a child has no IS, and a high score indicates the child's mastery of IS.

2.4 Psychometric properties of the ISS

Validity: The internal consistency of the scale was calculated by finding the correlation coefficient between each dimension score and the total scale score, and identifying whether they were statistically significant. The Pearson correlation coefficients for the four dimensions were 0.87 (eating), 0.89 (drinking), 0.74 (dressing and undressing), and 0.78 (personal hygiene and self-care), and all had probability values less than 0.05. In research by Richardson, the correlation coefficients for these dimensions were, respectively, 0.85, 0.84, 0.78, and 0.69, and all had probability values less than 0.05.

Reliability: Reliability was calculated using Cronbach's alpha, which for the four dimensions of the scale, respectively, was 0.73, 0.84, 0.90, and 0.81. The test was also re-applied to the same sample 21 days after the first application, and the Pearson correlation coefficients between the two applications were, respectively, 0.78, 0.72, 0.79, and 0.68; all had probability values less than 0.05.

The validity and reliability findings indicated that the scale had acceptable psychometric properties and could confidently be used to measure IS in the target sample.

2.5 Training Program

The training program used in this study was an interactive three-dimensional computer program whose elements were designed using the Cinema 4D program, version 25, and a group of images taken with 360-degree technology to form an artificial environment that placed the children who suffered from moderate DS in an artificial world. This pushed them to interact with activities that made them feel they were a part of this environment, which aimed to improve independent self-care skills, and could affect it and be affected by it.

The main goal of the training program used in this study was to verify the effectiveness of the environment built on VR in developing IS, namely eating, drinking, dressing and undressing, and personal hygiene and self-care, among participants who are children with moderate DS (children in the first experimental group; Group 1). The aim was to enhance their ability to practice their daily lives independently without the need for assistance from those training them. The importance of this training program was to improve the independence and daily lives of the participants by helping them perform their vital daily tasks independently, which ultimately, will increase their self-confidence and improve their quality of life.

The program was aimed at improving the general health and personal hygiene of children with DS, which enhances their general well-being and reduces the health problems associated with moderate DS. The program may also contribute indirectly to improving the social skills of these children, enhancing their social integration, and improving their personal relationships with others. The program had theoretical and applied foundations, relying on the principles of social learning theory, and opportunities were provided for the learning and practice of IS through interaction with a VR environment that simulated daily life situations related to self-care. The program also took into account the age stages and specific abilities of children with moderate DS (late childhood stage). It used VR to create an interactive and realistic environment that contributed to developing the IS of these children. The program also relied on the principles and techniques of applied behavioral therapy, which aims to change behavior and enhance skills by providing purposeful education, repeated practice, and positive reinforcement.

The researcher designed a special form to evaluate the children's performance during the training stage (the second stage of the training program) through three attempts for each task; 80% was considered to be the most appropriate percentage for correct performance, not 100%. The procedural limits of the program were to select a research sample of children with moderate DS from the "Obour Day Care" Center in Al-Ahsa. The program was implemented across a total of 50 sessions. The session duration was 20 minutes for each child. Three sessions per week for four months, from the beginning of September 2023 to the end of December 2023.

The training program based on VR was designed according to the "Addie Model" for the simplicity of its staged design process for dealing with educational design. This model consists of five main stages from which it derives its name: analysis, design, development, implementation, and evaluation. These were used to develop the program. The training program was delivered in three stages. The first stage (the introductory stage) included four sessions (Sessions 1–4), during which the researcher discussed some basic matters, including getting to know the children to achieve more familiarity and harmony, participating in activities familiar to the children, and providing reinforcements to them. The second stage (the training stage) included 38 sessions. Sessions 5–14 trained the children in eating skills, and Sessions 15–19 trained them in drinking skills. Dressing and undressing were taught in Sessions 20–31, while in Sessions 32–42, children were trained in personal hygiene and self-care skills. The final stage of the program (the evaluation stage) included eight sessions (Sessions 43–50) that evaluated the performance of the children; this was undertaken through a form specifically designed by the researcher for this purpose.

2.6 Data Collection

This study reviewed official records received from the "Comprehensive Rehabilitation Center for Persons with Disabilities," provided to the "Obour Day Care" Center, to collate data on the children's chronological age, IQ, and DS scores. These records were less than six months old, ensuring that the tools on which the children were evaluated had a high degree of validity and reliability in detecting intelligence and the degree of DS. Additionally, as discussed above, data on IS were collected using the ISS (Badawi, 2018).

2.7 Statistical Analysis

The study used SPSS version 26 and a set of nonparametric tests for the analyses. The Kruskal-Wallis test was used to identify the significance of the difference between the three study groups at the pre-measurement stage and to verify the homogeneity of the three groups. It was also used at the post-measurement stage to identify the significance of the differences between the three groups. In addition, the Wilcoxon test was used to determine the significance of the difference between the two paired groups, and the Mann-Whitney test was also used in the post-comparisons to search for the source of the difference between each of the two independent groups.

3. Results

3.1 Results Related to Research Question 1

Q.1. Is there a significant difference in the mean ranks of IS between the pre- and post-measurements for the first experimental group (using the VR program)?

It is clear from Table 1 that there is a statistically significant difference between the mean ranks for Group 1 in the pre- and post-measurements for the four ISS dimensions in favor of the post-measurement, as all the p-values (for each dimension and the total score) were less than 0.05. This indicates increased IS in the first experimental group, to which the training program based on VR was applied.

Table 1. Results of the Wilcoxon test for the differences between the mean ranks of Group 1 on the ISS pre- and post-measurements

Scale dimensions	Group 1 (pre- and post-test)	N	Mean rank	Sum of ranks	Z	*P*
Eating	Neg. Ranks	0	0	0	-2.264	0.024
	Pos. Ranks	6	3.50	21		
	Ties	0				
Drinking	Neg. Ranks	0	0	0	-2.271	0.023
	Pos. Ranks	6	3.50	21		
	Ties	0				
Dressing and undressing	Neg. Ranks	0	0	0	-2.214	0.027
	Pos. Ranks	6	3.50	21		
	Ties	0				
Personal hygiene and self-care	Neg. Ranks	0	0	0	-2.226	0.026
	Pos. Ranks	6	3.50	21		
	Ties	0				
Total	Neg. Ranks	0	0	0	-2.207	0.027
	Pos. Ranks	6	3.50	21		
	Ties	0				

3.2 Results Related to Research Question 2

Q.2. Is there a significant difference in the mean ranks of IS between the pre- and post-measurements for the second experimental group (using the regular program)?

It is clear from Table 2 that there was a statistically significant difference between the mean ranks for Group 2 in the pre- and post-measurements for the four ISS dimensions in favor of the post-measurement, as all the p-values (for each dimension and the total score) were less than 0.05. This indicates increased IS in the second experimental group, to which the regular program was applied.

Table 2. Results of the Wilcoxon test for the differences between the mean ranks of Group 2 on the ISS pre- and post-measurements

Scale dimensions	Group 2 (pre- and post-test)	N	Mean rank	Sum of ranks	Z	P
Eating	Neg. Ranks	0	0	0	-2.271	0.023
	Pos. Ranks	6	3.50	21		
	Ties	0				
Drinking	Neg. Ranks	0	0	0	-2.264	0.024
	Pos. Ranks	6	3.50	21		
	Ties	0				
Dressing and undressing	Neg. Ranks	0	0	0	-2.207	0.027
	Pos. Ranks	6	3.50	21		
	Ties	0				
Personal hygiene and self-care	Neg. Ranks	0	0	0	-2.214	0.027
	Pos. Ranks	6	3.50	21		
	Ties	0				
Total	Neg. Ranks	0	0	0	-2.201	0.028
	Pos. Ranks	6	3.50	21		
	Ties	0				

3.3 *Results Related to Research Question 3*

Q.3. Is there a significant difference in the mean ranks of IS between the pre- and post-measurements for the control group (no treatment)?

It is clear from Table 3 that there was no statistically significant difference between the mean ranks for Group 3 (control group) in the pre- and post-measurements for the four ISS dimensions, as all the p-values (for each dimension and the total score) were greater than 0.05. This indicates that there was no increase in IS among the control group, to which no training program was applied.

Table 3. Results of the Wilcoxon test for the differences between the mean ranks of Group 3 (control group) on the ISS pre- and post-measurements

Scale dimensions	Group 3 (control) (pre- and post-test)	N	Mean Rank	Sum of Ranks	Z	P
Eating	Neg. Ranks	2	1.50	3	-1.342	0.180
	Pos. Ranks	0	0	0		
	Ties	4				
Drinking	Neg. Ranks	2	1.50	3	-1.414	0.157
	Pos. Ranks	0	0	0		
	Ties	4				
Dressing and undressing	Neg. Ranks	3	3.33	10	-0.707	0.480
	Pos. Ranks	2	2.50	5		
	Ties	1				
Personal hygiene and self-care	Neg. Ranks	3	2.17	6.50	-0.557	0.577
	Pos. Ranks	1	2.50	3.50		
	Ties	2				
Total	Neg. Ranks	3	4.50	13.50	-0.647	0.518
	Pos. Ranks	3	2.50	7.50		
	Ties	0				

3.4 Results Related to Research Question 4

Q.4. Is there a significant difference in the mean ranks of IS among the three study groups in the post-measurement?

Table 4 indicates that there were statistically significant differences between the mean ranks of the three study groups in the ISS post-measurement scores. All the p-values for the four dimensions and the total score of the scale were less than 0.05. To identify which of these three groups caused these differences, the Mann-Whitney test was used to assess the differences between Groups 1 and 2, Groups 1 and 3, and Groups 2 and 3. The results are shown in Table 5.

Table 4. Results of the Kruskal-Wallis test for the differences between the mean ranks of the three groups on the ISS post-measurement score

Scale dimensions	Groups	n	Mean rank	df	X^2	*p*
Eating	Group 1	6	15.50	2	15.412	<0.001
	Group 2	6	9.50			
	Group 3 (control)	6	3.50			
Drinking	Group 1	6	15.17	2	14.774	0.001
	Group 2	6	9.83			
	Group 3 (control)	6	3.50			
Dressing and undressing	Group 1	6	15.50	2	15.348	<0.001
	Group 2	6	9.50			
	Group 3 (control)	6	3.50			
Personal hygiene and self-care	Group 1	6	15.50	2	15.380	<0.001
	Group 2	6	9.50			
	Group 3 (control)	6	3.50			
Total	Group 1	6	15.50	2	15.284	<0.001
	Group 2	6	9.50			
	Group 3 (control)	6	3.50			

Table 5 shows that there were statistically significant differences between Groups 1 and 2, Groups 1 and 3, and Groups 2 and 3. All the p-values were less than 0.05, which indicates that Group 1, which was trained in the VR-based training program, outperformed both Group 2 and Group 3 (the control group).

Table 5. The results of the differences between the mean ranks of the three study groups

The difference between the groups	Group 2		Group 3 (control)	
	Z	*p*	Z	*p*
Group 1	−2.913	0.004	−2.908	0.004
			Z	*p*
Group 2			−2.908	0.004

4. Discussion

The results of the study showed that the training program based on VR was an effective tool in developing the IS of children with moderate DS, as the participants showed a noticeable improvement in their abilities to carry out daily tasks related to self-care. It is suggested that this was due to the training program providing an interactive virtual environment that enabled the children to practice IS in a safe context that simulated real-life activities. The program also provided opportunities for interactive learning and repetition-based training, in addition to allowing participants to actively participate in and focus on performing tasks, which contributed to motivating the children and improved their abilities to perform and apply the targeted skills with confidence and proficiency.

The results of the study revealed that there was a difference between the first experimental group (to which the VR program was applied) in the pre- and post-measurements on the ISS in favor of the post-measurement. This result is consistent with studies by Gómez et al. (2018), Mohamed (2019), Lopes et al. (2020), Stander et al. (2021), and Michalski et al. (2022). The researcher attributes this to several factors that explain the difference between the two measurements, including technical factors: the training program based on VR provided intensive interactive training and a realistic simulation of situations that require IS, which motivated the participants and enhanced their learning. This helped the children to develop and improve their IS compared to their situation in the pre-measurement. In addition, the program instilled self-confidence and provided the necessary motivation and focus for performing the required tasks.

The results also showed that there was a difference between the second experimental group (to which the regular program was applied) in the pre- and post-measurements on the ISS in favor of the post-measurement. This result is consistent with studies by Badawi (2018), Hawass (2019), Obaidi and Zaerur (2020), Mustafa and Ibrahim (2021), and Al-Dakhil et al. (2023). This result may have occurred because the regular program included organized and sequential scientific steps with somewhat specific goals and activities aimed at developing IS. This result can also be explained in light of the positive effects of the program, which aimed to increase awareness of IS and develop strategies for dealing with independent tasks.

The results showed that there were no differences between the control group (which was not exposed to any intervention) in the pre- and post-measurements on the four ISS dimensions. This result is consistent with studies by Badawi (2018) and Hawass (2019). These results indirectly support the effectiveness of both the training program based on VR and the regular program in developing the participants' IS. This is because the control group was not exposed to any experimental procedures, and therefore no improvement in IS would be expected to occur since DS is a genetic disorder that affects development. It causes a delay in mental achievement and affects physical development, which means that children with moderate DS will suffer from difficulties in developing IS unless they are trained according to scientific principles.

The study revealed significant differences between the three experimental groups on the ISS post-measurement scores, with Group 1 (the VR group) showing superior results to the other groups. This result is consistent with studies by Badawi (2018), Gómez et al. (2018), Mohamed (2019), Hawass (2019), Lopes et al. (2020), Obaidi and Zaerur (2020), Mustafa and Ibrahim (2021), Stander et al. (2021), Michalski et al. (2022), and Al-Dakhil et al. (2023). The researcher suggests the results were more positive for the first experimental group (to which the training program based on VR was applied) over the second experimental group (to which the regular program was applied) because VR technology provided an interactive and realistic experience of situations that children with DS face in their daily lives, which provided them with more opportunities to develop IS (eating, drinking, dressing and undressing, personal hygiene and self-care skills) through their practical application. This contrasts with the regular program, which presented traditional training methods that were not as interactive and realistic as the technology based on VR, which was characterized by attracting the attention of the participants and exciting them to practice. That is, it was a fun experience for them.

5. Limitations and Future Studies

Despite the positive results of the study, the researcher faced several limitations, the most important of which was the small size of the sample, which was developed to exclude children who had other disabilities associated with DS. Furthermore, the available age range was from 8 to 12 years, which limits the generalizability of the results. Therefore, more programmatic studies with a larger sample should be conducted to confirm the effectiveness of VR; these studies should specify a longer time period, lasting for six months or one year. This will help to make optimal use of VR in developing independence skills in children with DS and obtain strong and statistically reliable results.

Taking into account other variables that could affect the effectiveness of the training program, such as family support, the study was also applied in a geographically limited environment; therefore, future research might expand the geographical area and the scope of participation to several centers or institutions to increase diversity and generalizability in the results.

In light of the above, future research is suggested: this includes conducting research to evaluate the sustainability of the effectiveness of a training program based on VR in the long term and following children with DS over a long period after the end of the program to evaluate the continuity of their improved independence skills. Future research may also conduct a study of the impact of the program used in this study. There are other degrees of DS, such as simple or learnable, which could be examined, especially for other age groups. The study could also be expanded to examine the effect of additional variables, such as family support and other environmental factors, on the effectiveness of the training program. Future research could also compare the effectiveness of VR with other technologies, such as AR and MR, which will contribute to determining which technology provides the best results for developing independence skills in children with DS.

6. Conclusion

The results of the study indicate that the training program based on VR is an effective tool for developing independence skills in children with moderate DS. Hence, VR represents an interactive and realistic environment that allows children with moderate DS to practice independence skills in a safe context that completely simulates reality. These children showed a noticeable improvement in their eating, drinking, dressing and undressing, personal hygiene, and self-care abilities. Participation in the training program based on VR technology also enhanced the active participation and focus of the participants and motivated them to engage with the targeted activities. The training program also provided opportunities for repeated training and repetitive learning, which contributes to promoting sustainability and transferring the skills learned to real-life situations.

7. Acknowledgments

The author acknowledges the Deanship of Scientific Research at King Faisal University in Saudi Arabia for financial support under (GRANT5870).

References

Akhtar, F., & Bokhari, S. (August, 2023). *Down syndrome*. https://www.ncbi.nlm.nih.gov/books/NBK526016/

Al-Dakhil, A., Al-Thumairy, N., & Al-Otaibi, H. (2023). The effectiveness of the "Teacch" program in developing some language skills and independence in children with Down syndrome. *Saudi Social Studies Journal, 11*, 57-72. http://search.mandumah.com/Record/1393155

Badawi, W. (2018). The effectiveness of a training program for developing independent and social skills among children with Down syndrome in Abha city. *College of Arts Research Journal, 29*(113), 3025-3075. https://doi.org/10.21608/sjam.2018.144521

Banoula, M. (2023, March 9). *What is virtual reality? Everything you need to know*. https://www.simplilearn.com/tutorials/artificial-intelligence-tutorial/what-is-virtual-reality

Faragher, R. (2023). *A Practical guide to educating learners with Down syndrome: Supporting lifelong learning*. Taylor & Francis.

Gómez, N., Venegas, A., Zapata, V., López, M., Maudier, M., Pavez-Adasme, G., & Hemández-Mosqueira, C. (2018). Effect of an intervention based on virtual reality on motor development and postural control in children with Down syndrome. *Revista chilena de pediatría, 89*(6), 747–752. https://doi.org/10.4067/S0370-41062018005001202

Grigal, M., Hart, D., & Papay, C. (2018). Inclusive higher education for people with intellectual disability in the United States: An overview of policy, practice, and outcomes. *People with intellectual disability experiencing university life*, 69-97. https://doi.org/10.1163/9789004394551_005

Guerrero, K., Umagat, A., Barton, M., Martinez, A., Ho, K., Mann, S., & Hilgenkamp, T. (2023). The effect of a telehealth exercise intervention on balance in adults with Down syndrome. *Journal of Applied Research in Intellectual Disabilities, 36*(2), 385-393. http://dx.doi.org/10.1111/jar.13068

Hawass, E. (2019). The effectiveness of a training program to develop self-care skills for children with Down syndrome. *College of Education Journal, 3*(119), 207-244. http://doi.org/10.21608/jfeb.2019.61329

Iberdrola. (2024, January). *Virtual Reality, the technology of the future*. https://www.iberdrola.com/innovation/virtual-reality

Kats, D., Skotko, B., de Graaf, G., Skladzien, E., Hooper, B., Mordi, R., Mykhailenko, T., Buckley, F., Patsiogiannis, V., Kavita; H., Donelan, K. (2023). Designing an international survey for organizations serving people with Down syndrome. *Journal of applied research in intellectual disabilities, 36*(3), 497-506. http://dx.doi.org/10.1111/jar.13071

Kim, K., Oertel, C., Dobricki, M., Olsen, J., Coppi, A., Cattaneo, A., & Dillenbourg, P. (2020). Using immersive virtual reality to support designing skills in vocational education. *British Journal of Educational Technology, 51*(6), 2199-2213. https://doi.org/10.1111/bjet.13026

Krell, K., Haugen, K., Torres, A., & Santoro, S. (2021). Description of daily living skills and independence: A cohort from a multidisciplinary Down syndrome clinic. *Brain Sciences, 11*(8), 1012. https://doi.org/10.3390/brainsci11081012

Lopes, J., Duarte, N., Lazzari, R., & Oliveira, C. (2020). Virtual reality in the rehabilitation process for individuals with cerebral palsy and Down syndrome: A systematic review. *Journal of bodywork and movement therapies, 24*(4), 479-483. https://doi.org/10.1016/j.jbmt.2018.06.006

Lorenzo, G., Lledó, A., Arráez-Vera, G., & Lorenzo-Lledó, A. (2019). The application of immersive virtual reality for students with ASD: A review between 1990–2017. *Education and Information Technologies, 24*(1), 127-151. https://doi.org/10.1007/s10639-018-9766-7

Lowood, H. (2024, January 3). *Virtual reality*: *Encyclopedia Britannica*. https://www.britannica.com/technology/virtual-reality

Mai, C., Isenburg, J., Canfield, M., Meyer, R., Correa, A., Alverson, C., Lupo, P., Riehle-Colarusso, T., Cho, S., Aggarwal, D., Kirby, R. National Birth Defects Prevention Network. (2019). National population-based estimates for major birth defects, 2010–2014. *Birth defects research, 111*(18), 1420-1435. https://doi.org/10.1002/bdr2.1589

MedlinePlus. (2023, February 21). *Down syndrome*. https://medlineplus.gov/downsyndrome.html

Michalski, S., Szpak, A., Ellison, C., Cornish, R., & Loetscher, T. (2022). Using virtual reality to improve classroom behavior in people with down syndrome: Within-subjects experimental design. *JMIR Serious Games, 10*(2), e34373. https://doi.org/10.2196/34373

Mohamed, R., Abdel-Rahman, S., & Aly, M. (2019). Virtual reality for motor rehabilitation of children with Down syndrome: Systematic review. *The Medical Journal of Cairo University, 87*(2), 1117-1123. https://doi.org/10.21608/mjcu.2019.53291

Mustafa, S. & Ibrahim, D. (2021). A digital training program for mothers to develop some independence skills for their children with Down syndrome. *Journal of Childhood and Education, 1*(45), 75-136. https://doi.org/10.21608/fthj.2021.169064

Obaidi, A. & Zaerur, L. (2020). The effectiveness of a proposed behavioral training program to develop self-care and social skills for children with Down syndrome moderate mental retardation. *Journal of Psychological and Educational Sciences, 6*(4), 50-75. http://ddeposit.univ-alger2.dz:8080/xmlui/handle/20.500.12387/5065

Ontario Institute for Studies in Education. (2022, December 17). *Virtual reality in the classroom*. https://guides.library.utoronto.ca/c.php?g=607624&p=4938314

Oreskovic, N., Agiovlasitis, S., Patsiogiannis, V., Santoro, S., Nichols, D., & Skotko, B. (2022). Brief report: Caregiver perceived physical activity preferences of adults with Down syndrome. *Journal of Applied Research in Intellectual Disabilities, 35*(3), 910-915. http://dx.doi.org/10.1111/jar.12979

Porter, H., Braza, M., Knox, R., Vicente, M., Buss, E., & Leibold, L. (2023). I think it impacts all areas of his life: Perspectives on hearing from mothers of individuals with Down syndrome. *Journal of Applied Research in Intellectual Disabilities, 36*(2), 333-342. http://dx.doi.org/10.1111/jar.13062

Powell-Hamilton, N. (2022, February). *Down syndrome*. https://kidshealth.org/en/parents/down-syndrome.html

Rafi, F., & Maricle, D. (2023). Down syndrome: What school psychologists should know?. *Communique, 51*(5). https://www.nasponline.org/resources-and-publications/cq-archive

Sani-Bozkurt, S. (2018). Identifying network structure, influencers and social mood in digital spheres: A sentiment and content analysis of Down syndrome awareness. *World Journal on Educational Technology: Current Issues, 10*(1), 10-19. https://www.ceeol.com/search/article-detail?id=963096

Santoro, S., Cabrera, M., Haugen, K., Krell, K., & Merker, V. (2023). Indicators of health in Down syndrome: A virtual focus group study with patients and their parents. *Journal of Applied Research in Intellectual Disabilities, 36*(2), 354-365. https://doi.org/10.1111/jar.13071

Sheldon, R. (2022, August 8). *Virtual reality*. https://www.techtarget.com/whatis/definition/virtual-reality

Shin, M., Siffel, C., & Correa, A. (2010). Survival of children with mosaic Down syndrome. *Am J Med Genet A, 152*A, 800-801.

Stander, J., du Preez, J., Kritzinger, C., Obermeyer, N., Struwig, S., van Wyk, N., Zaayman, J., & Burger, M. (2021). Effect of virtual reality therapy, combined with physiotherapy for improving motor proficiency in individuals with Down syndrome: A systematic review. *The South African journal of physiotherapy, 77*(1), 1516. https://doi.org/10.4102/sajp.v77i1.1516