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Original Article

Application and Effectiveness of Virtual Reality in Teaching Basic Concepts to Children with Autism Spectrum Disorder

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Abstract

Background: This study compares traditional teaching methods with cutting-edge virtual reality (VR) technology to assess its effectiveness in teaching basic concepts to children with autism spectrum disorder (ASD).

Methods: Thirty-two children with ASD were included in the study and randomly assigned to either the VR or the control group. For the VR group, a teaching material was developed as an easy-to-play VR game called Geometry Park to teach concepts of shapes and colors to children with ASD, by virtually traveling through a world filled with geometrical shapes in different colors and sizes. For the control group, similar teaching material was prepared using flashcards with shapes and colors similar to those in Geometry Park. Each subject underwent ten play-and-learn sessions. At the end of the sessions, the research assistant asked them to identify 23 shapes and colors using "test flash cards" and reported the scores for each item.

Results: The result of the two-sample t-test did not show a statistically significant difference between the means of the two groups ($P=0.45$), which might be a false negative due to Type II error. However, a medium effect size was observed for the VR group compared to the control group (Cohen's $d=0.39$).

Conclusion: The results of this experiment did not demonstrate a statistically significant difference between the VR and the control groups. However, a medium effect size was found for the VR group, which is "clinically significant".

Keywords: Autism spectrum disorder, Virtual reality, Teaching, Colors, Geometrical shapes

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Introduction

Autism spectrum disorder (ASD) affects approximately 1% of the world's population (1) and is associated with social impairments and developmental delays (2). Generally, children with ASD develop normally around 18 months of age, after which they may face developmental delays. Without appropriate treatment and education, these children may fall behind in years (3). Early interventions during this "golden treatment period" are crucial to help them keep up with normal development and achieve independence (4).

Virtual reality (VR) is an emerging technology that is extremely popular and has substantial potential to be employed for different purposes. Education is the second application and usage of VR globally, following gaming (5). Children with ASD typically learn better through images and are more visual (6). On the other hand, VR is engaging, visual, immersive, and exciting, usually allowing fewer distractions due to its virtual presence in the educational scene (7). Therefore, VR can provide an ideal platform for teaching different concepts to children with ASD.

Attempts have been made to take advantage of VR in teaching necessary skills to individuals with ASD. In 2013, Kandalaft et al from the United States published an article investigating the effect of virtual-reality intervention on improving cognition, skills, and social performance of autistic people. In this study, 8 high-functioning autistic subjects aged 18-26 participated in 10 training sessions over 5 weeks. The results revealed an increase in social cognition, theory of mind, emotion recognition, as well as work and social performance of subjects. Subjects were contacted at least 6 months later and asked to complete a questionnaire indicating whether they agreed or disagreed with the positive results of the treatment across 14 skills. Social and cognitive issues were mentioned. According to this article, 13 of these cases scored between 50% and 100%, indicating a very positive effect of VR-based treatment on the studied subjects (8).

In 2016, Didehbani et al from the United States investigated the effect of VR training on 30 autistic children and adolescents through 10 training sessions over 5 weeks. This study examined improvements in emotion recognition, social self-definition, executive performance, and attention, among which emotion recognition ($P=0.001$), social self-definition ($P=0.016$), and executive performance ($P=0.016$) exhibited improvements. According to the study, VR was non-immersive, resembling a computer game, with avatars similar to the subject and controlled by the treatment staff (9).

In the current study, we used VR to teach basic concepts such as colors and 2-dimensional (2D) and 3-dimensional (3D) shapes to children diagnosed with ASD. To test the effectiveness of VR as a teaching tool compared to traditional teaching tools, we compared it with a group of children with ASD who received the same teaching material using flash cards.

Materials and Methods

The protocol for this study was approved by the ethics board of Hamadan University of Medical Sciences. The study was designed as a randomized control trial (RCT), with the registration code IRCT20180707040370N8. Thirty-two children with autism participated, including 7 girls and 25 boys of Iranian ethnicity. Inclusion criteria required participants to be between 2 to 13 years old with an ASD condition diagnosed by a child psychiatrist. Exclusion criteria included the inability to tolerate the VR headset after 10 conditioning sessions or excessive anxiety that prevented participants from undertaking the experiments.

Subjects were divided into two groups: the VR and the control group. Control group subject allocation was concealed and completed using the Rand function in Excel to ensure proper randomization. The age range of subjects was 2-13 years. Before starting the experiment, all subjects underwent 10 conditioning sessions with VR content that was entertaining (Figure 1), excluding the teaching material of the main sessions. The duration of these conditioning sessions varied according to the subject's preference, with a maximum of 30 minutes. The objectives for holding the training/conditioning sessions were fourfold: 1) To ensure that motion sickness will not be a confounding issue during the main sessions, 2) To allow subjects with touch hyper-sensitivity enough time to adjust to wearing the headsets, 3) To help subjects with autism who experience extreme anxiety (caused by their autism) try the VR headsets, with 10 sessions providing enough time to subside their anxiety (for most of them); and 4) To eliminate the "freshness" effect of the technology for the subjects.

The main sessions consisted of 10 weekly sessions, each lasting 15 minutes. Experiments were started with 16 subjects per group, but due to the COVID-19 pandemic, only 16 subjects completed the experiment sessions (8 per group), resulting in a 50% drop-off rate. The teaching materials included 12 2D and 3D geometrical shapes (triangle, square, circle, rectangle, oval, cube, sphere, cylinder, cone, pyramid, diamond, and heart) and 11 different colors (green, orange, white, blue, red, yellow, purple, black, pink, brown, and gray). The control group was trained using flash cards (Figure 2) with the same training contents as the VR ones.

The Virtual Reality Game (Geometry Park)

As part of the training content for the intervention group, a VR game named "Geometry Park" (Figure 1)

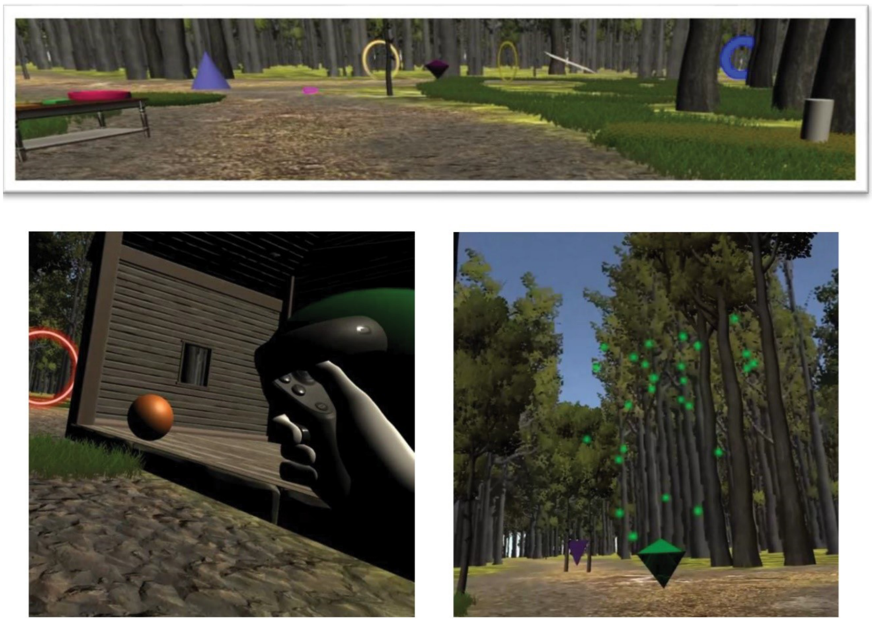

Figure 1. Three Screenshots of Geometry Park, the VR Educational Game for Children With ASD. *Note.* VR: Virtual reality; ASD: Autism spectrum disorder

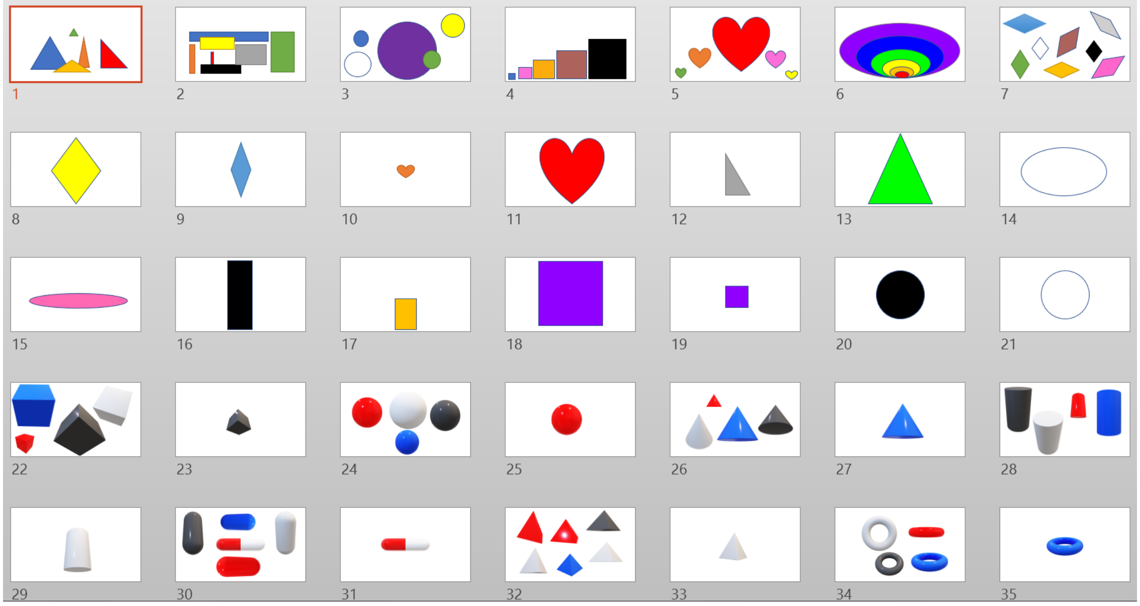

Figure 2. Flashcards Prepared for the Control Group With Educational Materials Similar to Geometry Park

was developed. This game was specifically designed for children with ASD to teach them the names of colors and geometrical shapes. When users try this game, they see themselves in a peaceful and safe jungle where they can wander around and interact with the objects: several 2D and 3D geometrical shapes that come in different colors. The caregiver who shares the view with the subjects guides them to approach the objects and knock them out. When children see the objects falling or flying in reaction to their hit, and when they hear the sound of hitting, they get excited and start looking for the next "goal". Through this simple and engaging game, children with ASD "gradually learn the names of shapes and colors. It is worth mentioning that since this game was designed for children with ASD, it needed to be easy to navigate; hence, after grabbing the touch controllers of the headset, the trainee only needs to use the joystick if there is not enough space for them in the room to walk. To knock out objects, they use their hands, just like in the real world.

Statistical Analysis

To compare the means between the two groups, a two-sample t-test was initially used. The Shapiro-Wilk normality test revealed that the control group complied with a normal distribution, but the VR group's data did not. Thus, to test the significance of the difference between group means, the Mann-Whitney U test (the non-parametric alternative to the two-sample t-test) was used. Dada analysis was then conducted SPSS software (version 16).

Results

Table 1 presents the results of the questionnaires completed at the end of the main sessions by the research assistant. The mean age and standard deviation of the subjects were 7.96 ± 2.62 years and 8.00 ± 3.16 years for the control group and the VR group, respectively. Each score in the table represents the sum of scores from each subject in both groups across 23 questionnaire items: 12 questions on geometrical shape names and 11 questions on color names. The descriptive statistics for the study, including the mean, standard deviation, and median for each group, are illustrated in Table 2.

Table 1. Total Score of Subjects of Each Group (Out of 23)

Control Group	VR Group
7.00	21.00
18.00	18.00
13.00	21.00
10.00	0.00
23.00	21.00
0.00	12.00
0.00	0.00
15.00	20.00

Note. VR: Virtual reality.

To assess the difference in mean scores between the two groups, a two-sample t-test with unequal variances was conducted. The P value was 0.45, indicating no statistically significant difference between the groups. However, Cohen's d was found to be 0.39, suggesting a medium effect size, which implies a "clinically significant" result. To further examine differences between the two groups, each of the 23 questionnaire items (12 shapes and 11 colors) was individually assessed using a two-sample t-test, which showed a significant superiority for the VR group for the purple ($P = 0.049$) and gray ($P = 0.041$) colors compared to the control group. Table 3 presents the mean and standard deviations for these two colors, which yielded significant results.

Discussion

In this study, we compared the effectiveness of teaching

Table 2. The Descriptive Statistics and Average Persentage of Correct Answers to the Questionnaires for Each Group

	Average Percentage of Correct Answers	Mean (P=0.45)	Standard Deviation	Median
VR Group	61.4	14.125	9.22	19
Control Group	46.7	10.75	8.21	11.5

Note. VR: Virtual reality.

Table 3. The Mean and Standard Deviation of Scores for the Two Items With Significant Results

		Mean	Standard Deviation
Gray Color (P=0.041)	VR Group	0.63	0.27
	Control Group	0.13	0.13
Purple Color (P=0.049)	VR Group	0.75	0.21
	Control Group	0.25	0.21

Note. VR: Virtual reality.

basic concepts of color and shape to children with ASD using a traditional approach (flashcards) and a novel approach (VR). The results of this study could not prove a statistically significant difference between the VR and the control group. However, a medium effect size (Cohen's d = 0.39) was observed for the VR group, which is "clinically significant".

Ip et al from Hong Kong conducted a study on 94 autistic children in 2018 and used the data from 72 children in the analysis. They divided the children into intervention and control groups (waiting list method) and placed them in a VR room (completely immersive) designed to enhance social and cognitive acquisition skills. Different social scenarios, including emotion control and calming strategies, were presented in 28 sessions over a 14-week period. The results showed improvements in the primary goals of the research, namely, emotion regulation (P = 0.025) and social-emotional interaction (P = 0.007), but the secondary goals did not improve (10). The results of the current study could not prove a statistically significant difference between the VR and the control group; however, the effect observed in the VR group was "clinically significant".

Didehbani et al reported that VR is non-immersive, resembling a computer game, with avatars representing the subject and treatment staff, which they controlled (9). Moreover, a review study found that VR-based platforms and equipment based on mainstream theories of rehabilitation and education show potential benefits for training social communication and interaction skills in individuals with ASD. Evidence-based practices suggest that incorporating VR into therapeutic or educational programs can improve the social functioning, emotion recognition, and language skills of individuals with ASD after the VR-based intervention (11).

It appears that due to the substantial drop-off rate resulting from the COVID-19 pandemic, the power of the study dropped, consequently increasing the likelihood of a Type II error. This led to the failure to statistically detect the difference between the control and VR group. In other words, the result of this study was false negative. Further research with adequate study power is warranted to reveal the real effect and statistically demonstrate the effectiveness of the VR approach for teaching basic concepts to children with ASD, compared to traditional methods such as using flashcards.

Conclusion

The results of this study did not find a statistically significant difference between the VR and the control groups. However, a medium effect size was found for the VR group, which is "clinically significant".

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Validation: Zohreh Salimi.
Visualization: Zohreh Salimi.
Writing–original draft: Zohreh Salimi, Ensiyeh Jenabi, Saeid Bashirian.
Writing–review & editing: Zohreh Salimi, Ensiyeh Jenabi, Mahdieh Seyedi, Katayoon Razjouyan, Saeid Bashirian.

Competing Interests

The authors declare that they have no conflict of interests.

Ethical Approval

This study was approved by the Ethics Committee of Hamadan University of Medical Sciences (Ethics No. IR.UMSHA.REC.1399.376) and registered in the Iranian Registry of Clinical Trials with the identifier IRCT20180707040370N8 (https://irct.behdasht.gov.ir/trial/49837).

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