Employing Elements of Virtual Reality to Enhance Social Skills Among Children With Attention-Deficit/Hyperactivity Disorder: Quasi Experimental Study

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Abstract **– Children with ADHD fail to establish good relationships with others and practice undesirable behaviors that disturb those around them. Additionally, this disorder may create difficulties in social performance and adaptation to different life contexts. Nonetheless, in light of recent technological advancements, traditional education programs no longer cover deficiencies resulting from this disorder. It is also no longer attractive among children with ADHD. Therefore, in this research study, the researchers designed four Google Cardboard Virtual Reality (VR) applications that were developed with several domain experts' supervision to enhance four social skills (greeting back, waiting for a turn during an ordering, not interrupting others while talking, and cooperating) among children with ADHD which had the potential to help them integrate smoothly into society. A quasi-experimental study was conducted for one group in the Developmental and Behavioral Disorders Clinics and Centers in Maternity and Children's Hospital in Najran Region, Saudi Arabia. The results were promising and showed an improvement in the social skills of the participants with mild or moderate ADHD symptoms. In contrast, there was no improvement in social skills in participants with severe ADHD symptoms.**

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1. Introduction

One of the neurodevelopmental disorders closely associated with aggravating social behavior problems during socialization is ADHD. Children with ADHD have various difficulties, such as hyperactivity, inattention, and impulsivity. These difficulties may negatively affect children's social functioning in their social life [1]. Therapy can be challenging for young people. As a result, intervening during childhood is critical [2]. In 2022, the prevalence of ADHD among children in Saudi Arabia varied from 3.4% to 16.4% [3]. ADHD may result in related health issues, such as anxiety and depression, which are estimated to be present in 36% of children with ADHD [4].
Furthermore, children with ADHD have higher levels of impairment in academic achievement (63%) and social performance (90%) than children without ADHD [4]. In most cases, parents and therapists are guided to utilize medication or stimulants, which are considered cognitive enhancers. However, they negatively influence a child's health if used frequently [5]. Thus, more creative approaches to socializing children with ADHD are required [6].

Considering non-pharmacological interventions as part of behavior modification for children with ADHD would be promising, with clear and specific goals to improve compliance, social performance, and quality of life [6].

In light of technical developments, learning for children with ADHD can be promoted in various activities [7]. For instance, VR technology is an interactive simulation created using computer hardware and software to give users a sense of reality that looks similar to the real environment [8]. VR applications can provide realistic, simplified, and safe experiences to experience learning situations tailored to their unique learning needs.

One predefined intervention cannot possibly meet the needs of all of these children due to the heterogeneity of the disorder [9].

In this research, and during the building phase, switching back and forth between all problem explication, defining requirements, design and development, demonstration, and evaluation were applied to illustrate the design process of the Google Cardboard VR applications. The development was conducted under the supervision of several domain experts to enhance four social skills among children with ADHD (greeting back, waiting for a turn during an ordering, not interrupting others while talking, and cooperating). The design requirements by domain experts provided a vision of the design process of the proposed information technology (IT) artifact in the context of considering the complications and symptoms of ADHD for children to reach the desired results. Google Cardboard VR applications have been adopted for Android smartphones within the Google Cardboard VR viewer. The Cardboard VR viewer is inexpensive, easy to use, and can be used individually without being an obstacle to working in the classroom or at home [10]. The study answered the following research question: (1) To what extent can VR elements such as (Avatars and Google Cardboard for Unity) enhance social skills among children with ADHD aged (6-12) years?

The structure of the paper is as follows: Section 2 displays the design requirements. Section 3 presents the proposed IT artifact. Section 4 shows the research method. Section 5 provides the results and discussion. Finally, Section 6 presents the conclusion.

2. Design Requirements

The section focuses on initial requirements, including design requirements and feedback provided by domain experts to improve the design of the proposed IT artifact. Initially, the target age group and the social skills children with ADHD lacked were identified by domain experts. Semi-structured interviews with domain experts were used to determine design requirements; Table 1 shows the characteristics of domain experts.

Table 1. The characteristics of domain experts

Domain Experts	Educational level	Years of Experience
Psychologist	Bachelor's degree	13
Speech therapist	Master's degree	10
A physician who specializes in behavioral disorders	PhD degree	22
Learning disability specialist	Bachelor's degree	6
Mother of a child with ADHD	Bachelor's degree	-

Undoubtedly, ease of use is the most important design requirement because children with ADHD do not need prior knowledge of the system or the use of complex equipment [11]. Table 2 below covers the design requirements for the proposed IT artifact.

Table 2. Design requirements

Design Principle	Complications of ADHD	Design Requirements
Ease of use	Using and wearing VR equipment makes children with ADHD feel extremely dizzy and faint.	No VR equipment, such as VR headsets, is used to display the scenes. On the other hand, it will show the scenes on an Android phone without needing headphones or loudspeakers.
	A child with ADHD cannot complete activities that require focused mental effort and find it difficult to follow written instructions.	Scenes are exported as applications in Google Cardboard VR mode that require no inputs or registration by the user. Furthermore, scenes are based solely on audio files.

The following are some of the domain experts' feedback:

- In the third scene, the recorded audio files were modified to a higher quality; thus, the audio would be apparent to the participating child, free from echo and distortion.
- In the scenes design stage, avatars such as (Ali's avatar, Ali's father's avatar, the seller's avatar, the teacher's avatar, Ali's mother's avatar, and the student's avatar) were modified and carefully reselected to fit the proposed scenario. Additionally, Ali's avatar has been unified in scenes so that the participating child can focus on the behaviors outgoing from Ali's avatar and how these behaviors were dealt with in the proposed scenarios. Furthermore, different scenarios and colors were used in each scene to attract the child's attention, encouraging him to watch the scenes.

3. The Proposed IT Artifact

The following section discusses the proposed IT artifact, including the VR elements (Avatars and Google Cardboard for Unity) in Section 3.1 and the following Google Cardboard VR applications (the first scene, the second scene, the third scene, and the fourth scene) in Section 3.2.

The proposed IT artifact—Google Cardboard VR applications was designed via the Unity game engine and visual studio for coding in the object-oriented C# programming language. The Mixamo auto-rigger tool also provides a set of characters and different high-quality animation elements. Then, human models rigged have been uploaded with complete skeletons and skinning weights. Also, animations were downloaded from Mixamo auto-rigger in FBX (Autodesk Filmbox) format and imported into the Unity game engine [12]. To develop Google Cardboard VR applications, Google released improvements as a plugin for the Unity game engine, for instance, the Google Cardboard XR Plugin for Unity [13].

On the other hand, the proposed IT artifact is applied through desktop platforms, mobile devices, and wearable equipment such as the Google Cardboard VR Viewer. The simulation representative runs on Windows 10 HP OMEN 17-w200nx Gaming Laptop, processor speed of 2.8 GHz, 7th Generation Intel® Core™ i7 processor, Intel® Core™ i7-7700HQ CPU, 16GB of RAM, and NVIDIA® GeForce® GTX 1060 (6 GB GDDR5 dedicated). The entire environment is designed to be compatible with Android smartphones, as depicted in Figure 1.

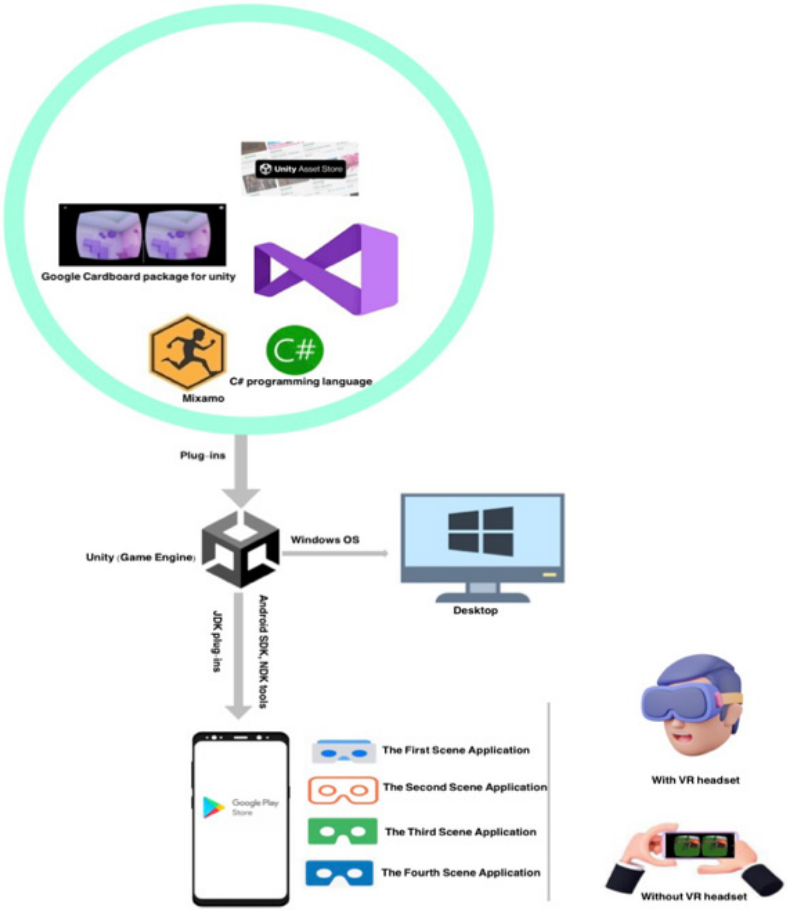

Figure 1. The IT artifact architecture

3.1. VR Elements

The Google Cardboard for Unity and avatars are the elements of VR used to develop the proposed IT artifact to enhance the social skills of children with ADHD. In the Google Cardboard for Unity, VR leaves long-lasting visual and audible impressions on users. Since the release of Google Cardboard in 2014, VR technology has been more broadly used [14]. This study used the Unity game engine to build scenes, including a Google Cardboard XR Plugin that converts the smartphone into a VR system [15]. The result is educational Google Cardboard VR applications where the scene is displayed on the smartphone screen with spilled left and right-eye views with a vertical line in between. The vertical line will align the user's phone on the Google Cardboard VR Viewer [13]. Undoubtedly, Google Cardboard's viewer portability and low cost (no cords needed) set it apart from other HMDs [16].

If the user wears a Google Cardboard VR viewer, he/she can tilt his/her head down, up, left, and right; the virtual environment is altered appropriately, according to the tilt direction of his/her head. In other words, Google Cardboard VR applications rely on the smartphone's motion sensors. When a user turns his/her head left, right, up, or down, the image is altered appropriately, effectively erasing the image's traditional frame boundaries.

In the second element, avatar-aided learning possibilities, such as role-playing or imitating social scenarios unavailable in the real world [17].

Ali's avatar is the main avatar around whom all the scenario's events revolve. There are undesirable behaviors by Ali's avatar that make him unacceptable to those around him, such as interrupting others while speaking, talking excessively, and having difficulty waiting for his turn. He does not cooperate with his family in household activities. As a result, others are reluctant to deal with him. Thus, six 3D avatars are selected to support the proposed social situations a child with ADHD may encounter, as illustrated in Figure 2.

Figure 2. 3D avatars

3.2. Google Cardboard VR Applications

VR has evolved into a teaching tool that can be utilized at home and in the classroom without complicated hardware or instructions for installation through Google Cardboard VR applications.

Users can enjoy the immersive VR experience with a smartphone compatible with Google Cardboard VR [18]. The user must open the app on the smartphone and then put the smartphone inside a cardboard viewer. After that, the viewer can be held in front of the eyes or worn on the head using a strap. The Android smartphone is placed in the front space of the Cardboard convex lens, and the phone's content is displayed on the screen; the user can have a real three-dimensional experience, as shown in Figure 3. The two lenses in the Cardboard merge the left and right scenes depicted on the phone screen to help the user perceive the depth of the 3D environment [10]. According to domain experts' recommendations, children with ADHD should not wear VR headsets for medical reasons. Thus, none of the participants wore the VR headsets during the experiment; more details are presented in the method section.

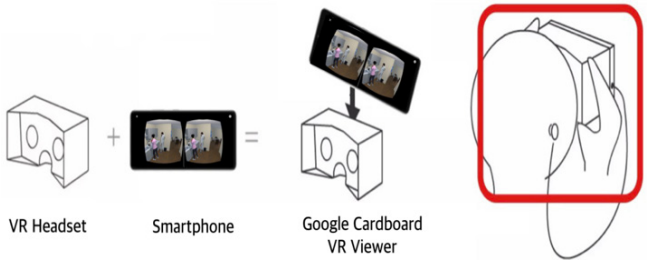

Figure 3. Use Google Cardboard VR Viewer

The four applications are freely available in the Google Play store and do not require user registration. Furthermore, the applications contain only audio dialogues, which make the child with ADHD focus on the main goal without being distracted. The applications are based on audio recordings in classical Arabic, in MP3 format, where the audio does not use unclear or hard-to-grasp words. The sections below explain each designed scene in the Google Cardboard VR application.

3.2.1. The First Scene

A classroom model was selected and downloaded from the Assets Store Unity to support the proposed virtual environment. Then, the model was edited and imported into Unity. The classroom model includes (a blackboard, tables, chairs, windows, curtains, computer devices, a small library containing several books, and walls) which impact the child's sense of immersion as if he were among his classmates.

The scene begins with a model of the school from the outside, surrounded by grass and trees, which move left and right with the wind (Figure 4 (a)). The school bell rings, and the camera moves to the classroom.

The teacher enters the classroom, raises his hand, and greets the students, saying: Peace, mercy, and blessings of God be upon you (السلام عليكم ورحمة الله وبركاته), (Figure 4 (b)).

All the students stand, raise their hands, and greet the teacher, saying: May the Peace, mercy, and blessings of God be upon you (وعليكم السلام ورحمة الله وبركاته), (Figure 4 (c)) and then sit on their chairs.

The teacher noticed that the child, Ali, did not say the greeting with his classmates.

The teacher asks child Ali to say a greeting, saying: I noticed, Ali, that you did not say the greeting; come on, say the greeting to me and your classmates (لا حظت يا علي إنك لم ترد التحية، هيا حييني و حي زملائك), (Figure 4 (d)).

Child Ali stands, raises his hand, and greets, saying: Peace, mercy, and blessings of God be upon you (السلام عليكم ورحمة الله وبركاته), (see Figure 4 (e)).
Then the teacher praises the child, Ali, saying: well done (أحسنت); (Figure 4 (f)).

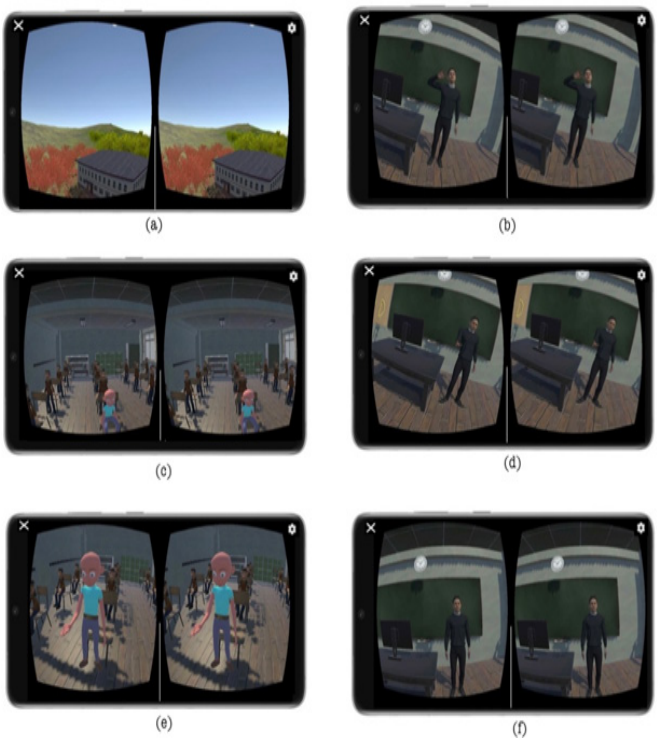

Figure 4. First scene sequence of scenarios

3.2.2. The Second Scene

A school garden model was selected and downloaded from the Assets Store Unity to support the proposed virtual environment. Then, the model was edited and imported into Unity. The school garden model includes (a cafeteria, grass, and trees).

The scene begins with a model of the school from the outside, surrounded by grass and trees, which move left and right with the wind (Figure 5 (a)). A school bell rings, and the students head to the cafeteria in the school garden (Figure 5 (b)).

The child, Ali, goes to the cafeteria (Figure 5 (c)) and bypasses his colleagues in the waiting line (Figure 5 (d)).

The seller orders child Ali to return to his rightful place. He moves his hand, saying: You have transcended your colleagues, Ali, in waiting line; come on, go back to your place and wait for your turn to buy (لقد تجاوزت زملائك يا علي في صف الإنتظار، هيا عد إلى مكانك و انتظر دورك في الشراء), (Figure 5 (e)). The child, Ali, raises his hand, saying: Well, well (حسناً حسناً), (Figure 5 (f)). Then, he returns to his place (Figure 5 (g)) and waits for his turn in the waiting line (Figure 5 (h)).

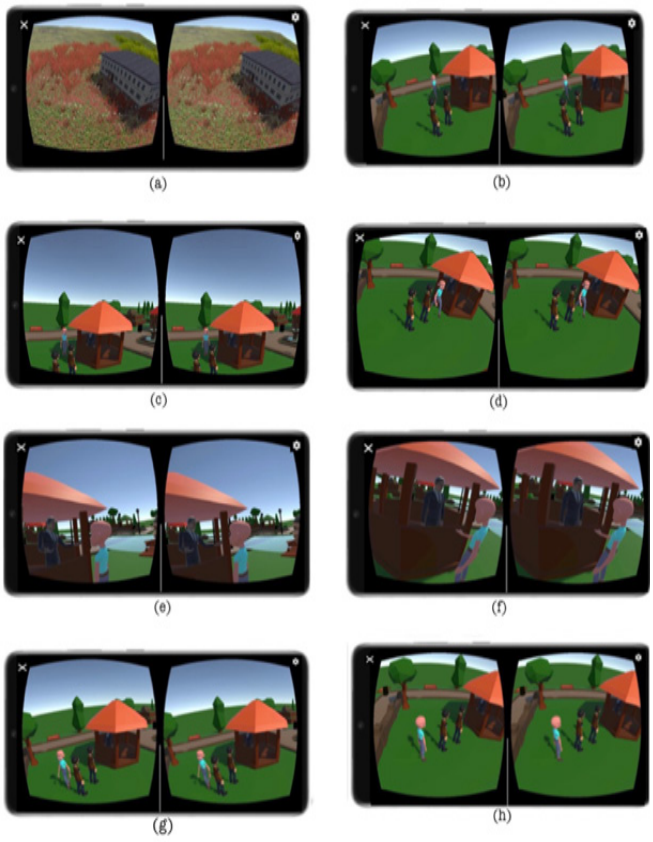

Figure 5. Second scene sequence of scenarios

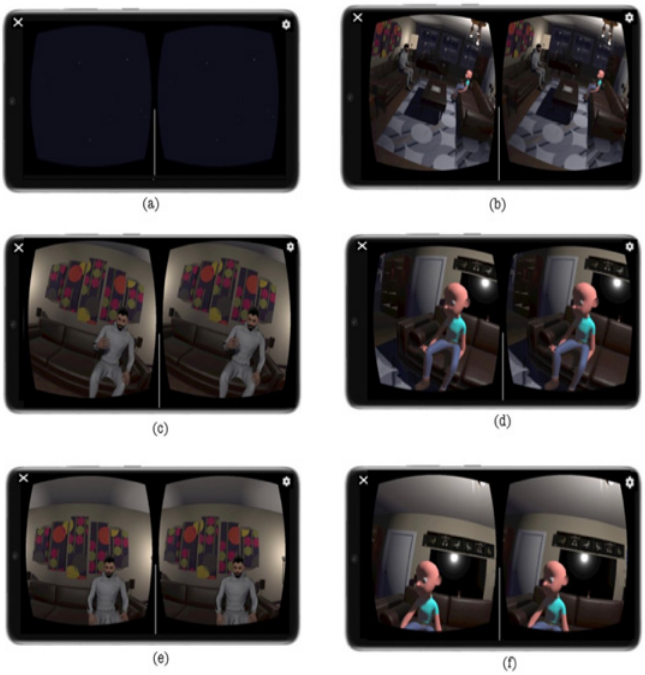

Figure 6. Third scene sequence of scenarios

3.2.3. The Third Scene

A living room model was selected and downloaded from the Assets Store Unity to support the proposed virtual environment. Then, the model was edited and imported into Unity. The living room model includes (a sofa, TV table, TV, windows, window blinds, mural paintings, carpets for the floor, a small library, a chandelier, and side tables).

The scene begins with a model of the sky in the evening, with rain audio (Figure 6 (a)); the camera then moves to the living room.

In the living room, Ali's father and his child, Ali, are seated across from one another on the sofas (Figure 6 (b)).

Ali's father begins to speak, moving his hands and saying: There are several etiquettes, my son, that must be (هناك عدد من الآداب يابني التي يجب ان تكون), (Figure 6 (c)).

Then, child Ali interrupted his father's speech, saying: Dad, Dad, Dad, I have several questions about the planets (أبي، أبي، أبي، لدى عدد من الأسئلة حول الكواكب), (Figure 6 (d)).

Ali's father asks his child Ali to listen to him until he finishes his speech. He raises his hand, saying: Ali, you interrupted my speech and did not let me complete a single sentence, which is a mistake. You should not interrupt my speech until I finish it. And then share with me talking parties (لقد قاطعت حديثي يا علي و لم تدعني أكمل جمله واحده و هذا خطأ يجب عليك عدم مقاطعه حديثي حتى انتهي منه و من ثم شاركني أطراف الحديث), (Figure 6 (e)).

The child, Ali, responds to his father's words and moves his hand, saying: Okay, Dad (حسناً يا أبي) and then listens to his father (Figure 6 (f)).

3.2.4. The Fourth Scene

A kitchen model was selected and downloaded from the Assets Store Unity to support the proposed virtual environment. Then, the model was edited and imported into Unity. The kitchen model includes (an oven, dining table, chairs, kitchen drawers, refrigerator, mixer, cake, bird, walls, and parquet floor).

The scene begins with a model of the sky in the early morning, with the audio of birds chirping (Figure 7 (a)), and then the camera moves into the kitchen.

Ali's parents enter the kitchen and start cooking (Figure 7 (b)).

Then, the child, Ali, enters the kitchen (Figure 7 (c)).

The child, Ali, wanders around the kitchen aimlessly (Figure 7 (d)), then throws a small toy he holds (a small car) on the kitchen floor, causing his parents to be disturbed while cooking (Figure 7 (e)).

Ali's father notices that the child Ali has excessive movement and does not participate with them in household activities.

Ali's father invites the child Ali to participate in cooking, raising his hand and saying: What do you think, son, to share with me and your mother in cooking (مارأيك يابني أن تشاركني أنا ووالدتك في الطهي), (Figure 7 (f)).

The child, Ali, raises his hand, saying: Okay, Dad (حسناً يا أبي) (Figure 7 (g)).
Then, the child, Ali, approaches his father and mother and shares their cook (Figure 7 (h)).

Figure 7. Fourth scene sequence of scenarios

4. Research Method

The following section discusses the study procedures in Section 4.1. Then, the measurements used to evaluate the effectiveness of the proposed IT artifact in enhancing social skills for children with ADHD are discussed in Section 4.2, and the characteristics of participants in Section 4.3.
This study obtained ethical approval from the General Directorate of Health Affairs in Najran Region with IRB (Log Number 2023-05 E). Then, all participants' data were collected after obtaining consent from their guardians to participate in this study. After that, a quasi-experimental study was conducted using the one-group pretest-posttest design. A pre-test questionnaire was done before the participants got treatments/used the IT artifact. The post-test questionnaire was conducted after the participants received treatments/used the IT artifact.

4.1. Procedure

The treatment duration was one month. In the first week, the participants, for seven days, were trained in the skill of greeting back. In the second week, the participants, for seven days, were trained in the waiting skill. In the third week, the participants, for seven days, were trained in the skill of not interrupting others while talking.

In the fourth week, the participants, for seven days, were trained in the skill of cooperating. All training was conducted using the developed VR applications.

The researchers met four mothers during their children's review appointments in the Developmental and Behavioral Disorders Clinic and Center on different weeks. Then, the researchers gave them paper copies of the informed consent to obtain their consent. The study's aims were explained to the participants' guardians in detail. Then, the researchers showed them the content of the proposed IT artifact and administered them paper copies of a 4-item pre-test questionnaire to measure the social skills of the participants' children. As for the other three, the researchers have taken their phone numbers from psychologists at developmental and behavioral disorders clinics and centers. The researchers contacted them through phone calls, explained the study's aims, and sent them the informed consent via WhatsApp. They read it and agreed to participate. Participants' guardians verbally answered the 4-item pre-test questionnaire via a phone call based on their observations of their children's behavior.

After completing the treatment, the participants' guardians completed a 4-item post-test questionnaire (the same items used in the pre-test questionnaire) through reading items of a post-test questionnaire for the participants' guardians via a phone call. For instance, after training the child on a greeting back skill for a week (seven days), the researcher read the questionnaire item "The child greets others." to the participating child's mother through a phone call. Based on the mother's observation of her child, she chooses the response from 1 to 5. Thus, other social skills were measured respectively. Participants' guardians verbally answered the 4-item post-test questionnaire via a phone call based on their observations of their children's behavior. The mothers (the participants' guardians) completed a pre and post-test questionnaire.

To ensure downloading applications and viewing scenes, four of the participating children who did not have Samsung devices were provided with Android smartphones. Also, the researchers communicated with the participants' guardians almost daily through phone calls to follow up with their children to open applications, watch the scenes, and not delete them until the participating child completed the specified period.

4.2. Analysis and Measurement

The questionnaire was designed to be 4-item so that each item measures one social skill. For example, the first item measures the skill of greeting back. The second item measures the skill of waiting.

The third item measures the skill of listening to others and not interrupting their talking. The fourth item measures cooperation skills. A five-point Likert gradient was used to interpret the respondents' responses, which were also dichotomized into "never," which means completely disagree; "Rarely," which means disagree; "Sometimes," which means neutral; "Often," which means agree; and "Always," which means completely agree. The responses were corrected by giving the following weights: (1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always). The pre and post-test questionnaire responses were processed using statistical package for the social sciences (SPSS) [19].

After that, statistical methods such as t-test and ANOVA were used after ensuring the data followed a normal distribution by conducting the Shapiro-Wilk test.

4.3. Participants

The final number of participants in this study was seven children with ADHD. The type of ADHD for all participants was a 'combined type' that includes symptoms of inattention and hyperactivity-impulsiveness. They were aged 6 to 12 years. The study sample's demographic data is shown in Table 3.

Table 3. The demographic data of the participants

Items		Frequency	Percent
Gender	Male	5	71.4%
	Female	2	28.6%
Symptom of ADHD	Mild ADHD symptoms	3	42.9%
	Moderate ADHD symptoms	2	28.6%
	Severe ADHD symptoms	2	28.6%
Total		7	100%

5. Results and Discussion

Initially, the Shapiro-Wilk test was performed to examine the data distribution and confirm that the data follows a normal distribution. After that, the paired samples t-test was used to test whether there were differences in social skills for participants before and after the treatment in Section 5.1. Then, an independent samples t-test was used to detect a difference in social skills on the independent variable (gender) before and after the treatment in Section 5.2. Additionally, ANOVA is used to compare the differences in social skills among participants with ADHD symptoms before and after treatment in Section 5.3.

5.1. Pretest - Posttest Overall Analysis

First, after uploading the data into the SPSS, a paired-sample T-test was used to test the mean of participants' social skills (N= 7) before and after treatment, considering all records (Table 4.).

The results illustrate a statistically significant difference in (the greeting back) skill among participants before and after the treatment, $p = 0.008$, where the mean skill in the participants improved from 2.286 to 3. Additionally, the findings indicate a statistically significant difference in (waiting for the turn during an ordering) skill among participants before and after the treatment, $p = 0.017$, where the mean skill in the participants improved from 2.286 to 3.143. However, the results illustrate a statistically significant difference in the (not interrupting others while talking) skill among participants before and after the treatment, $p = 0.018$, where the mean skill in the participants improved from 2 to 3.

Furthermore, the findings indicate a statistically significant difference in (the cooperating) skill among participants before and after the treatment, $p = 0.017$, where the mean skill in the participants improved from 2.286 to 3.143. Finally, the findings indicate a statistically significant difference in the four social skills among participants before and after the treatment, $p = 0.010$, where the mean social skills in the participants improved from 2.214 to 3.071.

Table 4. Paired samples t-test comparing social skills of participants (N= 7) before and after treatment

			Mean	Std. Deviation	t	Sig. (2-tailed)
The child greets others.	Pair 1	Pre-test	2.286	1.113	-3.873	0.008
		Post-test	3.000	1.291		
The child waits for his turn while ordering.	Pair 2	Pre-test	2.286	0.756	-3.286	0.017
		Post-test	3.143	1.069		
The child listens to others and does not interrupt them while talking.	Pair 3	Pre-test	2.000	0.817	-3.240	0.018
		Post-test	3.000	1.155		
The child cooperates with his family in household activities.	Pair 4	Pre-test	2.286	1.113	-3.286	0.017
		Post-test	3.143	1.574		
All social skills	Pair 5	Pre-test	2.214	0.466	-3.718	0.010
		Post-test	3.071	0.932		

(Note: If the p-value is less than 0.05, the result is significant. If the p-value is larger than 0.05, no effect was observed)

5.2. Analysis by Gender

Also, the independent samples t-test was used to understand whether there is a difference in social skills (greeting back, waiting for the turn during an ordering, not interrupting others while talking, and cooperating) on the independent variable (gender), which has two groups: male and female. Table 5 shows the sample consisted of five males and two females. The social skills of males before treatment (Mean = 2.150; SD = .548), compared to the social skills of males after treatment (Mean = 2.90; SD = 1.084).

The social skills of the male participants improved after the treatment. On the other hand, the social skills of females before treatment (Mean = 2.375; SD = .177) compared to the social skills of females after treatment (Mean = 3.50; SD = .000). The social skills of the female participants improved after the treatment.

Furthermore, there was no statistically significant difference between males and females in social skills before the treatment, p = 0.611, and after the treatment, p = 0.284. It could be because the sample is too small, resulting in the test being underpowered to detect a difference.

Table 5. An independent sample t-test shows differences in social skills by gender before and after treatment

	Gender	N	Mean	Std. Deviation	t	Sig. (2-tailed)
Pre-test	Male	5	2.150	0.548	-.542	.611
	Female	2	2.375	0.177		
Post-test	Male	5	2.900	1.084	-1.238	.284
	Female	2	3.500	0.000		

5.3. Analysis by Symptoms of ADHD

Table 6 shows participants' social skills with mild ADHD symptoms before treatment (M = 2.0833; SD = .52042) compared to after treatment (M = 3.1667; SD = .57735). The social skills of the participants with mild ADHD symptoms improved after the treatment. On the other hand, the social skills of the participants with moderate ADHD symptoms before treatment (M = 2.6250; SD = .53033) were compared to those after treatment (M = 4; SD = .70711). The social skills of the participants with moderate symptoms improved after the treatment. However, the social skills of participating children with severe ADHD symptoms before treatment (M = 2; SD = .00000), compared to after treatment (M = 2; SD = .00000). There was no improvement in the social skills of participants with severe ADHD symptoms after the treatment.

Table 6. Descriptive statistics for participants (N=7) by symptoms of ADHD

	Symptoms of ADHD	N	Mean	Std. Deviation	Std. Error
Pre-test	Mild ADHD symptoms	3	2.0833	.52042	.30046
	Moderate ADHD symptoms	2	2.6250	.53033	.37500
	Severe ADHD symptoms	2	2.0000	.00000	.00000
	Total	7	2.2143	.46611	.17617
Post-test	Mild ADHD symptoms	3	3.1667	.57735	.33333
	Moderate ADHD symptoms	2	4.0000	.70711	.50000
	Severe ADHD symptoms	2	2.0000	.00000	.00000
	Total	7	3.0714	.93223	.35235

One-way ANOVA is a test used to determine differences between three unrelated samples. For instance, comparing the differences in social skills among participants with mild ADHD symptoms, participants with moderate ADHD symptoms, and participants with severe ADHD symptoms before and after treatment.

Table 7 displays no statistically significant difference in social skills between participants by symptoms of ADHD before treatment, $F = 1.168$, $p = 0.399$. However, there was a statistically significant difference in social skills between participants by symptoms of ADHD after treatment, $F = 6.939$, $p = 0.050$.

Table 7. ANOVA test to compare the differences in social skills among participants by symptoms of ADHD

		Sum of squares	N	Mean	F	Sig.
Pre-test	Between groups	0.481	2	0.240	1.168	0.399
	Within groups	0.823	4	0.206		
	Total	1.304	6			
Post-test	Between group	4.048	2	2.024	6.939	0.05
	Within group	1.167	4	0.292		
	Total	5.214	6			

The efficiency of VR technology in assessing, diagnosing, and treating children with ADHD has stimulated new research in this field [20]. VR technologies provide various opportunities by adapting VR to user requirements. Therefore, domain experts determined the design requirements for the proposed IT artifact according to the needs of children with ADHD and presented it primarily as an educational tool. The quasi-experimental design involved one group of participants to observe differences in social skills before and after treatment. According to ADHD symptoms, after treatment, social skills improved in children with mild ADHD symptoms (42.9% of participants) and children with moderate ADHD symptoms (28.6% of participants). These results are consistent with the study of Adabla et al. [21], whose results showed that VR interventions improved various skills, such as developing performance, modifying behavior in the classroom, and attention abilities of children with ADHD. In contrast, there was no improvement in the social skills of children with severe ADHD symptoms after treatment (28.6% of participants).

The reason may be attributed to the fact that the IT artifact was not at the appropriate level to be presented as an educational tool to control some of the annoying behaviors that arise from a child with severe ADHD symptoms. However, due to the complexity of ADHD and the uniqueness of each ADHD case, it is difficult to provide an effective IT artifact for all children with ADHD because of the heterogeneity of this disorder.

Introducing VR technology, for example, into the classroom or home is still challenging due to the need for technical support and training users on how to use and operate VR equipment, in addition to the financial burden of obtaining headsets, software, and supporting hardware for VR [22]. However, technical advances in recent years and renewed interest in VR have made it more accessible to the general public [23].

Google Cardboard VR applications in educational contexts have provided a more realistic experience in simulating social situations. It contributed to attracting the participants' attention and improving their social performance with those around them.

It created an effective and safe environment away from the dangers of real life. Furthermore, designing the proposed IT artifact as a Google Cardboard VR app reduced the problems related to avoiding using VR applications due to the cost of VR equipment and the difficulty of using it for non-technicians. It also allowed participants to learn continuously at any time and place through the ability to download applications onto their smartphones. Using avatars and audio files in the proposed IT artifact helped children with ADHD interact better with content. The proposed IT artifact also moved smoothly from treatment centers to children's homes by providing children with smartphones running the Android OS and downloading applications on their own devices. Thus, participants' guardians managed to supervise their children which means they did not need to explain how to use VR equipment or rely on developers.

The use of VR applications in education can be a double-edged sword. Allowing children to participate in virtual educational experiences could expose them to manipulation, lead to health problems, and violate their privacy. Therefore, the use of VR applications requires adherence to strict data protection legislation to provide an essential educational opportunity [24]. Thus, during the design of the proposed IT artifact, the researchers were keen to design it in a simplified way that suits the capabilities of children with ADHD while taking into account the ethics of developing VR applications, such as preserving user privacy by avoiding the use of head-mounted display (HMD) and their sensors, which may be employed in capturing body movement and collecting the user's behavioral data and revealed his identity, thus acting as biometric data. The richness of these datasets may provide significant issues for users' data sovereignty and privacy [25].

On the other hand, VR headsets have been dispensed as they can cause motion sickness, stroke, seizures, dementia, nausea, and isolation. VR headsets are often described as too heavy, difficult to install, and uncomfortable. These technical shortcomings may limit the possibility of using VR technology in hospitals, schools, or even at home [26]. Additionally, Google Cardboard VR applications' performance and graphical fidelity cannot compete with more expensive VR solutions. Still, these applications can allow the general public to access VR with minimal financial outlay [23].

The Cardboard Google VR headset made designing Google Cardboard VR applications more difficult due to the functional limitations of this headset.

The user cannot interact with, move, and manipulate digital elements within the virtual environment. On the other hand, enhancing four social skills in children with ADHD for just one month was not enough to obtain the desired results. Some participants' guardians also ensured their children did not use smartphones for long periods. They were concerned that smartphones might change their children's traits and personalities and increase their tendency toward isolation, loneliness, and attachment to devices. Furthermore, the sample size was small, so there were no apparent differences in results between the groups before and after the treatment.

6. Conclusion

Due to children with ADHD lack of social skills, these children have difficulty adjusting to and integrating with society. Therefore, it was the researchers' duty to pay attention to developing an IT artifact that motivates the child with ADHD to correct unhealthy behaviors and help improve his lifestyle. On the other hand, the domain experts ensured that the IT artifact was not cumbersome so that the children could train in social skills daily, which helped the children change unwanted behaviors. Undoubtedly, the social skills improved significantly in participants with mild or moderate ADHD symptoms. In future work, the researchers would like to develop the proposed IT artifact to meet the requirements of children with severe ADHD symptoms to help them enhance their social skills and integrate into society.

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Ethical Approval

This study obtained ethical approval (IRB registration with KACST, KSA: H-11-N-081) (IRB Log Number 2023-05 E) from the General Directorate of Health Affairs in Najran Region, Saudi Arabia.

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