Virtual Reality based Therapy to Mitigate ADHD

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ABSTRACT

In this paper, we focus on virtual reality application to be used by special educators with a virtual reality high-end head mounted display (VR HMD). We have proposed the virtual reality system that is helpful for therapy to children with attention deficit hyperactive disorder (ADHD) in the age group of 6-10. The application simulates a virtual world, into which the user is transported into with the HMD, containing simple activities that are used by therapists to improve aspects like concentration, patience and memory in the children receiving therapy. These activities are timed and scored, and the times are sent to a remote database, by the VR application itself. This data can be further accessed by therapists through a website. A study was also conducted and the feedback of our proposed system has shown that most of the user found that children enjoyed the virtual world interaction.

Keywords
Virtual Reality, Child, Attention Deficit Hyperactive Disorder, Therapy, HMD, Tracking

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Introduction

Virtual reality is the term used to describe a three-dimensional, computer generated environment which can be explored and interacted with by a person. Unlike traditional user interfaces, VR places the user immures experience. Instead of viewing a screen in front of them, users are immersed and able to interact with 3D worlds.

The whole idea behind VR is to create illusions, and one could trace this back to simple concepts like illusion arts, or stereographs. What a stereograph does is it projects two images, taken in different angles, to the respective eyes, and this creates an illusion of a 3-dimensional image. This stereo vision is the fundamental concept behind many current-day VR hardware. VR hardware can be dated back to the 18th century. The stereoscope view master was invented in 1838. The term 'virtual reality' came to use around 1980s by a researcher named Jaron Lanier when he began developing goggles and gloves. An advancement in technology came when Sensorama was invented in the year 1956. It was produced and directed by Morton Heilig. He wanted the viewers to experience a movie in real time by simulating an environment that acted like a real city which the viewer drove through on a motorcycle. To add more immense feel there were mechanical sensors to simulate the vibration, smell, and the sound of the engine and so on. Later, many works emerged which used his invention as the foundation.

The current day scenario has changed drastically. VR is being incorporated into many fields, like medicine [1] [2], training, education [3], and is also being used for recreational purposes. VR games are trending, with hardware becoming more affordable and compact. Big software giants and game creators are targeting the new and improved wireless all-in-one varieties of virtual reality headsets as they appeal to a bigger target group.

There are mainly two types of VR display systems, the Cave Automatic Virtual Environment (CAVE) and Head Mounted Device (HMD). The CAVE is less known to people, and it is a setup consisting of an empty room, with 4 blank walls, and high-resolution projectors projecting onto the wall. The user inside the room, has to wear shutter glasses, and the projectors are synchronised to the shutter glasses. The frame rate is about 60 to give an illusion of 3D stereo vision. This system can only accommodate one user at a time, wearing the shutter glasses. When it comes to the question of sensory feedback, maybe smell and temperature and sound can be manipulated to make the experience more realistic.

The HMDs are commonly known and used by people. This is worn on the head, and there are two synchronised displays for both eyes, which use the principle of stereo vision to display the virtual world. The HMD is also tracked, either by sensors within the device, or external sensors placed strategically around the area that the user will stand. There is a wide variety of HMDs, ranging from cheaper, lighter ones that can be used with mobile phones, to heavy setups powered by high end GPUs. Naturally, HMDs can be much more convincing compared to CAVE systems.

Haptic feedback is a crucial part to create the illusion that the user is actually inside the virtual world. Some HMDs come with haptic controllers, that have buttons, triggers and joysticks to interact with the virtual world, and some can even give vibrational feedback when any interaction occurs. This, coupled with other sensory inputs can make the experience all the more immersive.

ADHD is a disorder [4], which falls under the mental illnesses umbrella, encompassing issues like impulsive behaviours, lack of attention and hyperactivity [5]. It is one of the most commonly diagnosed disorders in children and adolescents, while adults may be diagnosed with it too. A mean worldwide prevalence of ADHD of ~2.2% overall has been estimated in children and adolescents (aged <18 years).

Indications of the Disorder

The most common symptoms are hyperactivity, low attention span and impulsivity. Other symptoms include irritability or mood swings and forgetfulness and these could lead to learning disabilities. Many times, parents don't realise that their child has an actual problem and dismiss the symptoms saying that their child is just naughty or playful. If this continues on to adulthood, it could have many repercussions.

Existing Treatments

Treatments include behaviour therapy and, in some cases, medication. The aim of behaviour therapy is to inculcate good behaviours and eliminate bad behaviours. Behaviour therapy for young children could include games and activities to increase attention span, induce calmness, and improve communication skills[6-9]. Progress is measured over multiple sessions using different scales to gauge their improvement[10].

Literature Survey

Using VR for treating mental disorders is not a completely new concept, it began to gain momentum a few years ago. In fact, there is a type of therapy called Virtual Reality Therapy (VRT) [11-13] that puts a patient in a virtual simulation of either a stimulus or a situation to treat phobias or PTSD. There have been instances where stroke patients have regained partial muscle control by using VRT. Researchers have focussed either on detection or evaluation of severity of ADHD, and a few have proposed virtual reality as a therapy method. One study takes a subject, exposes them to a calming virtual reality experience for fixed periods of times in regular intervals, and studies its effects by using rating scales on the subjects [14]. Some studies used a non-immersive system and augment that with factors like physical movement [15]. Game based approaches with storylines have been created to investigate how virtual reality affects time perception in the subjects [16]. Adding external sensors like EEG sensors and eye tracking have also been tested [17] [18]. Dedicated assessment systems have also been made to see the how the student behaves in virtual scenarios like classrooms with distractions [19]. Studies also evaluate the testing systems by using rating scales [20]. Serious games have also been experimented with to see if they have effects on the participant's behaviours [21]. These studies have mostly concluded positively, and hope to implement their ideas as real products. One point to note is that none of the above-mentioned studies have created a tool to be used in conjunction with existing therapy methods. In [22] developed a VR class room along with the assessment model to help the clinicians in diagnosis of ADHD. The ones that have made very immersive experiences which may have repercussions related to physical health as virtual reality experiences may have effects if used for long periods of time.

Virtual Reality for ADHD

Studies on using VR for mental disorders such as autism and ADHD have been conducted, and some clinics have even adopted this to help their patients [23]. Usually, they simulate a familiar environment such as a classroom and observe how the patients react and give constructive feedback to them. The simulation may also deliberately show some distractions so that the therapists can see what actually distracts the patient.

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Advantages of Using Virtual Reality for ADHD

Lesser resources required for these activities and the patient and therapist don't have to physically be in certain places or own specific items to do these activities[24]. The therapist and other concerned people can observe exactly what the child is looking at from a first-person perspective as the child performs these activities, which cannot be done in conventional therapy. This can be done when using HMDs connected to a monitor. They can therefore instruct or explain to the child more appropriately.

Generally, children will be interested to experience a virtual world and will enhance the effect of therapy, while not all children like going to conventional therapy sessions [25]. Therapists can record and analyse precise statistics of the child's performance, and if necessary, can record the HMD feed of the child's sessions.

Disadvantages of Using Virtual Reality for ADHD

The disadvantages are that VR is a relatively new technology, not many may have access to it. There have been some cases of headaches or nausea with prolonged exposure to VR, but it is not observed in short and simple simulations with less motions. The HMD may be too heavy for younger children, and that is why we focus on the age group of 6-10

Prosposed Methodology

The application simulates a virtual world, into which the user is transported into with the HMD, with simple activities, that are used by therapists to improve aspects like concentration, patience and memory in the children receiving therapy. These activities will be timed and scored, and the scores will be moved from the VR application to an external MYSQL database hosted online, through remote scripts.

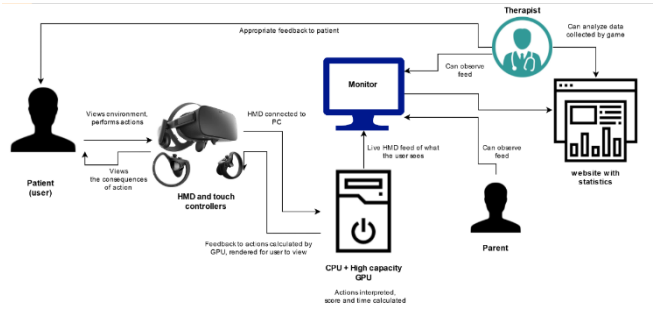


Fig.1. System Architecture diagram.

A website has also been created to retrieve the data from the DB and show the data in tabular and graphical formats, for the therapists to use and analyse. The website and the databases will be stored online.

Before using the application, the user, who is the patient here, has to be registered with the website and after doing so, each user receives a User ID. Then, the application is started, and the therapist accompanies the user who uses the application. After the completion of each activity, the scores are displayed to the user and have to be updated, and the Session ID has to be noted by the therapist. Then, the therapist has to go to their dashboard, and update the session details by selecting the Session ID and the corresponding Patient ID. Then, the system can display all the session details of each patient separately, along with their personal details.

Activity 1 State Diagram

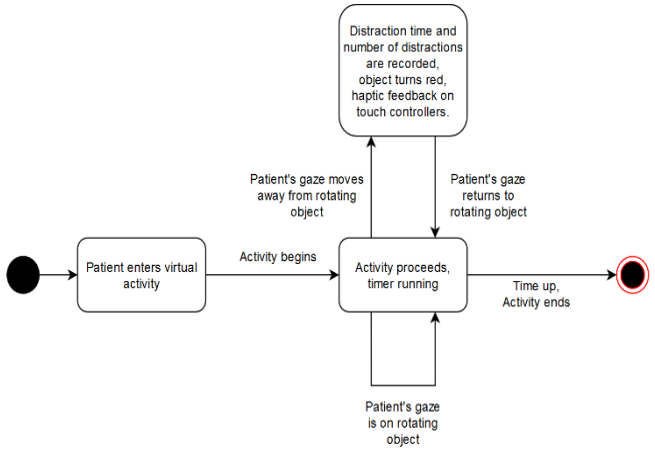


Fig.2. Activity 1 state diagram.

The goal of this activity is to improve concentration and calmness. The user is asked to continuously look at a rotating object in an outdoor environment. Here, the object used is a 3-dimensional star colored yellow. Other subtle distractions like trees and plants will be in place, but the user has to focus on the object. If the user looks elsewhere, the star turns red. Vibrational feedback is also given on the touch controllers. The position and angle of the headset is tracked and it is determined whether the user is looking at the star or not. This activity can be done in a seated position, while holding the touch controllers. The time can be adjusted in the initial settings menu. Total time, distraction time (time spent looking away) are recorded.

Activity 2 State Diagram

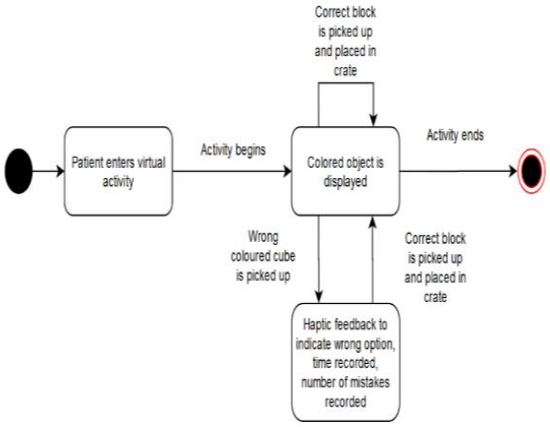


Fig.3.Activity 2 state diagram.

The goal of this activity is to improve concentration and non-impulsive thinking. The user will be shown an object of particular a colour. The user has to identify the colour of the object, and pick up the corresponding coloured cube from a set of different coloured cubes. If an incorrect cube is picked up, haptic feedback will be sent to the touch controllers. Each time an incorrect cube is picked up, a counter will note down the errors. Then, the user has to throw the correct cube into the crate to the right of them. When this is done, the next coloured object will be displayed. The number of coloured objects can be adjusted in the settings. The objects are simple ones like a book, a banana and so on. In a way, this activity also improves hand-eye coordination. The variables recorded are total time, idle time (when no cube is being held and the coloured object is being displayed), and distraction time (when the wrong cube is picked)

Activity 3 State Diagram

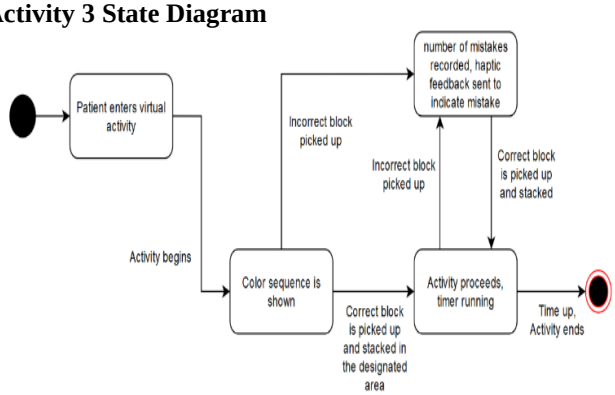


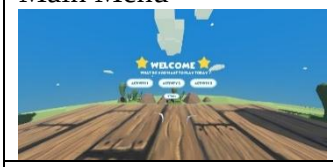
Fig.4. Activity 3 state diagram.

The goal of this activity is to improve memory and hand eye coordination. The user will be shown a sequence of 4 colors for 10 seconds, and a set of colored blocks will be placed nearby. The objective is to remember the sequence and stack the respective colored blocks on the ground, on top of each other. If a wrong block is picked up, haptic feedback on the controllers will be sent as reminders to pick up the correct colour. The number of sequences shown can be adjusted in the settings screen. The variables recorded are total time, idle time (when no cube is being held and the pattern has already been shown), and distraction time (when the wrong cube is picked).

Implementation

The application was developed using unity 2018.1. Various free assets were used to create the environment. Many concepts such as classes, interfaces, coroutines (synchronous and asynchronous) were implemented[26]. There is a total of 6 scenes in the application. The application runs on the oculus rift and touch controllers are also used. Activities have haptic feedback to keep the users' attention. The user interface is implemented with child friendly buttons, sliders and pointers, so that it is attractive, intuitive and self-explanatory. The following table summarizes what each scene in the application does.

Table I. Scenes and their Descriptions

Scene	Description
Main Menu 	The main navigation into the activities and the settings menu
Settings Menu 	Can adjust the settings of each activity like the amount of time for activity 1(1 to 3 minutes), number of coloured objects for activity 2, and number of rounds for activity 3.
Activity 1 	Contains the logic and environment of activity 1
Activity 2 	Contains the logic and environment of activity 2
Activity 3 	Contains the logic and environment of activity 3
Completion Scene 	Displays the score obtained, has the upload details button, and displays the session ID after the button is clicked.

The following are the screenshots of the head mounted display feed as seen through the monitor connected. The real experience offers a 270º field of view but it cannot be captured as screenshots

Accompanying Website

The website was built using PHP, HTML and CSS. It retrieves data from the hosted database connected to both this website and the virtual reality application. It can display patient details, and each patient's session information. The website is also the place where new patients and therapists can register. This website is hosted online. Some screenshots of the website are displayed below.

Dashboard

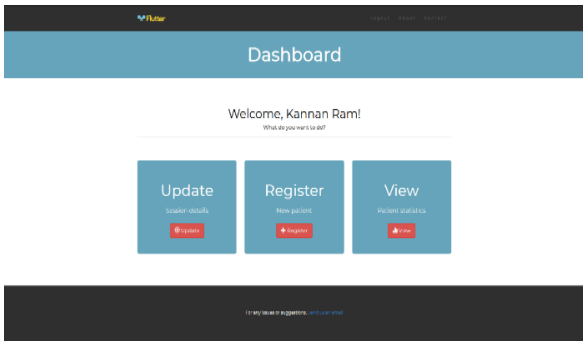


Fig.5. Website dashboard.

Session detail upload form

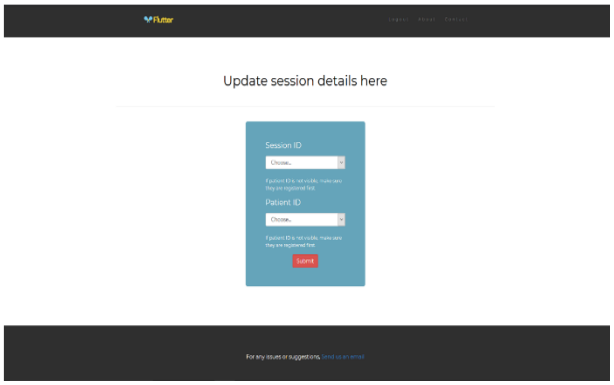


Fig.6. Session detail upload form.

Case study and Statistical analysis

A study was conducted to analyse the strengths and weaknesses, and see if any features can be added to the application, by requesting a group of professionals including psychologists, occupational therapists, and special educators to watch a video explaining the workings of the project and website and fill an online form about the same.

The group consisted of psychologists 11 (55%), special educators 5 (25%) and occupational therapists 4 (20%). To asses our system we framed the questioner regarding the effectiveness of the virtual world, interaction effectiveness

and the variables measured during the activities. To frame the questioner we have followed [27].
Following questions were asked. These questions followed likert scale: strongly agree, agree, somewhat agree, neutral, somewhat disagree, disagree and strongly disagree.

Table.II Questions asked and corresponding Options

S. No.	Question
Virtual world experience	
1.	I can understand the menu and it's easy to operate.
2.	The colour and over all look of the virtual world was attractive
3.	It was not much easy to select different activities.
4.	All the activities were designed very well and were good looking
Effectiveness of interaction	
5.	It was easy to interact with the virtual object
6.	Picking an object was easy
7.	It made me feel like I am interacting with real object
8.	Virtual objects were difficult to reach.
Effectiveness of activities	
9.	Activity 1 was designed well and was able to calculate the distraction time
10.	Activity 2 and 3 was designed to effectively measured the hand eye co-ordination
11.	Activities were easy to understand and operate.
12.	Activities were not able to perform well.
Overall system performance	
13.	Do you think this is an effective therapy method for children with ADHD?
14.	Rate the ease with which you were able to understand how to use this system.
15.	Do you think the child will be more interested and involved in the activities than a conventional therapy session?
16.	Do you think the application was intuitive and good looking?
17.	Rate the interface of the website
18.	Are the variables measured during the activity of good use?
19.	Would you recommend this type of therapy to your colleagues?
20.	Would you adopt the use of this system if developed fully?

The overall system performance was calculated by collecting the user response. The user response is calculated using following equations.

$$R_{VR\ Experience} = \frac{(\sum RQ1 + \sum RQ2 + \sum RQ4) - \sum RQ3}{4} \quad (Er$$

$$R_{interaction} = \frac{\sum RQ5 + \sum RQ6 + \sum RQ7 - \sum RQ8}{4} \quad (Er$$

$$R_{activities} = \frac{(\sum RQ9 + \sum RQ10 + \sum RQ11) - \sum RQ12}{4} \quad (Er$$

$$R_{system\ performance} = \frac{\sum_{i=13}^{20} RQ_i}{8} \quad (4)$$

Where RQi is the response of the user for ith question andR_(VR Experience),R_interaction, R_activities and R_(system performance)are the average responses of the user for virtual world experience, effectiveness of interaction, effectiveness of activities and overall system performance respectively.

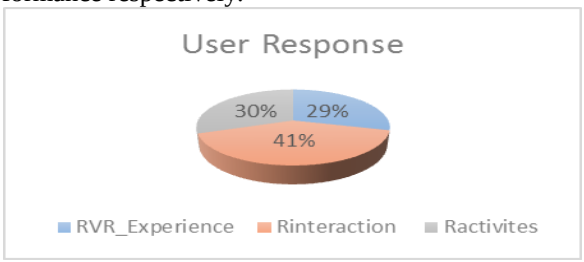


Fig.7. User Responces

The figure 7 shows the response of users collected to measure the VR experience, effectiveness of interaction experience and effectiveness of activities. Most of the user liked the interaction designed in virtual world whereas some have liked the virtual world effects and activities.
The feedback has been mostly positive, and we get to know that most professionals are willing to take the risk of trying this new type of therapy.

Conclusion

ADHD can cause many problems in the lives of the people who have it, affecting multiple aspects of their life like education, communication, and relationships. Use of VR technology can prove to be very useful in overcoming these issues. VR can provide an immersive experience that interests the children and hence increases the effectiveness of the therapy. This project to create one such application to help reduce the effects of ADHD in young children, and also act as a tool for therapists to assess the patient's progress. The feedback has been mostly positive, and a lot of advice from people who have learnt about this project has been received.
This implementation is targeted towards young children, and is meant to be used under therapist supervision only. Since the scope of this project did not involve asset creation, free assets had to be used. The prevalence of ADHD is quite high in India and although existing methodologies work for most of the patients, this application and similar projects, after going through many iterations of testing and rectification by therapists and other professionals, could actually make an impact. This project is merely the first step in creating an aid for therapists, and a lot more tweaking and

innovation is required to make this a proper solution. Adding more activities, with different objectives and suited for different subcategories of ADHD patients could be part of the future work. Addressing the other age groups apart from the current target group of 6 to 11 is necessary. A wide spectrum of mental conditions exists, and research has to be done to see if VR could be a viable solution to treat them.
The technical aspect can also be improved, by using wireless variants of the HMD for convenience and affordability, and optimising the code even further for quicker response times. Custom assets could be created for the application and more variables can be tracked. Other sensory inputs like sound can be incorporated to give a more immersive feel. VR development is a relatively new field and its capabilities are yet to be discovered.
On the whole, an elaborate research can be conducted in collaboration with psychologists and data science can be introduced to find new methods of solving problems.

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