Using Virtual Reality to Help Reduce Anxiety: A Pilot Study

***Abstract*—Anxiety is a common mental health condition that can be defined as a complex emotional state characterized by feelings of tension and worried thoughts. There are various treatment options available for anxiety, such as medication and therapy. However, recent research has explored the use of virtual reality in managing anxiety. Virtual Reality simulation will act as a channel for existing therapeutic methods to expose the subject to an alternate world that will help reduce the anxiousness they are experiencing. This research involved developing and testing two applications that incorporated principles of distraction therapy and guided meditation. Anxiety levels were assessed through continuous monitoring of the subject's blood pressure and heart rate during testing. These applications were tested on university students and produced positive results. The results showed that virtual reality is a reliable channel for delivering therapeutic techniques to reduce anxiety.**

***Index Terms*—Anxiety, Distraction therapy, Guided Meditation, Virtual Reality, Immersive Environment.**

I. Introduction

It is common to be nervous in a stressful environment. However, due to some factors or triggers, this feeling can become overwhelming resulting in stress, panic and high discomfort. In stressful situations, our bodies respond by releasing hormones such as adrenaline which triggers our 'fight or flight' response. However, in some cases this response can cause the person to be overwhelmed, leading to stress, panic, fear, and high discomfort. Although there are pharmacological methods [30] to treat anxiety, these medicines can have side effects. Virtual reality can recreate a safe environment and can help comfort the user. Furthermore, it can act as a channel for existing therapeutic methods to help deal with anxiety. Our study focuses on trying to reduce anxiety in a stressful environment that could not be avoided, such as students who are taking an exam and uses virtual reality as a channel for existing therapeutic methods to help reduce anxiety.

A. Anxiety and its effects

Anxiety is characterized as an intense and persistent fear or worry, which can be related to everyday situations or specific events, times, or places. While it is completely normal to be nervous, anxiety is a more severe emotional state that can disrupt daily functioning and lead to mental health issues. Symptoms of anxiety include excessive worrying, fear, restlessness, insomnia [1], sweating, trembling [26], increased heart rate, breathlessness [3], and elevated blood pressure [4].

Anxiety disorders refer to a group of mental disorders characterized by feelings of anxiety and fear, including generalized anxiety disorder (GAD), panic disorder, phobias, social anxiety disorder, obsessive-compulsive disorder (OCD) and post-traumatic stress disorder (PTSD). The effects of these disorders are more persistent and can impair a person's daily life [2].

We intend to quantify the level of anxiety by measuring parameters that change when a person is anxious. Further information regarding the parameters considered is provided in Section IV-B.

B. Virtual and Augmented Reality

The field of Virtual [6] and Augmented Reality (AR) [5] is gaining prominence due to its ability to offer personalized, immersive experiences that are easily accessible. It has proved to be useful in the automotive industry, the educational field as well as in the medical field [27]. The utilization of VR for alleviating chronic pain in adults is a prime example. The use of virtual reality (VR) was found to be effective in reducing acute pain during and after different medical procedures. By providing an immersive environment that distracted patients from the source of their pain, VR was able to provide temporary relief [15].

This study developed and tested two applications incorporating distraction therapy and guided meditation. Anxiety levels were assessed through continuous monitoring of participants' physiological responses. The applications were tested on university students and demonstrated the efficacy of virtual reality as a reliable channel for delivering anxiety-reducing therapeutic techniques.

II. Background

This section examines the existing applications that claim to help anxiety, therapy techniques, and the scales to measure anxiety. Additionally, the section provides a comprehensive review of prior research on the use of VR in addressing anxiety.

A. Existing Games to Reduce General Anxiety

Using games and other such applications to reduce anxiety is not a new concept. "Super Better" [10] is one such game. This application allows the user to 'fight' 'bad guys' which are certain habits that the user is trying to break. The application provides a daily set of challenges that the user needs to follow in real life which, on completion, provides a 'daily dose of power-ups'. "Flower" [11] is another game meant to help reduce anxiety. It relies entirely on visual representation to act as a distraction for the user and does not have any text

or dialog. The objective of the game is to distract the user long enough to calm them down. Another application that was developed to help with users' mental health is "Personal Zen" [12]. The user is presented with a questionnaire and a personalized set of goals is given based on their answers which determined their stress levels.

B. Therapy Techniques

While there are various types of medication available to reduce anxiety, we focus on non-pharmacological approaches to do the same. One such method is distraction therapy, which aims to reduce anxiety by encouraging a subject to turn his or her attention to something other than the on-going situation [13]. Another approach is meditation, which can promote relaxation and focus by directing the subject's attention to calming stimuli and eliminating stressful thoughts [24]. Guided meditation [23] is a form of meditation integrated into psychotherapy, that involves a guide leading the subject through the meditation session using various techniques such as soothing language, visualizations, or breathing exercises.

However, traditional therapy methods like distraction and guided meditation have limitations, such as requiring a calm and quiet environment that may not always be available. VR has the potential to overcome these limitations by providing an immersive and interactive environment that can transport the subject to a calming virtual world. In our study, we developed a VR applications to tackle the shortcomings of traditional therapy methods by creating a therapeutic and tranquil environment for subjects.

C. Existing Virtual Reality Applications for Anxiety

There are VR applications that exist in various industries. In this section, we will discuss a few examples.

Pre-operative Anxiety: Preoperative Anxiety is an anxiety due to fear of medical procedures, mostly surgery or operations. For research, a group of patients was put through a Virtual Operating Room Tour (VORT) before administrating anesthesia [8] [14].

Public Speaking Anxiety: The use of Virtual Reality Therapy (VRT) was employed to alleviate public speaking anxiety among university students, which is a type of social phobia [7].

Other non-pharmacological interventions such as cognitive-behavioral therapy, music therapy, aromatherapy, hypnosis, guided imagery relaxation therapy are becoming popular treatments for anxiety [9]. Augmented and virtual reality is currently being used to bring these concepts to life.

D. Existing scales of Anxiety

Measuring a subject's anxiety levels typically involves administering a questionnaire that is completed by a professional. Currently, the most widely used and evidence-based methods for measuring anxiety are subjective and rely on self-report from the subject [16]. Beck Anxiety Inventory (BAI) [16], State-Trait Anxiety Index (STAI) [16], and Hospital Anxiety and Depression Scale-Anxiety (HADS-A) [16] are the scales used to measure general anxiety. The STAI is among the most widely researched and widely used measures of general anxiety and chronic medical conditions [16]. The BAI is used as a measure to differentiate between anxiety and depression [17]. The most common use of the BAI is fibromyalgia [18] and arthritis [19]. The HADS-A scale is used in subjects to identify anxiety and depression symptoms. It includes an assessment of generalized anxiety including tension, worry, fear, panic, difficulties in relaxing, and restlessness [16].

III. Methodology

We classify anxiety levels into broad categories based on heart rate as shown in Table I. The values range from 60-220. These values are scaled down for classification, drawing inspiration from the Borg Rating of Perceived Exertion (RPE) scale [28]. First, we initialize the range from 0. So the new range will be 0-160. Dividing this by 10 will give us a new scale ranging from 0-16. Using this scale, subjects are classified into one of three categories. This pre-determined scale is used only once - to determine which game needs to be administered.

TABLE I
Classification of the subjects

Class No.	Scale	Reading
Class 0	0 - 5	Normal
Class 1	5 - 10	Mild to Moderate Anxiety
Class 2	10 - 16	Severe Anxiety

Based on this scale, two games were developed; each tailored to a specific class of anxiety. Subjects belonging to Class 1 were provided with a PC game. For subjects categorized under Class 2, a fully immersive VR environment was utilized. Details of each game are explained in this section.

The decision to opt for a PC game for Game 1, as opposed to a VR application like Game 2, was driven by the inherent complexity of the former, which demanded a higher level of user interaction facilitated by advanced input devices, such as a keyboard and a mouse. This augmented level of user interaction, in turn, implied that the application will hold the subject's attention and will be able to facilitate mild to moderate level anxiety.

A. Game 1: PC Game

Game 1 is a computer-based first-person movement game that uses the principles of distraction therapy. The game prompts subjects to solve puzzles and locate hidden treasures engage them in the game world and redirect their attention away from their anxiety. At the start of the game, the subject is placed in a small coastal town and given the task of uncovering hidden "keys" that are scattered throughout the environment. These keys are three-dimensional objects - a cube, a prism, and an octahedron - that the subject must locate. When a key is found, a larger version of the same is created at the subject's original spawn point, with only the vertices visible. The subject must then return to the spawn location and

Fig. 1. (a) Home Screen of the Game. (b) Key in the form of a Prism to trigger the vertices in the shape of a Prism. (c) When a vertex is selected it glows. The first vertex selected is blue and the second is green. (d) The subject is given instructions on player movement at the start of the game

complete the faces of this 3D model using triangles, which can be generated by selecting any vertices in a clockwise direction. The selected vertices glow to indicate the same. If a triangle already exists between the selected vertices, it is erased. Once all the faces of the model are completed, the subject can move on to find the next key. To navigate the town, players are provided with instructions at the start of the game as shown in Figure 1. The controls are similar to those used in other first-person PC games, with walking controlled by the arrow keys or the keys 'W, A, S, D', and running achieved by pressing and holding the 'shift' button. Subjects can look around by clicking and dragging the mouse, simulating the motion of turning their heads.

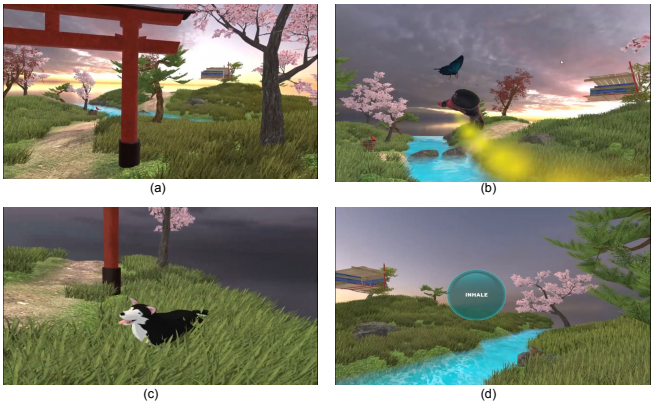

Fig. 2. (a) Virtual zen garden complete with cherry blossom trees and a tree-house. (b) Colored flares and a butterfly follow the subject's right-hand movements. (c) One of the many comfort dogs that are available throughout the environment. (d) Guided meditation instructing the subject to Inhale. The bubble expands when the command is 'inhale'.

B. Game 2: VR Game

Game 2 offers a fully immersive virtual environment designed for relaxation and it uses distraction therapy, as well as guided meditation. To access this virtual world, subjects are provided with a Head-mounted display (HMD) and controllers. Once in the virtual zen garden, they can use the controllers to teleport to different predetermined locations and explore the environment freely. A virtual pet dog and butterfly, along with colored flares, provide additional features that follow the subject's desired path. The game includes a deep breathing exercise that the subject must follow as shown in Figure 2. The instructions appear in the sky and include a voice-over that asks the subject to inhale, hold their breath, and exhale for a set duration, helping them to take deep breaths and relax. By immersing the subject in this environment and guiding them through meditation, the game aims to remove them from an anxiety-inducing environment and put them in a more relaxing setting. Game 2 only has two controls. The trigger button on the right-hand controller acts as a teleport button, enabling the subject to move to different predetermined locations. The touchpad on the left-hand controller allows for free movement in the environment, enabling the subject to navigate by holding the touchpad in the direction they want to move. There is no particular objective or end goal in this game. The subject is free to explore the virtual world at their own pace, take in the scenery, and relax.

IV. Testing

A. Technology and Hardware

1) Unity: The development of this project was done using Unity. Unity's cross-platform functionality aids in building applications that can be run on multiple platforms like Windows, Android, IOS, etc. Additionally, Unity offers development features specifically designed for VR programming, such as multi-platform support for various headsets, high-quality graphics with flexible graphic pipelines like Universal Render Pipeline and High Definition Render Pipeline, and advanced performance tools. These capabilities make Unity an ideal platform for VR development [20], [21].

2) Virtual Reality System: HTC VIVE Cosmos Elite was chosen as the VR system. It comprises of 2 VIVE Base Station 1.0, Cosmos Elite Headset and 2 VIVE controllers. Room-scale of approximately 11'5" x 11'5" is required for the tracking area. The Base Station 1.0 generates accurate external tracking. The VR setup used for this project is shown in Figure 3

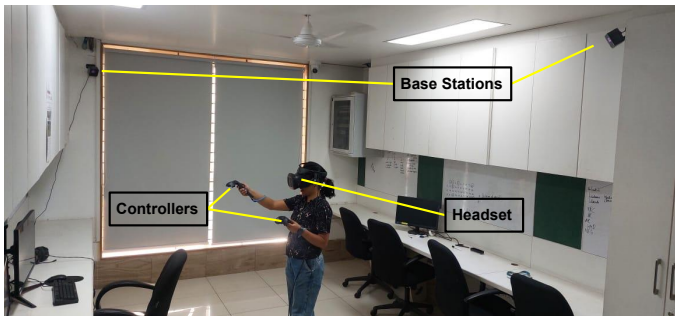

Fig. 3. The VR setup that was established for this project.

SteamVR is a platform for virtual reality that includes a software framework designed to allow subjects to experience VR content and games on supported VR headsets. It also functions as a VR platform, enabling users to access and play VR games and content.

The VIVE, which is compatible with SteamVR, offers freedom of movement and precision from all angles with SteamVR tracking and advanced controllers [22].

A motion faceplate is affixed to the front of a VR headset to enhance its motion tracking capabilities by detecting head movement and rotation. Additionally, the VIVE features on-ear, form-fitting headphones with integrated stereo audio to enhance the immersive experience. The VR System also includes several inputs such as a Multifunction trackpad, Dual stage trigger, Grip buttons, and an Integrated microphone. With a combined pixel resolution of 2880x1700, users can appreciate finer details within the VR application [25].

B. Parameters and Rating System

Prior research [31], [32] has shown that anxiety disorders can have an effect on the Heart Rate Variance (HRV) of an individual. Individuals with anxiety had significantly lower resting-state HRV than the healthy population. Further, it was also found that HRV is inversely related to heart rate [33]. Research has shown that anxiety can increase heart rate, systolic blood pressure, and can cause an increased mean arterial pressure [34]. Considering this information as well as available equipment, heart rate, and blood pressure were deemed suitable indicators for determining the presence of anxiety in the subjects under examination.

The subjects were administered the State-Trait Anxiety Inventory (STAI) test. Form Y1 [29] was given to assess the subject's current state of anxiety. The scores in this test can range from 20 to 80. A cut point of 39 - 40 has been suggested to detect clinically significant symptoms [16]. For the purposes of this study, the sample consisted of subjects who scored 39 or above on the STAI test. The subjects were varied across many categories: age group, sex, gaming experience and whether they had anxiety in general. The subject's heart rate in bpm and blood pressure was monitored and noted during the administration of the therapy technique supported by the proposed application. Subjects were asked to wear two smartwatches, one on each hand, and the readings were noted via blue-tooth on the watch apps.

The results were classified as positive or negative. If the value of the heart rate after the testing is lower than before, then it is a positive result. For blood pressure, non-escalation in value is a positive result.

To further analyze the results, a rating system was also introduced. Heart rate and blood pressure are the two parameters for this experiment and the rating is done separately for both of them as shown in Table II and III. The aim of the application is to see a reduction in these parameters of the subject.

Each subject is first classified into one of the categories of the tables (Table II and III). After the application is administered, they are classified again. If they remain in the same category, or they fall down a category, it is considered a 'positive' result. If they are in a higher category than before, it is considered a 'negative' result. As the rating system is based on intervals, individual values of heart rate were not of significance within this range by itself. For example, let us assume the heart rate was 76 bpm before the application was administered and it fell to 86 bpm after. Even though the heart rate has increased, it is still in the same interval and is not considered a negative result. The applications, put together, were tested on a total of 37 subjects.

C. Testing Process

In this study, heart rate and blood pressure measurements were taken throughout each application. Measurements were recorded before the application was administered, three times during the testing, and once after the testing. The level of gaming experience that a subject has may impact the test results, and therefore, subjects were categorized into two groups: those with gaming experience (G) and those without gaming experience (NG). The criteria for this categorization was based

TABLE II
THE RATING SYSTEM FOR HEART RATE AS PARAMETER.

Heart Rate Value Range	**Category**	**Rating**
60 - 100	Normal	0
100 - 140	Low	1
140 - 180	Medium	2
180 - 220	High	3

TABLE III
THE RATING SYSTEM FOR BLOOD PRESSURE AS PARAMETER.

Systolic (Upper#)		**Diastolic (Lower#)**	**Blood Pressure Category**	**Rating**
Less than 90	and	Less than 60	Low	0
Less than 120	and	Less than 80	Normal	1
120 - 129	and	Less than 80	Elevated	2
130 - 139	or	80 - 89	Higher Stage 1	3
140 or higher	or	90 or higher	Higher Stage 2	4

on the subject's familiarity with games that involve First Person Movement (FPM) controls, as these are typically easier to understand for individuals with gaming experience. Subjects were queried about whether they had any prior experience with anxiety (HA) or not (NA). Table IV provides a comprehensive overview of the number of subjects who participated in the testing of the applications, along with their corresponding classifications into the pre-determined categories.

TABLE IV
SUMMARY OF TEST SUBJECTS FOR ALL APPLICATIONS

Characteristic	Game 1	Game 2
Number of Subjects	14	23
Age (in years)	16-30	(18-40) G1 = 18-30 G2 = 30-40
Gender	9 Male, 5 Female	17 Male, 6 Female
Presence of Anxiety	4 HA, 10 NA	7 HA, 16 NA
Gaming Experience	9 G, 5 NG	8 G, 15 NG
Time Taken	No Time Limit	Controlled Simulation

V. RESULTS

A. Game 1

In regards to heart rate rating (based on intervals), all 14 participants exhibited a 100% positive result. As for blood pressure rating, there was a 93% positive outcome, with only one participant experiencing a slightly elevated blood pressure. The graph in Figure 4 displays the variation in the subjects' heart rates during the different phases of the application (as explained in section III-B). The data reveals a noticeable decline in the average heart rate during the initial stages, followed by a gradual increase over time. Nevertheless, the average heart rate remains slightly lower after the game is administered as compared to the level before.

1) Gender: Gender did not play any part in influencing the result.

2) Gaming Experience: Considering the age of the test subjects, gaming experience could be considered prominent. But the results showed no significant difference. The subjects with no gaming experience have all shown positive results in both heart rate rating and blood pressure rating.

3) Presence of Anxiety: 4 subjects reported to have experienced some form of anxiety and 3 of them showed positive reactions to the application.

4) Time Taken: Considering the age of the test subjects, gaming experience could be considered prominent. But the results showed no significant difference. The subjects with no gaming experience have all shown positive results in both heart rate rating and blood pressure rating.

B. Game 2

All 23 subjects showed a 100% positive result in the case of heart rate rating (based on intervals). The rating remained the same for 21 subjects while it was reduced for 2 subjects. Even individual heart rate values showed 95.65% of positive results with 22 out of 23 subjects experiencing lower heart rates after the simulation. For the subject with the exception, the heart rate value had only increased by 1 unit, leading to the same rating, nevertheless being a positive result. The blood pressure rating also had a positive result. 78.3% of the subjects had either a consistent rating or a reduced rating. The presented graph in Figure 5 illustrates the variation in the subjects' heart rates while immersed in the virtual environment (see section III-B). The data highlights a consistently slight decrease in the average heart rate as the subjects progress through the simulation.

1) Age: While the heart rating remains positive among both age groups, the blood pressure rating had a few exceptions. 78% of the subjects in Age Group 1 showed a decrease in heart rate while Age Group 2 had 67%.

2) Gender: Even if the rating for heart rate did not really show the influence of gender, it is interesting to see its variation in the results of blood pressure rating. 87.5% of the male subjects showed a decrease in heart rate while 67% of the female subjects showed a decrease in heart rate.

3) Gaming Experience: Even though 8 of them had prior experience, the nature of the result was not influenced, in fact, it was the opposite. The group with no gaming experience had a higher positive result than the one with gaming experience.

4) Presence of Anxiety: The heart rate value and rating had 100% positive results on subjects with and without anxiety.

5) Time Taken: It was found that the simulation time varied from person to person since each subject took different times to adjust to the environment but in totality the simulation lasted for approximately 8 minutes.

C. Analysis

Despite a slight increase in their heart rates and blood pressure, all subjects remained in the same category as mentioned in Table II and Table III, resulting in a 100% positive outcome for each of them. Taking decreased heart rate value into consideration, the results are 64.3%, and 95.65% positive for Game 1 and 2 respectively while for Blood pressure, the results are 93% and 78% positive.

Since subjects of both the applications saw a very slight variation in heart rate before and after the application was administered, merely reporting an increase or decrease in heart rate lacks sufficient detail without analyzing the exact magnitude of change. It is essential to examine the precise difference in heart rate. Table V displays the number of participants with an increased or decreased heart rate and the average bpm change.

The tabulated data indicate that Games 1 was successful in regulating the variability in heart rate, as the positive and negative impacts of the applications seemed to offset each other. However, Game 2, which was a VR game, stood out for

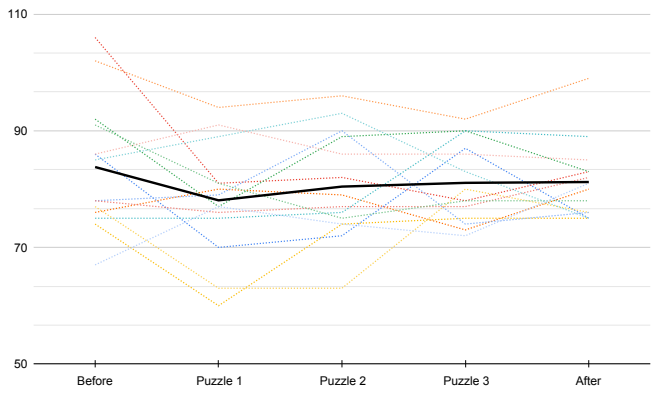

Fig. 4. Variation in heart rate for subjects who tested Game 1. The black line indicates the average heart rate of all the subjects.

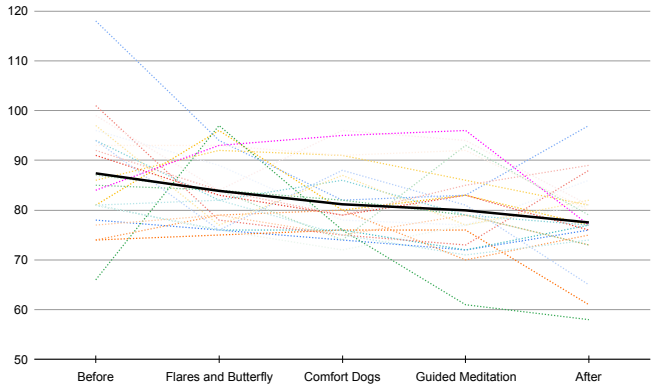

Fig. 5. Variation in heart rate for subjects who tested Game 2. The black line indicates the average heart rate of all the subjects.

its exceptional performance in reducing heart rate, suggesting that it effectively managed anxiety levels.

TABLE V
THE QUANTIFIED VALUES OF THE POSITIVE AND NEGATIVE IMPACT OF THE TWO APPLICATIONS ON HEART RATE

	Game 1	**Game 2**
No. of subjects with a positive result for heart rate comparison	9	22
The average decrease in heart rate (in bpm)	8.11	10.36
No. of subjects with a negative result for heart rate comparison	5	1
The average increase in heart rate (in bpm)	7.4	1

VI. Discussion

The applications are not intended to provide any form of behavioral therapy. Rather, their primarily is to address anxiety by providing immediate relief to subjects.The design of the applications is geared towards delivering a short-term solution to anxiety, and therefore, the study's focus is on assessing its short-term effects on the subjects. Although our research did not consider any experiments designed to evaluate how the therapy would impact the subjects well being in long term, we can make an informed guess as to whether it should either have a positive impact or surely shouldn't worsen the situation.

VR, although incredibly useful, has a few drawbacks. Prolonged exposure to immersive environments and the use of headsets have many side effects such as nausea, dizziness, eye strain, headache, and motion sickness. The applications also require the subject to be of sound mind and in the ability to move their hands and head.

VII. Conclusion and Future Work

In this study, two distinct games were developed to act as viable channels for distraction therapy and guided meditation. The results have shown the effectiveness of VR in reducing anxiety. However, it is important to note that this is only a pilot study and doesn't account for specific phobias or triggers that an individual may have. For example, Game 2 features virtual dogs that could cause discomfort for some participants. Future research could focus on increasing the customization of the virtual environments to provide the best possible calming setting for each individual.

It's important to note that while the games provide short-term relief, they don't offer a long-term solution for underlying anxiety issues. To enhance these applications, incorporating Artificial Intelligence and integrating other forms of therapy can be considered. We remain fascinated by the concept of virtual reality and recognize it as a stepping stone towards making a difference in the future.

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