Virtual Reality Approach for Reducing Preoperative Anxiety Using Distraction Therapy and Guided Meditation: A Pilot Study

Anusha Devanga[1], Armili Paturi[1], Ganachari Vydyam Manogna[1], Gauri Menon[1], Prasad B Honnavalli[1], Adithya Balasubramanyam[1*]

[1]CAVE Labs, Center for Internet of Things, PES University, Bangalore, 100190, Karnataka, India.

*Corresponding author(s). E-mail(s): adithyab@pes.edu;
Contributing authors: anushamdevanga@gmail.com; armili.0901@gmail.com; Manognagv12@gmail.com; gaurim2010@gmail.com; prasadhb@pes.edu;

Abstract

Preoperative Anxiety is a psychological state characterized by nervousness or uneasiness due to fear of medical procedures, mostly surgery or operations. Although it is perfectly normal to be nervous before a medical procedure, preoperative anxiety can have an impact on recovery time, procedure outcome, and the general comfort of a patient. Virtual Reality has proved to be an efficient channel to help reduce preoperative anxiety. Concepts of Augmented Reality are used to create a virtual world such that the patient in need is completely immersed in it, blocking out their connection to the real world and their situation. The simulation will act as a channel for existing therapeutic methods to expose the patient to an alternate world that will help reduce the anxiousness they are experiencing before their medical procedure. This research involved the development and testing of three virtual reality applications which used the principles of distraction therapy and guided meditation. Anxiety levels were determined based on continuous monitoring of the blood pressure and heart rate of the subjects during testing. It was observed that virtual reality is a reliable channel for therapeutic techniques for reducing anxiety and the results have looked promising.

Keywords: Pre-Operative Anxiety, Virtual Reality, Distraction Therapy, Guided Meditation

1 Introduction

Surgery or any medical procedure is known to be a cause of discomfort or nervousness. Although this feeling is common, the level of stress can ultimately have an effect on the patient. The emotional distress encountered by patients undergoing surgical procedures can be notably significant during the initial stages of the operation when they are provided with information regarding the surgical process, as well as during their hospitalization.

Our study focuses on the specific utilization of Virtual Reality (VR) applications for addressing these concerns, considering the availability of equipment and the identified need for such an application. VR can act as a channel to existing therapeutic methods for anxiety.

1.1 Preoperative Anxiety and its effects

Preoperative anxiety is defined as an unpleasant state of tension or uneasiness that results from a patient's doubts or fears before an operation. Studies [1] show about 80% of surgical patients experience preoperative anxiety. The main factors that bring about preoperative anxiety are as follows: the fear of the unknown, the idea of being sick, and the possibility of life-ending [3]. Preoperative anxiety can induce physiological changes such as hypertension, rise in body temperature [4], diminished immune responses, and longer wound healing [5]. Not only can it affect both surgical outcome and post-operative recovery [6], preoperative anxiety can sometimes be so severe that the patient needs to back out of the procedure itself. All these also chalk up to an increase in the usage of sedatives and anesthesia on the day of the surgery [2, 7]. By treating preoperative anxiety, we can prevent postoperative complications, reduce risks, and all together give the patient a better quality of recovery [2].
VR has shown promising results in reducing anxiety and pain in various medical procedures. Therefore, it is important to explore the potential of VR in managing preoperative anxiety, which can improve the overall experience and outcomes for patients undergoing surgery.

1.2 Virtual and Augmented Reality

Virtual Reality refers to a digitally simulated environment that can be interacted with using specialized electronic equipment, such as headsets or gloves. This technology enables subjects to immerse themselves in a computer-generated world and interact with objects and characters within it, creating a realistic and engaging experience. Augmented reality is morphing the real, physical world by projecting virtual images and characters. This can be done with projectors and screens. The difference between the two is that augmented reality merely makes changes by adding to the user's real-life environment whereas VR produces an entirely computer-generated simulation of another world. The field of virtual and augmented reality 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]. VR has been used as an analgesic for chronic pain in adults. It was found that VR helped decrease acute pain both during and after various medical procedures. VR simply distracted the patients from the cause of their pain and diverted their attention to an immersive environment, giving them relief from their pain for a short while [15]. Previous research has explored the use of VR as a way to ease preoperative anxiety among patients

The following is the structure of the research paper. Section 2 summarizes previous work in the field of games for reducing anxiety, therapy techniques, and the methods used to measure anxiety. Section 3 covers all stages of our approach, from the classification of subjects to a detailed description of all developed applications. Section 4 discusses the test setup, the technology used, and the sample set for each of the applications. Section 5 presents an analysis of our results and findings. Section 6 outlines the benefits and drawbacks of our research. Section 7 presents a concise overview of the key findings and conclusions drawn in the research paper, while the final Section 8 delves into potential avenues for future research.

2 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 preoperative anxiety.

2.1 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. Users are presented with a list of mental health issues such as concussions, sleeping problems, anxiety, and so on. 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 game allows the user to change the direction of a gust of wind, which in turn carries petals around. When a petal touches a flower, more petals emerge. 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.

2.2 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 patient to turn his or her attention to something other than the ongoing situation [13]. Another approach is meditation, which can promote relaxation and focus by directing the patient'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 patient 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 in a clinical setting. VR has the potential to overcome these limitations by providing an immersive and interactive environment that can transport the patient to a calming virtual world. In our study, we developed three VR applications to tackle the shortcomings of traditional therapy methods by creating a therapeutic and tranquil environment for patients.

2.3 Virtual Reality used for Preoperative Anxiety

Several studies have shown the effectiveness of VR in reducing pre-operative anxiety. A group of patients was put through a Virtual Operating Room Tour (VORT) before administrating anesthesia [14]. It was found that giving patients information about the surgery and making the patients familiar with the operating theater made the patient less nervous [8]. The anxiety among patients was checked using a questionnaire and compared with the results of those who didn't undergo the tour. While VORT did not have an impact on preoperative anxiety, patients rated the tour highly and found it useful for preparing for surgery. The favorable ratings of VORT could be attributed to its ability to alleviate uncertainty and meet the patients' information needs.[14].

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

2.4 Existing scales of Anxiety

Measuring a patient'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 patient [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]. It includes assessment of symptoms such as nervousness, dizziness, inability to relax, etc. The most common use of the BAI is fibromyalgia [18] and arthritis [19]. The HADS-A scale is used in patients to identify anxiety and depression symptoms. It includes an assessment of generalized anxiety including tension, worry, fear, panic, difficulties in relaxing, and restlessness [16].

We intend to quantify the level of anxiety by measuring parameters that change when a person is anxious. These parameters include feeling nervous, restless or tense, having an increased heart rate, hyperventilation, sweating, having trouble sleeping, feeling weak or tired, trembling, and having trouble concentrating [26]. For this research, we chose Heart rate and Blood Pressure as the two main parameters keeping in mind the available equipment.

3 Methodology

We classify anxiety levels into broad categories based on heart rate as shown in Table 1. 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 four categories. This pre-determined scale is used only once - to determine which game needs to be administered.

Table 1 Classification of the subjects

Class No.	Scale	Reading
Class 0	0 - 4	Normal
Class 1	4 - 8	Mild to Low Anxiety
Class 2	8 - 12	Moderate Anxiety
Class 3	12 - 16	Severe Anxiety

Based on this scale, three games were developed; each tailored to a specific class of preoperative anxiety. Subjects belonging to Class 1 were provided with a mobile-based application, while those in Class 2 were offered a PC game. For subjects categorized under Class 3, a fully immersive VR environment was utilized. Details of each game are explained in this section.

3.1 Game 1

Game 1 is an Android application prescribed for subjects who show a low anxiety level. It is a mobile game based on the concept of 'finding the hidden object'. Three scenes, a cafe, a playground, and an office respectively, are hidden in a small city as shown in Figure 1.

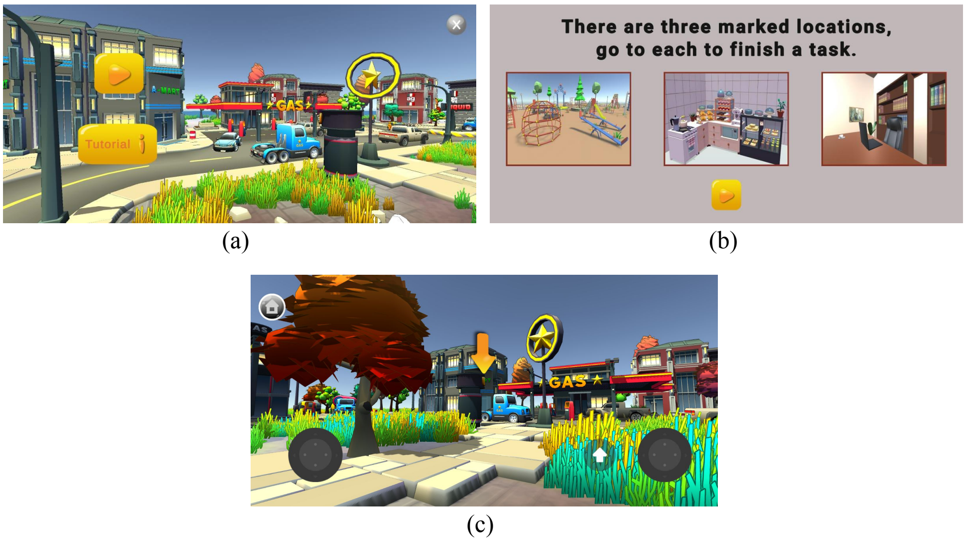


Fig. 1 (a)Home screen of the game. showing a play, tutorial, and exit button on the screen. (b) The introduction screen shows what the scenes look like. (c) Control buttons are displayed on the screen. The down arrow (orange color) points to a portal that leads to the Cafe. Similar arrows are placed for the other two scenes

The subject must walk around the city and find these scenes, which can be accessed via portals set at pre-defined locations. Each scene has five hidden objects. The goal is for the subject to find the objects in each scene as shown in Figure 2.

Fig. 2 (a) Playground scene. (b) Cafe Scene. (c) Office Scene. (d)(e)(f) Prompts for the hidden objects displayed in the playground, cafe, and office respectively.

The subject can walk and look around using the two on-screen joysticks provided. A jump button is added as well to let the subject hop over small obstacles. The game also has a tutorial for using these controls as shown in Figure 3.

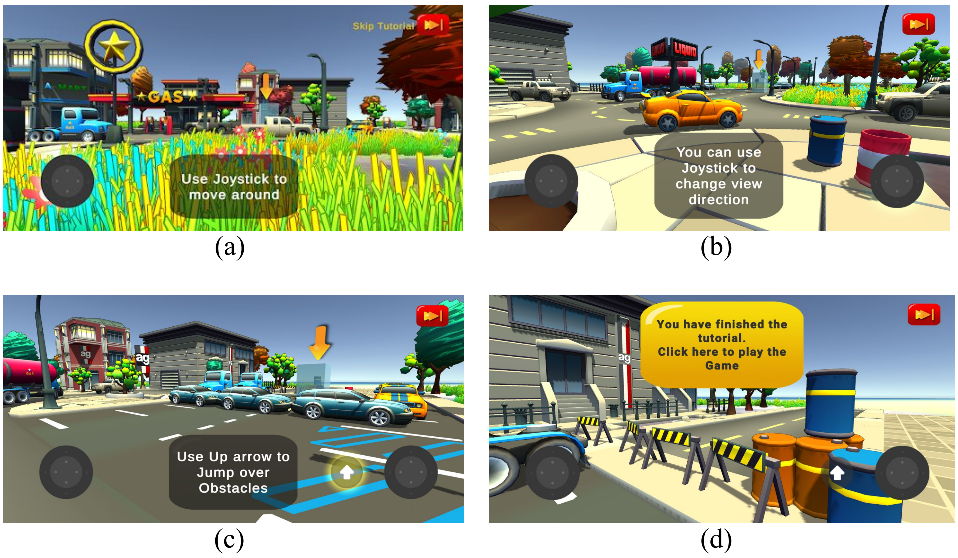


Fig. 3 (a) Tutorial for Game 1 showing how to use controls. (b) Control buttons are added one after the other to allow the subject to get acquainted with the controls. (c) Each button is added when the subject reaches the 'portal' which is below an arrow. (d) End of tutorial prompting the subject to start the game

Huge orange arrows are added in the sky to indicate where the scenes are located. The subject is free to visit the scenes in any order they please, take any route to get there or just simply walk around the city. In the scenes, they need to look for the hidden objects and tap on them to 'find' them. When they do so, a counter on the top of the screen is incremented to show how many objects they have found and how many are left as shown in Figure 4(a) and 4(b).

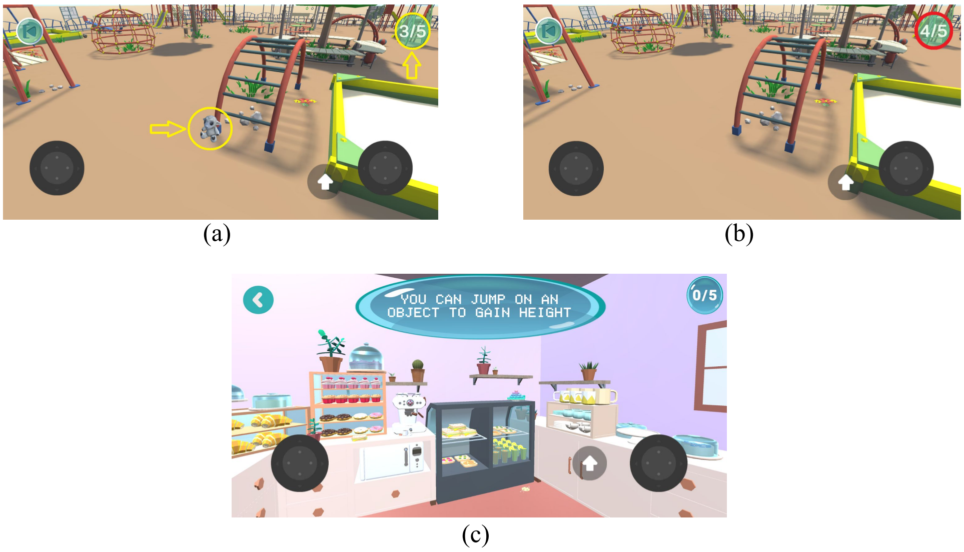


Fig. 4 (a) Stuffed toy and counter showed on the screen. (b) When the stuffed toy is 'found' the counter is incremented. (c) In the cafe scene, a subtle clue is presented to nudge the individual towards discovering a concealed cookie.

The subject is free to leave the scene at any time. However, when they find all the objects a prompt shows up asking them to find the next scene. The position of the hidden objects is randomized so the subject can return to the scenes again. This way the objects are not in the same place as before. The game relies on visual representation, but the text is added to help the subject through the game. To remove the chance of stress and frustration, hint prompts are added to the game as shown in Figure 4(c). These prompts appear if the subject has not found a hidden object after a certain amount of time. The prompts do not point to the position of an object but rather give hints as to possible ways the subject can look.

The game has been designed to incorporate vivid color schemes with the aim of captivating the user's attention. Furthermore, the controls have been crafted with the intention of being similar to those of other first-person mobile games, thereby facilitating ease of use and user familiarity. Despite consideration, a timer was excluded from the game, as competitive games can elicit anxiety and the cognitive load on the user was intended to be minimized.

3.2 Game 2

Game 2 is for subjects who show a moderate level of anxiety. This game is based on treasure hunting and is a computer-based game. The subject is dropped into a small coastal town as shown in Figure 5.

Fig. 5 Various scene snapshots of the coastal town where the treasure hunt game is set.

The subject must locate hidden keys scattered throughout the town. These keys are small, three-dimensional objects in the shape of a cube, a prism, and an octahedron, respectively. Once a key is discovered, a larger version of it is generated with only the vertices visible, where the subject initially spawned. After finding the keys, the subject must return to the spawn location and use triangles to complete the faces of the 3-dimensional model. Selecting vertices in a clockwise direction generates a triangle, and the selected vertices glow to indicate the selection. The first vertex is blue, the second is green, and the third is pink as illustrated in Figure 6. If a triangle already exists between the selected vertices, it is erased. Once all the model faces are completed, the subject must search for the next key.

(a)

(b)

(c)

(d)

Fig. 6 (a) An interactive key in the form of a floating prism is used to activate the vertices arranged in the shape of a prism. (b) Upon selection, a vertex becomes illuminated. The first vertex glows in blue. (c) Clicking on the third vertex generates a pink triangle between the selected vertices. (d) This image displays a fully completed prism. Before finding the next key, the subject must finish all faces of the object.

At the beginning of the game, subjects are provided with instructions on how to navigate the town. The controls are comparable to those used in other first-person PC games, utilizing arrow keys or the keys 'W, A, S, D' for movement. Holding down the 'shift' button enables the subject to run. To look around, players can click and drag the mouse, simulating the motion of turning one's head. Figure 7 illustrates how these instructions are presented to the subject.

Fig. 7 (a) Subjects receive instructions on player movement when the game starts. (b) Instructions regarding the keys and puzzle completion are also provided in detail to the player.

In resemblance to Game 1, Game 2 presents a vivid and vibrant setting, with conventional controls akin to those of typical computer games. Nevertheless, it represents an advancement: surpassing the mere objective of locating an item, it incorporates a puzzle that must be resolved alongside the item's discovery. The decision to opt for a PC game for Game 2, as opposed to a mobile-based application like Game 1, 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 users would need to focus more intently on the game, potentially resulting in a more effective distraction from their preoperative anxiety.

3.3 Game 3

Game 3 is intended for individuals who exhibit a higher degree of anxiety, whereby it aims to alleviate their distress by relocating them from their present anxiety-provoking surroundings and immersing them in a tranquil environment. This game acts as a channel for relaxation therapy as well as distraction therapy and guided meditation. The subjects are given a Head-mounted display (HMD) and controllers to access the virtual environment. Subjects are put into a virtual zen garden where they are free to walk around as shown in Figure 8.

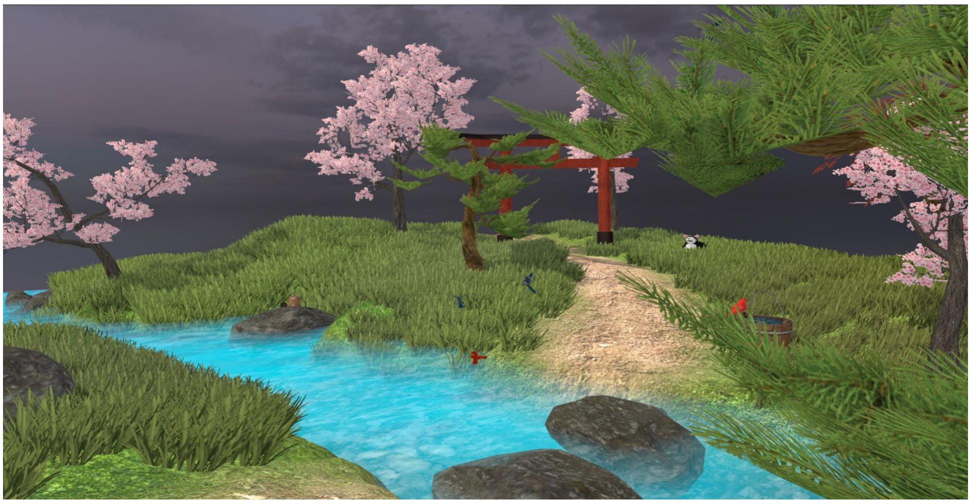
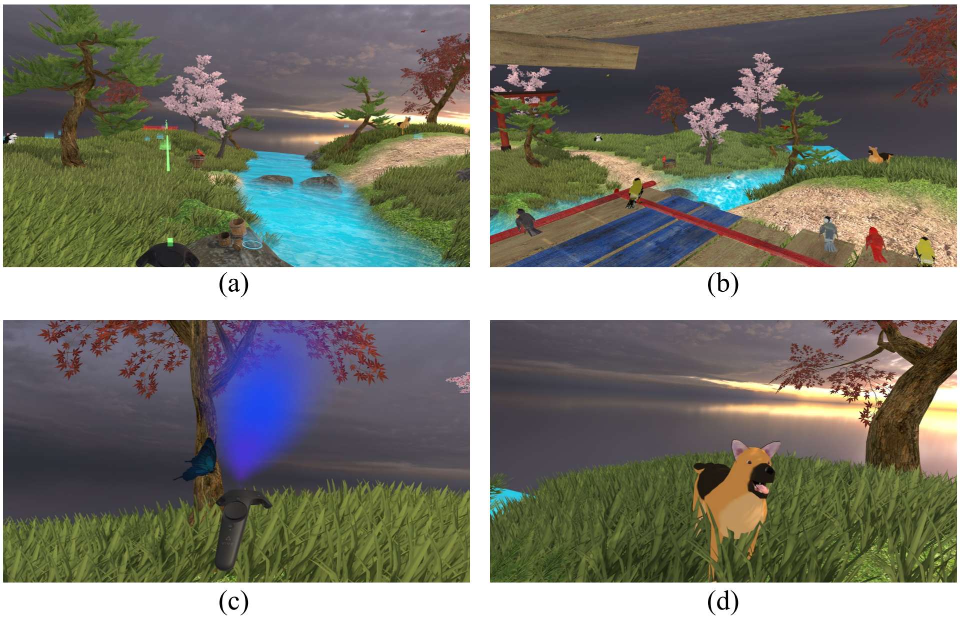


Fig. 8 Virtual zen garden complete with cherry blossom trees.

The game lets the subject use the controllers to teleport to different predetermined spots in the garden. A virtual pet dog is also available, which follows the subject around the garden. A virtual butterfly, along with colored flares, is also another feature in the game that follows a path the subject desires as shown in Figure 9.



(a) (b) (c) (d)

Fig. 9 (a) Meditation spot is clearly labeled. (b) By visiting the designated teleportation spot, the subject can access the treehouse located above as it is connected to one of the teleportation spots. (c) The subject's right-hand movements are accompanied by a butterfly and colored flares. (d) One of the many comfort dogs that are present in the environment.

In addition to guiding the subject through the game, a deep breathing exercise is also incorporated. The game displays instructions, as depicted in Figure 10, accompanied by a voice-over prompting the subject to inhale, hold their breath, and exhale for a predetermined duration. This technique encourages the subject to take deep breaths, effectively using the game as a tool for guided meditation. The ultimate aim is to alleviate the anxiety of a subject, particularly in a stressful environment like a hospital room, by transporting them to a more serene location and diverting their focus away from medical procedures.

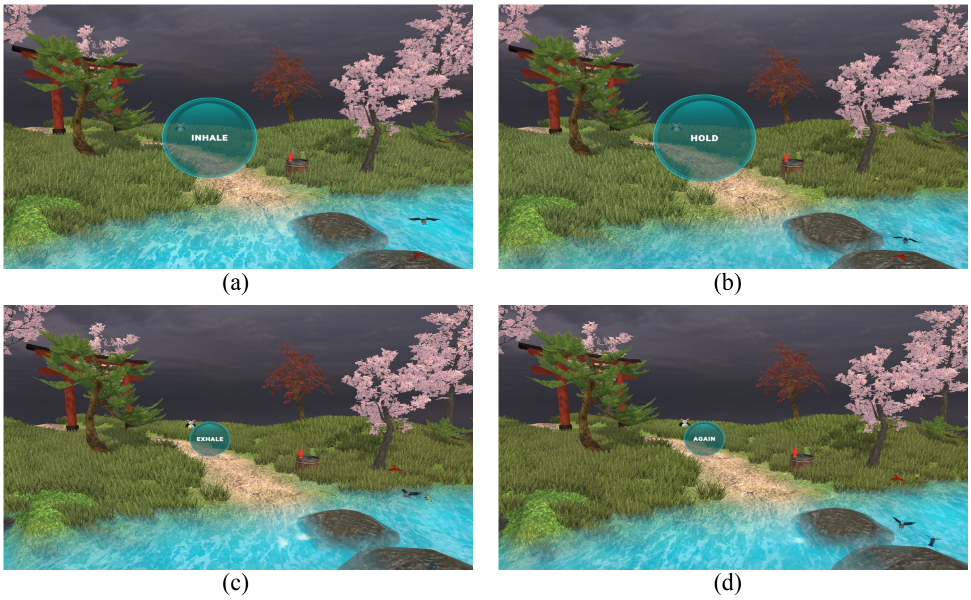


Fig. 10 The subject is directed through a guided meditation involving four steps: (a) inhaling, indicated by an expanding bubble, (b) holding, signified by a constant bubble size, (c) exhaling, represented by a deflating bubble, and (d) repeating the sequence.

There are only two 'controls' for this game. The trigger button at the back of the right-hand controller acts as a teleport button. When held down, the predetermined spots appear in the environment in the form of blue circles and a ray appears from the controller. Subjects need to point to the spot they want to teleport to. When they do so, the blue circle turns green and the subject needs to let go of the button to teleport to this spot. The other control is the touchpad on the left-hand controller. This is for free movement in the environment. The subject can navigate through the environment by holding the touchpad in the direction they want to move in. There is no clear objective or 'end goal' for this game. Subjects can look around and take their time to enjoy the virtual world.

4 Testing

4.1 Technology and Hardware

4.1.1 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. Unity's Asset Store offers pre-made assets that can be easily downloaded and imported, which saves time in asset creation and environment setup, a typically time-consuming aspect of game development. 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].

4.1.2 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 11

SteamVR is a platform for virtual reality that includes a software framework designed to allow users to experience VR content and games on supported VR headsets. It provides features for room-scale VR, allowing users to move around and interact with virtual environments in a physical space. 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. To avoid user discomfort, a high refresh rate is crucial, and the VIVE has a refresh rate of 90Hz. Additionally, SteamVR supports Unity Editor mode, which allows users to test their VR applications directly on their device by pressing Play in the Editor [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. Typically, the faceplate contains sensors that enable more accurate tracking. The VIVE headset’s motion faceplate, for example, uses six camera sensors to increase the user’s range of motion. 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, as shown in Figure 12. With a combined pixel resolution of 2880x1700, users can appreciate finer details within the VR application [25].

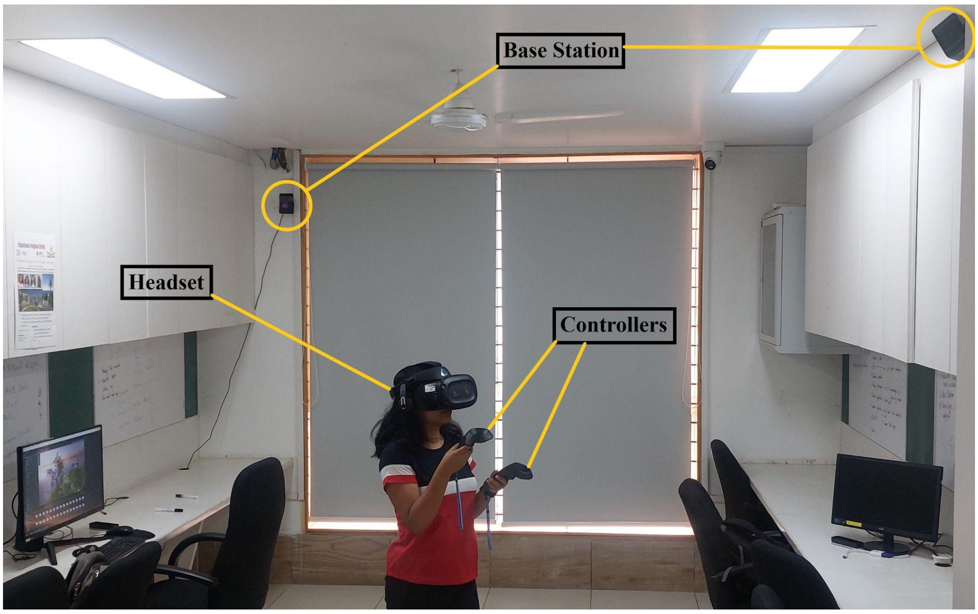


Fig. 11 The VR setup that was established for this project.

Fig. 12 The various input tools available on the controller.

4.2 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 preoperative anxiety can increase heart rate on arrival to the operating room, increase systolic blood pressure, and can cause an increased mean arterial pressure among patients [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 2 and 3. The aim of the application is to see a reduction in these parameters of the patient.

Table 2 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

Each subject is first classified into one of the categories of the tables (Table 2 and 3). 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

Table 3 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

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 77 subjects. While 104 individuals were invited to participate, 27 were unable to do so due to various reasons as mentioned in section 4.5. The efficiency of the applications was evaluated through the feedback obtained from the participating subjects. Additionally, exclusion criteria were established to account for the inability of some prospective participants to take part in the study.

4.3 Selection of Subjects

After disseminating information about the study, 104 individuals expressed their interest to participate as potential subjects. From this pool, only those who met the eligibility criteria were selected. This process resulted in a final sample size of 77 subjects for the study.

4.4 Motivation of subjects

The aim is to address the issue of pre-operative anxiety by giving the study participants a sense of control. To achieve this, all subjects were given the free will to test the VR application, and they were given a choice to decline participation. By providing patients with the choice to participate, we hoped to empower them and reduce their anxiety about the situation. Offering tangible incentives was also considered but believed that self-motivation would be more effective [30]. To ensure that patients understood the study and the VR environment, they were provided with a clear and detailed explanation of the research, the applications, and the potential benefits and side effects of the VR environment. The patients were also given the opportunity to ask questions, and written consent was obtained to ensure that they fully understood the study and its implications.

4.5 Exclusion of subjects

Several potential participants declined to take part in the study due to various reasons.
1. Older subjects reported finding the application controls too complex and feared that using the technology might make them more anxious
2. Some individuals expressed interest in experiencing the VR environment but expressed concerns about possible adverse effects of an HMD, such as headaches and

nausea, which deterred them from participating.
3. Some subjects were uncomfortable with providing written consent for the use of their personal data in the study, leading to their decision not to participate.

4.6 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 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 4 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 4 Summary of test subjects for all applications

Characteristic	Game 1	Game 2	Game 3
Number of Subjects	40	14	23
Age (in years)	(16-50) G1 = 16-30 G2 = 30-40 G3 = 40-50	16-30	(18-40) G1 = 18-30 G2 = 30-40
Gender	24 Male, 16 Female	9 Male, 5 Female	17 Male, 6 Female
Presence of Anxiety	19 HA, 21 NA	4 HA, 10 NA	7 HA, 16 NA
Gaming Experience	21 G, 19 NG	9 G, 5 NG	8 G, 15 NG
Time Taken	No Time Limit	No Time Limit	Controlled Simulation

In both Game 1 and Game 2, participants were afforded the freedom to choose any path to solve the puzzles and were not subjected to any time constraints. Game 3 was a controlled simulation.

5 Results

5.1 Game 1

Based on the data collected, the analysis of heart rate ratings indicates a 100% positive outcome, indicating that the ratings remained consistent or decreased to a lower interval, as previously outlined in section 4. While 38 subjects had the same rating, 2 of them experienced a reduced rating. 67.5% of subjects experienced lowered heart rates. The rating for Blood pressure showed a 75% positive result. 17 subjects maintained the same rating while 13 had reduced ratings. Figure 13 presents the correlation between the variation in the subject's heart rate against the various phases of the game (as explained in section 3.1). The data clearly indicates that on average, the heart rate decreases slightly as the subject progresses through the application and the variation in the heart rate substantially increased indicating reduction in anxiety levels.

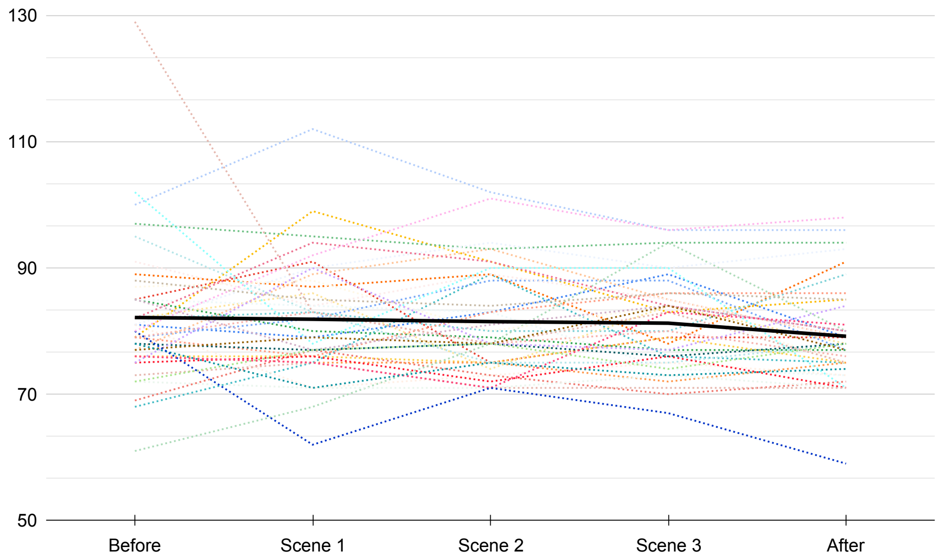


Fig. 13 The variance in heart rate for subjects who tested Game 1. The black line indicates the average heart rate across all subjects during the various phases of the game.

5.1.1 Age

Regarding individual heart rate values, Age Groups 1, 2, and 3 demonstrated positive percentages of 85%, 90%, and 50%, respectively. Notably, Age Group 2 exhibited the greatest influence, suggesting that the game could be effectively targeted toward adults between the ages of 30 and 40.

5.1.2 Gaming Experience

The results revealed that subjects without gaming experience had a positive outcome of 63.2%, while those with gaming experience had a positive outcome of 71.4%. Upon comparing these results, it was observed that although subjects with gaming experience had a higher proportion of positive outcomes, the difference in positive percentages between both groups was not significant enough to suggest that a lack of gaming experience would have a negative impact on the overall outcome.

5.1.3 Gender

Gender, as a characteristic, does not appear to have any significant impact on the simulation.

5.1.4 Presence of Anxiety

The results indicated that pre-existing anxiety (HA) had a more adverse effect on blood pressure ratings compared to the absence of anxiety (NA). Specifically, 68.4% of individuals with anxiety and 81% of those without anxiety showed positive response following the simulation.

5.1.5 Time Taken

Out of the 10 subjects who spent more than 15 minutes in the simulation, 60% experienced a drop in blood pressure and 70% experienced a decrease in heart rate.

5.2 Game 2

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 14 displays the variation in the subjects' heart rates during the different phases of the application (as explained in section 3.2). 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.

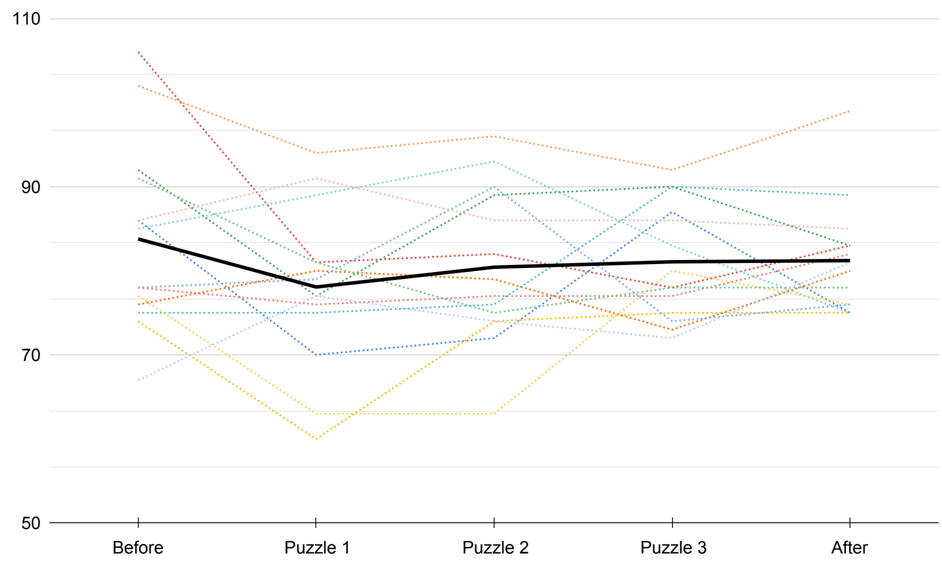


Fig. 14 Variation in heart rate for subjects who tested Game 2. The black line indicates the average heart rate of all the subjects.

5.2.1 Gender

Gender did not play any part in influencing the result.

5.2.2 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.

5.2.3 Presence of Anxiety

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

5.2.4 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.

5.3 Game 3

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 15 illustrates the variation in the subjects' heart rates while immersed in the virtual environment (see section 3.3). The data highlights a consistently slight decrease in the average heart rate as the subjects progress through the simulation.

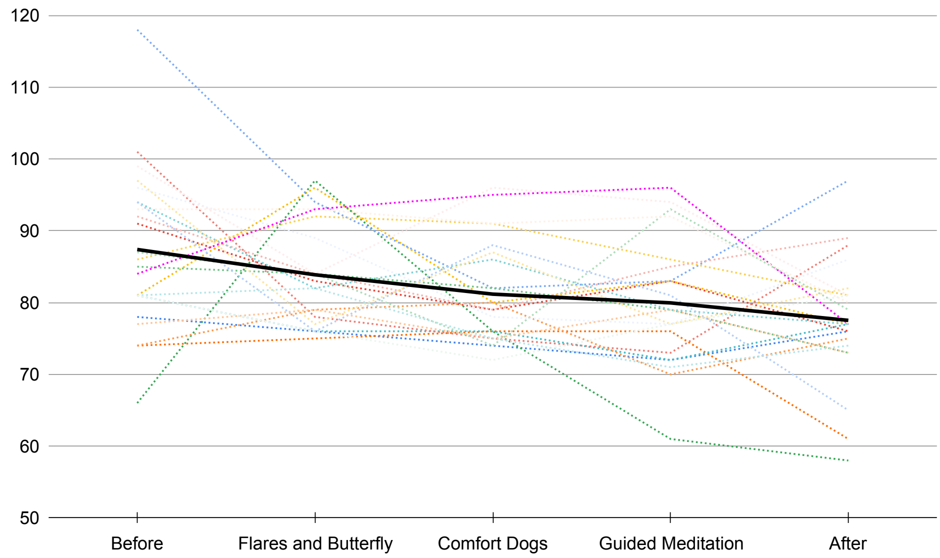


Fig. 15 Variation in heart rate for subjects who tested Game 3. The black line indicates the average heart rate of all the subjects.

5.3.1 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%.

5.3.2 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.

5.3.3 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.

5.3.4 Presence of Anxiety

The heart rate value and rating had 100% positive results on subjects with and without anxiety.

5.3.5 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 all the simulation lasted for approximately 8 minutes.

5.4 Analysis

Despite a slight increase in their heart rates and blood pressure, all subjects remained in the same category as mentioned in Table 2 and Table 3, resulting in a 100% positive outcome for each of them. Taking decreased heart rate value into consideration, the results are 67.5%, 64.3%, and 95.65% positive for Game 1, 2, and 3 respectively as shown in Figure 16. For Blood pressure, the results are 76%, 93%, and 78% positive as shown in Figure 17.

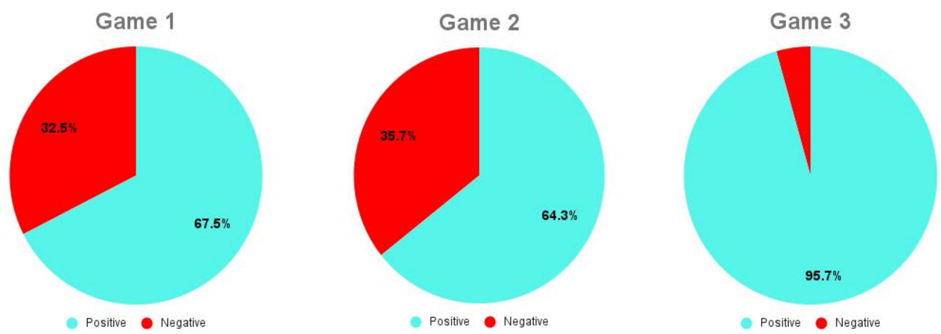


Fig. 16 Heart Rate Comparison of all applications

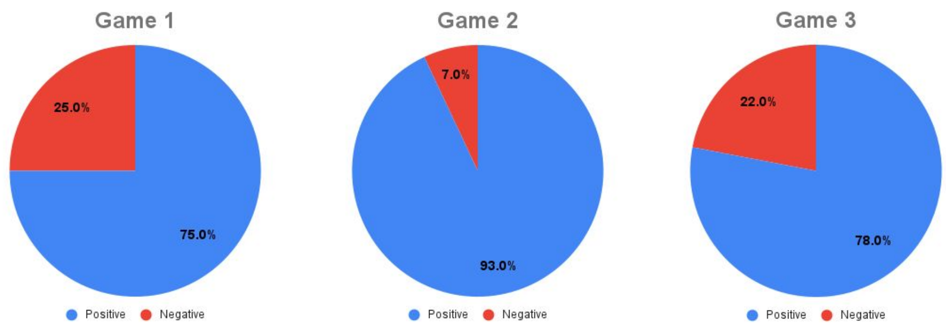


Fig. 17 Blood Pressure Mapping of all applications

Since users of all three 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 5 displays the number of participants with an increased or decreased heart rate and the average bpm change.

The tabulated data indicate that Games 1 and 2 were successful in regulating the variability in heart rate, as the positive and negative impacts of the applications seemed to offset each other. However, Game 3, which was a VR game, stood out for its exceptional performance in reducing heart rate, suggesting that it effectively managed anxiety levels.

Table 5 The quantified values of the positive and negative impact of the three applications on heart rate

	Game 1	**Game 2**	**Game 3**
No. of subjects with a positive result for heart rate comparison	27	9	22
The average decrease in heart rate (in bpm)	8.22	8.11	10.36
No. of subjects with a negative result for heart rate comparison	13	5	1
The average increase in heart rate (in bpm)	7.92	7.4	1

In graph 18, three subjects, one from each game were randomly selected, and their heart rate variability during the simulation was plotted. The results indicate significant variations in heart rate during the simulation, which suggests that the subjects were distracted from their current situation, thereby providing evidence for the effectiveness of the applications.

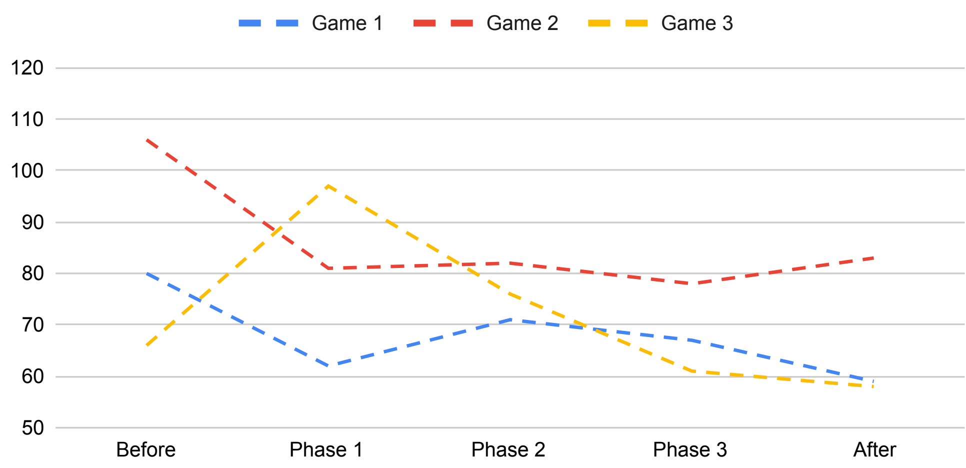


Fig. 18 Heart Rate Comparison of all applications

6 Discussion

The applications are not intended to provide any form of behavioral therapy. Rather, their primary goal is to address pre-operative anxiety by providing immediate relief to subjects. The design of the applications is geared towards delivering a short-term solution, and therefore, the study's focus is on assessing their 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.

Substances like sedatives are often used to address preoperative anxiety, but VR offers a non-pharmacological alternative for calming patients. The detrimental effects of preoperative anxiety extend beyond the patient's well-being, as it can also result in substantial financial costs for the medical industry. For instance, increased dosages of analgesics and canceled surgeries can lead to substantial billing. Additionally, the patient's comfort level can be severely compromised by anxious thoughts. 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. This would mean that patients with issues with their hands and neck will not benefit from the application if they can use it at all.

7 Conclusion

The use of VR technology to alleviate preoperative anxiety is a well-established approach. In this study, three distinct applications were evaluated as viable channels for distraction therapy and guided meditation. The outcomes revealed that the third game exhibited the most promising results in mitigating preoperative anxiety. It was also observed that as participants' age increased, they showed lesser familiarity with digital games, which led to a greater need for attention towards the controls and applications. Interestingly, this increased attention facilitated engagement with the games and helped participants shift their focus away from their current environment. In order to provide greater clarity regarding the effectiveness of the application, it would be beneficial for future studies to delve deeper into its impact on different levels of anxiety, given that the current research serves as a pilot study.

8 Future Work

This project has proved to be successful on some levels. However, it is but a step in the use of VR to help relieve preoperative anxiety. By using machine learning and artificial intelligence, one can modify the games with more features and settings to better fit the patient. Although the applications use therapeutic methods, they can still be considered a prototype. The applications do not take into consideration people's fears and phobias. The third application in particular works under the assumption that the subject does not have a fear of water or animals. These features can be disabled in case the phobia exists in the subject but there are no replacements. Further improvements can be made by taking into account behavioral therapy and other techniques that can make the VR effects longer lasting. The applications are rudimentary but the experiments and their respective inferences show that the idea behind the project is true. Using VR to exhance therapy techniques is a new and exciting field. The possibilities seem to be endless, the only limit being imagination.

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Statement and Declarations. The data that support the findings of this study are available on request from the corresponding author, [Adithya Balasubramanyam]. The data are not publicly available as it contains information that could compromise the privacy of research participants.

Conflicts of interest. The authors declare no conflict of interest.

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