Interactive Virtual Rooms: A New Approach to Anxiety and Pain Management

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***Abstract*—The coveted concept of utilizing Virtual Reality (VR) as a method for both medical and therapeutic treatment has been a subject of interest over the past few decades. VR immersive technologies can increase engagement and motivation in therapy and enable tailored scenarios. Previous studies using this technology, namely on burn patients, have demonstrated that VR has the potential to reduce anxiety and pain response during treatment, sparing expenditures in both traditional pain and anxiety relieving options. This paper presents a VR application, consisting of several rooms with relaxing activities inside which the user can navigate and interact with the objects. The application, designed in Unreal Engine for the HTC Vive Pro headset, was evaluated for its ability to create relaxing stimuli. Experimental results with volunteers indicate that it is easy to interact with the virtual environment, demonstrating high levels of presence and immersion and reporting a reduction in stress and anxiety levels.**

***Index Terms*—Pain, Burn Patients, Chronic Pain, Preoperative Anxiety, Sleep Quality, Anesthesia, Mindfulness, Virtual Reality, Sensory Stimulation, Serious Games**

I. Introduction

Preoperative anxiety, a prevalent psychological state occurring before surgery, can adversely affect postoperative outcomes. Individuals experiencing preoperative anxiety exhibited a higher incidence of nausea, vomiting, and dizziness compared to those without such anxiety. In addition, other studies have shown that the preoperative sleep quality of patients suffering from preoperative anxiety is worse than that of patients exempt from this condition, leading to a more arduous recovery process. Furthermore, high preoperative anxiety is related to more severe postoperative pain and an increased requirement for analgesia and anxiety relievers [1].

VR technologies could suggest a potential alternative to the commonly administered analgesia and anxiolytics. Thus far, western medicine as had pharmacological control over pain as its centrepiece, however, researchers are starting to recognize that various pain modularity systems can be accessed through cognitive manipulation. Variables such as attentional state, emotional context, hypnotic suggestions, attitudes, expectations or anesthesia-induced changes in consciousness have now been shown to alter both pain perception and forebrain pain transmission in humans [2]. Assuming that certain emotional states can be achieved through VR use, it is imperative to determine how effective these virtual scenarios are at suggesting these emotional shifts for the users. Users unfamiliar with VR technologies can feel overwhelmed and confused when too much visual information is presented to them in a way that they are not accustomed to. The design of controllers and the haptic feedback they provide also play a vital role in how the user navigates in the environment, suggesting that if the controls feel more artificial, they will draw more attention away from the visual and auditory stimuli of the scenarios.

In a Snoezelen or multi-sensory stimulation environment (MSE) room, sensory stimulation can include visual, proprioceptive, and vestibular inputs, tailored to the specific objectives of the session and the individual needs of the patient, for instance mental, physical, or behavioral impairments [3]. The success of MSE is evidenced by its ability to reduce both physical and emotional stress, which in turn enhances concentration. Furthermore, MSE can be used as an introductory method for developing cognitive strategies for progressive relaxation [4].

This paper suggests an accessible and calming VR experience that takes away the users' attention from their perceived pain and anxiety. The subsequent parts of this paper consist of a background section, which provides context and foundational information relevant to the topic, and a section including the overall system construction with the components and software involved. The user experience session outlines the methodology involved in the development of our VR MSE rooms, a description of the evaluation procedure alongside the questionnaires and measurements needed to validate the experiment, and lastly a discussion of the results and conclusion.

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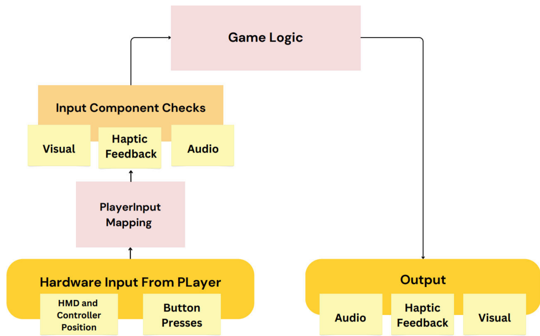

Fig. 1: System's architecture flow diagram.

II. Background

Although there are plenty of VR applications that are built upon the concept of mindfulness and relaxation, very few actually are targeted with their main focus on preoperative anxiety and postoperative care. However, a more relevant study at the University of Washington showed the outstanding impact that a VR experience, known as SnowWorld had on its participants. For this experiment, a series of burn patients were invited to play a simple game in a snowy virtual scenario while being treated for their scar tissue and dead skin. During the study, one of the original creators stated "Patients reported significantly less pain when distracted with VR, with “worst pain” ratings during wound care dropping from “severe” to “moderate” [5]. The six patients who reported the strongest illusion of “going inside” the virtual world, reported the greatest pain reduction effect of VR, dropping from “severe pain” with no VR to “mild pain” during VR". Another lab member then concluded that VR works in this setting because it reduces the brain's concentration on the pain, “In order to experience pain you have to be conscious of pain". Besides inquiries on the participants, these conclusions were also supported by brain scans of patients engaging in VR during painful experiences, which reveal a decrease in pain-related brain activity. This observation indicates that VR is not only altering the patient's perception of incoming pain signals but is also modifying the neural processing of these pain signals, as stated by Hoffman [6] [7]. VR in pain treatment: young age and no previous anesthetic experience commonly coexist, thus indicating that age is related inversely to anxiety scores [8] [5].

III. System Design

Our VR software leverages *Unreal Engine 5's* features [9] like high-fidelity textures, intricate lighting models, and advanced post-processing effects without compromising performance. The system's architecture flow diagram is represented in Figure 1. It ties with the chosen HTC VIVE PRO 2 headset, which offers other advantages, such as 5K resolution and 120Hz refresh rate, greater audio immersion provided by its integrated headphones with 3D spatial and Hi-Res audio capabilities. This HTC headset and its controllers also allow for more precise and reliable tracking, employing SteamVR Tracking 2.0 as well as the MetaXR plugin for input mapping, enabling expansive play spaces with two base stations for optimal coverage [10]. The standard setup includes a tethered connection to ensure the high data transfer rates required for its high-resolution displays and to maintain low latency.

IV. Evaluating User Experience

A. Methodology

Users begin their virtual journey by entering the lab factory room, called the Lobby Room (see Figure 2), which was modeled to replicate the laboratory room (top corner). The second room, presented in Figure 3, aims to replicate the traditional Snoezelen definition mentioned beforehand, a meditation-oriented room with lava lamps and colored lights, guided meditation, and overall, a place where the user can feel more relaxed. The following rooms provide a more natural feeling, resembling real-world scenarios for users who found the Snoezelen uncanny, focusing now on activities. For instance, the third room recreates the art room on a beach terrace, with multiple throw-able paint balloons and graffiti cans that enable drawing in mid-air. Lastly, a musical studio, composed of several instruments, including a guitar, a drum set, and an electronic keyboard, is also considered, with emphasis on visual and audio stimuli. Navigation in the virtual environment requires the participants to walk freely while interacting with multiple available objects.

The approach taken to set up most grabbable objects, or static meshes, as they are commonly referenced inside the unreal editor, was made by adding collision boxes adjusted to the corresponding static mesh's vertexes. By doing so, we then set the users motion controller to be capable of holding the static mesh once the controller and the collision box begin to overlap. Furthermore, all grabable objects are affected by gravity, and have different behaviors according to their attributed weight. All musical instruments were set up similarly, as well as the level transition mechanism. In the case of the drum set and the keyboard included in the music studio, multiple hitboxes were set that would play a desired sound once the user's controller begins the overlap function. Once inside the arts room, the paint balloons, besides being grabable also cause a splatter effect to be projected on the surface it is thrown at. Depending on the normal vector of the surface hit and if a certain velocity of the balloon thrown is achieved, a decal is spawned and a splatter sound is played in the location hit. Spraying is also possible, employing Spline Mesh Components, deforming a single Static Mesh along a two-point spline. These two points correspond to the starting position and current position of the spline, which spawns the deformed mesh as long as the player is pressing the mapped button (see Figure 3).

B. Evaluation Procedure

The experiments were performed at the Factory Lab, located inside the chemistry department of the University of Coimbra. Initially, the participants were given a brief introduction to the procedure, including instructions on how to control the virtual

Fig. 2: Lobby room, resembling the lab (in top corner).

reality pawn with the VR headset and its controllers. Then, one by one, the participants were invited to enter the room where the HTC VIVE PRO 2 headset system was installed. After aiding the participants in equipping the headset, they were allowed to navigate a VR lobby room, resembling that same laboratory for one minute so that they could get familiarized with the headset and its controllers and clear any possible doubts. After this first trial, the researchers provided the participants with a description of all the interactable assets inside the three different rooms they were about to navigate, along with instructions on how to interact with them. Users were required to change between the distinct rooms to begin or conclude a room experience, as explained in the instructions. Lastly, the participants were told that their only goal was to freely explore and interact with the different rooms, only to change between rooms every minute, which they were notified about when the time came. The researchers concluded and evaluated the procedure by requesting the participants to answer a series of custom-made questionnaires in Portuguese, which included the IPQ, SUS, and PANAS-VRP questionnaires.

C. Variables and Evaluation Instruments

After the virtual tour, to assess factors such as presence and immersion experiences, the researchers instructed the participants to fill out a modified version of the Survey on Experiences in Virtual Worlds, the IPQ questionnaire [11] [12]. Furthermore, the researchers administered the SUS [13] and PANAS [14] questionnaires to evaluate the perceived usability of the system and the participants' emotional state, respectively.

D. Participants

Amongst the 8 participants, with an average age of 20 years old, only 2 had slight previous experience with VR headsets. None of them had prior knowledge of the experience or involved technologies. Five female and three male participants voluntarily experienced the different virtual scenarios and the ethical principles of the research were respected.

E. Results

The results from the Portuguese version of the IPQ, regarding *Global Presence*, *Spatial Presence*, *Involvement* and

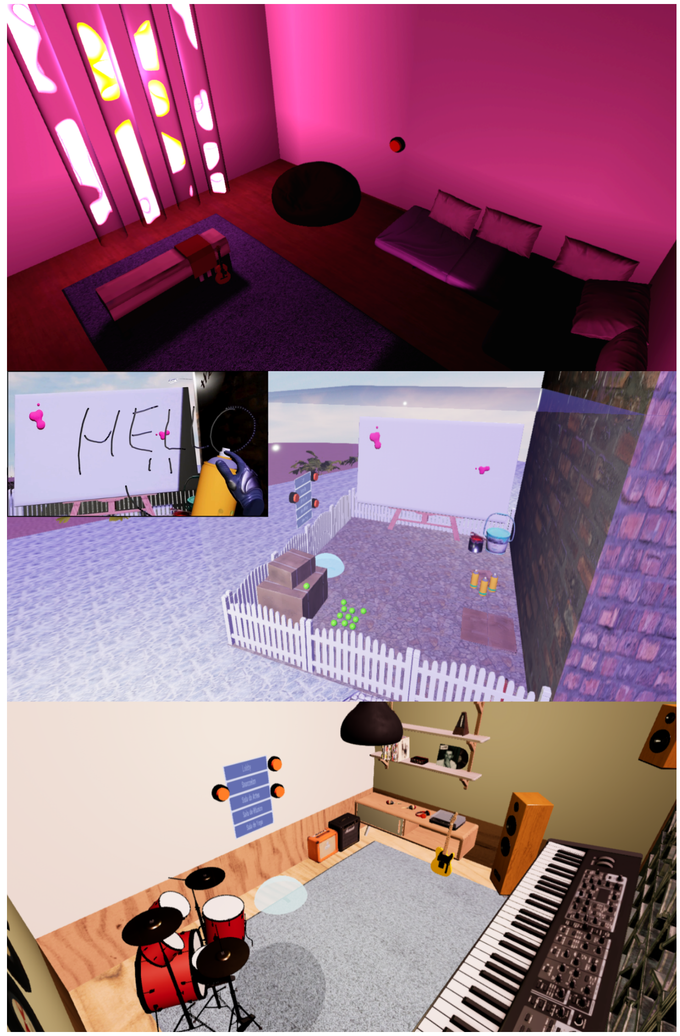

Fig. 3: A traditional Snoozelen as a place for relaxation and mindfulness practices (top), a terrace by the beach, with different painting tools (middle) and a graffiting example on the corner, and a music room including various playable instruments (bottom).

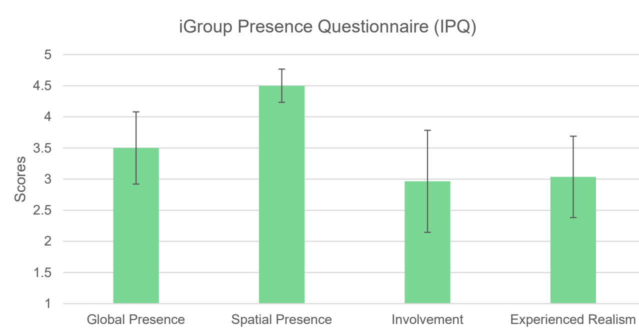

Fig. 4: iGroup Presence Questionnaire - Results for Global Presence (GP), Spatial Presence (SP), Involvement (INV), Experienced Realism (REAL)

TABLE I: ANAS-VRP questionnaire results.

Interested	Nervous	Enthusiastic	Frightened	Inspired
4.5	1.3	4.8	1.0	3.9
Active	**Scared**	**Guilty**	**Determined**	**Tormented**
3.9	1.0	1.0	3.4	1.0

Experienced Realism are shown in Figure 4. Although the values obtained for spatial presence seem to be up to par, some improvements can still be obtained regarding involvement. Since the HTC VIVE PRO 2 Headset offers limited haptic feedback, only provided when grabbing objects, external devices might help cover this factor.

As for the system usability, a SUS score of **82.5**% was obtained from the questionnaire Portuguese version, which translates to the highest grade of A. Granting that some users were hesitant at first, given the lack of experience with virtual environments, after the first trial in the lobby room, the participants could effortlessly comprehend the controls and felt encouraged and motivated after successfully interacting with the tutorial room and the first level transition. Table I presents the results obtained from the PANAS-VRP questionnaire [14], to assess positive and negative affect/moods induced by the VR experience.

F. Discussion

Participants were able to successfully interact with most of the activities in the various virtual rooms and consistently reported a strong sense of presence, feeling as if they were physically within the environments. This immersive quality transcended the boundaries of the real world, effectively transporting users into virtual scenarios. While the virtual nature of the rooms was demonstrably evident as reported, participants still found the environments highly engaging and distinct from their everyday experiences. This suggests a successful creation of virtual spaces that are not only close to realistic but also captivating.

The experimental results from the PANAS survey reveal that participants showed increased motivation to complete their assigned tasks following a short session in virtual environments. Additionally, the participants experienced greater relaxation and peacefulness while maintaining engagement, suggesting that the MSE could effectively serve as a mental preparation stage for therapy. However, the testing conducted is restricted. Since the MSE was tested solely on a small group of individuals, it would be inappropriate to extend these results to patients with different mental disorders, as their responses could vary significantly from those of healthy individuals. The great majority of the participants also pointed out that the cable connecting the headset to the desktop computer was the most prevalent factor when it came to breaking immersion, due to regular tangling and hindering of the user movement.

V. Conclusion

In this paper, we explored the requirements and specifications for multi-sensory stimulation environments (MSEs) as an alternative to therapy and pharmacological solutions for pre and post-operative anxiety and pain. We developed a series of virtual reality rooms complemented with interactive activities relying on head-mounted displays (HMD) and hand controllers to provide stimuli, usable by anyone, including healthcare specialists for patient therapy. After development, the app was released to beta testers to validate its usage and benefits. Analysis of the feedback, namely Presence and Immersion (IPQ), System usability (SUS), and Positive and Negative Affect Schedule (PANAS-VRP) questionnaires, demonstrated that the proposed environments have to capacity for leisure, showing increased engagement stimulation, and therapeutic purposes, particularly in mental preparation for treatments.

In future work, wireless adapters for the HTC VIVE 2 Set are considered, so that the user movement doesn't feel as restricted. Additionally, we aim to administer PANAS, before and after the experiment, and provide users with textural stimulation complementing the tactile feedback provided by the hand controllers. Further research could explore integrating other sensory modalities, such as smell and taste. We believe this might contribute to a higher involvement during the experience.

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