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RESEARCH ARTICLE

Can Immersive Virtual Reality Environments Improve Stress Reduction? Experimental Design With Progressive Muscle Relaxation Training

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ABSTRACT Psychological relaxation techniques are now fundamental in stress-management and anxiety-disorder prevention training. Progressive Muscle Relaxation (PMR) stands out among various other training programmes. However, some limitations restrict its widespread usage, such as the requirements for a therapist to be in attendance and for patients to close their eyes during treatment. In such cases, support through immersive Virtual Reality (iVR) during the training procedure may be a suitable solution. In this study, an iVR application was developed for individuals undergoing PMR training, and an experimental design with both independent and subjective measures was conducted to compare this novel approach with conventional PMR training. The study was validated in two population groups: nursing undergraduates (one training session, n=63) and undergraduates following a test anxiety programme (complete training procedure: 7 sessions, n=13). The results pointed to high satisfaction and relaxation levels across all groups. No significant differences were found between the two methodologies, suggesting that the iVR application could be a useful tool in both educational and clinical contexts. In the long experience group (7 sessions), the iVR students showed higher interest which may have contributed to adherence to the entire training procedure. Furthermore, the iVR tool demonstrated potential suitability users unable to follow conventional procedures, exemplified by a student who, due to her own anxiety-related symptoms, felt very uncomfortable when instructed to close her eyes during the relaxation training.

INDEX TERMS Anxiety disorders, progressive muscle relaxation, psychology, serious games, virtual reality.

I. INTRODUCTION

The use of methods to control arousal, such as relaxation techniques, has been widely supported in the scientific literature, since the publication of such seminal works as Progressive Relaxation [1] and Das Autogene Training [2]. Specifically, the development of this research area has been linked to potential applications within the field of Health, particularly Mental Health [3], [4]

Interest in relaxation has recently moved beyond the clinical setting, because of the importance of "tension" in the development of personal disorders or discomfort.

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Relaxation is considered a very important resource for people to control their daily stress, to prevent disorders, and consequently to improve their quality of life [5]. In that way, relaxation techniques are considered to be an instrument at the service of personal self-control. Relaxation is seen as an incompatible or antagonistic response to the physiological effects of anxiety and sustained arousal [6]. As a result, relaxation is considered an appropriate and sufficient procedure to treat different problems, such as anxiety [7], [8].

One widely used type of relaxation in a clinical setting is Differential or Progressive Relaxation [5]. First developed by Jacobson in 1929, the patient is encouraged to identify the signals from tense muscles and, once they have done so, to use the skills they have learned to reduce them (*i.e.*, to relax) [1]. It is a procedure through which complete relaxation of the whole organism or specific relaxation of a part of it can be achieved. The terms 'differential' and 'progressive relaxation' are used to indicate that the procedure is based upon distinguishing the sensations produced by tensing and relaxing muscle groups. It also means that one part of the body can be specifically (differentially) relaxed, while others may remain tense (*e.g.,* when walking, the face can be relaxed, but the legs and trunk must maintain some tension) [9], [10].

Unfortunately, the original procedure developed by Jacobson is highly effective, but requires lengthy learning periods, which is a characteristic that limits its applicability. Several authors have modified and shortened the procedure, while trying to maintain its benefits. The programme presented in this research is based both upon Jacobson's research and upon subsequent therapeutic developments [7], [8], [10]. The procedure is referred to as Progressive Muscle Relaxation (PMR) training, because it involves multiple training sessions, in which the individual internalizes the technique, so as to apply it in daily life [11]. While the new short versions of the training may be perfectly well adapted to modern-day needs, they can still be improved through the integration of emerging technologies [12].

Immersive Virtual Reality (iVR) can be defined as a Virtual Reality (VR) system that can be used to fully immerse an individual in the virtual world and interact with it through moderately natural interactions and movements [13]. iVR is implemented through a Head-Mounted Display (HMD) to achieve this sense of presence and immersion, which effectively isolates individuals from their real-world surroundings [13], [14].

iVR is making inroads into such fields as Education, Training [15], Medicine, and Sports [16], with very positive outcomes, due to the benefits that its intrinsic features can offer. For instance, it enhances learning experiences, due to its capacity for immersion [17], and enables individuals to engage in scenarios that are either too perilous or excessively distressing to face in the real world [18]. Likewise, the inherent novelty of this technology captivates users, prompting them to explore such unique experiential opportunities [19].

Psychology is another field where this technology is widely utilized. In this field, iVR has not only been employed as a tool for well-being, as with mindfulness training [20], but it can also be a valuable resource for mental health professionals, as it offers a platform for crafting personalized scenarios capable of simulating real-life experiences [21]. For instance, it can also be utilized for exposure therapy [22] and the treatment of post-traumatic stress [23]. Empirical evidence has extensively demonstrated how iVR environments can significantly enhance the effectiveness and scope of relaxation techniques such as body scans and PMR techniques [12], [24], [25]. It was suggested in a systematic review of Virtual Reality applied to relaxation for the general population that VR relaxation experiences were a useful and acceptable tool for promoting relaxation and reducing stress among the general population [25]. Pleasant virtual environments, which often include stimuli derived from contact with virtual nature, improved relaxation and relaxation-related variables, such as stress [26]. In most of the studies included in the review, relaxation scores were significantly higher in the iVR group than in the control group. Pleasant and immersive virtual environments support and promote relaxation, stress reduction and positive mood [27], [28]. iVR therapy also holds the potential to overcome the constraints of conventional visual exposure therapy. As an example, it can assist patients with the visualization of stimuli and environments that they might otherwise struggle to mentalize, providing therapists with extensive control over the images that patients are visualizing [18]. Moreover, it enables complete multisensory immersion in the virtual experience, which facilitates the control of external disruptive stimuli [29]. Furthermore, a systematic review was conducted to synthesize the evidence on VR relaxation for stress management among people with mental health problems [30]. All studies included natural virtual environments and provided evidence on the feasibility, acceptability, and short-term effectiveness of VR for relaxation and stress reduction. The evaluation of effectiveness in this type of research is typically carried out using two complementary approaches: an objective one, based on physiological measures [31], and a subjective one, relying on questionnaires. However, most studies predominantly rely on subjective evaluations, with instruments such as the STAI standing out due to their ease of administration and analysis, as well as their strong psychometric validity [32].

However, it is true that some limitations and aspects for improvement have also been pointed out in some studies, such as the one by Pardini et al. [12], who investigated the use of VR to promote relaxation and to reduce state anxiety. They highlighted relaxation techniques such as PMR, body scanning, and deep breathing, as effective, accessible and inexpensive. In that study, the effectiveness of personalised VR environments was compared to standard ones, based on

user preferences. Its authors obtained preliminary results, as they were unable to test the effectiveness of specific relaxation techniques in combination with VR environments compared to other techniques.

Similarly, the same authors [24] conducted a randomised controlled pilot study to investigate whether PMR techniques combined with a personalised VR scenario could promote psychological well-being and facilitate the recall of relaxing images more than the standard complementary intervention integrating PMR techniques and guided imagery. Their contribution provided new insights into the importance of personalising digital interventions according to user perspectives, needs, and preferences. However, they pointed out that to generalise and to validate the effectiveness of their findings further, the participation of participants within both clinical and non-clinical populations should be considered in the context of their different socio-demographic characteristics. They also suggested that future studies should consider structuring the relaxation protocol with more VR sessions for a better understanding of the impact of a virtual scenario on relaxation. Another aspect to consider is the introduction of a control group that receives the training session with the physical presence of a therapist.

In the current research, an iVR application has been developed with the primary focus on PMR training for individuals. To validate its effectiveness, a comprehensive protocol for PMR implementation and evaluation was followed, comparing outcomes from traditional training with those obtained using the iVR application. The study involved two different population groups: nursing degree students from the University of Burgos, who only followed one training session; and students from the University of Burgos, who participated in a Test Anxiety Control programme and completed the full training (7 sessions). Both groups were divided into two subgroups: conventional training with a professional and training using an iVR application.

The remaining sections of this paper are organized as follows. In Section II, the PMR training is introduced, along with the requirements associated with the conventional training. In Section III, the objectives and the research questions of the study are presented. The development of the experience encompassing the design of the iVR application, participant descriptions, the selected measures, and the data-analysis techniques taken into consideration are all reported in Section IV. Summary results of the experience, accompanied by a detailed discussion and comparisons with recent works, are presented in Section V. Finally, in Section VI, the conclusions are outlined.

II. PROGRESSIVE MUSCLE RELAXATION TRAINING

As mentioned above, the PMR training programme presented in this study was performed following the progressive relaxation scheme of Jacobson [1], but using a more abbreviated version than that of Bernstein and Borkovec [7], developed by Pintado and Llamazares [10]. This programme is used at the University Health Service of the University of Burgos (UHSUB) as part of the programs offered to university students to help them cope with their anxiety.

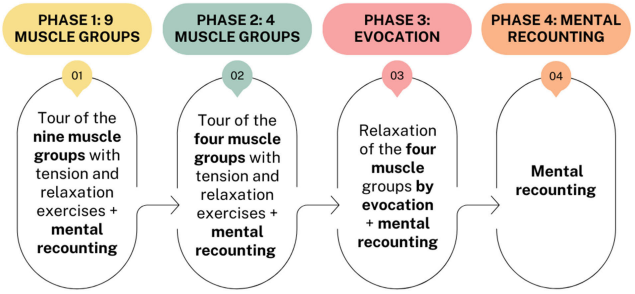

FIGURE 1. Phases of the progressive muscle relaxation (PMR) training developed by Pintado and Llamazares [10].

The logic of the relaxation training is based on learning to identify tension/relaxation in each area of the body with a detailed pathway. They then progress from these detailed paths to more extensive ones, replacing the tension/relaxation exercises with mental paths to achieve relaxation with only one mental path. Finally, what has been learned under optimal conditions is generalized to the usual and exceptional conditions of everyday life [8], [9].

Specifically, the PMR training consists of 6-to-8 sessions (depending on the individual's needs) distributed across four phases [10], as summarized in Figure 1. The PMR training guide is as follows: 1st Phase, 9 Muscle Groups (9MG, two sessions); 2nd Phase, 4 Muscle Groups (4MG, two sessions); 3rd Phase, Evocation (two sessions); and 4th Phase, Mental Recounting (one session). When referring to ''Muscle Groups'', individuals are guided to tense and to relax different muscles of the body, organized by specific anatomical regions. The term ''Evocation'' is used when only the muscle groups are mentioned, prompting the individual to tense and relax them almost automatically. During the ''Mental Recounting'', the muscle groups are slowly mentioned, and the individual must recall the sensation of relaxation associated with each one. Table 1 shows the progressive relaxation training procedure with both 9MG and with 4MG.

During the development of the PMR training in the standard procedure (accompanied by a therapist), certain difficulties may arise that hinder its proper implementation. For instance, many individuals admitted that they struggled with concentration while closing their eyes during the exercise, often finding their thoughts wandering, and becoming preoccupied with other matters [33]. Furthermore, there were reports of individuals feeling self-conscious about closing their eyes and performing relaxation movements in front of another person, due to a variety of inhibitions [34]. That discomfort can, in consequence, lead to nervous laughter and attempts to engage in conversation with the therapist, thereby causing complete distraction and preventing relaxation. Finally, long therapies may produce boredom and abandonment before achieving any expected results. Those issues can be resolved, by adapting the training for the

TABLE 1. Progressive muscle relaxation (PMR) procedure of the first phase with nine muscle groups (9MG) and of the second phase with four muscle groups (4MG).

9MG	
Muscle Group	**Exercise**
Right arm	Stretch out your arm and tighten your fist.
Left arm	Stretch out your arm and tighten your fist.
Forehead	Raise your eyebrows. Feel tension in the temples, your forehead, and at the base of the scalp.
Eyes	Close and tightly squeeze your eyes shut.
Jaw	Press your teeth together to retract the corners of your mouth.
Neck/Shoulders	Bend your neck forward, raise your shoulders, and tuck your chin under your chest.
Abdomen	Harden the stomach and pull it inwards.
Right leg	Stretch your leg and foot to tighten anterior and posterior muscles.
Left leg	Stretch your leg and foot to tighten anterior and posterior muscles.
4MG	
Muscle Group	**Exercise**
Arm muscles	Tighten the muscles in both arms simultaneously.
Face muscles	Frown, squeeze the eyes together, and retract the corners of the mouth, trying to bring the teeth together, imagining that something is preventing them from meeting.
Neck/Shoulders /Abdomen	Tuck in your stomach and pull your shoulders up towards your ears.
Leg muscles	Tense the muscles of both legs at the same time.

PMR technique using iVR. For instance, the requirement to keep the eyes open in iVR prevents distraction caused by internal thoughts [35]. Moreover, iVR can provide visual cues to guide individuals in performing actions such as deep breathing and muscle tension [36]. Additionally, HMD creates a closed and secure virtual environment, free from external judgments. A natural environment and soothing sounds further contribute to fostering relaxation [37]. Finally, it can be also a valuable tool in therapy, so that the therapist can concentrate on observing the implementation of the relaxation technique, rather than simply reading out a guide.

III. OBJECTIVES

Based on the limitations of conventional PMR implementation and the possibilities of iVR environments, the main objective of this study was to determine whether there were significant differences between the students trained either with PMR using the conventional training method or with the iVR application developed in this study. Any such differences could be due to (1) perceived satisfaction; (2) tension and anxiety indicators; and (3) relaxation levels. That objective was studied in two types of population: (1) a group of students of the Psychopathology subject of the Nursing degree, who were trained in the first PMR session (9MG) to carry out a practical activity in the classroom; and (2) a group of students who were trained with the complete training (7 sessions), as they participated in the UHSUB Test Anxiety Control programme.

These objectives lead to several hypotheses:

- H1: Progressive Muscle Relaxation training, whether conducted conventionally or using an iVR application, will be equally effective among the participants.
- H2: Participant satisfaction, whether after the conventional training or after the training using an iVR application, will be comparable among the participants.
- H3: Indicators of tension and anxiety, whether after the conventional training or after the training using an iVR application, will be reduced to the same extent among the participants.
- H4: Relaxation levels, whether after the conventional training or after the training using an iVR application, will be similar among the participants.
- H5: Three key aspects (satisfaction, tension and anxiety indicators, and the relaxation level) will be influenced by the number of sessions.

Experimental applied research was performed to evaluate the achievement of the main objectives and to address the research hypotheses. Six Research Questions (RQs) are presented below in relation to each type of population. The first three refer to the group of nursing degree students (RQ1, RQ2, and RQ3), and the last three are related to the group of students with test anxiety (RQ4, RQ5, and RQ6). Each question refers to one of the 3 identified outcomes: user perceived satisfaction, tension and anxiety indicators, and level of relaxation.

- RQ1: Will the *satisfaction* levels of the nursing students with the first PMR session depend on the type of training that they receive (Conventional *vs*. iVR)?
- RQ2: Will the *tension and anxiety indicators* of the nursing students after the first PMR training session depend on the type of training that they receive (Conventional *vs*. iVR)?
- RQ3: Will the *relaxation* levels of the nursing students after the first PMR training session depend on the type of training that they receive (Conventional *vs*. iVR)?
- RQ4: Will the *satisfaction* levels of students with test anxiety following the complete PMR training depend on the type of training that they receive (Conventional *vs*. iVR)?
- RQ5: Will the *stress and anxiety indicators* of students with test anxiety following the complete PMR training depend on the type of training that they receive (Conventional *vs*. iVR)?
- RQ6: Will the *level of relaxation* of students with test anxiety following the complete PMR training depend on the type of training that they receive (Conventional *vs*. iVR)?

The intention of this research is to fill the existing gaps within the scientific literature, such as the need to compare PMR training with and without iVR [27], [30], [38]. Moreover, the first iVR application developed for the complete PMR training, based on the version of Bernstein and Borkovec, is presented in this research.

IV. MATERIALS AND METHODS

Having defined the PMR technique and the objectives of this research in a pre-production phase, the design and the development of the iVR application were undertaken. Subsequently, convenience sampling was used to form two (Test Anxiety Students -TAS, and Nursing Students -NS) groups to assess the utility of the application. Finally, the procedure to be followed for the groups involved in the experimental design and the evaluation phase of this procedure were defined.

A. DESIGN AND DEVELOPMENT OF THE IVR APPLICATION: "PMR VIRTUAL TRAINING"

The most common iVR environments for relaxation are based on 360º videos of natural scenes that are easily developed. Among their various advantages is a realistic environment within which an individual can feel fully immersed [35]. They also present a significant shortcoming: having recorded the 360º videos, the environment cannot then be adapted. In response to that limitation, the development of a modifiable iVR environment was therefore prioritized in this research, based on 3D-modelled objects and scenarios. This approach provides the therapist and the developer with the capability to change the point of view, to add sounds and elements, and to modify the scenario according to individual needs. For instance, it opens up the possibility of adapting the environment to individual physiology, potentially utilizing a biofeedback system [39]. A degree of adaptability that might otherwise be unattainable with a 360º video.

The application developed includes various environments that users can choose based on their preferences: a beach with the sound of waves, a campsite with the sound of a campfire and a river, and an underwater setting with animal sounds and bubbles. Natural environments involving water, such as beaches, and scenes characterized by bluish tones have been shown to facilitate relaxation in previous studies (*e.g.*, [40], [41]). According to Attention Restoration Theory, natural environments are capable of capturing involuntary attention, enabling individuals to disregard negative stimuli such as anxiety, which in turn elicits a positive emotional response and reduces stress levels [42]. For the purpose of this study, participants completed the PMR training within the beach environment to ensure consistency across sessions. The application performance begins with a neutral environment (Figures 2A and 2B), where participants select the training phase and report their subjective anxiety levels prior to the experience. Subsequently, participants engage in the training within the beach environment (Figure 2C). This environment features large stones, palm trees, sand, and a lighthouse. Additionally, the water, which has a certain level of transparency, moves, creating the sensation of waves on the sand. In sync with the waves, a couple of boats can be seen floating in the distance. On the sand, small assets such as a sandcastle, seashells, etc., are also present. The environment is not overly cluttered to avoid distracting the user, allowing them to focus on the training.

Low poly that represents unrealistic elements with very few polygons was the chosen visual style [43]. A desaturated colour palette was selected for the environments because those tones are associated with calmness and evoke a sense of peace. The colour palette is dominated by shades of blue, and green elements have been included as recommended by the literature [44]. In moments of muscular tension, the scene will be tinted with red (Figure 2D). The colour is interpreted by the brain as representing danger or aggressiveness, thereby enhancing the sensation of discomfort [45]. Two types of sound were included, that enhanced the sensation of relaxation. Firstly, binaural sounds generated by various sources were included [46]. This auditory technique aids users when spatially locating objects within their surroundings, fostering a greater sense of immersion in the environment, and influencing their mood [47]. In this instance, natural and water sounds were incorporated, which soothed emotions, alleviating symptoms of anxiety [37]. Secondly, a soothing voice guided the users as they followed the PMR training. It calmly instructed users on the actions that could be taken. Whenever the users were required to tense their muscles, the volume of the voice increased, to intensify the sensation of discomfort [48]. Furthermore, the option to enable text-based auditory guidance was incorporated (Figure 2E), an unfeasible option in conventional therapy, which nevertheless adapts the application for use among people with hearing loss [49].

Straightforward and easily learned interactions with the environment were part of the design intent. At the initial level, users are prompted to make selections by fixating their gaze on the option they wish to choose. However, no interaction is required with the application during the relaxation phase. It means that users have their hands free to focus on the relaxation technique, minimizing any possible distraction, due to pressing buttons or navigating the environment. Moreover, this design eliminates the need to learn how to use controllers, making the application accessible to individuals of all backgrounds. By avoiding artificial locomotion and relying exclusively on natural head and body movements, the likelihood of cybersickness is significantly reduced. Users are only able to move around their own physical position, with limited head and body rotation; full exploration of the virtual environment is not intended, as it is not the purpose of the application. By relying exclusively on natural physical movement for interaction, the sensory mismatch that often causes symptoms such as dizziness or discomfort is minimized.

Several programmes were used to create these environments. First, Blender was employed to model the environments and assets. Subsequently, Unreal Engine was utilized to integrate the 3D models into a virtual environment and for level programming. The resulting application, called "PMR Virtual Training", consisted of 4 levels corresponding to the phases of Jacobson's PMR training developed by Pintado and Llamazares [10]. A script corresponding to each phase was included in the application that was designed for

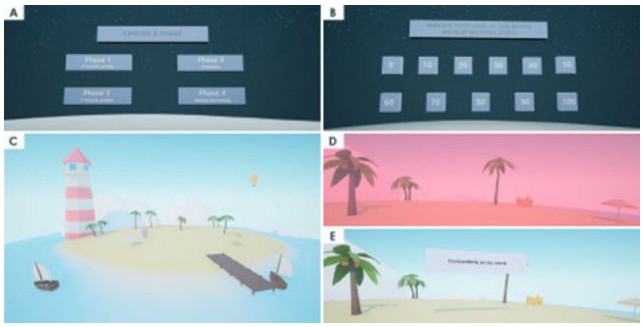

FIGURE 2. Examples of the 3D models and the virtual environments within the application: (A: choice of phase; B: various levels of Subjec-tive Units of Distress (SUD); C: view of the environment; D: view of the tension phase; E: written text for visual support).

the University of Burgos Health Care Services. This script has been used for years with the university population within this university-based service and has consistently yielded positive outcomes. A sample video of the PMR Virtual Training application can be found at the following website: https://xrailab.es/cases/pmr-virtual-training/. The video shows additional options available in the application beyond those selected for this study, such as the option to include an avatar to guide the participant around the environment and to select different environments.

The application was developed with the intention of being used on Meta Quest 2 devices (1832 × 1920 pixels per eye resolution) connected to a computer via cable, but due to its simplicity, it is compatible with any other immersive virtual reality device. Thanks to the use of Low Poly environments and other optimizations, the application does not require much storage space and can run on low-end devices. In this study, six Meta Quest 2 headsets were used, each connected to a computer with a minimum GPU requirement of an RTX 2060.

B. PARTICIPANTS

In this research, a comparison is drawn between the implementation of PMR training using two different methodologies. First, the Conventional training method (C) was employed, involving the intervention of a therapist. The therapist gave verbal instructions to perform the tasks while the participants carried out the exercise with their eyes closed. The second group performed the PMR training using the iVR application (VR). It enjoyed the benefit of visual support within the virtual environment throughout the exercise. Participants testing the iVR application used Meta Quest 2 devices that were connected to a computer. The participants were randomly assigned to either of the two groups. The duration of each session was around 20 minutes.

Two distinct target groups were utilized, to assess the effectiveness of adapting the PMR training developed by Pintado and Llamazares [10] to iVR. Firstly, the application was validated in a class of 63 nursing students following the ''Psychopathology'' study module of the Nursing degree programme at the University of Burgos. No exclusion criteria were established, as all the nursing students participated in a

TABLE 2. Descriptive statistics for the nursing students sample.

Type of Sample		
Nursing Students (NS) (n=63)		
[M_{age}=21.73; SD_{age}=4.06]		
$Range_{age}$=18-43		
	Gender	
	Male (n=8)	**Female (n=55)**
	[M_{age}=20.25; SD_{age}=1.03]	[M_{age}=21.93; SD_{age}=4.29]
	$Range_{age}$=19-22	$Range_{age}$=18-43
	Type of Training	
Conventional (C-NS) n=33	Male (n=3)	Female (n=30)
iVR (VR-NS) n=30	Male (n=5)	Female (n=25)
Total (NS) n=63		

Note: M=Mean; SD=Standard Deviation

PMR exercise included in the course curriculum. However, the students only participated in the first session of the first phase of the PMR relaxation technique due to time constraints. In the whole class, 33 randomly selected students were following the conventional training (C-NS), while 30 students were using the iVR approach (VR-NS), as can be seen in Table 2.

Secondly, a group of 13 individuals enrolled in a Test Anxiety Control programme at the UHSUB was selected for the experience (the TAS group). These students were receiving psychotherapy for diagnosed states of anxiety and had voluntarily agreed to participate in the programme. The inclusion criterion for the students was that they presented symptoms compatible with test anxiety and the exclusion criterion was that they had a serious mental disorder. The descriptive data for this population can be found in Table 3. Among those participants, 6 individuals followed the conventional approach (C-TAS), while the remaining 7 utilized the iVR application (VR-TAS). The students were randomly assigned to the two groups, except one student who, due to her own anxiety-related symptoms, felt very uncomfortable when instructed to close her eyes during the relaxation training. As a result, the VR group was considered more suitable for her.

The two samples (NS, TAS) used in this study were selected through convenience sampling. The nursing students who participated in this study were enrolled in the 2023/2024 academic year. The TAS group included students from both the 2023/2024 and 2024/2025 academic years. It should be noted that, although both samples were formed of undergraduate students, so a low age range might have been expected, the samples presented a very high age range (up to 25 years), which played a major role in the results of this study.

C. PROCEDURE

The overall experience consisted of the four distinct phases shown in Figure 3. During the first phase, participants were administered the Inventory of Tension and Anxiety Indicators

TABLE 3. Descriptive statistics for the test anxiety students sample.

Type of Sample		
Nursing Students (NS) (n=13)		
[M_{age}=23.31; SD_{age}=6.31]		
$Range_{age}$=19-43		
	Gender	
	Male (n=1)	**Female (n=12)**
	[M_{age}=26]	[M_{age}=23.08; SD_{age}=6.54]
	$Range_{age}$=26	$Range_{age}$=19-43
	Type of Training	
Conventional (C-NS) n=6	Male (n=1)	Female (n=5)
iVR (VR-NS) n=7	Male (n=0)	Female (n=7)
Total (NS) n=13		
Note: M=Mean; SD=Standard Deviation		

(pre), to assess their subjective anxiety levels and perceived tension in different areas of the body [50]. In the second phase, participants engaged in the PMR training, following either the Conventional or the iVR method. The C-NS group followed their training simultaneously in the same classroom, accompanied by the teacher (a psychology professional). Despite the training being conducted simultaneously, it was not compromised as it was performed in silence and with the eyes closed. The VR-NS participants conducted the Virtual Reality training in groups of 5-6 individuals for logistical reasons, as shown in Figure 4. Each participant used an HMD connected to a computer. The size of the room and the arrangement of the computers meant the participants were more than 2 meters apart. No conventional headphones are attached to the device, although its sounds are emitted very close to the ear of the wearer. The low sound emitted by each device and the distance between them meant that the participants could only hear their own device. The HMD also provided visual isolation in so far as the participants' eyes were covered. For the Test Anxiety students, all users completed seven sessions of the four phases of the PMR. As those participants were engaged in an activity that was part of the anxiety reduction program, they followed the training individually in a smaller, noise-free room. In an effort to make the conditions of both groups (Conventional training and iVR) as similar as possible, the application displayed the virtual environment and a voice that guided the experience, corresponding to the auditory guidance provided by the instructor in the conventional training. Exactly the same script was used for both groups. The main difference between the two experiences was the visual support of a written text for those iVR users with special needs.

In the third phase, participants once again completed the Inventory of Tension and Anxiety Indicators (post), to indicate their final levels of subjective anxiety and muscle relaxation. Additionally, during that phase, participants completed a self-registration report to assess their overall experience. Finally, the participants were instructed to repeat

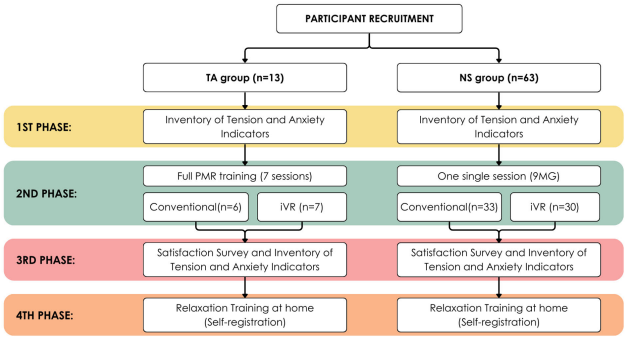

FIGURE 3. Organization of the groups during the experience and recording of measures.

FIGURE 4. Participants using the PMR virtual training application.

the fourth and the last phase of the PMR training on a daily basis (without the guidance of the professional or a virtual application) at home. They were provided with a sheet of paper to evaluate this home-based training, on which they were asked to note down their subjective anxiety levels before and after performing the PMR technique, to identify the areas where they felt most and least relaxed at the end of the training, and to report any difficulties that they may have encountered (Self-registration of Relaxation Training). The report was then sent to the UHSUB for processing.

D. MEASURES

Subjective data were collected to compare the conventional training with the iVR application. These data included measures of satisfaction with the training sessions, an inventory of tension and anxiety indicators, and self-reports of relaxation training.

1) SATISFACTION SURVEY

An *ad hoc* satisfaction survey was designed with 15 questions, to measure satisfaction with the relaxation training that was rated on a 1-to-5 point Likert-type scale (1 = not at all; 5 = totally). Specifically, the range of scores for this satisfaction survey was a minimum score of 15 and a maximum score of 75. The participants were asked about the following points: the relaxation session (duration, organization, clarity

of purpose, information offered, distractions, concentration, boredom); whether they felt supported by the therapist leading the session; whether they enjoyed the experience; and the utility of that type of training. The questions with an inverted scale were taken into account, specifically those where higher scores negatively impacted satisfaction (questions 7 and 11). The survey was designed to enable both the Conventional and VR groups to provide post-training feedback based on their experiences. Both groups answered an identical set of questions, facilitating a comparison of the results between the two groups. In this study, the Cronbach's Alpha coefficient (or the internal consistency) of the results of the satisfaction survey pointed to reasonable reliability indicators for both groups of students [52]: NS α =.82 (very reliable) and TAS α =.61 (reliable). Exploratory and confirmatory factor analyses would be needed in future studies, in order to improve the validity of the scale.

2) INVENTORY OF TENSION AND ANXIETY INDICATORS

The presence of tension reported by the students both before (pre) and after (post) each relaxation training session was collected, in order to measure subjective anxiety. To do so, the Tension and Anxiety Indicator Inventory was administered [50]. The inventory is closely focused on attention to the presence of physical signs of anxiety [51]. Specifically, it consists of 16 items to be rated on a 1-to-4 point Likert-type scale (1 = a little; 4 = a lot), assessing the following points: tension in different parts of the body (forehead, neck, chest, shoulders, stomach, face, and other parts of the body); sweating; heartbeat; heat in the face; coldness of the skin; trembling (hands, legs, and other parts of the body); uncomfortable sensations in the stomach; nausea; holding things too tightly; scratching parts of the body; onychophagia; teeth grinding; and problems with language. This instrument is grounded in a theoretical framework that conceptualizes anxiety as a multidimensional construct with prominent somatic components, particularly physiological symptoms of arousal [52]. It also aligns with established theories that emphasize the role of somatic feedback in the perception and regulation of emotional states.

In this study, reliability indicators (internal consistency) were found for the two groups of students through Cronbach's Alpha: Nursing Students α =.85 (highly reliable) and Test Anxiety Students α =.98 (highly reliable).

3) SELF-REGISTRATION REPORT OF RELAXATION TRAINING

As part of the relaxation training, both groups of students (nursing and test-anxiety students) were asked to complete a self-registration report, after each of the training sessions and after each of the sessions at home. In this self-registration report, students were required to indicate the day, time, and location where they were conducting the training; the chosen relaxation phase; the areas of their body that felt most relaxed and least relaxed after the training; any problems encountered during the training; and their relaxation level after completing the session (quantified on a scale of 0 to 10, where 0 = not at all relaxed and 10 = fully relaxed).

The NS group completed the self-registration report in class after the training session. The test anxiety students group completed it after each of the 7 training sessions in UHSUB and after each of the home practice sessions.

The use of subjective measures in this study is supported by both theoretical and practical considerations. Given that anxiety and relaxation are inherently personal experiences, self-report tools offer a direct and meaningful way to capture participants' internal states. Moreover, such instruments have shown strong reliability and validity in assessing emotional responses, particularly in settings where physiological measurement is impractical [32].

E. ETHICS

This study was reviewed and fully approved by the Bioethics Committee of the University of Burgos, with reference number IR-22/2023. The report submitted to the committee outlined the entire protocol, the voluntary nature of participation (through an informed consent form that explained the entire study), and the anonymization of the data. In the case of participants from the TAS group, anonymization was not possible because the use of the application was part of a clinical procedure, and the professionals needed to track the users' progress. For the nursing degree students, they completed the questionnaires under a pseudonym to ensure that their identities could not be traced. This study was conducted in accordance with the principles of the Declaration of Helsinki, ensuring the ethical treatment of participants throughout the research process.

F. DATA-ANALYSIS TECHNIQUES

As experimental applied research, a randomized design with two independent groups was used, representing two relaxation training conditions: Conventional *versus* iVR. A 2 × 2 factorial design (type of training, gender) was applied to the NS sample, and a single-factor design (type of training) was applied to the TAS sample. The analyses were performed with the SPSS v.28 statistical package [52].

A descriptive analysis of the answers and a reliability analysis using Cronbach's alpha (α) were also performed for the Satisfaction Survey and the Inventory of Tension and Anxiety Indicators. Preliminary analyses [skewness, kurtosis, Kolmogorov-Smirnov (>50 participants) and Shapiro Wilk (<50 participants) tests] were performed to check the normality of the sample and the homogeneity of variance between groups. After analyzing the data, it was determined that the assumptions of normality and homogeneity of variance were met, such that parametric tests could be conducted for the NS population. For the TAS population, given that the sample size assumption was not met, non-parametric tests were employed. Subsequently, the following tests were performed to analyze the data addressing the research questions:

The following analyses were conducted for the NS sample:

- Student's t-test for: (1) related samples to test whether there were statistically significant differences between the scores collected before (pre) and after (post) relaxation training; and (2) for independent samples to test whether there were differences between the different measures that were collected for both training groups (Conventional *vs*. iVR).
- A one-way fixed-effects ANOVA (training type), and the eta-squared effect size (η^2) [small, medium, and high effect sizes, respectively, within the ranges of 0.10-0.29, 0.30-0.49, and 0.50-1 [54] were used to check for inter-group differences.
- Likewise, a two-factor fixed-effects ANOVA [type of training (Conventional *vs*. iVR) and Gender (Male *vs*. Female)] and the η^2 effect size were used to check for possible gender differences between the two training methods.
- A single-factor fixed-effects ANCOVA (type of group with the pre-scores as the co-variate) and its η^2 effect-size were used to check for inter-group differences.
- A two-factor fixed-effects ANCOVA (type of group, gender, and co-variate pre-scores) was used to check for any interaction between factors.

For the TAS sample, the following analyses were performed:

- A Mann-Whitney U test was used to determine whether there were significant differences in the collected measures between the two training groups (Conventional vs. iVR). Pearson's r was used as the effect size measure.
- A Wilcoxon Signed-Rank test was conducted to examine whether there were statistically significant differences between pre- and post-relaxation training scores.

V. RESULTS

In this section, the results of the research questions (RQ) are described. The analysis of the results will be conducted in the subsequent subsections of this section, split between the two groups: NS (Study 1) and TAS (Study 2).

A. STUDY 1: NURSING STUDENTS

In Table 4, the Mean (M) and the Standard Deviation (SD) for each item of the satisfaction survey are displayed for the group of nursing students. The best scores for each sample are outlined in bold.

The Student's t-test was used to test **RQ1 ["Will the *satisfaction* levels of the nursing students with the first PMR session depend on the type of training (Conventional *vs*. iVR) that they receive?"]** for independent samples. The mean satisfaction levels of the students in the first training session (9MG) following the conventional training (C-NS) and with Virtual Reality (VR-NS) were 4.21 (SD=.312) and 4.12 (SD=.502), respectively. Student satisfaction levels were high in both groups, although no statistically significant differences were found $t(58)$=.780, p=.438. Students reported comparable levels of satisfaction with both types of training.

There were statistically significant average differences for some survey items, albeit only a few. According to Item 2, students trained in iVR perceived the duration of the session as significantly longer compared to those who underwent conventional training. Item 5 suggested that students trained in iVR found the information provided during the relaxation session significantly clearer than the students who had followed the conventional training. According to Item 6, students trained with iVR knew significantly better what they had to do at all times compared to students trained with the conventional methodology. According to Item 8, students who had followed the conventional training showed significantly better concentration levels than students trained with iVR. According to Item 12, students who followed the conventional training believed that it could assist them in their personal situation more than the iVR solution for iVR students. In summary, the iVR students appeared to have a better grasp of what to do, although their concentration levels were worse; something that might be attributable to ambient noise in the iVR training room, a factor that will be addressed in future research. It may also be due to the novelty effect associated with new technologies [19] that would increase the cognitive load during the PMR session.

Despite the absence of significant differences, the other items reinforced the results of the items with statistical significance. First, the students trained with iVR obtained higher means for Item 3, Item 4, Item 7, Item 11, and Item 15. Those students perceived a well-organized session, clear session objectives, and would recommend the experience more than the students who had followed the conventional training. As shown in Table 4, these items with higher means in the iVR group were associated with lower standard deviations, reflecting greater homogeneity in student responses. Second, they reported more distractions and a greater sense of boredom. As illustrated in Table 4, items related to iVR with lower mean scores had higher standard deviations, indicative of more polarized student responses. In particular, some older students reported physical discomfort with the HMD, which may have contributed to these mixed reactions. Finally, students on the conventional training obtained higher means for Item 1, Item 9, Item 10, Item 13, and Item 14. Those students had a better overall opinion of the session, felt that they had enjoyed greater professional support, enjoyed the experience more, perceived the training to be of greater utility, and looked forward to using it on a daily basis, compared to the opinions of the students trained with iVR.

Student t-tests for paired samples were first performed to test **RQ2 ["Will the *tension and anxiety indicators* of the nursing students after the first PMR training session depend on the type of training (Conventional *vs*. iVR) that they receive?"]**, to check whether there were significant differences between the pre- and post-training-session tension and anxiety indicators for each of the two groups. Subsequently, a Student t-test for independent

TABLE 4. Student's t test for independent samples in nursing students.

Item	Conventional M	Conventional SD	iVR M	iVR SD	p[a]	d
1. Did you find the number of sessions appropriate?	**4.50**	.50	4.39	.95		
2. Did you find the duration of the session adequate?	2.97	.47	**3.39**	.62	*	.55
3. Did you find the organization of the sessions satisfactory?	4.38	.66	**4.61**	.49		
4. Was the objective of the session clear to you?	4.41	.71	**4.54**	.63		
5. Was the information provided during the session clear?	4.50	.62	**4.79**	.41	*	.53
6. Did you know what you were supposed to do at all times?	4.45	.50	**4.79**	.41	*	
7. Did you feel distracted by your environment?	**2.41**	.91	2.82	.86		
8. Were you able to concentrate and maintain attention during the session?	**4.00**	.67	3.46	1.03	*	.46
9. Did you feel accompanied by the professional during the session?	**4.72**	.69	4.57	.69		
10. Did you enjoy the experience?	**4.34**	.79	4.11	1.34		
11. Did you get bored during the sessions?	1.75	.71	**1.96**	1.26		
12. To what extent do you think this experience will help you in your personal situation?	**4.22**	.70	3.68	1.02	*	.86
13. Do you think it was useful to learn this type of relaxation?	**4.34**	.54	4.14	.84		
14. Do you think you will use what you have learned in this experience in your daily life?	**4.00**	.91	3.71	1.04		
15. Would you recommend this experience?	4.44	.56	**4.46**	.57		

Note: Asterisks in the p column indicate significant diferences; d=Cohen's d effect size where <0.20 is very small, 0.20-0.49 small, 0.50-0.79 moderate, 0.80 large

samples was performed, to check whether the tension and anxiety indicators showed significant differences between the two training groups (Conventional *vs*. iVR). Likewise, a one-factor fixed-effects ANCOVA was performed on the group type and the co-variate pre-scores.

Statistically significant differences [$t(30)$=6.93, p=<.001] were found between the mean pre (M=1.85, SD=.48) and the mean post (M=1.32, SD=.34) total scores for the tension-and-anxiety indicators of nursing students trained with the Conventional method (C-NS). A mean effect size was found of d=.422. Likewise, statistically significant differences [$t(26)$=7.04, p=<.001] were also found between the mean pre-total score (M=1.76, SD=.41) and the mean post score (M=1.26, SD=.37) of students who were trained with Virtual Reality (VR-NS). A medium effect size of d=.349 was noted. The data suggest that both training approaches, conventional and iVR, in the first relaxation session (9MG) were effective in reducing student stress and anxiety indicators. Notably, no statistically significant differences were observed between the two types of training (Conventional *vs*. iVR) [$t(56)$=.649, p=.51], indicating comparable effectiveness in reducing stress and anxiety during the short single-session experiences at the proposed statistical level. There were also no statistically significant differences between the intervention groups when comparing their pre-training levels of tension and anxiety [$F_{(1,55)}$=.077, p=.783, ^2_p=.001].

A two-factor fixed-effects ANCOVA was applied to test whether the reduction in the stress and anxiety indicator varied based on gender (male vs. female) and training group (conventional vs. iVR). The pre-scores of the stress and anxiety indicator were used as the covariate, and the 2 effect size was calculated. As can be seen in Table 5, the corrected model assessing the overall effect of all the factors was significant (p=.001), indicating that the model significantly explained part of the variance of the dependent variable (post-pre differences in scores for reporting stress and anxiety).

Specifically, the corrected model explained 43% of the variance ($R^2_{adjusted}$ =.430). Although there were no significant results for the main effects (gender p=.253 and type of training p=.100), the interaction gender*type of training showed significant effects (p=.027). This result showed that the relationship between the type of training and the reduction of stress and anxiety indicators was not the same for men and women (*i.e*, it fluctuated according to gender).

Particularly, male students lowered their tension and anxiety levels after training in the first relaxation session (9MG) (M= -.56; SD=.457) more than the female students (M= −.51; SD=.378). This greater decrease appeared to occur to a greater extent in the conventionally trained male group (M= - 1.05; SD=.53) than in the iVR-trained group (M= −.36; SD=.313). Crucial to note when interpreting the results was that the sample size for the male group was very low (8), while it was 55 for the female group (see Table 6 for descriptive statistics); besides, the female group showed a higher dispersion in age (4 times higher than the male group). So, the significant imbalance between groups may have had a considerable impact on that result.

A single-factor fixed effects ANOVA was performed (with the type of training as the independent variable), to test **RQ3 ["Will the *relaxation* levels of the nursing students after the first PMR training session depend on the type of training (Conventional *vs*. iVR) that they receive?"]**. The mean relaxation level of the conventionally trained participants in the first relaxation session (9MG) was 6.29 (SD=2.24) and that of the iVR-trained students was 6.17 (SD=2.42). No statistically significant differences were found between the relaxation levels of both groups. [$F_{(1,59)}$=.043, p=.836, ^2_p=.001]. Both types of relaxation training in the first session (9MG) appear to have had a similar impact on increasing the relaxation levels of nursing students, at least at the proposed statistical level. The type of training did not seem to influence the achievement of higher relaxation levels among the students. These results are in

TABLE 5. Tests of inter-subject effects. Dependent variable: Differential post-pre score.

Origin	Type III sum of squares	df	Quadratic mean	F	Sig.	Partial $\eta 2$	Non-centrality parameter	Observed power[b]
Corrected model	4.010[a]	4	1.002	11.765	<.001	.470	47.060	1.000
Intersection	.428	1	.428	5.026	.029	.087	5.026	.595
Caution$_p re$	3.302	1	3.302	38.757	<.001	.422	38.757	1.000
Gender	.114	1	.114	1.338	.253	.025	1.338	.206
TypeTraining	.239	1	.239	2.807	.100	.050	2.807	.377
Gender*TypeTraining	.439	1	.439	5.147	.027	.089	5.147	.605
Error	4.516	53	.085					
Total	23.779	58						
Total corrected	8.526	57						

[a]R-squared = .470 (Adjusted R-squared = .430)
[b]Calculated at alpha = .05

TABLE 6. Descriptive statistics. Dependent variable: Differential post-pre score.

Gender	Type of Training	M	SD
Male	1st Session 9MG Conventional	-1.05	.539
	1st Session 9MG iVR	-.36	.313
Female	1st Session 9MG Conventional	-.49	.399
	1st Session 9MG iVR	-.53	.356
Total	1st Session 9MG Conventional	-.53	.422
	1st Session 9MG iVR	-.50	.349

line with the findings related to RQ2 for anxiety and tension levels.

A two-factor, fixed-effects ANOVA (type of training - conventional *vs*. iVR- and gender -male *vs*. female-) and its ^{2} effect-size were applied, to check whether the level of relaxation could vary according to the gender of the participants and the training group to which they belonged. No significant results, neither for the main effects (Gender $F_{(1,57)}$=1.067, p=.306; and Training-Type $F_{(1,57)}$=2.215, p=.147), nor for interaction (Gender*Training-Type $F_{(1,57)}$=3.716, p=.059), were found. Therefore, neither the gender of the trainee, nor the type of relaxation training, whether separately or jointly (interaction) considered, affected the post-training relaxation-levels.

B. STUDY 2: TEST ANXIETY STUDENTS

In Table 7, the Mean (M), Standard Deviation (SD), Median (Md), and Mean Ranks (MR) for each item of the satisfaction survey are presented for the TAS group. The best scores for each item are highlighted in bold.

A Mann-Whitney U test was conducted to address **RQ4 [“Will the satisfaction levels of students with test anxiety following the complete PMR training depend on the type of training (Conventional vs. iVR) that they receive?”]**. The median satisfaction score for students in the conventional training group (C-TAS) was 4.31 (mean ranks = 5.10), while the median for the iVR training group (VR-TAS) was 4.37 (mean ranks = 5.90). This difference was not statistically significant [U = 14.50, z =.424, p =.671], indicating that students in both training types were equally satisfied. Additionally, for informational purposes, the means and standard deviations were calculated: C-TAS (M = 4.28, SD =.10) and VR-TAS (M = 4.27, SD =.27).

The results of a Mann-Whitney U test applied to the differences between the medians and mean ranks of each item of the Satisfaction Survey, as shown in Table 7, indicated statistically significant differences only for Item 13 [U = 2.50, z = -2.44, p =.03]. The large effect size (r = 0.77) suggested that students trained with iVR found it more useful to learn this type of relaxation technique compared to those trained using the conventional method.

An analysis of the items with no significant differences showed that the students trained with iVR had higher scores for Item 1, Item 7, Item 8, Item 12, and Item 15. Item 1 suggested that the number of sessions was perceived as more appropriate in the iVR training group. The results for Items 7 and 8 suggested that students trained with iVR were slightly more distracted but were better able to maintain their focus during the training. Item 12 suggested that iVR training was more beneficial in the personal lives of the students compared to conventional training. Finally, according to Item 15, the iVR group would recommend the experience more than the conventional training group.

Besides, some items obtained higher scores in the conventional training group compared to the iVR, although with no significant differences. Item 2 suggested that the duration of the sessions was sufficient for the conventional training group, while in iVR, they were perceived as short. According to Item 2.1, the time between sessions was perceived as longer in the conventional group. It may be attributed to the anxiety control intervention administered to that group on the same day. The iVR group had to attend on a different day than the anxiety control intervention, leading them to visit the UHSUB more than once a week. Both groups had very high scores for Items 3, 4, 5, 6, and 10, although conventional training was perceived slightly better in terms of session organization, the objectives of each session, the information provided, knowing what to do at each moment, and the enjoyment of the experience. According to Item 11, conventionally trained students felt more boredom than those trained with iVR, although in both groups, they were never or almost never bored. Item 14 suggested that conventionally trained students felt that this relaxation would be more useful in their daily lives than those trained with iVR, although both groups considered it a very useful tool.

TABLE 7. Student's t test for independent samples in nursing students.

Item	Conventional M(SD)	Conventional Md(MR)	iVR M(SD)	iVR Md(MR)	p[a]	r
1. Did you find the number of sessions appropriate?	3.00(.00)	3.00(5.00)	**3.20(.44)**	3.00(6.00)		
2. Did you find the duration of the session adequate?	**3.00(.00)**	3.00(6.00)	2.80(.44)	3.00(5.00)		
2.1. Did you find the time between sessions adequate?	**3.20(.44)**	3.00(6.40)	2.80(.44)	3.00(4.60)		
3. Did you find the organization of the sessions satisfactory?	**5.00(.00)**	5.00(6.00)	4.80(.44)	5.00(5.00)		
4. Was the objective of the session clear to you?	**4.80(.44)**	5.00(6.10)	4.40(.89)	5.00(4.90)		
5. Was the information provided during the session clear?	**4.80(.44)**	5.00(6.00)	4.60(.54)	5.00(5.00)		
6. Did you know what you were supposed to do at all times?	**4.80 (.20)**	5.00(5.60)	4.60 (.89)	5.00(5.40)		
7. Did you feel distracted by your environment?	1.80(.83)	2.00(5.10)	**2.20(1.30)**	2.00(5.90)		
8. Were you able to concentrate and maintain attention during the session?	4.40(.89)	5.00(5.30)	**4.60(.54)**	5.00(5.70)		
9. Did you feel accompanied by the professional during the session?	5.00(.00)	5.00(5.50)	5.00(.00)	5.00(5.50)		
10. Did you enjoy the experience?	**4.80(.44)**	5.00(6.00)	4.60(.54)	5.00(5.00)		
11. Did you get bored during the sessions?	1.40(.54)	1.00(6.00)	**1.20(.44)**	1.00(5.00)		
12. To what extent do you think this experience will help you in your personal situation?	4.00(.00)	4.00(5.00)	**4.20(.83)**	4.00(6.00)		
13. Do you think it was useful to learn this type of relaxation?	4.00(.00)	4.00(3.50)	**4.80(.44)**	5.00(7.50)	*	.03
14. Do you think you will use what you have learned in this experience in your daily life?	**4.40(.54)**	4.00(5.80)	4.20(.83)	4.00(5.20)		
15. Would you recommend this experience?	4.60(.54)	5.00(5.00)	**4.80(.44)**	5.00(6.00)		

M = Mean, SD = Standard Deviation, Md = Median, MR = Mean Rank, p = Significance, r = Effect Size (Pearson's r).
Means and standard deviations were calculated for informational purposes, although they are not the primary indicators for interpreting the results.

Finally, for Item 9, both groups scored equally, indicating that they felt equally accompanied by a professional during the experience.

The Wilcoxon signed-rank test and the Mann-Whitney U test were applied to test **RQ5 ["Will the stress and anxiety indicators of students with test anxiety following the complete PMR training depend on the type of training (Conventional vs. iVR)?"]**. Both analyses were used to determine whether significant differences existed in the reduction of stress and anxiety indicators between pre- and post-tests and between the two training groups (Conventional vs. iVR).

Firstly, statistically significant differences were found in the C-TAS group between the pre-test total median score (Md=2.03) and the post-test total median score (Md=1.39) on the stress and anxiety indicator [Z=-2.201, p=.028]. The mean rank (negative) was 3.50, with a large effect size (r=.610). Additionally, for informational purposes, means and standard deviations were calculated: pre-test total (M=2.09, SD=.27) and post-test total (M=1.46, SD=.34). Similarly, in the VR-TAS group, statistically significant differences were observed between the pre-test total median score (Md=1.87) and the post-test total median score (Md=1.23) [Z=-2.366, p=.018]. The mean rank (negative) was 4, also with a large effect size (r=.656). Informationally, means and standard deviations were calculated: pre-test total (M=1.81, SD=.24) and post-test total (M=1.25, SD=.11). The results suggested that the complete relaxation training, whether delivered through Conventional or iVR methodologies, effectively reduced stress and anxiety indicators among students experiencing test anxiety.

Secondly, no statistically significant differences were found between the two training types when considering the post-test scores [U=11, z=-1.429, p=0.181]. This suggests that both training methods had a similar impact on reducing stress and anxiety indicators. Additionally, no statistically significant differences were observed in the total tension and anxiety indicator when comparing the Differential Score (pre- vs. post-test) between the two groups of students with test anxiety [U=28, z=1.00, p=0.366]. These findings indicate that both the Conventional and iVR training methodologies similarly reduced stress and anxiety indicators, demonstrating comparable effectiveness at the proposed statistical level.

Finally, the Mann-Whitney U test was performed to address **RQ6 ["Will the level of relaxation of students with test anxiety following the complete PMR training depend on the type of training (Conventional vs. iVR) that they receive?"]**. The median relaxation score for students trained using the conventional (7-session) relaxation program was Md=7.29 (mean rank = 5.20), while for students trained with iVR, it was Md=7.23 (mean rank = 6.67). This difference was not statistically significant [U=19, z=0.730, p=0.537]. Additionally, the means and the standard deviations were calculated: C-TAS (M=6.98, SD=0.92) and VR-TAS (M=7.53, SD=0.93).

Both types of relaxation training were equally effective at increasing the relaxation level of students with test anxiety. The type of training had no direct relation with higher relaxation levels among the students.

Among the iVR group of students, there was an exceptional case of an individual with borderline personality disorder. Whenever all the students had to shut their eyes, the individual experienced difficulties concentrating on the technique, due to some symptoms of the disorder and was therefore placed in the iVR group. That action was taken to assess the feasibility of following the treatment with the visual support of that application. The person in question successfully completed the entire training, thanks to the

visual support provided by the virtual environments and on-screen text.

VI. DISCUSSION

The following presents the results of this preliminary research in both population groups, based on the research questions, and their correlation with the findings from other studies.

A. STUDY 1: NURSING STUDENTS

Regarding the nursing students who comprised the largest group (n=63), but only followed one PMR session, both groups (Conventional and iVR training) reported high satisfaction levels, highly reduced tension and anxiety levels, and medium-high relaxation levels. These initial results are promising and suggest that the PMR procedure, even in its brief form, could be suitable for use in such settings [10]. Furthermore, the use of iVR appears to have the potential to enhance the effectiveness of this method, although it is important to note that brief experiences with new technologies may sometimes influence task performance in unexpected ways [15]. Interestingly, nursing students trained conventionally reported higher concentration and better attention during this single session, as well as a perception that the training would be more beneficial in their personal situation compared to those trained with iVR (Satisfaction Survey). This difference in concentration and potential for greater distraction in the iVR group might have been influenced by environmental factors, such as ambient noise in the room, given that many students participated at once. Moreover, the conventional training group generally reported greater enjoyment of the sessions, felt they received more support from the instructor, and believed the experience would be more applicable to their daily lives compared to the iVR group. However, these differences did not reach statistical significance. These findings could be attributed to various factors, such as the novelty effect of iVR, which might have led some students to focus more on the technology itself than on its content [19]. Additionally, one student, due to personal anxiety-related symptoms, felt very uncomfortable when instructed to close her eyes during the relaxation training. In similar cases, students with no HMD at home, may not have perceived the long-term utility of iVR.

The NS group trained with iVR reported that the sessions seemed significantly longer, although the information provided in the session was clearer, and they consistently had a better idea of what they had to do compared to the group of conventionally trained students. Likewise, although not significantly, the iVR group seemed to perceive better organization, had a clearer understanding of the session's objective, and would recommend the experience more than the conventional training group. Despite those affirmations, the iVR group apperared to feel slightly more distracted and bored. These results could potentially be attributed to the current perception of new technologies as engaging and having active content, which contrasts with the nature of relaxation applications [56].

In both groups of nursing students, tension and anxiety levels (Inventory of Tension and Anxiety Indicators) were significantly reduced after the training session, and no differences were found between both types of training. Similarly, in both groups, medium-high relaxation levels (Self-registration of relaxation training) were achieved after the training session without any difference between both types of training.

When comparing these results with previous findings from other researchers who have applied relaxation training sessions to the general or non-clinical population, it seems that they are generally consistent. For instance, Jeong and colleagues developed a four-week iVR self-training programme, in which participants could learn PMR in a virtual training room [5]. Their iVR programme was a self-learning mobile application that provided relaxation training without human assistance. They used healthy volunteers aged between 19 and 60 and divided them into two training groups, one with iVR, and one with a worksheet. They found that all psychological and psychophysiological measures tended to decrease after self-training, and no significant differences were found between both groups. They pointed to an advantage of the iVR training, in so far as the participants found it easier to understand the method of execution, as they could observe the actual movement of the avatar and listen to the explanation. As a result, they learned the training content more easily than the worksheet group. Likewise, other authors applied a single session of iVR-guided relaxation to children and adolescents (7-21 years) with post-operative pain [57]. They found reductions in pain intensity and unpleasantness, anxiety, and discomfort. The authors concluded that a single short relaxation session using VR showed transient reductions in that type of population. Another research project showed that one advantage of VR relaxation was emphasized, in so far as neither prior knowledge nor training were required, and VR relaxation could be directly used to reduce stress and to relax. Compared to common practices such as meditation and mindfulness, VR involved shorter processes and directly captured the attention, involving fewer distractions [58].

B. STUDY 2: TEST ANXIETY STUDENTS

The TAS group (n=13) following the 7 training sessions of the PMR training reported the following satisfaction results (Satisfaction Survey) with the training. The students trained conventionally in the relaxation technique found the duration of the sessions more appropriate, as well as the time between sessions and the overall organization of the training. However, the iVR group considered the number of sessions to be more suitable. Additionally, the C-TAS group felt that they had clearer session objectives, that the information was clearer, and that they knew what to do at all times, although the differences with the iVR group were minimal. The VR-TAS students felt slightly more distracted by the real environment, but they were better able to maintain concentration during the sessions. On the other hand, those

trained conventionally seemed to enjoy the experience more, although they also became more bored. Finally, the VR-TAS students felt that this experience helped them in their personal situation, would recommend it more, and, above all, found it much more useful for learning this type of relaxation compared to those trained conventionally. However, the C-TAS group felt they would use the technique more in their daily life.

As for the reduction in their level of tension and anxiety (Inventory of Tension and Anxiety Indicators) after completing the training, there was a significant reduction in both groups. Both types of training were similarly effective in reducing stress indicators across each of the four training phases. Finally, both groups recorded high relaxation levels (Self-registration of relaxation training) after training. There were no significant differences between groups, so that both types of relaxation training were effective. In both cases, relaxation levels were maintained and improved throughout the four phases.

These results were in line with the most recent scientific literature. For example, the efficacy of a five-session PMR training using iVR was the subject of a research study [27]. The main results were that the participants reported the programme to be very useful. In addition, they reported significant remission of pain thresholds, related anxiety, and tension, and their relaxation levels significantly improved. They also noted that the changes obtained with the training were maintained and systematically improved throughout the training sessions. For the authors, iVR offers a methodological advantage: precise and controlled dosing of training to ensure consistency, standardisation, and adherence. Likewise, in other research, comparisons have been drawn between the use of iVR and other methodologies, leading to the conclusion that iVR is a valuable tool that can bring long-term benefits. For example, some authors analyzed the effects of PMR and iVR application in reducing anxiety among patients undergoing knee operations [59]. They found significant differences between the experimental group and the control group in the mean satisfaction and anxiety reduction scores in favour of PMR applied with iVR. In the same direction, it has been observed that iVR relaxation sessions reduced pre-operative dental anxiety compared to standard care routines [60]. It has also been demonstrated that iVR, specifically an application called VRelax, has provided necessary, effective, and easy-to-use self-care relaxation interventions, to improve psychiatric symptomatology with better results than standard relaxation exercises [38].

Finally, some noticeable differences were observed between the two groups of students. Firstly, the nursing-student group perceived the training as less useful, recommended it less, and did not seem to have a strong belief that they would ever use it in their daily lives compared to the test anxiety student group. This finding could potentially be attributed to the fact that test anxiety students had first-hand experience of the complete training and its benefits, which may have led them to better understand its long-term utility, whereas nursing students only completed one session and could only imagine the complete training. As a result, there was less perceived boredom in the test anxiety student group compared to the nursing student group. A surprising result was that all students reported perceiving the presence of the teacher or professional to a high degree, even though they could neither see nor hear the teacher in the iVR group.

C. EVALUATION OF HYPOTHESES

The evaluation of the hypotheses proposed at the beginning of the study is addressed in this section.

Regarding **H1 (“PMR training, whether conducted conventionally or using an iVR application, will be equally effective among the participants.”)**, the results indicated that there were no significant differences between the effectiveness of PMR training whether with the conventional or the iVR method. Both groups (nursing students and test anxiety students) showed significant reductions in both tension and anxiety indicators following the training, regardless of the method used. These findings seem to indicate that implementing PMR using iVR was as effective as the conventional method in reducing stress and anxiety. Additionally, the comparable relaxation levels in both groups provide some support for H1, suggesting that the use of iVR did not appear to compromise the efficacy of progressive relaxation training.

With respect to **H2 (“Participant satisfaction, whether after the conventional training or after the training using an iVR application, will be comparable among the participants”)**, the participants of both groups reported high levels of satisfaction, although some differences were observed in specific aspects. For example, nursing students who used iVR perceived that clearer information was provided during the session and felt that they understood the training better compared to the students who followed the conventional training. However, they also reported experiencing lower levels of concentration and greater distraction, which could likely be attributed to the novelty of the technology and the ambient noise in the iVR room. Overall, global satisfaction seemed to be similar for both methodologies, providing some support for H2.

Regarding **H3 (“Indicators of tension and anxiety, whether after the conventional training or after the training using an iVR application, will be reduced to the same extent among the participants”)**, significant reductions in tension and anxiety indicators were observed among both the nursing students and test anxiety groups after the PMR training session, with no significant differences between both training methods. These findings suggest that both methods, at the proposed statistical level, were similarly effective at reducing stress and anxiety levels, thus providing support for H3. The use of iVR is a promising alternative for students who struggled with conventional procedures, as in the case of the student who, due to her own anxiety-related

symptoms, felt very uncomfortable when instructed to close her eyes during the relaxation training.

In relation to **H4 ("Relaxation levels, whether after the conventional training or after the training using an iVR application, will be similar among the participants")**, the results showed no significant differences between the relaxation levels of the students whether trained with the iVR or the conventional method. Both groups achieved medium-high relaxation levels after the training, supporting H4. The similarity in relaxation levels across both methods suggest that using iVR did not appear to negatively affected the relaxation capabilities of the participants.

Finally, regarding **H5 ("Three key aspects (satisfaction, tension and anxiety indicators, and the relaxation level) will be influenced by the number of sessions")**, there was a progressive trend in the reduction of tension and anxiety indicators and an increase in relaxation levels among the group of students with test anxiety who completed the full seven-session training, as the sessions progressed. These findings suggest that the number of sessions may have been an important factor in maximizing the benefits of PMR training. The results also showed that students who had completed all the sessions with iVR training reported higher levels of interest and adherence compared to those who had followed conventional training, providing some support for H5.

VII. CONCLUSION

Firstly, the aim in this study has been to evaluate the impact of iVR as a factor in the improvement of a type of muscle relaxation: progressive or differential relaxation, an aspect that has only been addressed in very few studies. This study implements a comprehensive protocol for the training and evaluation of the effects of the PMR technique. It compares traditional PMR training with training delivered through the iVR application. Two samples of university students followed the training: nursing students (non-clinical sample receiving a single session) and students with test anxiety (clinical sample receiving the full training). Both groups reported high levels of satisfaction with the training. Similarly, both groups of students significantly reduced their levels of tension and anxiety and achieved high relaxation levels after the relaxation training.

Secondly, this study provides preliminary evidence of the applicability and perceived effectiveness of iVR-based PMR training in both clinical and educational settings. The results suggest that the integration of iVR technology into well-established relaxation protocols does not diminish their effectiveness; on the contrary, a non-significant trend toward improvement was observed. Given that the implementation of full differential relaxation training in clinical populations is often time-consuming and resource-intensive, the use of iVR may help reduce associated costs by facilitating partial self-management of the training. This approach allows users to achieve a high degree of muscular relaxation within a relatively short time frame, an important consideration for university psychological care services. Additionally, an iVR-based training protocol may offer more personalized and inclusive support, particularly for individuals with specific physical or psychological needs. This was exemplified in the current study by a participant who experienced significant discomfort when instructed to close her eyes due to anxiety-related symptoms, and who was nevertheless able to complete the training using the iVR application.

This study presents several limitations that should be acknowledged. First, the absence of objective physiological measures such as heart rate variability or electrodermal activity restricts the depth of analysis regarding users' stress responses. While the use of validated self-report instruments provides valuable subjective data, the incorporation of biosignals would enhance the robustness of future evaluations. This initial version of the study was conceived as a first step toward validating the design and usability of the system across real-world contexts, and upcoming iterations aim to integrate biofeedback features to dynamically monitor and respond to users' emotional states in real time. Second, the sample size, particularly within the clinical group of individuals diagnosed with test anxiety, was relatively limited. While the findings offer encouraging preliminary insights, further research with larger and more diverse clinical populations is essential to generalize the results and explore differential effects. Third, the lack of a long-term follow-up limits the ability to assess the durability and persistence of the observed effects. Future studies should include longitudinal measurements to evaluate the sustained impact of the intervention over time. Finally, although this version of the intervention was designed for general accessibility, future work should focus on evaluating its impact in populations with special needs, such as individuals with hearing loss or those experiencing severe mental health conditions. The immersive and visual nature of the VR environment may offer advantages in such contexts, especially for individuals who are typically excluded from traditional PMR formats due to communication or sensory barriers.

The iVR application includes the option for users to choose their preferred environment. However, during this study, the same scenario (a beach) was consistently used, so that the variable remained constant. It likewise has the option to activate an avatar that performs the same movements that the individual must replicate, providing greater visual support. That option was also disregarded in this study to ensure that the iVR training and the Conventional training were as similar as possible. In the near future, the application will be validated and each individual will be able to choose the virtual environment in which they wish to conduct the relaxation training and whether or not they wish to activate the avatar. As a personal choice, it may increase the sense of control and improve both motivation and relaxation outcomes, as has been demonstrated in previous studies [5], [12], [61]. Furthermore, the integration of a biofeedback system with biosensors (heart rate, electrodermal activity, etc.) is planned, providing real-time physiological data both to the individual

and the application. This tool has shown promising results, particularly in applications related to psychology [39], [62]. With these advancements, relaxation training will become more effective by offering a personalized experience tailored to each individual.

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