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A USER-CENTRED APPROACH TO RELAXATION AND ANXIETY MANAGEMENT IN CLINICAL AND NON-CLINICAL SETTINGS:

THE USE OF CUSTOMIZED VIRTUAL REALITY SCENARIOS EXPERIENCED INDEPENDENTLY OR IN COMBINATION WITH WEB-BASED RELAXATION TRAINING

Un approccio incentrato sull'utente per promuovere il rilassamento e la gestione dell'ansia in contesti clinici e non-clinici:
indagine del ruolo di scenari virtuali personalizzati erogati in modalità autonoma o in combinazione con training di rilassamento in modalità *web-based*

Thesis written with the financial contribution of Fondazione Bruno Kessler (FBK)

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The underlying principles are that therapy shouldn't just focus on diagnosing and treating disorder, maladjustment, suffering, etc. […] Therapy should recognize, use and build a patient's existing strengths and resources rather than view the client as flawed and disordered.

(Hefferon & Boniwell, 2011, p. 233)

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ABSTRACT

Virtual reality (VR) is widely used to treat various mental diseases and helps facilitate multisensory stimulation, sense of presence, and achievement of relaxation. Recent research shows that VR scenarios representing, for instance, visual and auditory elements of natural relaxing environments can facilitate the learning of relaxation techniques, such as Body Scan and Progressive Muscle Relaxation Training (PMR). The customization of the VR scenarios could be an element that further facilitates relaxation, allowing participants to experience more realistic emotional conditions, increasing relaxation, sense of presence, and perception of security in the virtual context. Due to a lack of research in the field the main objective of the current Ph.D. thesis is to investigate if customized, relaxing VR scenarios, used alone or in association with standardized relaxation training protocols, allow the management of anxiety. The first study (Chapter 3) investigated anxiety symptoms, user experience, and individual preferences regarding exposure to a customized and non-customized relaxing VR environment combined with a Body Scan audio track-based guiding session. The study was based on a cross-over design and a mixed-method approach with a convenience sample of 20 individuals from a non-clinical population. Findings indicated that customized scenarios could have a role in enhancing the subjective perception of relaxation, immersivity, and pleasure compared to non-customized virtual settings.

The second pilot study (Chapter 4) further investigated the role of standard exposure to relaxing Guided Imagery (GI) with PMR to enhance the perception of relaxation and the role of VR in overcoming possible limitations of in-imagination exposure compared to the usual procedure. The study is a randomized pilot study on a total of 108 individuals from a university sample. The study involved three following experimental conditions: “PMR training by Zoom & VR exposure”, “PMR training by Zoom & GI exposure”, “PMR training by Audio-track & VR exposure”. The objective was to understand if the use of VR helps to 1) enhance relaxation and the decrease of anxiety, and 2) recall the image and being immersed in the relaxing scenario in a latter self-directed session even without use of VR. Another aim was to investigate the role of two different web-based procedures (by Zoom and based on audio-tracks) on reducing state anxiety during the first learning session of the PMR. The main results indicated that customized virtual scenario can promote a greater reduction of the self-perceived state anxiety compared to the imaginative condition, as well as to recall of the strategies learned during the relaxation protocol. Independently of the type of web-based relaxation training administered before, VR

is more effective than in-imagination exposure in allowing a subjective reduction of the state of anxiety and arousal experienced.

The last proof-of-concept study (Chapter 5) investigated the impact of customized-relaxing VR scenarios to manage anxiety on a sample of 23 participants with cognitive impairment. The primary objective was to assess the impact of VR on self-reported and observational levels of motion-sickness, engagement, and pleasantness in older adults living with cognitive impairment and residing in long term care. Distinct from most studies in this field, the current study intended to provide personalization of visual and audio stimuli over offering a selected number of outdoor settings. For this reason, the secondary aim was to investigate if customized, relaxing virtual environments can positively impact feelings and state anxiety. A third goal was to investigate the usability of the VR apparatus from the perspective of long-term care health staff and understand feasibility in clinical settings. From a general perspective, the exposure to the VR apparatus was well tolerated, and no severe or notable adverse side effects were reported. Participants expressed verbally or manifested with non-verbal behavior a general state of interest, awareness, engagement, and enjoyment during the VR exposure showing appreciation of the experience. Reports collected during the intervention showed that the exposure to a realistic, natural, and above all, personalized virtual environment adapted to users' preferences and needs, prompted reactions, such as reminiscence of melancholic memories, the aesthetic appreciation of what they were seeing, the sense of safeness and protection in an appreciated context. The general increased relaxation state and the reduction in worry/anxiety post-VR, both self-reported and observed, support the hypothesis that VR can serve as a restorative or stress-reducing experience.

The studies shed light on possible future applications of VR relaxation environments for clinical and non-clinical purposes. The customization of VR-based scenarios has been suggested as an element that may promote relaxation, and few studies have studied this topic. Furthermore, in light of the COVID-19 pandemic, innovative VR treatment protocols are increasingly requested and helpful in managing relaxation, also due to the possibility to be administered with greater flexibility, in several different contexts, and independently from the presence of the therapist. The introduction of VR and web-based training could have a positive impact on reducing psychotherapy sessions' need and cost, as it allows a partial self-management of the treatment. If the combined administration of a customized VR relaxation scenario and PMR is effective in obtaining a better subjective perception of relaxation compared to the standard procedure, this could enable the users to do relaxation with greater autonomy. For this reason, exploring alternative and effective ways of providing PMR could extend the treatment administration options, especially in situations where the standard procedure is more difficult to be realized. Moreover, the third study of the present thesis (Chapter 5) contributed to the growing body of literature focusing on empirically evaluating the acceptability and potential impact of immersive VR in long-term care settings, with specific considerations for frail older adults with varying degrees of cognitive, sensory, and mobility impairments. Differently from previous work, we evaluated the effect of customizing the VR experience in this setting and use case. This represents a valuable step forward compared to the standard "one-size-fits-all" approach adopted in most of the studies in the field of VR. At the same time, while personalization could improve acceptability by accommodating and tailoring the VR environment in light of patients' preferences, it might lead to potential challenges in its deployment. Since customized and user-centred approaches require more involvement and effort by those responsible for administering the therapy, it is also critical that we seek their input on the design of the interventions to ensure their adoption and sustainability over time. In this study, we considered the viewpoints of the healthcare staff, which brought valuable insight into the patient's previous history and usual emotional patterns and reactions. Despite some limitations, this research contributes to advancing scientific knowledge related to the customization of VR experiences and their related impact on acceptability and potential clinical efficacy in frail older adults.

INTRODUCTION

The study of user experience in VR scenarios has attracted the interest of the scientific community despite, on our knowledge, most published works remaining on a theoretical level and lack empirical evidence. Furthermore, VR started to be deployed in association with different types of standard relaxation programs. These programs usually included more directive relaxation techniques that imply greater involvement of the physiological response (e.g., Progressive Muscle Relaxation), as well as fewer directive procedures which may rely mostly on the cognitive functioning control (e.g., Meditation) or the physiological feedback (e.g., Autogenic Training) (e.g., [1-6]). The Progressive Muscle Relaxation training (PMR) protocol is based on how our nervous and skeletal systems work. Over-activation of the sympathetic nervous system is primarily responsible for excessive skeletal muscle activity, and PMR is an efficacious technique in reducing activation. This process has an indirect positive effect on other physiological parameters (e.g., heart rate frequency). The training consists of learning how to tense and release several muscle groups from the bottom to the top of the body. Evidence suggests that stress-competing relaxation techniques are among the most effective training programs to enhance psychological resources and reduce psychological distress [7]. There are different types of protocols based on their duration, including abbreviated procedures consisting of 5-6 sessions [8,9]. The participant is requested to learn to discriminate between tension and relaxation of the various muscle districts and to learn, recognize, and maintain a state of relaxation. The holding and releasing activities allow proprioceptive stimulation from peripheral sensory afferents to the higher nervous system regions via the spinal cord and the brainstem as a “bottom-up” pathway [10-12]. Also based on these processes, the PMR is considered one of the most effective and adaptable techniques for relaxation, anxiety management, stress, and depression reduction considering different kinds of target populations (e.g., non-clinical individuals, patients with cancer, chronic pain, osteoarthritis, heart disease, chronic headache, anxiety, depression) [13-17]. Complementary methods that imply the administration of integrated cognitive and behavioral procedures are studied to manage anxiety, stress, depression, and pain, particularly in cancer patients. Notable is the integration of the PMR training and the Guided Imagery (GI) used to enhance and facilitate the effect of relaxation, reducing anxiety and depression symptoms [17-19]. There are several advantages to combining standard relaxation techniques with VR technologies [6]. VR tool is easily

applicable, engaging, user-friendly, and provides comprehensive testing, training, and treatment possibilities. In addition, VR technologies can be characterized as tools of accurate control and measurement [20]. Indeed, VR enables the user's full involvement, controlling for interfering external stimuli [21,22]. Based on evidence, we intended to investigate if the concurrent exposure in a customized VR relaxing scenario, rather than in the GI only, and the administration of the PMR procedure promote a better effect on anxiety reduction, allowing a sense of relaxation, engagement, and psychological well-being.
Moreover, there are controversial data about the PMR administered in vivo or via audio recording [23,24]. To the best of our knowledge, promising outcomes have been found on the efficacy of online relaxation training (e.g., Brief Mindfulness-Based Intervention, PMR; [25,26]), but no recent evidence exist regarding the comparison between training administered in a remote modality or with an audio recording. In light of the potential benefits of using new technologies in administering relaxation procedures, we also intended to explore the PMR's efficacy in a remote situation via Zoom and audio.
In Chapters 3 and 4 of the thesis, the standard relaxation techniques administered in combination with the virtual scenarios are the PMR and a short Body Scan session derived from PMR and adapted to be administered in a single session.

The background underlined in Chapter 5 is based on the growing evidence of the positive impact of being immersed in natural environments on physical and mental health [27-29]. In healthcare facilities, allowing older adults to have recreational and pleasant experiences in natural environments, especially if they have a cognitive and physical impairment, although challenging, can be beneficial [30]. However, participating in organized outdoor activities may prove difficult for this population due to their reduced motor ability, the fear of injury during movement, as a side effect of medication, and weather conditions. Overall, evidence shows that even if unable to engage directly in a natural environment, visible exposure to nature scenes can be beneficial, reducing hospital length-of-stay and drug consumption [31-33]. Based on these findings, it is desirable to identify alternative strategies for providing older adults with exposure to natural scenes while accounting for barriers to mobility, autonomy, and safety concerns. A potentially innovative method to overcome these obstacles could be the deployment of VR. Indeed, VR technologies have been demonstrated to reduce isolation and increase engagement across several populations [34]. VR systems consist of technologies that provide the user with multiple sensory inputs through, for example, visual and auditory displays and can have varying degrees of immersion.

Immersive visual information is generally conveyed through displays, where the interface allows exposure to content that can be explored in 360 degrees, as with Head-Mounted Displays (HMDs). Auditory information can be provided via headphones, some of which are embedded directly into the HMD. VR-based interventions have been successfully deployed for addressing many clinical conditions, such as specific phobias, social anxiety, panic disorder, post-traumatic stress disorder, and depressive disorders [35]. Evidence suggests that immersive virtual scenarios can improve the quality of life in older adults' in healthcare facilities, highlighting a positive impact on behavioral and psychological symptoms. VR was also found to overcome some barriers that can hinder participation in recreational activities, such as the difficulty of moving in the environment. To our knowledge, few studies have investigated the feasibility and effectiveness of using immersive virtual environments for managing anxiety and promoting a state of relaxation in populations of elderly individuals with impaired physical and cognitive functions [36-39]. Moreover, there is a lack of research on customizing virtual scenarios for therapeutic purposes. Some published research has highlighted how using VR HMD promotes the management of depressive and anxious symptoms in older people [40,41]. Appel et al. [36] concluded that exposure of people with cognitive and physical impairments to realistic and natural immersive scenarios in virtual reality through an HMD is safe and feasible.

These findings encourage future studies to investigate the role of virtual reality scenarios' customization used alone or in combination with other standardized relaxation techniques to understand if these types of novel procedures facilitate relaxation and the management of anxiety.

A brief overview of the rationale underlying the three studies is presented in Chapters 1 and 2 of the thesis. Chapter 3 reports the first feasibility study conducted, aimed at investigating the experience of users to obtain preliminary data about preferences, pleasure, satisfaction, engagement, immersivity, sense of presence and the subjective perception of relaxation and state-anxiety when exposed to a standard and a customized relaxing VR scenario. Chapter 4 presents the next phase of the research informed by the results of the previous study. It illustrates a pilot study regarding the role of relaxing customized VR environments in improving relaxation and managing anxiety if administered in integration with PMR and compared to the guided imagination technique, a standard intervention commonly administered in combination with PMR.

Chapter 5 presents a proof-of-concept study on a clinical sample in which the primary objective was to evaluate the impact of VR on self-reported and observational levels of motion-sickness, engagement, and pleasantness in older adults living with cognitive impairment and residing in long-term care. Specifically, the current study intended to provide customization of visual and audio stimuli, offering a selected number of outdoor settings. For this reason, the secondary aim is to investigate if customized, relaxing virtual environments can positively impact feelings and state anxiety. A third goal is to investigate the usability of the VR apparatus from the perspective of health staff working in long-term care to understand better the acceptability and potential adoption of our solution in these clinical settings. The Chapter 6 provides a summary of the overall results emerging from the above-mentioned three studies, with particular focus on implications and future perspectives of using customized virtual scenarios for promoting relaxation and reducing anxiety in clinical and non-clinical populations. Overall, the current study provides a gateway for future research to explore the benefits and effects of virtual scenarios as a means of treatment and therapy in various populations.

PART 1

THEORETICAL OVERVIEW

CHAPTER 1.

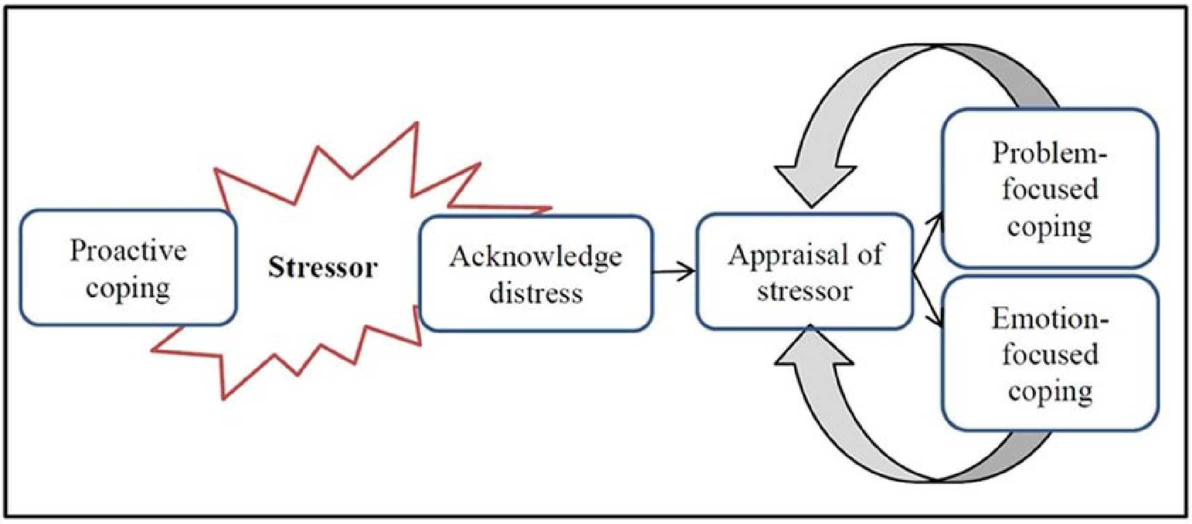
RELAXATION: A COGNITIVE AND BEHAVIORAL FRAMEWORK PERSPECTIVE

1.1 The Cognitive and Behavioral Theory of Relaxation

The American Psychological Association (APA) defined Relaxation as *1) abatement of intensity, vigor, energy, or tension, resulting in the calmness of mind, body, or both; 2) the return of a muscle to its resting condition after a period of contraction* [42].

Throughout history, one of the most extended theories that first explained the processes implied in relaxation is the *Arousal-Reduction Model*, based on the conceptualization of relaxation as the reduction in arousal [43-45]. Since the importance of determining other variables that allow conceptualizing relaxation, other extended models have been developed over time, suggesting an alternative idea defined as a transactional process involving not only arousal but also factors helpful in understanding the peculiar conditions that influence stressful situations (external stimuli, coping resources, cognitive appraisal) (Figure 1), included anxiety, as a negative emotion that mediate between stimuli and the physiological reactions pattern [46,47].

Figure 1. Schematical representation of the Transactional Model of Stress and Coping by Lazarus and Folkman [46].



Source: Jensen et al. [48].

Beliefs, and cognitive components, in general, were started to be investigated as the focal points on which to act for facilitating relaxation. Smith et al. [49] identified three cognitive processes to be considered as the "active ingredients" of any type of relaxation activity: 1) *Focusing* the attention on stimuli for a defined period; 2) The ability to desist from being committed to other concurrent goal-directed activity; 3) The capacity of tolerating and accepting uncertainty, unfamiliar, or paradoxical experiences.

In general, the cognitive-behavioral model of relaxation comprises a series of subsequent steps that imply initial and gradual management of relaxation; the learning and deployment of the mentioned cognitive processes (focusing, passivity, and receptivity), the capacity to learn and distinguish the tension and relaxation states; the ability to associate and use other more symbolic strategies able to allow the learned-relaxation technique [49].

All of these cognitive and behavioral strategies for relaxation can be extended to different types of techniques that are adapted based on the type of approach, such as physical (e.g., Breathing), unrestrictive to mental strategies (e.g., Somatic Focusing, Thematic Imagery), restrictive to mental strategies (e.g., Contemplation), [50, 51].

Progressive Muscle Relaxation technique (PMR) can be included in the physical approach category since it is less demanding in terms of mental and cognitive strategies compared to techniques such as hypnosis training, and it can be considered a simple and flexible relaxation strategy [52]. The PMR fits well with the above-mentioned cognitive and behavioral features since it requires (1) focusing on and discriminating sensations of muscles tension and tension release, (2) taking a passive attitude after generating tension, and (3) tolerating temporary variegate feelings and emotions such as boredom, frustration, and discomfort until relaxation skills begin to develop [52].

On the other hand, techniques such as Guided Imagery (GI) imply more internalized and top-down processing (e.g., focusing on mental content, physical passivity, and receptivity) [49]. From a cognitive load requested perspective, contemplation, and meditation (e.g., Mindfulness-Based Stress Reduction training) should be considered among the most demanding in terms of cognitive resources [49].

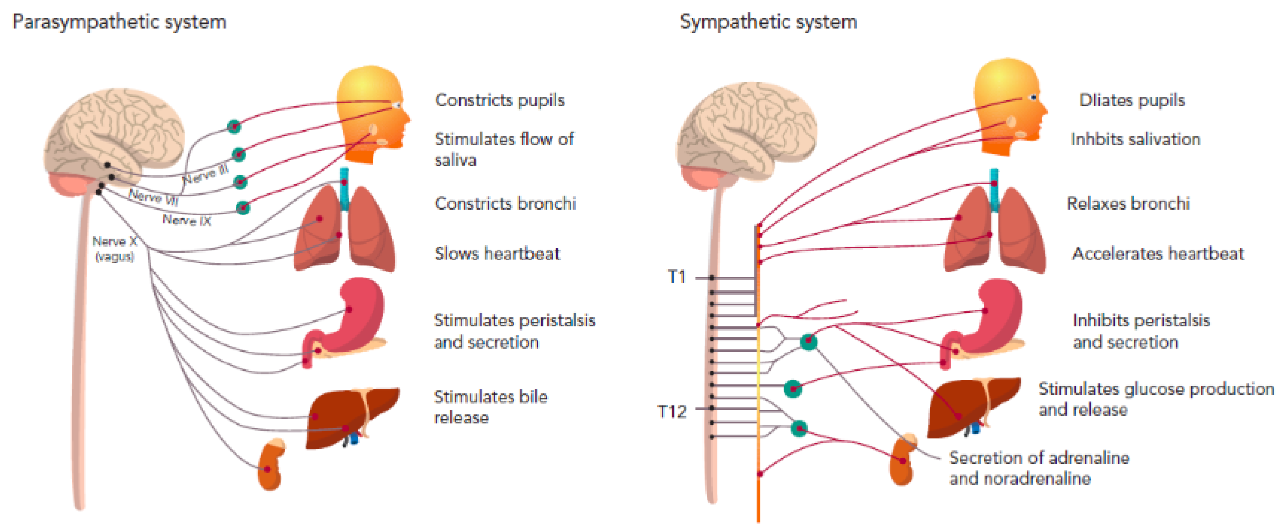
Choosing between different techniques, or combining two or more relaxation strategies, is fundamental because it allows one to identify the best type of intervention according to the users' needs, preferences, cognitive features (e.g., the ability to extensively focus attention on a specific activity) and other aspects that impact the effectiveness of relaxation intervention, such as personality characteristics and emotional functioning (e.g., distress tolerance, emotional regulation). All the impacting features have been considered in choosing a relaxation intervention for each individual.

1.2 The Progressive Muscle Relaxation training: a standardized somatically oriented relaxation technique that works

Progressive Muscle Relaxation training (PMR), also called the "Jacobson Relaxation method" or "Progressive Muscle Relaxation", is an evidence-based, actively engaging relaxation technique developed by the physiologist Edmund Jacobson [53] in which the main aim is to learn tension and relaxation of the different muscles districts in order to acquire a strategy to allow relaxation and reduce anxiety and mental stress [54].
PMR involves physiological effects opposite to those carried out by psychological stress and anxiety. It is used to promote the reduction of the Sympathetic Nervous System based on evidence that overactivation of the sympathetic autonomic nervous system contributes to excessive skeletal muscle activity. The earlier studies assumed that the reduction of skeletal muscle activity allows decreasing the activity of the sympathetic nervous system, in correspondence with the negative feedback from the skeletal muscle proprioceptors to the ascending reticular activation system and hypothalamus. Then, resting muscles send slight or no feedback information from the skeletal muscle proprioceptors to central brain structures, decreasing autonomic activation (e.g., [55-56]), with a corresponding increase of the Parasympathetic Nervous System activity; in this model, research observed decreasing heart rate and blood pressure, oxygen consumption, sweat gland activity, motor-physical activity, and a variation of brain waves patterns (e.g., [57-60]).

Due to these neuro-functional processes, we can therefore specify that the PMR is based on "top-down" and "bottom-up" neuronal processing [61]. To resume, the "top-down" way sends input from the central nervous system areas to peripheral areas to contract muscles and gradually release the tension. The "bottom-up" process is involved during the active holding and releasing of bodily tension that produces proprioceptive stimulation from peripheral muscles to the brain via the spinal cord and the brainstem. This exchange of sensory, emotional, and cognitive information should help strengthen the awareness and learning of the muscle districts' subjective state of tension and relaxation so that it can be replicated more automatically to stimulate relaxation and deactivation even in conditions experienced as stressful by individuals. For a general overview of the Sympathetic and Parasympathetic systems involved in these processes, see Figure 2.

Figure 2. Overview of the Sympathetic and Parasympathetic Systems.



Source: Singh et al. [61].

Since PMR does not involve particularly complex cognitive resources, its application can be extended to any person with different health conditions. The PMR technique involves a number of sessions established based on the purpose and level of detail to be devoted to the musculature of each body district. The first part of the training involved sessions in which participants must actively contract and release muscles of the dedicated body district, focusing on the feelings generated focally [62]. As stated, the number of sessions can vary. For example, the initial training in all muscle groups may require more than 100 sessions over several months or even years [63]. The PMR has been modified to make it more effective and easier to apply (e.g., [55, 64]). Joseph Wolpe [65] deployed PMR as a counterconditioning method to manage phobias in the systematic desensitization technique. Also, to facilitate participant compliance during the training, subsequent revised versions of PMR were suggested by Paul [66] and formalized by Bernstein and Borkovec (e.g., [56]). Revised PMR consisted, for example, of the reduction of the tension-release cycle times, the tension-release practice considering all 16 muscle groups in every training session, and the introduction of useful metaphors to help participants understand better the rationale that underlies the PMR training (e.g., the analogy with "pendulum" movement to explain the importance of exercising tension before releasing muscles). Abbreviated forms of PMR are advantageous in terms of saving cost and time. A meta-analysis considered studies that have deployed the revised Bernstein and Borkovec protocol [55], concluding that abbreviated PMR could effectively treat various disorders [26].

The effects of the PMR technique have been widely demonstrated in numerous studies (e.g., [67, 68, 69]). For instance, empirical evidence showed that PMR is effective in reducing tension and anxiety in different types of target samples that experience anxiety related to a stressful job activity and have a medical or psychological disorder (e.g., non-clinical individuals, patients with cancer, chronic pain, osteoarthritis, heart disease, chronic headache, anxiety, depression, asthma, headache, tinnitus) (e.g., [70-75]).

1.2.1 The PMR to manage anxiety disorders

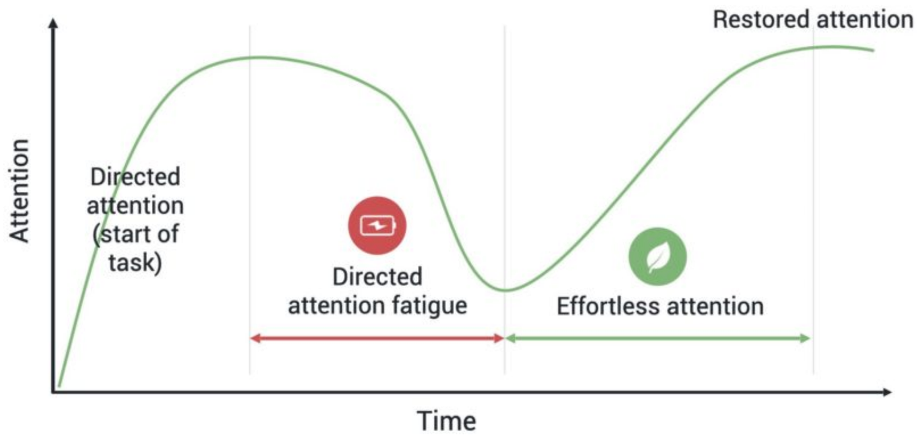
Anxiety can be defined as an emotion manifested through heterogeneous cognitive and behavioral symptoms and signs (e.g., tension, worried thoughts, and physical changes like increased blood pressure and heart rate frequency). It is considered a future-oriented, long-acting response broadly focused on a diffuse threat [76]. The core feature that sets out anxiety as a pathological condition is that it is based on unreal or distorted beliefs about the threat or worry stimuli. Moreover, anxiety goes from an adaptive emotional reaction to a pathological one when it becomes disproportionate to the stimulus and/or persists above the adaptive limits, leading to a weakened and pervasive everyday functioning [47]. Anxiety disorders are among the most prevalent psychiatric disorders, and anxiety symptoms can be observed in various mental and organic disorders. Relaxation techniques constitute one of the therapeutic approaches to managing anxiety, comprised the Jacobson's training, which is effective for multiple health conditions (e.g., 78). As stated above, one of the main applications of PMR is to manage anxious symptoms related to different diseases and stressful situations in daily life (e.g., 79-83).

1.3 Imagining natural, relaxing environments based on the Guided Imagery technique: An effective relaxation strategy to manage anxiety and promote relaxation

To our knowledge, four main theories help explain why interaction with nature benefits humans. The *Attention Restoration Theory* (ART) [84, 85], the *Stress Reduction Theory* (SRT) [86, 87], the *Perceptual Fluency Account* (PFA) [88], and the *Prospect-Refuge theory* [89].

- The *Attention Restoration Theory* assumes the presence of two types of attention processes. One is named "directed attention" and is commonly required to voluntarily direct attention on effortful tasks for extended periods (e.g., tasks during the working activity). The other is named “effortless attention”, and it arises in a more involuntary, effortless, and automatic manner since intrinsically interesting or exciting stimuli induce it. It has been seen that the natural environment has the power to elicit effortless attention, enabling individuals to restore the ability to direct attention. These processes are supported by natural environments requiring less top-down directed attention and restoring the cognitive system [84,85], (Figure 3).

Figure 3. Graphical representation of the Attention Restoration Theory (ART).



<u>Source</u>: Kaplan, S. [84].

- The *Stress Reduction Theory*, proposed by Ulrich et al. [87], suggests that natural environments allow positive emotions and decrease negative thoughts and emotions, with a consequent impact on positive changes in physiological activities. Ulrich et al. [87] argue that humans are evolutionarily equipped to respond quickly to threatening stimuli in natural settings and that individuals will be ready to quickly acquire restorative responses that may strongly apply in natural settings. Positive affect evoked by some environmental stimuli blocks negative affect and thoughts and enables more rapid, complete psychophysiological stress recovery.

- The *Perceptual Fluency Account* links our positive affective responses to natural stimuli to the ease of processing such stimuli and assumes that the restoration of attention and stress reduction are by-products of this processing fluidity [88]. In this context, is postulated that fluency induces less effortful processing and then increases positive affect, which increases attention.

- The *Prospect-refuge theory* suggests that people prefer landscapes that offer both prospects (a clear field of view) as well as places to hide [90]. Supporting this theory, research has shown that nature walks that had high prospects led to higher cognitive restoration compared with nature walks that had low prospects [91].

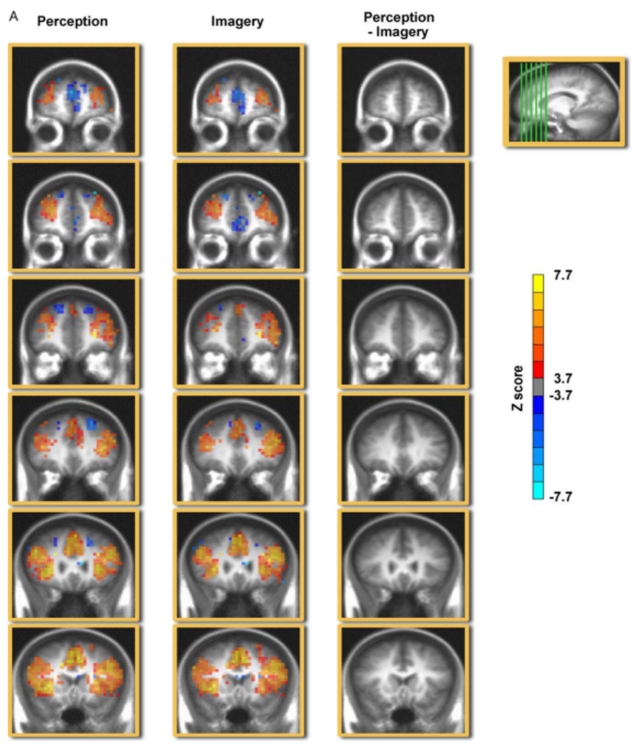
Figure 4. Graphical representation of the Prospect-refuge theory. A) strong refuge; B) prospect-refuge balanced; C) Prospect.

Source: Conrad (1993), unpublished Master-Thesis; Dosen, & Ostwald [89].

Also based on these framework theories, a considerable amount of research investigated both the bottom-up (e.g., perceptual features of the natural scenarios) and the top-down processes as well (e.g., individuals' features, dispositions, preferences, and needs), showing that exposure to natural environments has positive benefits for psychological health and well-being, and it constitutes an effective intervention for the management of anxiety symptoms (e.g., [92-93]).

Exposure to natural environments may not always be possible, and some contexts and situations make contact with nature more challenging, for example, living in long-term facilities, in high-density urban environments, or where therapy is undertaken in a confined room without direct access to the natural world [94]. To overcome these obstacles, different strategies are usually adopted. Considering the similarity between the imagery and the perceptual systems, a validated standard intervention that has shown to be helpful in increasing positive affective states (e.g., [95]) is the creation of mental imagery based on personalized natural and relaxing scenarios. This type of intervention is commonly known as Guided Imagery (GI), a widely structured method flexibly used in cognitive and behavioral therapy [96]. GI involves instructional guidance that invokes sensory experiences (visual, auditory, haptic, and taste-smell experiences) and allows behavioral and physiological responses [97, 98]. The instructional guidance and the strong focus on the engagement of participants help gain greater perceptual detail of the images generated, which creates a more realistic mental representation during the relaxation exercise [99]. GI has been used as an effective intervention for anxiety by generating relaxing states through mental processes [100-103]. An explicit addition of the natural environment to the GI process might overcome difficulties in physical access to nature and enhance relaxation and deactivation. Interventions using GI of naturalistic scenarios might be an accessible and cost-effective intervention for anxiety reduction and lend support to the growing evidence of the benefits of nature on mental well-being. Due to the sensory system's elicitation, literature has highlighted that GI events could be experienced as real events [104]. Further, there is evidence that visual mental imagery and visual perception share similar representations and are similarly processed [105, 106]. Indeed, imagining scenarios compete with perception processes if both are elicited, suggesting they use common cognitive processes (e.g., visual perception is affected once a visual image is held) [95, 107-108]. Moreover, even though some sensory processes may be engaged differently in visual imagery and perception, cognitive control processes function similarly in both imagery and perception, as has been revealed [109].

Figure 5. An illustrative representation of the pattern of similarity between visual perception and visual imagery in frontal, parietal, temporal, and occipital regions.

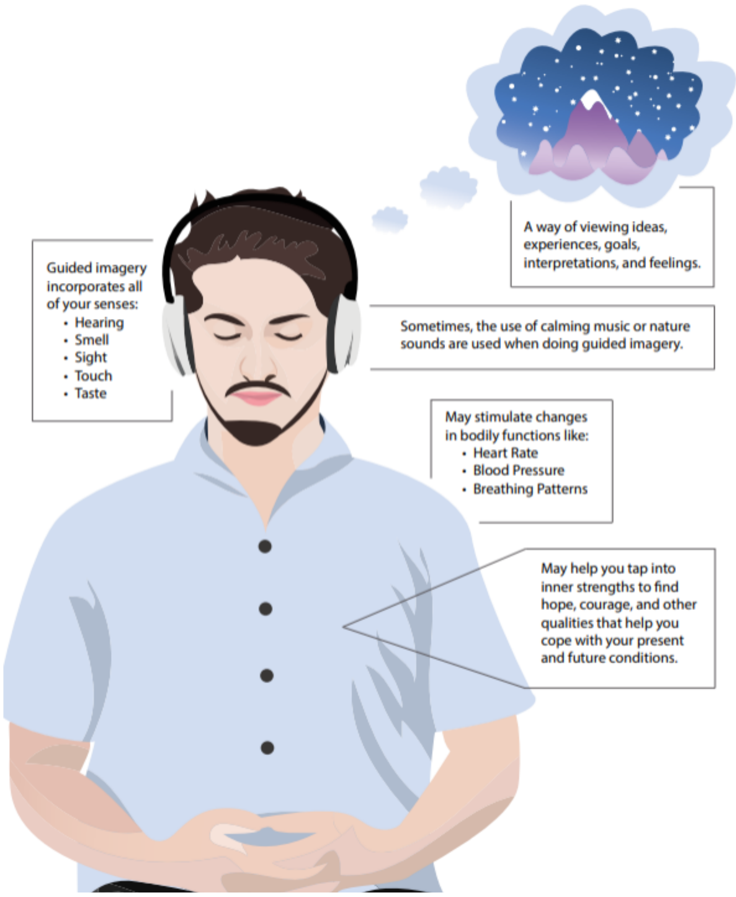


Source: Ganis et al. [109].

Numerous studies across a wide range of populations have demonstrated a link between GI and anxiety [110-117]. The evidence-based literature assumed that imagery is compelling for anxiety symptoms because anxiety is more likely to be responsive to perceptual-sensory representation than representational systems (e.g., language) that evolved later in the developmental process. And that both imagery and the real experience facilitate similar immediate perceptual experiences that directly influence corresponding emotional brain systems [101]. In the same scientific paper, Holmes and Mathews [101] stated that imagery acts as an 'emotional amplifier' with the capacity to modify emotional states. A 2016 study by Ji et al. [98] strongly indicates that GI can be deployed as a technique to treat anxiety symptoms. It has also demonstrated that anxiety-reducing effects can emerge from the imagery of the natural world without incorporating suggestive relaxation cues, a common element in guided-imagery scripts. In one study conducted to evaluate the effects of GI on intraoperative anxiety for patients undergoing abdominal surgery under spinal anesthesia, GI techniques were shown to significantly reduce anxiety [118]. Another study investigating the effects of 20 minutes of guided imagery on preoperative anxiety significantly reduced anxiety and cortisol levels [119]. Yet another study showed that hospital nurses working during the COVID-19 pandemic trained in GI, compared to controls, significantly decreased anxiety [120].

More than that, the use of GI is revealed outside of the medical setting. One study evaluating nature-versus-urban-based guided imagery as an intervention for anxiety found a significant decrease in state anxiety among adults imagining urban and natural settings [94]. The effect was most substantial for nature-based guided imagery. Another study showed significant increases in self-forgiveness scores following seven five-minute guided imagery sessions [121]. The Nguyen et al. [94] study aimed to investigate the effect of a nature-based GI intervention on state anxiety reduction and highlighted that GI could reduce anxiety, especially if naturalistic imagined scenarios were experienced, independently of gender and the ability to imagine imagined scenarios. These results confirmed how powerful exposure to naturalistic imagery scenarios is in facilitating a state of relaxation. Highlighting the flexibility of GI usage that can be undertaken not only during therapeutic sessions, overcoming accessibility barriers of taking up psychotherapy (e.g., therapy costs), and supporting the effect of being exposed to a naturalistic environment on psychological well-being [94].

Figure 6. An illustrative representation of a Guided Imagery session with a brief description of related features and consequences due to its deployment.



Source: https://connectcare3.com/resources/guided-imagery/

1.4 Complementary methods for relaxation: The bolstered effect in the PMR and GI combined administration

Studies have demonstrated the effectiveness of complementary training that combines the effects of PMR and GI in intensifying relaxation and reducing distress, anxiety, depression, quality of life, and the perception of pain in patients with various medical conditions or during pregnancy [17,18,122-126]. This complementary approach can promote a higher sense of relaxation during training sessions, but it should also be integrated with recalling a state of relaxation during everyday activities.

The combined method introduced by Baird et al. [17] is composed of 8 steps:

1) Setting a comfortable and protected natural environment in which to relax;

2) Recreating an imagined scene involving different senses;
3) Guiding the user in focusing on breathing;
4) Using passive progressive relaxation techniques;
5) Recalling the imagined scene to direct the attention on pleasant stimuli;
6) Feeling a release from pain and activation (e.g., imagining a decrease of painful sensations);
7) Imagining to move into the scene by continuing to use focused breathing and relaxation;
8) Ending the session ("*Breathe deeply. When you are ready, allow the image to fade. Stretch and open your eyes*").

To resume, combining PMR and GI techniques amplify the effect of shifting attention from anxious and painful stimuli, driving attention to pleasant information, and promoting relaxation. Indeed, physical relaxation makes visualization easier, reducing responsiveness to stress as it transforms stressful situations from adverse reactions of fear and anxiety into positive images of well-being [127, 128]. As GI positively impacts emotional symptoms and PMR is more physical, administering these techniques can enhance the effect on relaxation [129].

When PMR and GI are concurrently administered, the relaxation session starts with PMR to help participants focus attention and facilitate the muscles' release. Then the therapist suggests an image of a relaxing, calm, or comforting place (e.g., sunset or moonlight, sitting on a hot or warm beach, floating on the water or through space) [127].

This therapy helps to deviate the attention from the physical and psychological discomfort by staying concentrated on pleasant imagery, which can decrease anxiety and pain, reduce analgesic intake, and bring down tension, anguish, fear, heart frequency, and blood pressure, besides promoting psychological well-being, energy, and sleep (e.g., [130, 131]).

Moreover, these techniques encourage self-efficacy and active participation in the treatment process [132, 133]. Relaxation therapy combined with GI is a widely used intervention that can effectively promote clinical results [124].

Therefore, it is fundamental to investigate health interventions, also considering novel and easy-to-deploy procedures to facilitate the application of this effective relaxation training.

1.5 Why have PMR and Guided Imagery, among the relaxation techniques, been considered in the current Ph.D. thesis?

PMR and GI, other than meditation approaches such as Mindfulness, are helpful training techniques for improving physical and psychological health outcomes (e.g., 134). Since many approaches work to manage anxiety and induce relaxation, the best perspectives from which clinicians might start selecting one or more relaxation techniques are the treatment goals and the users' preferences, needs, and abilities. The PMR and the GI relaxation training are commonly experienced as more familiar and tangible than Mindfulness training by individuals that are used to having concrete thinking styles, psychiatric vulnerabilities, or cognitive impairments (e.g., 135). Moreover, previous research highlighted how the PMR is an empirically validated clinical treatment to reduce negative stress responses [24], characterized by other advantages such as the low-cost of this type of intervention, ease of teaching to users with heterogeneous abilities and socio-anagraphic characteristics [136]. Indeed, the PMR has shown successful results in various clinical populations [62, 137-139], non-clinical samples, such as corporate workers and college students [64, 140, 141], and age groups ranging from adolescents to older adults [142, 143]. As stated before, PMR studies with college students have shown positive results, including anxiety reduction [64, 138].

Moreover, several physiological and psychological benefits of PMR, such as its contribution to lowering blood pressure, cortisol, heart rate, fatigue, anxiety, and pain, have been demonstrated in previous studies [64, 139-145]. Considering evidence from literature, the current Ph.D. studies aim is to preliminary investigate the feasibility, acceptance, and the impact on psychological constructs (such as feelings, state and trait anxiety, arousal, depression) in order to inform following more rigorous studies that will be implemented considering people with medical and psychological problems (e.g., chronic pain, cancer, dementia, anxiety and stress disorders).

CHAPTER 2.

THE USE OF VIRTUAL REALITY TO PROMOTE RELAXATION

2.1 What are the advantages of Virtual Reality technology in promoting relaxation and managing anxiety?

The American Psychological Association (APA) defines Virtual Reality (VR) as a "*simulated three-dimensional environment created through the memory, graphics, and processes of a computer. It is often used to create simulated environments for activities such as flying a plane or exploring space, which are expensive or dangerous to experience directly. Supporting hardware and software tools, including gloves and head monitors with real-time feedback, are often used to immerse and train humans in this virtual reality*"[1]. Starting from the last part of the last century, the scientific community began to consider VR a valuable and effective application for diagnosing and treating a wide range of medical and psychological problems [146-148]. The opportunity to deploy VR primarily focused on the cost-benefit analysis of this new technological tool. The cost-benefit balance is essential in evaluating psychological therapy's effectiveness [148]. *Cost* is about the commitment that an individual or an organization provides in terms of money, time, and emotional involvement, and *benefit* refers to the effectiveness of a treatment (e.g., the outcome achieved in the shortest time is possible to reach). For example, in treating anxiety, one of the gold-standard techniques used to expose individuals to managing specific phobias is the behavioral exposure technique traditionally deployed gradually, starting from the "*in-imagination*" to the "*in vivo*" exposure (Figures 1A-1B).

[1] https://dictionary.apa.org/virtual-reality

Figure 1. Illustrations of the "Imaginal behavioral exposure therapy" (Figure 1A) and the "*In vivo* behavioral exposure therapy" commonly used to treat Panic Disorder and Agoraphobia.

1A.

1B.

Source: https://cbt4panic.org/3-types-of-graduated-exposure/ [149]

In the in-imagination condition, participants learn to cope with their phobic stimuli through mental images; imagining scenarios could be considered a fairly inexpensive solution in economic and emotional terms, as it implies exposure that usually occurs in the therapist's office and does not put the person in very uncomfortable situations from an emotional point of view, but it may potentially be not effective since individuals may have difficulty imagining scenarios. On the other hand, in the *in vivo* condition, participants are gradually exposed to real phobic environments; this exposure strategy can be considered more effective, overcoming limitations that imagining has concerning effectiveness, but it is a more onerous solution since it implies higher costs in terms of money, time and emotional involvement by individuals. VR can fill these standard exposure modalities' costs and benefits ratio gaps. Indeed, VR shall facilitate exposure to phobic or stressful stimuli more than imagination because it permits to recreate an environment similar to reality and is less invasive than in vivo exposure. Therefore, it is assumed that exposure in a virtual environment can facilitate subsequent *in vivo* exposure due to its potential to facilitate immersiveness and the sense of presence, reducing the gap between imagination and reality.

This cost and benefits model can be translated considering the potentiality of using VR to learn to relax. Indeed, a fortiori due to the Sars-Cov-19 pandemic, innovative VR treatment protocols are increasingly requested and helpful in managing relaxation [150], also due to the possibility to be administered with greater flexibility in several different contexts and independently from the presence of the therapist. Delivering an entire relaxation protocol (e.g., complementary intervention strategies such as PMR and GI) in the presence of the psychotherapist could require a considerable investment in economic and temporal terms for users. The introduction of VR could reduce the number of psychotherapy sessions needed and their cost, as it allows partial self-management of part of the treatment.

Furthermore, in the case of patients with medical problems, the integration of VR could facilitate the administration of the relaxation intervention during specific invasive treatments (such as chemotherapy). If the merged administration of a customized VR relaxation scenario and PMR is effective in obtaining a better subjective perception of relaxation than the standard procedure, it could allow the users to do relaxation with greater autonomy. For this reason, assessing the efficacy of the PMR and GI in alternative ways could extend the treatment administration, especially in situations where the standard procedure is more challenging to be realized, based on the principle that "*the more vivid and realistic are the relaxing images in the imagination of the client, the easier it will be to obtain a relaxation response*" [148].

The main advantages of VR can be summarized as follows [151]:

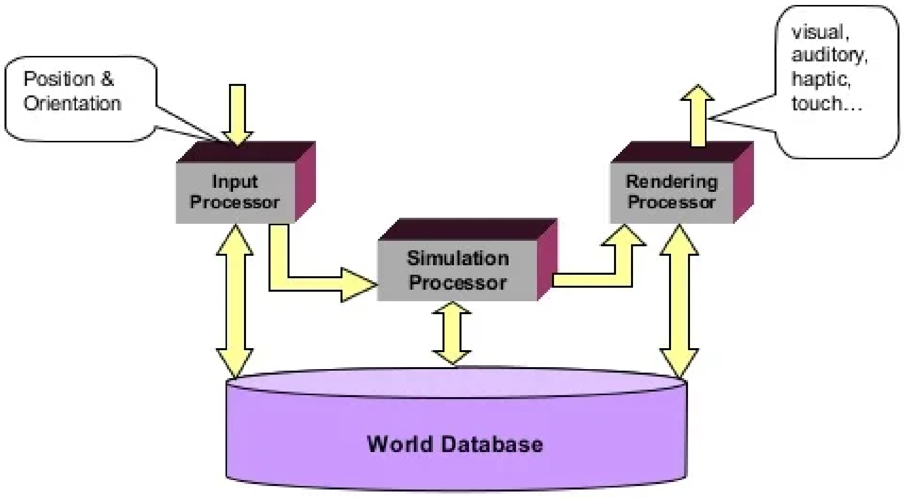
1) Cost: VR exposure is less costly since it does not require the therapist to go to the feared place with the patient.
2) Availability: VR permits exposure to situations that are difficult to access or less effective based on imagination. Since VR exposure does not require users to have particular abilities in imagining or visualizing scenarios.
3) Engagement: Sense of presence, immersion, interaction, and exposure to valuable stimuli offered by VR improves the engagement of the intervention, favouring participants' adherence to the interventions.
4) Control and Self-Efficacy: Exposure to virtual reality allows nearly complete control of everything that happens in the situation experienced by the person in the virtual scenario. In addition, the therapist can still know what is happening in the virtual context. Moreover, feeling in control may increase patients' feelings of self-efficacy.
5) *Realism and presence*: VR exposure permits people to feel present, experiencing the VR context as real.
6) Going beyond reality: Virtual contexts allow the creation of situations or elements that may be difficult to occur in the real world.
7) Safety: In the virtual context, users have the possibility to control the computer-generated scenario, with the consciousness that the technology can be switched off anytime.
8) Privacy and confidentiality: VR offers significant advantages of increased privacy and confidentiality.

The next sections of the current Chapter will focus on clarifying virtual reality's main features and potential, proceeding in detail in describing its application in experimental protocols aimed at promoting relaxation.

2.1.1 Software and Hardware equipment components

Virtual reality integrates real-time computer graphics and various sensory inputs to create a close-to-reality computer-generated world with which users can interact. The technological components of VR are composed of *input devices*, *output devices*, and the *virtual environment* [152]. The cores of a VR system are the *simulation and rendering processors* essential for reproducing the actions that will take place in the virtual world by analysing the user input, determining the actions that will take place in the VR scenario, and creating sensory images that depict a virtual world. The main components of the architecture of a VR system are represented in Figure 1.

Figure 1. The architecture of a VR system.



Source: Virtual reality (slideshare.net)

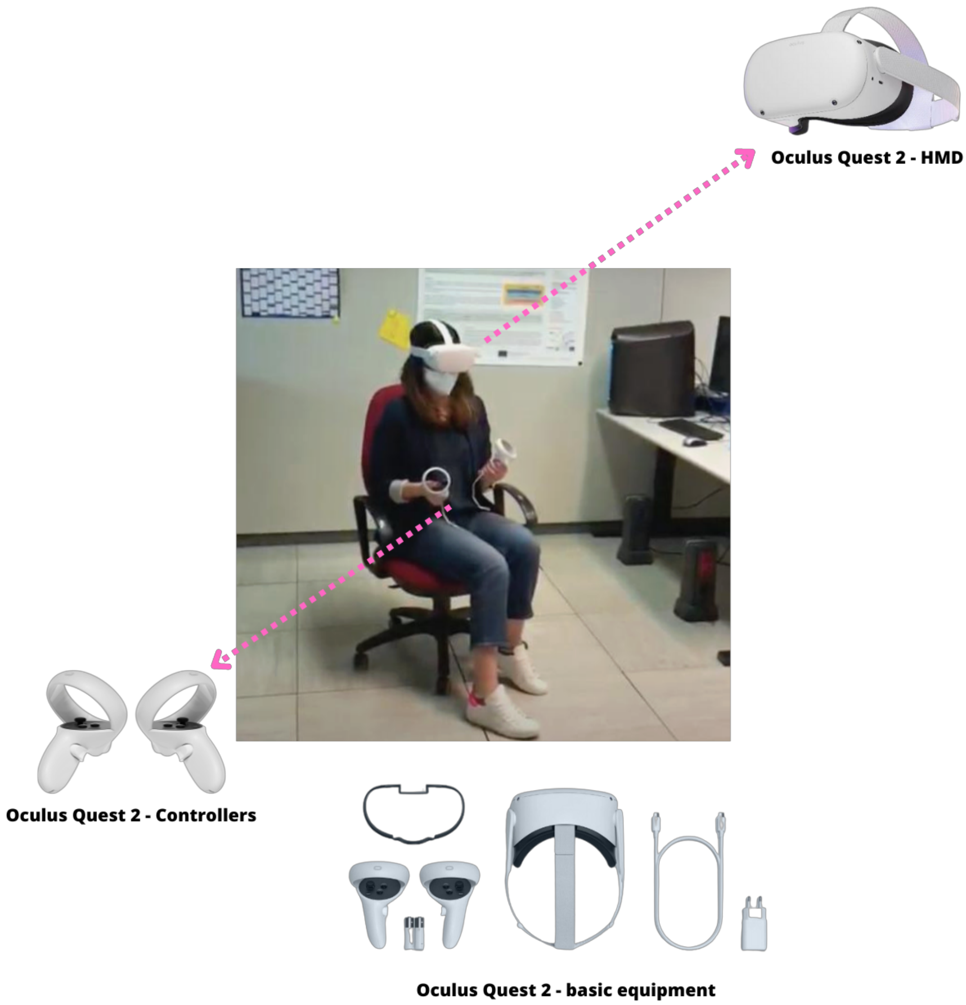
Input devices consist in sensors and trackers that allow users to interact with the virtual environment (e.g., Tracking devices: datagloves, head-positioning sensors, embedded cameras, eye-trackers; Pointing devices: six-degrees-of-freedom mouse, trackball, joystick) [35].

Output devices provide continuous computer-generated information to the user through different sensory modalities, such as visual, auditory, olfactory, and haptic feedback, via input devices like data gloves [35]. To maximize the immersiveness and sense of presence in the virtual environment, the graphical user interface is commonly mediated through a Head-Mounted Display (HMD), such as a helmet or goggles containing two small television screens and stereo earphones. The user can explore and navigate in the virtual world through motion-tracking devices attached to the HMD, which enable the computer to adapt the field of view to the user's movements.

The *virtual environment* is the computer-generated 3D virtual scenario designed to be explored so that users can interact with virtual content.

HMDs are considered the most common immersive VR technology since they permit the focalization of the entire visual contact into the virtual scenarios world in which an internal display replaces different kinds of computer-generated stimuli [35] (Figure 2). The sensors embedded in the HMD allow the perception of the stimuli in different viewing positions.

Figure 2. Example of Oculus Quest 2-HMDs worn by one of the experimenters and Oculus Quest 2 basic equipment.



Another advanced and expensive immersive VR technology is, for example, the cave automatic virtual environment (CAVE) [153]. Non-immersive VR systems use high-resolution monitors (desktop or laptop screens) as output devices. Still, they need help to wholly clog the visual channel of the user, and their interactive abilities could be improved (e.g., due to the lack of movement tracking). Virtual environments that are not immersive include 3D video games and 3D computer modelling applications [35].

2.1.2 Virtual contexts' core "active agents": Sense of Presence and other strictly-related constructs for the comprehension of VR experience

A successful virtual experience gives users a sense of presence—as though they are physically immersed in the virtual environment. This sensation is achieved by fencing real-world stimuli experienced through computer-generated stimuli. Two of the essential aspects that bear and sustain the power of VR technology are "Sense of Presence", defined as an experiential quality in virtual environments about the perception of interaction with the virtual context as to "be into the VR scenario" rather than the surrounding physical environment [154], and "Immersion" a condition more influenced by the technical aspects of a virtual system that facilitate users in experiencing a position in the virtual context close to the real world. The more the technical components facilitate immersiveness and can sensorially separate the user from the physical world, the easier it is to feel a sense of presence [155,156].

Heterogeneous perspectives exist about the Immersion construct. As stated above, some models considered immersion an objective characteristic of a virtual system [157]. Others define immersion as a psychological condition derived from the perception of being included in an environment with which to interact [158]. While other conceptualizations suggest an integrated perception in which perceptual immersion and psychological immersion are defined [159, 160].

In any case, immersion is a strictly related construct to the Sense of Presence.

Sense of Presence is a multidimensional construct composed of a dynamic interaction of multisensory data and cognitive processes [161]. One of the first research groups introducing the Sense of Presence concept was Akin et al. [162] group which defined "presence" as a condition that occurs when "*At the worksite, the operator receives sufficient quantity and quality of sensory feedback to provide a feeling of actual presence*". Slater et al. [157] defined presence as the perception of immersion in a virtual environment, which is affected by the users' attention and the subjective perception of reality of the computer-generated environment.

Slater et al. [163] also gave a preliminary conceptualization of differences between immersion and presence, defining immersion as the "fidelity about physical reality generated by the display and interaction system" [161]. Based on the Slater et al. model [164], *Media and User Features* are considered the two categories of variables that provide for the experience of a user's presence. *Media features* are characterized by "media form" and "media content" variables. In referring to the "media form", Sheridan [165] introduced three principal categories impacting presence 1) the amount of sensory information; 2) the level of control participants have on the sensor devices; 3) participants' ability to modify the virtual scenario. On the other hand, *User Features* are about the individual dispositions (e.g., the ability to focus attention), which are counted as inter- and intra-differences in interacting perceptual-motor abilities, mental state-traits variables (e.g., attentional selection, absorption, and dissociation processes) [166], personal needs, preferences, values, involvement [158], past experiences with VR and required tasks, expectations regarding the mediated experience, and susceptibility to motion sickness [e.g., 161]. Moreover, the sense of presence is studied from a sociocultural perspective [167] in which the features of different kinds of experiences characterized by different social contexts impact the possibility of having experiences mediated by personal and cultural-mediated values.

Several studies highlighted and allowed the validation of different measures to investigate the sense of presence, starting from multidimensional structured models. Schubert et al. [168] shed light on a three-factor solution composed of "Spatial Presence", "Involvement", and "Realness". Lessiter et al. [169] identified a four-factor solution similar to Schubert et al.'s. (2001), characterized by "Physical Space", "Engagement", "Naturalness", and "Negative Effects".

Considering Sense of Presence as a subjective and internal feeling elicited by sense perceptions (*quale/qualia* in the philosophy literature), assessing it is generally considered extremely difficult [170]. For this reason, heterogeneous methods are usually used to assess this construct and can be classified into "Objective measures" (e.g., behavioral observation and psychophysiological detections) and "Subjective measures" (e.g., self-report questionnaires). Ideally, objective, and subjective features should be complementarily investigated to obtain a more comprehensive status of participants' experience while interacting with virtual environments [161].

Despite the intrinsic limitations (e.g., 171), self-reported questionnaires are essential to obtain information from the user's personal perspective also in the field of new technologies since they are generally considered sensitive and reliable [172]. To limit bias, self-reported measures should be filled out immediately after exposure [173]. Questionnaires are commonly based on three different forms of evaluation: *scales* (e.g., from 1 to 10, what level of being there did this virtual environment offer?); *paired comparative method* (e.g., which system offered more presence?); *comparative method by similarities among distinct modes* (e.g., put this light as bright as the strength of presence you have experimented in this VR system) [174].

The *Presence Questionnaire* (PQ), developed and validated by Witmer et al. [175], is among the most used self-reported measures. The PQ comprises 32 items on a 7-point Likert scale that measures presence after using a VR tool. The questionnaire gained consistent acceptance. The PQ has four sub-scales: a) "Involvement"; b) "Sensory Fidelity"; c) "Adaptation/Immersion", and d) "Interface Quality".

Another well-known scale is the *ITC-Sense of Presence Inventory (ITC-SOPI)*. This self-reported questionnaire emphasizes the media user experience [169]. The ITC-SOPI, including 44 items measured through a five-point Likert scale, has four factors: "Sense of Physical Space": a sense of being located in a physical space depicted by the media system; "Engagement": a sense of involvement with the content of the mediated environment; "Ecological Validity": a sense of naturalness and believability of the depiction of the environment itself and events within the environment; "Negative Effects": the negative experiences associated to an immersive media, such as eye-strain, headache, sickness.

Other commonly used self-reported measures are the *UCL Presence questionnaire* [176,177], the *Reality Judgement Presence questionnaire* [178], and the *Igroup Presence questionnaire* [179].

On the other hand, objective measuring instruments are not without limits. They have the advantage of not interfering with the virtual experience and allowing it to overcome the limits given by subjective reports but investigate variables not directly related to the sense of presence since it has no physical manifestation objectively measurable [180]. Commonly, objective psychophysiological measures, performance, and postural response assessment [174]. In general, arousal is considered one of the most common physiological correlates of presence (e.g., [170]), and it is investigated through the detection of heart rate frequency and rate-variability, skin's electric conductance, reflex motor behaviors and VR event evoked cortical responses.

2.2 Using Virtual Reality for Relaxation in Non-Clinical and Clinical Populations

As mentioned before, the *Attention Restoration Theory* (ART) sheds light on how exposure to natural contexts can reduce stress, regulate mood, and positively impact daily life activities

[84, 181]. These processes are allowed by the powerful impact natural settings have in providing psychological distance from mental concerns (e.g., a sense of "*being away*"), being effortless, permitting to drive attention to interesting and valuable stimuli ("*fascination*"), supported by an environment of substantial aim ("*extent*"). VR is a technology that can help expose people to virtual naturalistic scenarios, overcoming obstacles that prevent them from visiting real natural environments. Moreover, exposure to pleasant virtual nature scenarios has been shown to provide similar positive effects to actual nature in increasing relaxation, as well as decreasing stress, arousal, and anxiety [182, 183].

Systematic reviews have shown evidence of the application of VR to promote relaxation both in non-clinical and clinical populations [184, 185].

Riches et al. [184], on 19 studies in their systematic review, globally showed that VR could be considered a feasible and acceptable tool to promote relaxation in people without a clinical diagnosis, underlined how virtual environments with pleasant, natural stimuli have the potentiality to enhance relaxation compared to control samples. Riches et al. [184] suggested that the VR tool should be useful to promote relaxation also if it is used at home and at the workplace [185, 186] by considering evidence from studies that highlighted the benefits of VR on relaxation and stress management in worker populations highly exposed to stress [187, 188]. Specifically, studies conducted on healthy young adults (e.g., college students) confirmed that VR is an acceptable, feasible, tolerated, and effective tool for inducing positive emotions and a general state of well-being, highlighting the primary role of immersion, interactivity, VE contents, and sensory modalities in improving the psychological outcomes [189-192]. Usually, the VR contents play a central role in allowing positive emotions [193], and Pavic et al. [194] underlined how most of the studies that obtained effective results involved scenarios derived from natural settings. Several studies confirmed that exposure to virtual nature increases positive emotions, contributes to decreasing negative emotions [183, 189, 192, 195-197], and positively impacts physiological arousal, further confirming its relaxing and restorative properties [183, 195, 198]. Similar benefits of real and virtual nature have been observed when using highly-immersive HMDs [195, 199].

Other studies have investigated the effect of natural virtual environment contents compared to artistic reproduction in a virtual context [200, 201] and virtual crowded urban environments [202]. The superiority of natural virtual scenarios emerged, compared to virtual art settings, in generating the "sublime" effect, heightened positive emotions, and resource restoration [200, 201]. Furthermore, compared to overpopulated urban environments, natural virtual scenarios elicited stronger positive emotions in a sample of young adults [202].

With respect to the preferred sensory modality for inducing positive VR experiences, some studies suggest that it is better to include auditory stimuli other than visual stimuli [198, 203]. Usually, auditory stimuli are composed of music and/or ambient environmental sounds (e.g., birds chirping, waves, etc.), or positive narratives (e.g., 189, 192]. The added value of olfactory and tactile stimulation has been explored in one study, but even if other variegated sensory stimuli could contribute to enhancing positive effects, it seems that auditory and visual information on their own are sufficient in VR for relaxing participants [182].

From the assessment perspective, it has been highlighted that VR's efficacy in inducing targeted emotions has mainly been investigated with self-reported questionnaires (e.g., 204, 205]. Some studies evidenced psychophysiological measures confirming VR's capacity to decrease arousal [206]. As stated, the most common physiological indices investigated in this field are skin conductance and heart rate frequency or variability. Other psychophysiological measures used are electromyography, cortisol blood/urine/saliva levels, or electroencephalography assessment [191, 198, 207, 208].

Considering clinical samples, an increasing number of studies highlighted that virtual reality could be used in various healthcare settings to promote relaxation and manage anxiety in individuals that received a medical or psychological diagnosis such as Generalized Anxiety Disorder, Post Traumatic Stress Disorder, Stress-related problems, Eating disorders, Depression, Psychosis, Attention Deficit Hyperactivity Disorder, Autism Spectrum Disorder (e.g., 209-213].

As specified in Riches et al. [185], most of these studies used a variety of nature-related virtual scenarios, such as beaches, forests, islands, mountains, lakes, and waterfalls that usually required individuals to assume a seated position wearing a headset that reproduced both audio and visual elements.

Figure 3. Example of Oculus Quest 2-HMDs worn by one of the participants during the experimental administration.

In some experimental conditions, to manage and investigate psychophysiological indices, biofeedback was connected with the virtual software and hardware piece of equipment, enabling users to change features of the virtual environment, such as the movement or intensity of a waterfall based on the individuals' actual biometric parameters (e.g., [214]).
Some studies used stressful virtual environments or exercises (e.g., mathematical tasks), against which to compare virtual relaxation environments (e.g., [215]).
In general, positive findings emerged regarding the acceptability and feasibility of using VR as a relaxation tool with clinical populations [216], and encouraging outcomes also emerged from the clinicians' perspective, since the use of VR seems to be able to reduce pressure on clinicians, and healthcare operators in general (e.g., [210]).
VR in a clinical context is generally considered a low-intensity intervention for people with a mental health diagnosis (e.g., [212]), especially if users do not have the possibility of experiencing real natural contexts [36]. Indeed, it is essential to mark how VR could be beneficial for users that lack access to real-world nature (e.g., people who live in healthcare facilities). A growing number of studies have investigated the use of VR for elderly users [217]. In healthcare facilities, allowing older adults to have recreational and pleasant experiences in natural environments, especially if they have a cognitive and physical impairment, although challenging, can be beneficial [30]. Participating in organized outdoor activities may be limited by reduced motor ability, the fear of injury during movement, as a side effect of drugs, and weather conditions. Overall, evidence shows that even if unable to engage directly in a natural

environment, visible exposure to natural scenes can be beneficial, reducing hospital length-of-stay and drug consumption [30-33]. Evidence suggests that immersive virtual scenarios can improve the quality of life in older adults' healthcare facilities, highlighting a positive impact on behavioral and psychological symptoms [218]. Brimelow et al. [219] used a VR immersive scenario with users living in a residential facility characterized by heterogeneous cognitive impairment levels. The authors reported minimal side effects associated with using VR and a positive impact on the psychological well-being and pleasure related to use.

Indeed, some published research has highlighted how using immersive virtual scenarios promotes managing depressive and anxious symptoms in older people [36, 220]. Appel et al. [36] investigated the feasibility of using relaxing virtual environments to promote positive emotions, involvement, and a state of general well-being, as well as managing negative emotions such as boredom, apathy, anxiety, and a sense of isolation. Specifically, discomfort and collateral symptoms potentially associated with using the HMD (such as nausea, headache, eye discomfort, and interference with other medical devices worn) have been assessed, such as the preference for audio and visual stimuli in the VR scenario, their involvement within the virtual context and the impact on the state of anxiety. All participants completed the research without experiencing or reporting adverse side effects related to using the HMD. From a qualitative point of view, positive feedback is associated with the experience and the perception of a greater state of relaxation.

The authors concluded that exposure of people with cognitive and physical impairments to realistic and natural immersive scenarios in virtual reality through an HMD is safe and feasible. These findings encourage future studies to investigate the role of VR scenarios' personalization.

Additional research that inspired the current study was conducted by Moyle et al. [221]. The authors deployed a peculiar VR context named "Virtual Reality Forest", designed to expose users to an immersive context based on an interactive screen to improve the quality of life of people with dementia living in care facilities. In this study, the main aim was to obtain information about users' moods, apathy, and engagement. The scenario was composed of visual and audio stimuli. During the exposure, participants had the possibility to select seasons (spring and autumn) and different types of virtual objects through hand and arm movements. Residents, family members, and staff received positive feedback globally. Participants experienced higher levels of engagement, pleasure, activation, and fear during the exposure to the virtual forest than the control sample. Moreover, the authors affirmed that differences in users' preferences should be considered a main factor limiting the versatility of the VR Forest.

Overall, several studies confirm VR's efficacy for inducing positive emotions and relaxation in healthy middle-aged, elderly users [222, 223], or among residents of long-term healthcare facilities [36, 219, 221]. In order to induce relaxation and manage anxiety and arousal, most studies deployed natural-based virtual environment contents [36, 219, 221, 224], considering their identified benefits and safety of use [36, 202].

Moreover, Riches et al. [185] highlighted that VR seems to have short-term effectiveness in promoting relaxation, and it is more or equally effective if compared to non-virtual relaxation training in reducing stress, suggesting that VR relaxation may complement existing relaxation techniques or offer users other relaxation and stress reduction options.

Indeed, VR can be administered as a standalone tool or combined with other cognitive behavioral therapy strategies with the aim to tailor a treatment to the needs and preferences of each user as a way of creating a treatment that is also sustainable over time.

Even if positive outcomes emerged from using VR as a relaxing tool, there are few studies on customizing virtual scenarios for therapeutic purposes [3]. Moreover, even if studies showed positive outcomes [1, 225, 226, 227], little is known about the impact of the combination of customized virtual reality scenarios and standardized relaxation techniques on users (e.g., Progressive Muscle Relaxation, Mindfulness-Based Stress Reduction, Body Scan) (e.g., 1, 184, 209). In the next paragraph, we report the main evidence-based research on the impact of customized virtual environments to promote relaxation and manage anxiety.

2.3 The Customization of Virtual Reality Scenarios to Enhance Relaxation

With the choice of naturalistic scenarios, customization of the virtual reality context is considered a key approach that promotes relaxation [3], enabling users to experience environments closer to their preferences and needs, increasing their sense of presence, and security [228]. A recent study proposed a personalized and customized VR model for relaxation based on critical variables (e.g., emotional states of people) that were modelled and controlled by an algorithm to customize the VR environment according to users' needs and profiles [5]. However, to the best of our knowledge, few studies have explored the role of the personalization of VR-based scenarios on the user experience and the effect of the integration of relaxation training in VR. One of the most recent studies in this direction showed that being exposed to a virtual environment for relaxation, including a body-scan-guiding audio track, may help improve the participants' relaxation compared to a VR condition including a breathing control audio-track [1].

As stated by Pizzoli et al. [3], a personalized and customized VR context implies the definition of a peculiar "design of the VR environments" that, by starting from the valuable personal life events of users, generates perceptive features to be included in the VR environment to facilitate engagement, reminiscences, and general positive feelings in the user. Such descriptions should be accurate, carefully recorded, and should include multi-sensory details: visual, tactile, auditory, and even olfactory elements, based, for example, on picture, audio, and music stimuli.

Previous studies have shown that embedding autobiographical stimuli into the VR environment helps to promote a subjective and vivid emotional connotation of the experience strengthening the sense of presence [182, 189], and that different emotional states (e.g., relaxation and joy), were evoked through autobiographical stimuli presented in different sensory modalities (picture, audio, music, autobiographical recall), suggesting that autobiographical contents in VR may play a valuable role in subjective emotional experience [3]. In a customized VR environment, the element of recalling the previous safe place would enhance feelings of security and peace, while in emotion regulation training, providing affective connotated stimuli could help emotion regulation and arousal modulation by giving the user the occasion to confront their relevant life events [4]. Verbal instructions can guide relaxation, such as bringing attention to muscle activation and breathing [e.g., 53] or induced through cognitive representations of positive thoughts and stimuli [229, 230] and the customization of VR can be changed based on the relaxing technique employed in the specific intervention, rather it would stress a user-centered environment and autobiographical engagement [4] to enhance the sense of presence and affective involvement.

One of the main advantages of customized virtual scenarios is that they can be deployed in a flexible manner and integrated with the relaxing technique employed [4]. Furthermore, in a relaxing environment, customizing the elements in the virtual scenarios based on preferences and inspiration to safe places visited by the user before can improve the sense of security in the VR context [4].

From a methodological standpoint, the customization of the VR environments should be based on the user experience field to provide information to design virtual scenarios coherently with users' needs [228].

As written above, relevant properties of personal memories would be organized in terms of macro and sub-categories (e.g., perceptual aspects such as form and colour of objects; content aspect, such as the meaning to be communicated through discourses present in the VR; etc.) and the system would operate such properties dynamically during any VR instance, to maintain a set level of immersion and the emotional reaction by the user, continually monitored through psychophysiological indexes.

To briefly recap, considering the above-mentioned premises, studying the user experience related to customized VR scenarios to promote relaxation has attracted interest in the scientific community although most of the studies published so far adhere to a theoretical perspective. In the following chapters, novel studies investigating the feasibility and applicability of customized virtual scenarios for relaxation will be illustrated to further understand the role of the customization component in VR scenarios.

2.4 Main research gaps to be further investigated

As described in this overview of the recent state-of-the-art studies, due to its descriptive potential, virtual reality technology is widely deployed in the mental health field [35]. The theoretical benefits of virtual reality-based therapy are clear, particularly for anxiety disorders. In this context, VR is valuable for providing exposure to natural and relaxing scenarios to improve relaxation and reduce distress and anxiety (e.g., [183]). Shreds of evidence in this field shed light on its application for clinical and non-clinical populations (e.g., [184, 185]). In general, the use of VR is helpful in overcoming several barriers that standard relaxation procedures present since it is less costly, promotes the availability of relaxing content that could be difficult to generate in imagination, it is able to promote the sense of presence, immersion, and engagement closer to what can be obtained in a real situation but in a safer context [151]. Moreover, VR technologies have the potential to offer a customized experience in virtual scenarios tailored to the needs and preferences of users. This user-centered approach can amplify the positive effect related to the virtual experience, allowing individuals to experience more realistic emotional conditions, like those experienced in everyday life, enhancing relaxation, the sense of presence, and a perception of security in the virtual context (e.g., [3,4]). Jeong et al. [215] preliminary study is one of the first that investigates the feasibility of an innovative VR-based relaxation program in which diaphragmatic breathing and PMR were deployed using a VR application focused on learning the relaxation strategies, reviewing, and doing exercises on what has been learned and practice in an outdoor VR scenario. Outcomes revealed that the virtual program deployed was feasible and shed light showing that, after PMR, the level of tension of participants in the VR condition was significantly lower than what was observed in the control group, suggesting that the relaxation program can be used by healthy individuals to practice and improve relaxation. Even if at a preliminary stage, the literature showed promising evidence inducing the structuring of research protocols in which virtual reality is included as a means to facilitate the delivery of relaxation protocols that work but can be hindered by various difficulties, including duration and cost. VR-based training can reduce the cost of treatment deployed in a standard modality, increasing the number of training scenarios thanks to the possibility of customizing and introducing elements that arouse a sensory stimulation more similar to reality than can be achieved with guided exposure in the imagination. Moreover, the use of VR and web-based training allow the users to learn from their personal site [231], avoiding the necessity of moving to the therapist's office. Indeed, in term of cost and site, web-based training are useful and effective in promoting self-training or rehabilitation (e.g., [232]) also because can be used in a safe context in which sessions can be accessible in a repetitive manner, whenever users like to practise, facilitating the learning process [215]. Based on current evidence-based studies, future research should further investigate the psychological benefits of natural virtual environments in VR relaxation, taking into account the variety of possible natural stimuli available [184]. Moreover, considering the lack of studies in this field, it is useful to further investigate VR's greater effect in reducing anxiety and promoting relaxation compared to GI.

The next chapter illustrates the results of three different studies aimed at investigating the feasibility and preliminary effectiveness of human exposure to personalized and customized VR scenarios to manage anxiety and promote relaxation. The VR scenarios were experienced alone or integrated with standardized relaxation techniques with the intent to increase and facilitate the deployment of interventions overcoming difficulties or gaps that characterize standard treatments.

PART 2

⊣⊢

THE RESEARCH STUDIES

CHAPTER 3.

CUSTOMIZED REALISTIC VIRTUAL REALITY SCENARIOS FOR RELAXATION

The current Chapter outlines the first study of the Ph.D. program published in the *International Journal of Environmental Research and Public Health* journal [233].
The research is a Proof-of-Concept study characterized by a cross-over and mixed-methods design primarily aimed at exploring the user experience of a sample of users from the general population exposed to customized and non-customized naturalistic virtual reality scenarios both integrated with a single-session Body Scan technique derived from the PMR. Furthermore, the current study had the objective of preliminary investigating if a customized VR context helps to support engagement, positive emotions, and in decreasing state-anxiety.
As stated in Chapter 2, the potentialities that the customization of auditory and visual virtual elements have in increasing relaxation, engagement, sense of presence, and security have been indicated by previous research. However, the lack of studies in this direction led us to conduct further investigation aimed at extending the state-of-the-art on the impact of customized VR scenarios, suggesting the role of customization as a promising component in facilitating engagement and promoting a higher perceived state of relaxation.

STUDY 1. Investigating the User-Experience of Customized Virtual Reality Environments for Relaxation: A Proof-of-Concept Study

3.1 Theoretical background and aims of the study

As mentioned in Chapter 1, different types of techniques and protocols enabling relaxation exist (e.g., Progressive Muscle Relaxation Technique, body scan, deep breathing, and meditation) and their contribution in promoting a general state of well-being is well recognized (e.g., 234). The Body Scan is a shorter and lower-cost technique based on progressive and gradual learning of moving attention to different parts of the body [235], with a significant impact on the promotion of somatic awareness and the management of distress (e.g., 236).

Even if the Body Scan technique is easy-to-use, standard relaxation procedures in a real context may be less practical to realize in several circumstances, and data suggest that VR can facilitate the learning of relaxation techniques through VR exposure to natural environments [1].

Digital interventions allow the reduction of the costs related to standard psychotherapy treatments (e.g., [237]), and highlight that being exposed to a virtual relaxing environment, including a body-scan-guiding audio track, may help improve the participants' relaxation [1].

Based upon this assumption, we considered that the users' perceptions need to be more deeply assessed. A systematic study of the user experience and usability related to the use of a technological tool is essential to understand and enhance the deployment of hardware and software components (e.g., [238]). The assessment of subjective experience and usability includes various elements that need to be tailored to the intended use of the virtual environment [238]. First, motion simulator disease must be evaluated as an element that can affect the VR experience and could include headaches, salivation, eye strain, nausea, and a general state of discomfort. The assessment of features related to the quality of VR graphics (e.g., resolution, movement of visual elements, shapes, colour contrast), physical performance, and synchronization (e.g., the delay between the user's movement into the virtual context and what the user expected to perceive), as well as user interface layouts is essential since they could influence the subjective experience. The assessment from the users' perspective helps in providing direct feedback from individuals and it permits obtaining different types of information, such as guidance support and a sense of presence [239]. Stanney et al. [240] suggested using the Multi-criteria Assessment of Usability for Virtual Environments (MAUVE) to systematically evaluate users' experience and usability in the VRE context. This evaluation system includes ten criteria divided into two main categories.

The Virtual Environment System Interface comprises:

- *Interaction features*: 1) "Wayfinding" (the possibility for the user to know their position and direction in the environment); 2) "Object Selection"; 3) "Manipulation"; 4) "Navigation" in the virtual environment.
- *Multimodal System Output,* including "Visual", "Auditory", and "Haptic" features.

The Virtual Environment User Interface is, in turn, divided into:

- *Engagement* (such as sense of presence and immersivity).
- *Side Effects* (comfort, sickness, after-effects).

To further understand the role of the customization component in VR scenarios, the main aim of our exploratory study was to investigate the experience of users to obtain preliminary data about preferences, pleasantness, satisfaction, engagement, immersivity, sense of presence, and the subjective perception of relaxation and state-anxiety when exposed to a standard or a customized relaxing Virtual Reality Environment. Inspired by the user experience's approach described above and to generate empirical evidence both from qualitative and quantitative data, we obtained information about the physical discomfort related to the heaviness or encumbrance of the head-mounted display, the simulator-sickness, the wayfinding, and the experience of the auditory and visual elements, both in the standard and customized scenarios. The study design was based on a mixed-methods approach inspired by the Obesity-Related Behavioral Intervention Trials (ORBIT) model since it helps in focalizing on the administration of behavioral treatment development at their pre-clinical and pre-efficacy phases. Indeed, the ORBIT framework [241] is generally used for the design (Phase Ib) of digital interventions and their preliminary testing (Phase IIa). In this phase, a proof-of-concept implementation of the customized VR scenario was realized, and preliminary testing was completed to investigate the level of engagement and the user experience with a convenience sample of non-clinical individuals. In this context, it is useful to apply a cross-over experimental design characterized by a within-subjects method where users act as their controls in a pre–post comparison. The sample size can be small because the focus is mainly on the user experience outcome, and sample size estimation is not required. Moreover, the sample can be selected from accessible individuals since this phase will aim to understand if the intervention deserves an increased depth of analysis, improvement, and further testing.

We hypothesized that: (1) relaxing VR scenarios promote relaxation and reduce state-anxiety symptoms; (2) the possibility of customizing the VR environment can be perceived as more engaging for users. Following a human-centered approach to enhancing the effect of standard interventions, we present below the main outcomes of our design and preliminary testing phases.

3.2 Methodology

3.2.1. The Virtual Environment Design

The hardware equipment was composed of an "Alienware m15 Ryzen Edition R5" workstation (CPU 5900HX, 32Gb ram, 1Tb SSD RTX3070 8Gb), a link cable (PC VR; USB 3 Type-C–

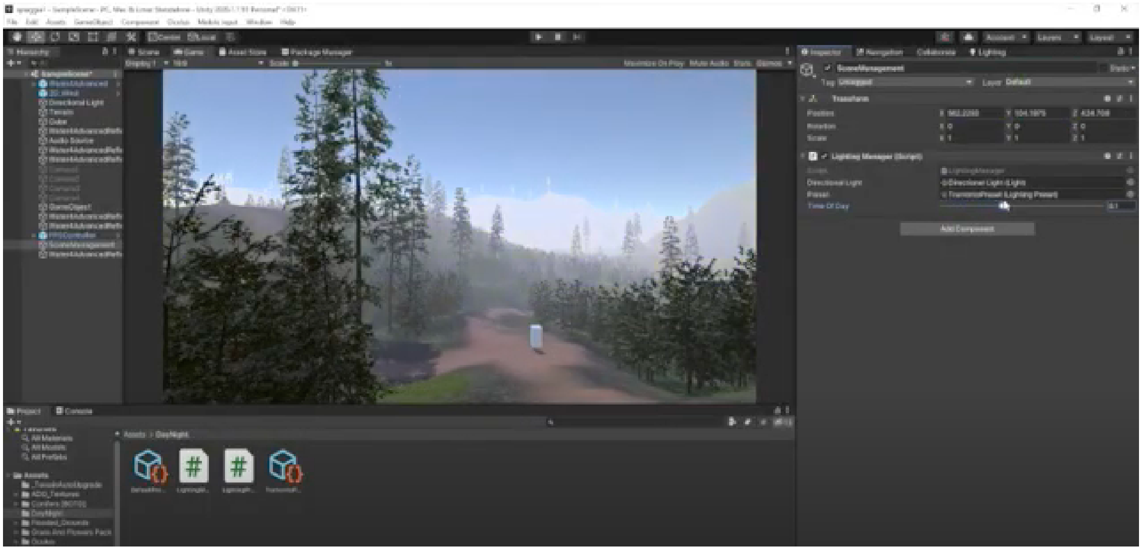
5m), and an Oculus Quest 2® head-mounted display connected to the workstation (see Figure 1).

Figure 1. Hardware equipment (Fig.A. Oculus Quest 2® head-mounted display; Fig.B. USB 3 Type-C–5m; Fig.C. Alienware m15 Ryzen Edition R5).

The Oculus Quest 2 was adopted because it is cheaper and easier to use than similar devices. This goes in the direction of our mission to expand the use of this framework for psychological treatment in daily life. Since, as described in Chapter 2, the auditory and visual stimuli in a virtual context are good enough to obtain a satisfactory relaxation state [242], the software environment was characterized by a series of 360° natural environments composed of auditory stimuli drawn from the freesound database[2], and the visual stimuli were developed based on Unity®[3], Polyhaven[4], and HDRIhaven[5] (in Figure 2 a picture depicted the ongoing process of making one of the virtual contexts).

[2] https://freesound.org/
[3] https://unity.com/
[4] https://polyhaven.com/
[5] https://polyhaven.com/hdris

Figure 2. A picture depicted the ongoing process of making one of the virtual contexts.



The VR environment was developed by the Digital Health Research Lab at Fondazione Bruno Kessler (FBK) Research Center (Trento, Italy). Figure 3 is a picture of the experimenters throughout the development process of the decision tree characterized by all of the functions that are visible on the PC and were useful to select the customized audio and visual stimuli.

Figure 3. The experimenters during the Decision Tree process.

Based on this set-up, users had the possibility to choose to have their preferred relaxing experience in one of three realistic scenarios that may be selected and customized with the support of a technical operator: a mountain, a marine, and a countryside environment. To build the virtual environments to allow a state of relaxation, we were inspired by indications from the literature on the main features to follow to build a relaxing context that promotes a perception of well-being (e.g., 1, 195, 243).

For each selected environment, the participants had the option to customize a series of sub-categories of components, including different types of sounds (e.g., animal sounds, wind rustle, type of music), visual stimuli (e.g., the presence of people, objects, or animals), the user position in the virtual space, the presence of people, and to change the time of day and weather conditions (examples are shown in Figures 4 and 5).

Figure 4. Example of the marine virtual space from the PC view with the series of icons related to the different customizable variables.

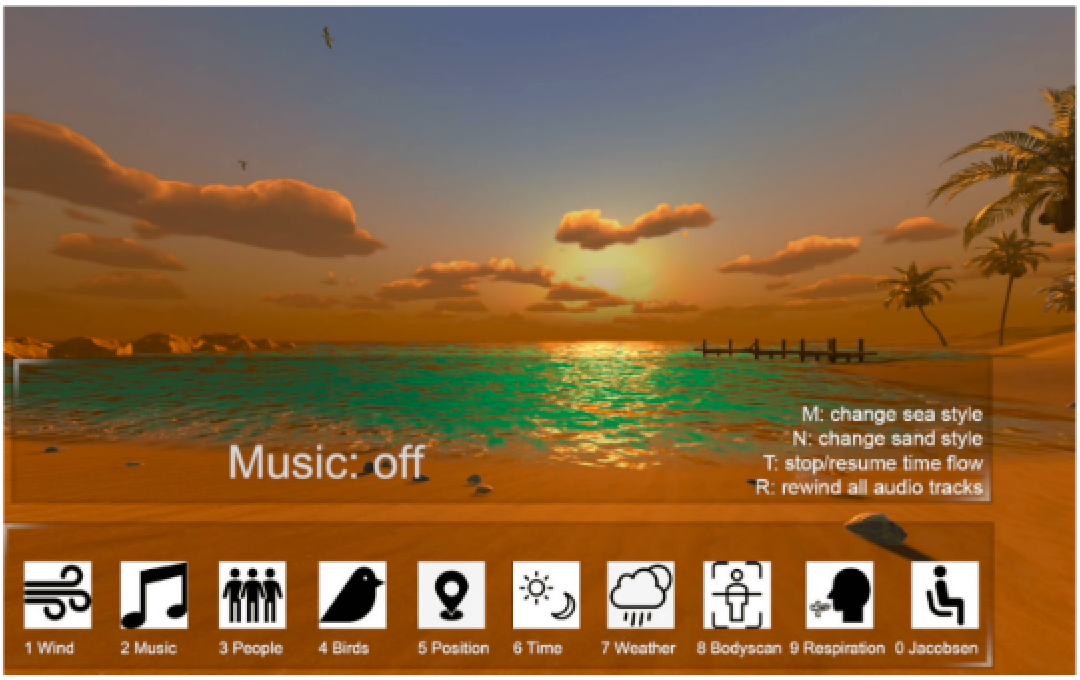
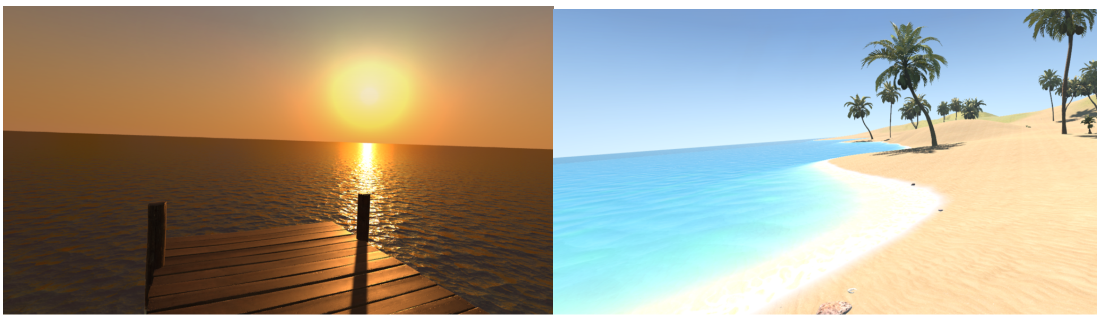
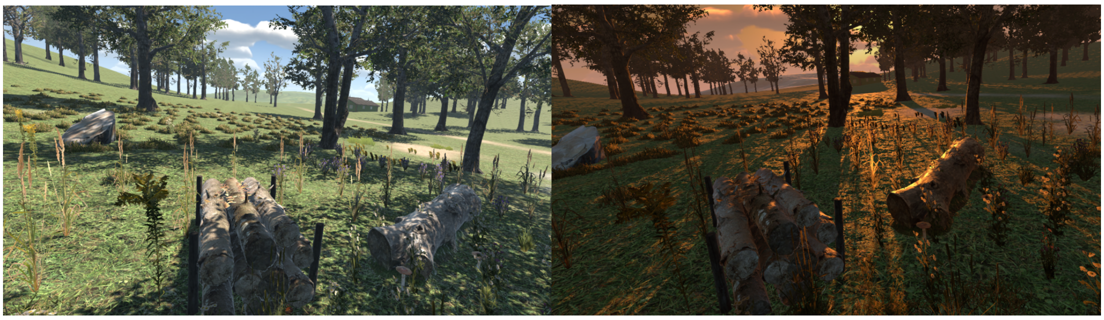


Figure 5. Examples of the different scenarios showed through the Oculus Quest 2 device.





The technical operator and the experimenter could personalize virtual scenarios based on a PC's dashboard interface connected to Oculus Quest 2 via a cable. Specifically, the interface presented a series of icons related to the different customizable variables (such as, music, wind, weather conditions, time of day, and presence of people) (Figure 4). The connection between the PC and the viewer allowed the operator to see what the participant was observing during the experience.

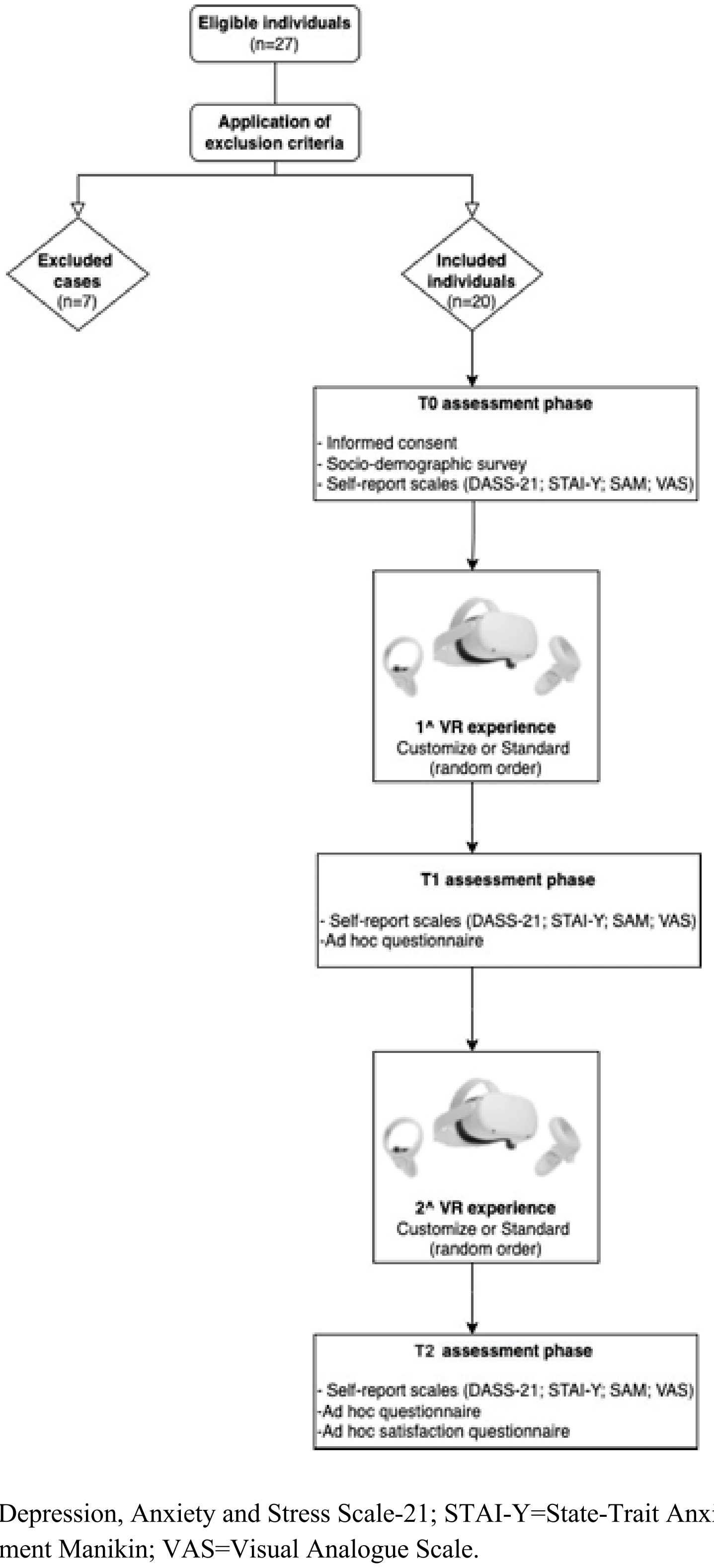
The natural VR scenario was integrated with a Body Scan audio track provided by the HMD that focused on the different parts of the body and sensations experienced in a gradual sequence. The audio track was adapted from the body scan exercise as part of the Mindfulness-Based Stress Reduction program and the PMR [9, 244]. The track lasted 7 min. The body scan technique was deployed in the current research by following the results of Pizzoli et al. [1], which showed that this technique had a more effective impact on relaxation than breathing exercises.

3.2.2. Participants Recruitment and Procedure

The current study is based on a convenience sample of individuals from the general population and was executed between 10 August 2021 and 25 September 2021. The recruitment phase is based on a snowball sampling method, carried out via email. All experimental sessions took place at the Center for Health and Wellbeing–Fondazione Bruno Kessler, Trento (Italy). The procedure phases are resumed in Figure 6.

A total of 27 individuals agreed to participate in the study. After applying the exclusion criteria, 20 were included in the analysis. The exclusion criteria were: 1) participant had a mental disorder diagnosis; 2) a score on the *State-Trait Anxiety Inventory-Y2* (STAI-Y2) indicating moderate or severe trait-anxiety levels (*raw cut point* > 50; [245, 246]; 3) a score > 9 on the *Depressive Anxiety Stress Scale-21* (DASS-21) - Depressive Scale; 4) a score > 6 on the *DASS-21 - Anxiety Scale*; 5) a score > 10 on the *DASS-21 - Stress Scale* [247, 248]. Seven of the participants were excluded since they did not meet the inclusion and exclusion criteria. In phase T0, individuals signed the informed consent to participate in the research. They also filled out a socio-demographic survey and a series of self-report scales to investigate distress, depressive and anxiety symptoms, the perceived relaxation level, and emotional states. Then, the participants were invited to wear the head-mounted display to be exposed to a short body-scan-guided relaxation session either with a default-standard VR condition or a customized Virtual Reality Environments (VREs). The order of presentation of each type of VR condition was randomized, and a mixed-methods approach was deployed to collect data. The customized VR experience was personalized according to the participant's preferences on the type of environment, music background, meteorological conditions, presence of objects or other participants, and daytime (first administration phase). Then, in phase T1, the individuals filled out the measures administered during phase T0 to measure their state of anxiety and emotions, in addition to an ad-hoc questionnaire deployed to collect evidence on usability, sense of presence, immersion, engagement, and VRE-related symptoms. Afterward, they were exposed to a second VR experience in a different virtual environment. During phase T2, the participants filled out the same self-report tools of phase T1. Then, the researchers asked the participants what VR conditions they preferred and if they had suggestions for improvements. The assessment procedure took about 45–50 min to be completed, the VRE personalization took approximately 10–15 min, and the Body Scan session lasted about 7 min. All participants knew they could ask to interrupt the experience at any stage (see Figure 6).

Figure 6. Flowchart of the procedure.



Notes: DASS-21=Depression, Anxiety and Stress Scale-21; STAI-Y=State-Trait Anxiety Inventory-Y1 and Y2; SAM=Self-Assessment Manikin; VAS=Visual Analogue Scale.

3.2.3 Materials used in the assessment phases

To investigate the study's primary constructs, we relied on the following self-report questionnaires and open-ended questions, typically used to measure VR scenarios, to collect quantitative and qualitative data:

- The *Socio-demographic survey* consisted of the following variables: gender, age, nationality, mother tongue, level of education, marital status, employment status, type of medical disorder/illness/disease (such as some neuromuscular disorders), or a psychological problem previously diagnosed. Participants were also asked to report if they were taking drugs, had already experienced relaxation activities to manage anxiety in the past, or were familiar with the use of virtual reality devices.
- The *Ad Hoc Questionnaire for Virtual Reality* investigating different aspects of Virtual Reality scenarios and User Experience was composed of the following sections:
  - 1) The *Virtual Reality Symptom Questionnaire (VRSQ)* [199, 249] is a dichotomous measure aiming to assess symptoms of cyber sickness. Eight items investigate general cybersickness effects, such as fatigue, headache, nausea, and concentration difficulties, and the other five are about visual effects, for example, blurred vision and tired eyes;
  - 2) The 36 items, based on a 7-point Likert scale, were inspired by the *Presence Questionnaire and the Immersive Tendencies Questionnaire* [158] and offered a qualitative set of information. The items investigating aspects, such as the realism of the environments (13 items) (e.g., "*How natural did your interactions with the environment seem?*"), engagement (three items) (e.g., "*I felt involved by the visual elements that surrounded me within the virtual environment*"), immersiveness (nine items) (e.g., "*How immersed were you in the virtual environment experience?*"), the tools' usability and quality of the interface (six items) (e.g., "*How much did the control devices interfere with the performance of assigned tasks or with other activities?*"), and emotional states (eight items) (e.g., "*During the experience, I felt tense*"), were modified to be adapted to the virtual reality environment;
  - 3) At the end of the entire procedure, an open-ended questions assessed if the participant preferred the standard or the customized VRE. Cronbach's alpha for each sub-group was calculated (0.69<Cronbach's alpha<0.88); 4) We

administered the ad hoc satisfaction questionnaire to assess the usefulness of the customized VRE (cVRE) body scan procedure; specifically, based on a dichotomous question, the participants were asked if they considered the body scan audio track helpful or not in promoting relaxation, and two open-ended questions were asked to investigate criticisms or suggestions for improvements.

- The *Depression, Anxiety and Stress Scale-21 (DASS-21)* [247, 248] is a self-report questionnaire of 21-items, seven items per subscale, investigating depression, anxiety, and stress. Items are answered according to the presence and intensity of symptoms in the last week on a 4-point Likert scale (0–3). Based on the original version, DASS demonstrated good internal consistency. In addition, psychometric analyses of the Italian samples showed that the questionnaire investigated general distress plus three additional orthogonal dimensions (anxiety, depression, and stress) and demonstrated good internal consistency, temporal stability, and criterion-oriented, convergent, and divergent validity. The DASS-21 reliability in this study population was adequate, with a Cronbach's alpha of 0.90 for the total score, 0.78 for the depression scale, 0.71 for the anxiety scale, and 0.90 for the stress scale.
- The *State-Trait Anxiety Inventory-Y (STAI-Y)* [245, 246] is a self-report questionnaire comprising two different 20-item scales investigating state- and trait-anxiety. State-Anxiety could be defined as a transitory anxiety reaction to an event, or a condition perceived as adverse, characterized by feelings of tension, apprehension, nervousness, and worry. Trait-Anxiety is, instead, a more stable feature related to perceiving stressful situations, such as dangerous or threatening situations in general, or as a frequency response in abnormal conditions. Each item is evaluated using a 4-point Likert scale (1–4). The total score for both scales ranges from 20 to 80, with higher scores indicating more severe anxiety. For the Trait-Anxiety score (investigated with the STAI-Y2), Cronbach's alpha was equal to 0.80, indicating a good internal consistency. Regarding the State-Anxiety (measured with the STAI-Y1), Cronbach's alpha indices for all three of the administrations ranged from 0.84 to 0.94.
- The *Self-Assessment Manikin (SAM)* [250, 251] is a non-verbal imagery-based assessment technique that directly measures the pleasure, arousal, and dominance associated with a person's affective reaction to various stimuli. The pencil-and-paper version required placing an "X" either on or between each of the five figures (resulting in a 9-point scale). The meaning of each scale is described to respondents, and they are asked to place the "X" on the figure (or between the figures) that best represents how

they currently feel. *Valence* is depicted from positive (a smiling figure), to neutral to negative (a frowning figure). Arousal ranges from high arousal (eyes wide open) to low arousal (eyes closed). When the same figures were used, the arousal scale also depicts the intensity of arousal with additional imagery over the abdomen area that ranges from high intensity (imagery representing an explosive-like burst) to low intensity (imagery representing a tiny pinprick). Finally, dominance/control ranges from feeling controlled or submissive (a petite figure) to feeling in control or dominant (a huge figure).

- The *Visual Analogue Scale (VAS)* measured relaxation and sense of presence before and after each VRE. Specifically, the participants had to express how relaxed they felt on a line of 10 cm in length (VAS_relax: 0 = not at all relaxed; 10 = completely relaxed; VAS_sense of presence: 0 = absent; 10 = complete). These data collection methods were deployed in parallel for a holistic and multidimensional understanding of the VR experiences. In Table 1, the data collection methods and their analysis are summarized.

Table 1. Summary of measuring instruments and data analysis performed.

Data collection method	Analysis captured
SOCIO-DEMOGRAPHIC SURVEY	*Descriptive analysis.* Frequencies, means, and standard deviations related to socio-demographics variables.
VIRTUAL REALITY SYMPTOM QUESTIONNAIRE	*Descriptive analysis.* Frequencies related to cybersickness variables.
QUESTIONNAIRE INSPIRED BY THE *PRESENCE QUESTIONNAIRE* AND THE *IMMERSIVE TENDENCIES QUESTIONNAIRE*	*Descriptive analysis.* Means and standard deviations. *ANOVAs repeated measures* to compare the self-reports scores taken at two different time points.
OPEN-ENDED QUESTION – VR SCENARIO PREFERRED	*Descriptive analysis.* Thematic analysis, Frequencies related to what VR scenario has been preferred.
AD HOC SATISFACTION QUESTIONNAIRE	*Descriptive analysis.* Frequencies.
DEPRESSION, ANXIETY AND STRESS SCALE-21 STATE-TRAIT ANXIETY INVENTORY-Y SELF-ASSESSMENT MANIKIN VISUAL ANALOGUE SCALE	*ANOVAs repeated measures* and *Paired-samples t-tests*.

3.3 Results

Anonymized data were processed by using SPSS Statistics version 27 software [252]. Based on the DASS-21 and the STAI-Y distributions, the range of skewness and kurtosis was from −0.974 to 1.408, falling between −2 and +2. For this reason, data are reasonably normally distributed [253, 254]. Moreover, the Kolmogorov–Smirnov and the Shapiro–Wilk tests were carried out for the DASS-21 total score, the STAI-Y2 total score, the STAI-Y1 pre-VR exposure, the STAI-Y1 post-standard VR exposure, and the STAI-Y2 post-personalized VR exposure; data were not statistically significant (*p-values*>.05), and this constitutes further evidence of the normal data distributions. First, Cronbach's alpha was performed for each self-report questionnaire's subscales. Secondly, the frequencies, means, and standard deviations were calculated to explore the sociodemographic features. To control the order effect of the VR scenarios (standard VRE versus cVRE), multivariate ANOVAs were conducted considering all of the questionnaires administered at the two different time points after the standard and cVR experience. Descriptive data about users' experiences, preferences, and engagement were derived from the frequencies. Moreover, the participant's responses to the open-ended question relating to the preferred VR scenario were analyzed by SP and SC using thematic analysis and reported as frequencies. Data were analyzed thematically following an inductive, data-driven approach based on the procedure outlined by Braun and Clarke [255]. The data codes were consistently generated, grouped into themes, and applied to the data set to generate frequencies. ANOVAs repeated measures were calculated for the psychological scales assessed at different time points (T0, after the standard or customized VRE). Paired-sample t-tests were performed to compare the self-report scores taken at three different time points (T0, after standard or customized VRE) and to investigate the impact of the VRE scenarios on the psychological constructs analyzed. A *p-value* equal to or less than .05 was considered statistically significant.

3.3.1 Preliminary Analysis

A comparison between groups was made to control the order effect of the standard and customized VR scenarios (see Table 2). No statistical differences emerged, meaning the two VRE scenarios' administration order had no effect.

Table 2. Comparison between randomization orders.

	Randomization order group	M (SD)	F (1,18)	p
SAM_V_T1	1 2	3.5 (1.1) 2.8 (1.5)	1.47	ns
SAM_A_T1	1 2	5.2 (2.4) 7.2 (1.9)	4.13	ns
SAM_D_T1	1 2	4.8 (2.2) 6.2 (1.7)	2.55	ns
VAS_RELAX_T1	1 2	7.8 (1.6) 8.2 (1.1)	0.43	ns
VAS_PRESENCE_T1	1 2	6.6 (2.4) 7.9 (2.1)	1.67	ns
SAM_V_T2	1 2	2.4 (0.8) 2.1 (1.3)	0.64	ns
SAM_A_T2	1 2	5.8 (2.7) 7.4 (2.1)	2.22	ns
SAM_D_T2	1 2	5.6 (1.7) 6.4 (1.7)	1.18	ns
VAS_RELAX_T2	1 2	7.6 (0.9) 8.4 (0.9)	2.95	ns
VAS_PRESENCE_T2	1 2	7.6 (0.9) 8.4 (0.9)	3.43	ns
STAI-Y1_T1	1 2	28.2 (7.6) 27.1 (4.5)	0.16	ns
STAI-Y1_T2	1 2	25.2 (3.9) 25.6 (4.7)	0.04	ns
REALISM_T1	1 2	100.2 (14.3) 103.2 (19.8)	015	ns
REALISM_T2	1 2	105.1 (17.5) 108.6 (12.9)	0.26	ns
ENGAGEMENT_T1	1 2	10.9 (2.2) 10.6 (2.9)	0.07	ns
ENGAGEMENT_T2	1 2	10.3 (2.9) 12.3 (1.4)	3.82	ns
IMMERSIVITY_T1	1 2	11.8 (5.5) 13.9 (3.1)	1.81	ns
IMMERSIVITY_T2	1 2	17.2 (1.5) 16.1 (2.4)	1.11	ns
USABILITY_T1	1 2	17.1 (3.1) 14.1 (3.7)	3.86	ns
USABILITY_T2	1 2	16.5 (3.5) 15.1 (3.4)	0.82	ns
EMOTIONAL STATE_T1	1 2	46.7 (7.5) 43.80 (8.4)	0.66	ns
EMOTIONAL STATE_T2	1 2	45.70 (7.1) 47.30 (6.1)	0.30	ns

Notes: T0 (assessment before VREs); st (assessment after standard VRE); p (assessment after customized VRE); M (SD)= Mean (Standard Deviation); DASS_Tot= Depression, Anxiety and Stress Scale-21_Total score; DASS_D= Depression, Anxiety and Stress Scale-21_Depression scale; DASS_A= Depression, Anxiety and Stress Scale-21_Anxiety scale; DASS_S= Depression, Anxiety and Stress Scale-21_Stress scale; STAI-Y2= State-Trait Anxiety Inventory-Y2 (regarding trait anxiety features); STAI-Y1= State-Trait Anxiety Inventory-Y1 (regarding state anxiety features); SAM_V= Self-Assessment Manikin_Valence; SAM_A= Self-Assessment Manikin_Arousal; SAM_D= Self-Assessment Manikin_Dominance/Control; VAS= Visual Analogue Scale.

3.3.2 Sociodemographic Characteristics of Participants

The current sample was composed of 16 (80%) women. The mean age of the participants was 34.2 (SD = 10.6; min.: 19; max.: 58), and the mean of the school years was 18.9 (SD = 3.6; min.: 11; max.: 26). Twelve (60%) of the participants were single or non-cohabitant, and eight (40%) were married or cohabitant. Nine (45%) participants were pursuing a Ph.D. program, one was a university student, and ten (50%) were employed. No participant had a diagnosed psychological problem. Seven (45%) participants were familiar with relaxation techniques to manage anxiety and stress symptoms, and six (30%) had previously experienced VR for entertainment. Means and standard deviations of total and subscales self-report scales are described in Table 3.

Table 3. Means and Standard Deviations related to self-report scales' scores.

Questionnaire	M (SD)
DASS_Tot	9.9 (6.9)
DASS_D	2.5 (2.5)
DASS_A	1.7 (1.9)
DASS_S	5.7 (3.6)
STAI_Y2	34.9 (6.1)
STAI_Y1 (T0)	32.7 (9.1)
STAI Y1 (st)	27.7 (6.1)
STAI Y1 (p)	25.4 (4.2)
SAM_V (T0)	3.3 (0.7)
SAM_V (st)	3.2 (1.3)
SAM_V (p)	2.2 (1.1)
SAM_A (T0)	5.5 (1.7)
SAM_A (st)	6.2 (2.4)
SAM_A (p)	6.6 (2.5)
SAM_D (T0)	5.5 (1.4)
SAM_D (st)	5.5 (2.1)
SAM_D (p)	6 (1.7)
VAS_Relax (T0)	5.9 (1.6)
VAS_Relax (st)	8 (1.3)
VAS_Relax (p)	8.2 (1.6)
VAS_Sense of Presence (st)	7.3 (2.3)
VAS_Sense of Presence (p)	8 (1.1)
Realism (st)	101.7 (16.9)
Realism (p)	106.9 (15.1)
Engagement (st)	10.8 (2.6)
Engagement (p)	11.3 (2.5)
Immersivity (st)	12.9 (4.5)
Immersivity (p)	16.6 (2.1)
Usability (st)	15.6 (3.7)
Usability (p)	15.8 (3.4)
Emotional_state (st)	45.3 (7.9)
Emotional state (p)	46.5 (6.4)

Notes: T0 (assessment before VREs); st (assessment after standard VRE); p (assessment after customized VRE); M (SD)= Mean (Standard Deviation); DASS_Tot= Depression, Anxiety and Stress Scale-21_Total score; DASS_D= Depression, Anxiety and Stress Scale-21_Depression scale; DASS_A= Depression, Anxiety and Stress Scale-21_Anxiety scale; DASS_S= Depression, Anxiety and Stress Scale-21_Stress scale; STAI-Y2= State-Trait Anxiety Inventory-Y2 (regarding trait anxiety features); STAI-Y1= State-Trait Anxiety Inventory-Y1 (regarding state anxiety features); SAM_V= Self-Assessment Manikin_Valence; SAM_A= Self-Assessment Manikin_Arousal; SAM_D= Self-Assessment Manikin_Dominance/Control; VAS= Visual Analogue Scale.

3.3.3 Qualitative Results

In the next sub-paragraphs, information about the user acceptance of the hardware- and software- variables characterizing the VR experiences is provided.

- *Is the VRE Preferable with or without the Body Scan Audio Track?*

The participants' reports regarding the VR experiences and the body scan audio track showed that the body scan was considered helpful in promoting relaxation by 18 (90%) of the participants. Two individuals considered this track useful if administered alone; they reported having difficulty concentrating on the environment and the audio track content simultaneously and expressed interest in trying the experience with the audio track by imagining the relaxing environment.

- *Usability, Physical Discomfort in Wearing the Head-Mounted Display, and Simulator Sickness*

All of the users affirmed that Oculus was very easy to wear and use since the experimenter provided technical support during the session. Six (30%) individuals recommended improving the Oculus Quest 2 wearability to allow greater grip and more comfort. In the suggestion section, three of them stated that they would prefer to choose the position in which to stay during the activity (e.g., lying down), and also to manage the feeling of heaviness and encumbrance associated with the head-mounted display. Regarding the assessment of the cybersickness symptoms, two (10%) of the participants referred to mild headaches and burning eyes experienced towards the end of the VRE session with the Oculus exposure.

- *Graphics Quality, Synchronization, and Wayfinding VRE-Related*

Information on the graphic quality was obtained about the perception of the audio and visual elements. All participants reported that audio stimuli, such as animal sounds, wind rustle, and wave movement, felt good and were consistent with the scenario. As for the visual elements, all of the individuals appreciated the colors and shapes of the objects that made up the context, evaluating them as very or totally engaging and very similar to reality. All of the individuals felt able to actively explore the environment as they decided to move their heads and gaze into the virtual context. Moreover, the way they moved around the VR scenarios and the synchronization between their movement and what they saw seemed very (15 participants; 75%) or extremely (five participants; 25%) realistic to them. Moreover, users expressed a need to know their position and direction in the VREs.

- *Realism of the Virtual Environments*

Regarding the level of realism of the auditory and visual elements offered by the VREs, nine (45%) individuals considered the animal sounds very similar to reality (e.g., the sound of birds), 10 (50%) found the meteorological sounds extremely realistic (such as the wind and raindrops), and nine (45%) of the participants appreciated the way that the visual effects related to the meteorological conditions. Seven (35%) individuals evaluated the placement of the visual elements in the environment as very similar to a real context. Six (30%) of the participants affirmed that the colors, lights, and reflections at the transition from one moment to another of the day were very similar to real stimuli, and nine (45%) considered the movement of birds and clouds to be realistic. Moreover, most of the participants (16; 80%) did not appreciate the presence of humans in the VR context. They instead preferred to imagine the presence of someone close to them during the VR experience. Finally, five (25%) users specified that the perception of the countryside's synchronous movement of the leaves and flowers was artificial, suggesting a less uniform fluctuation.

- *Preferred VR Environment between Standard and Personalized*

Eighteen (90%) of the individuals preferred the customized environment. All participants expressed a subjective point of view based on their preferences. Overall, four main themes were identified as the most influential factors affecting the participants' choices in the VREs for relaxation (Table 4): (1) the correspondence with the environment they would have chosen in a real context (relaxing as in reality); (2) the reminiscence; (3) the possibility to choose and control the elements of the VRE (control); (4) the realism of the stimuli (see Table 4).

Table 4. Themes and quotes by users.

Main theme	User quotes
"Relaxing as in reality"	„Especially for the birdsong which is what I feel when I rest in the country" (**Participant 2**). „I preferred the personalized environment because it reflects more of a context in which I relax in reality" (**Participant 9**). „I find it easier to relax in the mountains" (**Participant 10**). „Because, even in reality, when I have to relax I choose to go to the seaside" (**Participant 11**). „The elements around me reflected an environment that generally makes me feel good, and relaxed" (**Participant 8**). „If I want to take a break from everything, I usually go to the mountains" (**Participant 3**). „I could select a context that generally relaxes me" (**Participant 13**). „I usually feel more comfortable at the seaside, that's why I chose it" (**Participant 6**). „I prefer the seaside to the countryside in reality. I can associate it more with a sense of relaxation" (**Participant 16**). „There were elements that helped me to relax as in everyday life" (**Participant 5**). „This is very similar to my favorite place in reality" (**Participant 7**). „It is similar to the place where I feel better about relaxing" (**Participant 17**). „Because it represents a context that recalls the relaxing places in reality, and this was helpful" (**Participant 18**). „I could recreate a more similar environment to the one that really relaxes me" (**Participant 14**). „It was similar to the beach I choose to relax" (**Participant 12**). „The seaside is one of the environments that I choose when I want to relax and disconnect my head" (**Participant 19**).
"Reminiscence"	„The countryside scenario reminds me of the area from which I come. This makes me feel at home" (**Participant 1**). „The very fact of having been able to choose" (**Participant 15**). „I chose the mountain environment because I associated many beautiful memories with it" (**Participant 9**). „Also, because, as a child, I always went to the seaside, and it was beautiful. This context somehow reminded me of it" (**Participant 19**).
"Control"	„I decided what to insert in the environment. Then I liked it more!" (**Participant 17**). „First of all because I could decide" (**Participant 19**). „It was my choice" (**Participant 16**).
"Realism of the stimuli"	„In the standard context I found more elements similar to reality, I felt more comfortable" (**Participant 20**). „The seaside seemed more like reality and, although it was not the environment I had chosen, in the end I preferred it" (**Participant 4**).

Of these 18 users, 16 (89%) said it represented the real context in which they would choose to relax, and they found the possibility of customizing the elements very important, to make the VRE more alike not only the preferred context but also the place in the real world where they would go to relax. Three (17%) individuals reported that the most important thing related to customization was the perception of controlling and deciding the setting, which was felt to be very impactful on their motivation to practice VR relaxation experiences. Four (22%) of the participants reported that the chosen VRE and the way they could personalize it reminded them of the places they experienced in their childhood. Even though they might have found another virtual setting more realistic, they chose the one in which they would relax better as, in their opinion, this had a significant impact on the possibility of experiencing a subjectively adequate level of relaxation. Finally, two (10%) individuals preferred the standard VR environment saying that by finding it more realistic, they felt much more comfortable in that setting.

- *Differences between Self-Report Administration after Standard and Customized VR Experiences about Immersivity, Sense of Presence, Realism, Engagement, Usability, Subjective Arousal Perception, Sense of Relaxation, and Pleasantness*

Even if the order effect of exposure to the two VR scenarios was controlled, a within-subject design was limited by the possibility that the participants realized the aim of the research, affecting their responses. In this regard, the following analyses were conducted to inform our design, by considering the subjective experience that the participants had when they were exposed to the standard and customized VREs. Comparisons using Multivariate ANOVA, between the assessments conducted after the standard and customized VRE, showed a difference for the Immersivity scale ($F_{(1,19)}$=11.33; *p-value*<.01; $\eta 2$=0.37) with a higher sense of immersivity experienced after the customized VR condition compared to the standard one. No differences emerged for the *Usability* ($F_{(1,19)}$=0.10; *p-value*>.05), the *VAS_Sense of Presence* ($F_{(1,19)}$=2.75; *p-value*>.05), the *Realism* ($F_{(1,19)}$=3.54; *p-value*>.05), the *Engagement* ($F_{(1,19)}$=1.06; *p-value*>.05), and the *Emotional State scales* (F(1,19)=0.57; *p-value*>.05). Repeated Measures ANOVA, conducted to compare the three assessment phases, showed statistically significant differences between the three assessment time points (T0-T1-T2) for the STAI-Y1 ($F_{(2,18)}$=12.21; *p-value*<.001; $\eta 2$=0.58), the *SAM-Valence* ($F_{(2,18)}$=8.49; *p-value*<.05; $\eta 2$=0.49), the *SAM-Arousal* ($F_{(2,18)}$=4.21; *p-value*<.05; $\eta 2$=0.25), and the *VAS-relax* ($F_{(2,18)}$=50.56; *p-value*<.001; $\eta 2$=0.85). No differences emerged for the SAM-Dominance ($F_{(2,18)}$=1.47; *p-value*>.05). Paired-sample t-tests were conducted as a post-hoc analysis to understand the origins of the differences between the three assessment time points. As shown from the STAI-Y1 and the VAS relax scale (Table 5), state-anxiety symptoms were higher before both the standard and the customized VR experiences. Indeed, individuals expressed, on average, a lower feeling of relaxation and more intense activation and anxiety levels before the exposure to both of the VR scenarios (t STAI (T0)/STAI (st)=3.20; *p-value*<.01; t STAI (T0)/STAI (p)=4.97; *p-value*<.001; t VAS_rel (T0)/VAS_rel (st)=−6.25; *p-value*<.001; t VAS_rel (T0)/VAS_rel (p)=−2.52; t SAM_A (T0)/SAM_A (p)=−2.46; *p-value*<.05). Moreover, higher relaxation levels were experienced after the customized VR experience rather than the standard one (t STAI (st)/STAI (p)=2.20; *p-value*<.05; t VAS_rel (st)/VAS_rel (p)=−9.95; *p-value*<.001). Regarding the Valence of emotions, the participants referred to having experienced a greater degree of pleasantness after the customized VR setting (t SAM_V (T0)/SAM_V (p)=3.80; *p-value*<.01; t SAM_V (st)/SAM_V (p)=2.97; *p-value*<.01).

Table 5. Paired Samples t-Test between psychological constructs administered at three different times.

	t (1,19)	***p-value***
STAI Y1 (T0) / STAI Y1 (st)	**3.20**	**<.01**
STAI Y1 (T0) / STAI Y1 (p)	**4.97**	**<.001**
STAI Y1 (st) / STAI Y1 (p)	**2.20**	**<.05**
SAM_V (T0)/ SAM_V (st)	0.42	ns
SAM_V (T0) / SAM_V (p)	**3.80**	**<.01**
SAM_V (st) / SAM_V (p)	**2.97**	**<.01**
SAM_A (T0) / SAM_A (st)	-1.58	ns
SAM_A (T0) / SAM_A (p)	**-2.46**	**<.05**
SAM_A (st) / SAM_A (p)	-1.29	ns
VAS_relax (T0) / VAS_relax (st)	**-6.25**	**<.001**
VAS_relax (T0) / VAS_relax (p)	**-2.52**	**<.05**
VAS_relax (st) / VAS_relax (p)	**-9.95**	**<.001**

Notes: T0 (assessment before VREs); st (assessment after standard VRE); p (assessment after customized VRE); M (SD)= Mean (Standard Deviation); STAI-Y1= State-Trait Anxiety Inventory-Y1 (regarding state anxiety features); SAM_V= Self-Assessment Manikin_Valence; SAM_A= Self-Assessment Manikin_Arousal; SAM_D= Self-Assessment Manikin_Dominance/Control; VAS= Visual Analogue Scale.

3.4 Discussion

The primary aim of the current research was to investigate usability, preferences, pleasure, satisfaction, engagement, immersivity, sense of presence, and the subjective perception of relaxation and state-anxiety of users whether being exposed to a standard or a personalized relaxing VREs, concurrently with a body scan audio track. The presence of an audio track integrated with the VR scenario was appreciated by most of the individuals who considered this complementary approach a useful strategy for focusing their attention on the activity and promoting relaxation. This feature deserves further investigation by further studies that should include other conditions in which users experience either the audio track or the VR scenario alone. Regarding the device's usability, wearing the head-mounted display interfered to a limited extent with exposure to the VRE. To inform our future studies, it will be essential to consider some of the participants' recommendations about the possibility of improving the Oculus Quest 2 fit by adopting a peculiar support (e.g., a faceplate head, a strap mount) for the head-mounted display that balances the distribution of the device's perceived weight, reducing interference. Useful self-reported indications were also obtained about the synchronization and wayfinding of the VRE and the auditory stimuli that contribute to rendering visual stimuli and the experience in general, more realistic. One interesting finding concerns the presence of virtual persons in VRE. While the depiction of people was not generally appreciated, most participants reported having a tendency to imagine at least another person in the virtual reality scenario. This underlines the potential contribution of imagination to the recreation of a realistic context of relaxation if the elements also represent human beings. A higher sense of immersivity was referred to by the users when they had the opportunity to customize the VRE. This means that customization has generated a greater feeling of being present in the VR environment [158, 256]. Participants experienced a higher level of comfort after the customized virtual reality experience. Interestingly, based on their self-reporting, the factors that contributed to the pleasure and preference for customized virtual scenarios were: (1) the correspondence of the customized VR with the relaxing context they would have chosen in reality; (2) the reminiscence; (3) the possibility of choosing and controlling elements in the VR context; (4) the realism of the stimuli. Regarding users' preferences for the customized or standard VR scenarios, no differences emerged in our sample between male and female participants, both from a preliminary quantitative analysis and a qualitative assessment. Other studies have shown how useful virtual reality can be to promote relaxation and reduce anxiety [1, 183, 257]. In line with these outcomes, our data suggest that exposure to a VR relaxing environment promoted the perception of reduced state-anxiety symptoms and facilitated a sense of relaxation, independently of the possibility to customize the VR context per se. Furthermore, when users had the opportunity to customize the virtual scenarios to build their preferred relaxing environment, they felt a more subjective state of relaxation than when they experienced the standard VRE. These findings on customization hold promise as they highlight the importance of deploying a user-centric design approach [3, 5] in adapting the VRE stimuli to fit the needs of individuals and to promote a positive attitude and a better engagement with the relaxation training. Customization can also help make virtual contexts more enforceable than standard VRE. Future studies are expected to shed more light on this. The study of different types of relaxation training techniques (e.g., body scan, diaphragmatic breathing, PMR), embedded in different types of VREs (e.g., customized versus standard) should be further investigated in relation to the control group conditions. At times, even well-established and effective training relaxation programs are not appreciated by the participants. Indeed, in the current research, two individuals reported experiencing boredom and discomfort with the body scan technique, adding that the experience was engaging only thanks to the VRE. Otherwise, they did not appreciate the relaxation training, considering it too dull. Thus, integrating exposure to relaxation training with VRE could also help to better fit users' needs and support motivation to learn a valid relaxation technique that would not be experienced alone. Even if the current research and other studies have begun to investigate the combined role of VRE and relaxation training, so far, the results are still preliminary to prove that a specific relaxation technique, alone or combined with a VRE, is more efficient than others [1]. Therefore, randomized controlled studies should be conducted, comparing different experimental conditions with appropriately sized samples. Since not all of the relaxation training could be suitable for each person, it is empirical to consider individuals' preferences and characteristics by investigating customization and promoting the validation of more specific and appropriate treatment protocols based on the users' needs. Furthermore, the relaxation training described in this study involves an active role of the individual in promoting relaxation. Future studies may evaluate the role played by coping strategies and the Locus of Control [258] in influencing anxiety to understand if having an internal LoC could help to promote a better sense of relaxation by using the learning acquired during the procedure. As well, it would be interesting to determine if coping strategies change over time by comparing the pre-and post-exposure assessment. Another relevant aim for future investigations should be to evaluate in more depth the positive emotions experienced during the procedure and investigate the impact of the vividness of visual imagery on the sense of presence perceived during VR exposure [259]. This study has some limitations that affect the generalizability of our findings. The sample size limits the studies reliability. The experimental conditions were not compared with a control group, limiting the findings' relevance for clinical practice. Nevertheless, the current study's findings are encouraging, but controlled and randomized trials should be conducted to investigate the efficacy of this type of digital relaxation intervention, including the deployment of a between-subject design approach to control intervention, including the deployment of possible "experimental demand" bias. It would be useful to stratify the participants' sample according to socio-demographic variables, and to increase its size. Future studies could also include validated standardized surveys of the local target population. Ultimately, together with the effective self-report questionnaires administered in this work, future studies may also foresee deploying more objective physiological assessment methods, such as skin conductance and heart rate variability measures to assess relaxation and state-anxiety.

3.5 Conclusions

The described study extends the state-of-the-art research on the impact of customized VREs, suggesting the role of customization as a promising component in facilitating engagement, and promoting a higher perceived state of relaxation. These preliminary results contribute to the planning of future studies investigating the effect of relaxation training in customized VREs on large-scale clinical and non-clinical samples. The efficacy and effectiveness of VRE for relaxation are likely to encourage the deployment of these digital interventions to promote mental well-being, making them more sustainable and scalable in the clinical practice. Overall, the personalization of clinical interventions by deploying a user-centered design approach helps to better consider people's needs to improve their motivation and engagement, with positive implications for their well-being. Our exploratory outcomes are promising for implementing between-subject experimental design studies that should also be focused on deploying VR settings to improve and manage limits related to mental relaxing imagery techniques. This field of investigation could shed more light on the role of VR environments in favoring relaxation and autonomy, reducing costs, and improving the deployment of treatments, particularly needed during pandemic conditions. Access to effective online relaxation training protocols can be beneficial for administering psychological interventions, especially in situations where there are restrictions to face-to-face treatment. In conclusion, the current research's findings provide a better understanding of the user experience and preferences for the customization of

VREs for relaxation, paving the way for more extensive future analyses on the role of these solutions in supporting digital interventions for mental well-being.

CHAPTER 4.

CAN CUSTOMIZED, RELAXING VIRTUAL REALITY SCENARIOS ENHANCE EFFICACY IF ADMINISTERED WITH WEB-BASED PROGRESSIVE MUSCLE RELAXATION TRAINING? AN INNOVATIVE COMPLEMENTARY METHOD

The present chapter provides an overview of the second study of the Ph.D. program. The related research protocol is published in the *Journal of Medical Internet Research - Research Protocol* [260], and the results related to the principal aims of the project are under review by the *Journal of Medical Internet Research - Mental Health* (Pardini et al., under review). The current research is registered as a clinical trial in a publically accessible primary register that participates in the WHO International Clinical Trial Registry Platform (ClinicalTrials.gov; registration number: NCT05478941; link: https://clinicaltrials.gov/ct2/show/NCT05478941).

The current contribution is about a longitudinal, between-subjects, 3-armed randomized controlled trial aiming to compare three treatment conditions to investigate the impact on state anxiety of Progressive Muscle Relaxation Technique (PMR), associated with a customized, relaxing scenario in Virtual Reality (VR), and the role of VR scenarios in facilitating the recall of relaxing images and the sense of presence in the virtual environment. A secondary objective is to understand if two different web-based relaxation intervention strategies (deployed by Zoom platform or based on a structured series of audio-track) can contribute to reducing anxiety and stress.

As stated in the previous Chapter 1 and 2, VR can facilitate exposure to stressful or relaxing stimuli and enables individuals with difficulties visualizing scenes to be involved in a more realistic sensorimotor experience. It also facilitates multisensory stimulation, the sense of presence, and the achievement of relaxation. VR scenarios representing visual and auditory elements of natural relaxing environments can facilitate the learning of relaxation techniques such as PMR. As aforementioned in Chapter 1, a complementary standardized technique deployed to reduce anxiety symptoms is the integration of PMR and Guided Imagery (GI). Indeed, exposure to a pleasant imaginary environment can help establish an association between a relaxing scenario and the relaxation technique, consequently promoting relaxation. Empirical evidence has shown that VR scenarios can positively impact the effects of relaxation techniques by enabling people to experience emotional conditions in more vivid settings (e.g., [183, 195, 198]). The findings from the literature, including the current study, will help shape the experimental design to be applied to future randomized controlled trials, also considering clinical samples. Results outline how VR could be considered a more engaging and helpful technique in promoting relaxation and decreasing anxiety levels than GI by making visualization more accessible and helping people face more realistic sensory experiences. Assessing the efficacy of the PMR in alternative delivery modes may extend its applications, especially in situations where the standard procedure is more challenging to be administered. To our knowledge, an equivalent study has yet to be published on this matter.

STUDY 2. CUSTOMIZED, NATURALISTIC VIRTUAL REALITY SCENARIOS COUPLED WITH WEB-BASED PROGRESSIVE MUSCLE RELAXATION TRAINING FOR THE GENERAL POPULATION: A PILOT STUDY

4.1 Theoretical background

4.1.1 Virtual Customized Scenarios as an alternative to Guided Imagery

In working adults and university students, the prevalence of anxiety and stress is increased, predisposing to physical diseases and general repercussions on well-being [261, 262].

The situation has worsened with the SARS-Cov-2 outbreak, which has impacted individuals' general well-being worldwide [263, 264]. Different types of standardized relaxation interventions (e.g., Mindfulness-based Stress Reduction, Jacobson's Progressive Relaxation Techniques, Schultz's Autogenic Training, Abdominal Relaxations, and Visualizations) before, during, and after SARS-Cov-2 have been shown to reduce anxious and stressful symptomatology in university students [264, 265] with a more significant effect when integrated with other complementary techniques such as GI [17, 19]. GI is useful in creating mental imagery and refocusing attention on pleasant and relaxing imagined visual, auditory, tactile, or olfactory sensations, resulting in specific psychological and physiological responses, such as relaxation reduction of the autonomic nervous system responses [17, 266, 267].

As more broadly stated in Chapter 1, the PMR is considered one of the most effective and adaptable techniques for relaxation, anxiety management, and stress reduction considering different kinds of target populations (e.g., non-clinical individuals, patients with cancer, chronic pain, osteoarthritis, heart disease, chronic headache, anxiety, and depression) [1, 6, 22, 233, 268]. Complementary methods that imply the administration of integrated cognitive and behavioral procedures are studied to manage anxiety, stress, depression, and pain, particularly in populations such as patients with cancer. Notably, the integration of PMR and GI enhances and facilitates the effect of relaxation, reducing anxiety and depression symptoms [1, 3]. The integration of PMR and GI can promote a higher sense of relaxation during training sessions, allowing the application of complementary techniques to cope with stress experienced in daily activities [17, 269-272]. As stated before, the GI technique permits to imagine an undefined number of scenarios that are subjectively perceived as relaxing and safe.

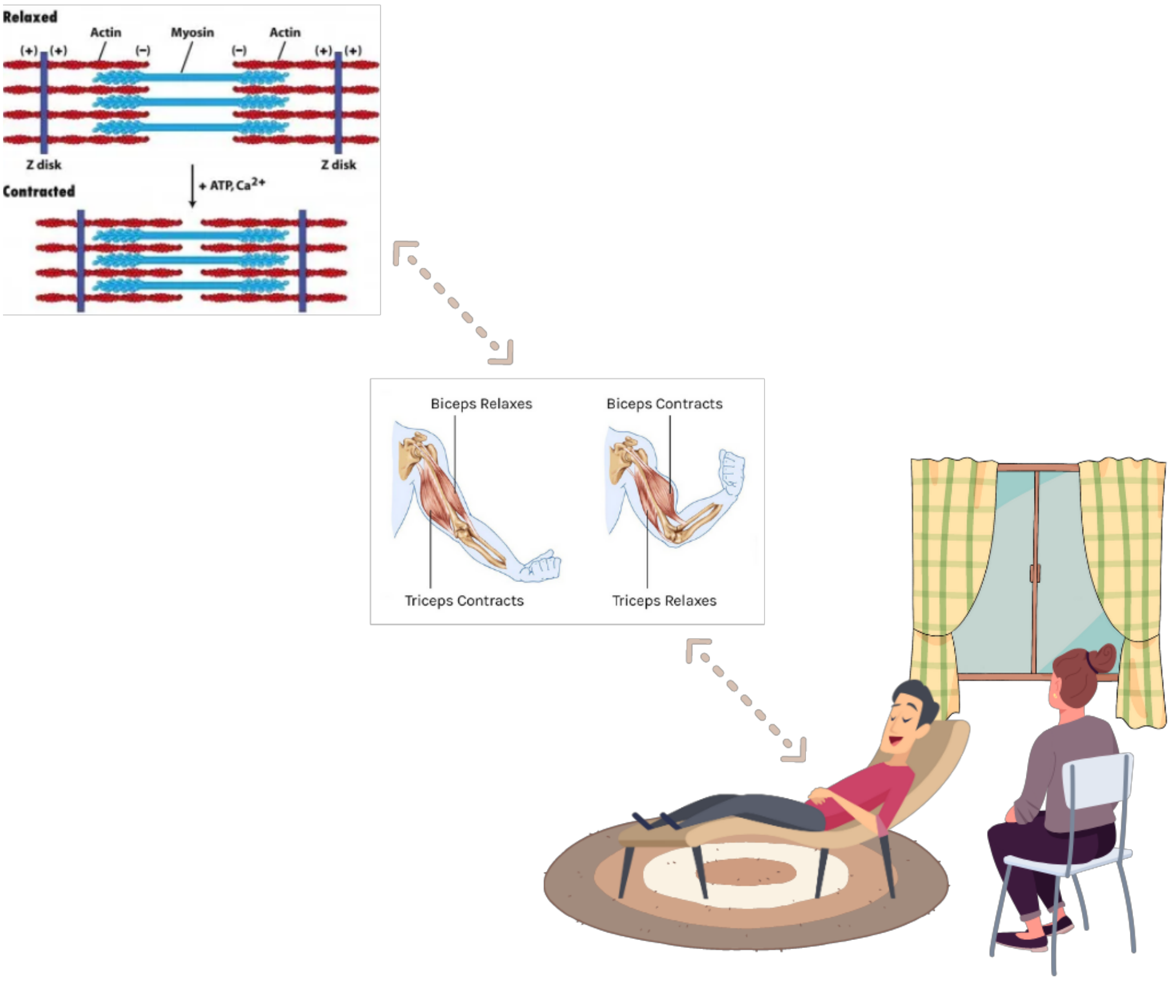
Starting from this background, we hypothesized that the possibility to customize a relaxing scenario, according to individual preferences and in a more immersive context through VR technology, could more effectively promote relaxation and anxiety reduction than using GI only. Various studies demonstrated that being immersed in virtual natural environments facilitates the lowering of anxiety and stress symptoms in college students [17], also in association with different types of relaxation training (e.g., body scan, muscle relaxation training) [18-21].

VR is a usable, engaging, and user-friendly technology that promotes a full multisensory immersion in the virtual context, facilitating the control of disturbing external stimuli [15,16, 4,5]. As stated in Chapter 2, VR is widely used to treat various mental diseases [1], also in association with different types of standardized relaxation training, and it facilitates the sense of presence, immersion, and relaxation [2,3]. Moreover, as previously anticipated in Chapters 2 and 3, the customization of stimuli characterizing VR scenarios could further promote a more realistic and engaging experience, enhancing relaxation, sense of presence, and perception of security in the virtual context (e.g., 3, 233, 268), offering people a more realistic emotional experience, reflecting their needs and preferences [e.g., 4]. Considering the positive impact of GI associated with PMR on allowing relaxation, it may be hypothesized that exposure to a more vivid, closer-to-reality virtual experience may turn out to be helpful in further improving the relaxation learning promoted by the PMR and in decreasing anxiety symptomatology.

4.1.2 Web-based Psychotherapy Interventions to promote relaxation

The first part of the standard PMR training, named "*active PMR*", implies a series of active sessions in which people learn how to tense and release the different muscle groups from the bottom to the top of the body to recognize the subjective state of muscle relaxation; the relaxation of the muscle areas of the body reducing tension interfering with the skeletal muscle activity. These previous active PMR phases are essential and are typically administered face-to-face by a psychotherapist or a healthcare operator trained to conduct the PMR (for a visual representation, see Figure 1).

Figure 1. Representation of what usually happens in the psychotherapist room during the PMR training. The first two images are schematic representations of some of the processes that occur at the muscular level during muscular contraction and relaxation. Specifically, the actin and myosin movement is represented in relaxed versus contracted muscle. Less contact between actin and myosin produces less force (Sources: Lodish, H. (2013). Molecular Cell Biology. UK: W. H. Freeman; https://tommorrison.uk/blog/anatomical-movements).



By considering the effective results of web-based interventions in reducing stress among college students [273] and the relevant advantages that online therapy can offer (e.g., saving costs related to attending psychotherapy sessions), we assumed that assessing the efficacy of PMR in alternative settings may facilitate the administration of treatment when the implementation of the standard procedure is not possible (Figure 2).

Figure 2. Representation of web-based interventions in which the therapist deploys the web-based session via conference call.

The usefulness of web-based relaxation interventions is supported by studies showing how an online procedure led to significant results equal to in-person interventions [274, 275]. One of the first studies investigating the effect of comparing different types of relaxation techniques web-based deployed during the COVID-19 is by Pizzoli et al. [276], in which a series of audio clips were remotely delivered by following three different intervention approaches: 1) auditive natural stimuli (e.g., water sounds), 2) breathing regulation, 3) body scan. Results showed that all three techniques had positive effects on perceived relaxation and stress, concluding that the audio clips were effective in inducing a calmer psychological state, providing novel insights, and suggesting the deployment of further studies to investigate the effect of delivering more than one session treatments. In particular, studies should assess differences in the efficacy of longitudinal exposure to relaxation sessions and correct for the effect of training or habituation low-cost web-based interventions to reduce preoccupation and anxiety in the general population and people with anxiety symptomatology [276].

In investigating the impact of web-based psychotherapy interventions on psychopathological outcomes, there are controversial results regarding a PMR procedure administered in vivo or via audio-tracks [8, 9]. To our knowledge, no recent study addresses the comparison among training sessions administered in vivo, in a remote modality, and via audio-tracks.

Starting from the state of the art knowledge and the impact also due to SARS-CoV-2 in the proliferation and permanence of online interventions, with the help of technological tools that promote autonomy in the psychotherapy administration, we intend to explore PMR's efficacy in a remote situation delivered via both the Zoom platform and audio-tracks deployed by the Moodle platform. Indeed, online treatments promote users' independence in managing psychotherapy techniques, leaving time for other face-to-face psychotherapy activities that require the active involvement of both the patient and the therapist. Assessing the efficacy of PMR in alternative settings may facilitate the administration of treatment where it is impossible to implement the standard procedure. It may also increase the positive impact of abbreviated relaxation sessions and the deployment of a combination of relaxation methods with patients who have chronic pain or must be exposed to invasive medical treatments [18, 67].
In light of the evidence described, we aimed to deploy the active PMR sessions remotely via Zoom or Audio-track, accessible through the Moodle platform, and the last complementary session in the therapist's presence, exposing people to a passive progressive relaxation session with GI or VR.

4.2 Aims and hypotheses

The purposes of the present research project are as follows:

1. Investigating if a customized, relaxing scenario in VR can facilitate relaxation and anxiety operationalized as based on lower state anxiety and heart rate frequency comparing the three experimental conditions.

Hp1: *Even if a general reduction in state-anxiety in all three groups is expected, it has been hypothesized that VR is more effective than in-imagination exposure in allowing relaxation and decreasing state anxiety and heart rate* (e.g., 199, 277, 278, 279).

2. Single-session web-based relaxation intervention outlined positive effects on perceived relaxation and stress (e.g., 276), suggesting the future deployment of studies aiming to investigate the effect of more than one session treatments to assess differences in the efficacy of longitudinal exposure to relaxation sessions in participants belonging to clinical and general populations [276]. For this reason, our second aim is to investigate the effect of the entire relaxation protocol on state anxiety for all three groups. Specifically, we wanted to see whether one of the two web-based training interventions impacted more on the perceived state of anxiety.

Hp2: *It has been hypothesized that a general reduction in state-anxiety in all three groups during the relaxation training can occur [276]. Moreover, we wanted to investigate if groups differed in state anxiety based on the type of relaxation training received.*

3. To understand if VR promotes a better sense of presence and engagement in the scenario than GI after Session 6 (T1) and if it helps to recall the image and be immersed in the relaxing scenario in Session 7 (T2).

Hp3: *Since a high sense of presence during VR exposure seems to contribute to increasing skill learning (e.g., [280]), it has been assumed that a greater perception of presence and engagement in the VR scenarios and facilitation in recalling the image at T2 can be observed in individuals previously exposed to the VR condition.*

4. Investigating if the sense of presence, immersivity in the scenario, and the perception that the virtual environment is realistic induced a more significant reduction in state anxiety after the virtual reality experience.

Hp4: *Even if based on different aims, a positive relation between the sense of presence and anxiety has been revealed in studies that explored the efficacy of virtual reality exposure therapy (e.g., [281]). We expected to observe a positive effect of the sense of presence, immersivity, and perception of realistic components in the VR environment on state anxiety after the VR experience.*

5. Investigate the differences between and within groups regarding trait anxiety, stress, depression, and coping strategies at T0 and T2.

4.3 Methodology

4.3.1 Ethics Approval

This study protocol involving human participants was General Data Protection Regulation compliant and developed following the Declaration of Helsinki (Italian law 196/2003, European Union General Data Protection Regulation 679/2016). The institutional review board of the Interdepartmental Ethical Committee of Psychology (17 Area) of the University of

Padova (Italy) approved the study protocol on May 28, 2021 (approval number 4213). In February 2022, the trial was tested based on a convenience sample of five volunteers from the general population. Then, it was decided to introduce the following questionnaires: the *Coping Orientation to the Problems Experienced-New Italian Version (COPE-NVI)* [282], the *ITC-Sense of Presence Inventory (ITC-SOPI),* [169, 199], the *Vividness of Visual Imagery Questionnaire (VVIQ)* [283, 284], and the *Test of Visual Imagery Control (TVIC)* [283, 284]. The amendments and supplementations have been accepted, and the protocol received the final approval of the institutional review board of the Interdepartmental Ethical Committee of Psychology (17 Area) of the University of Padova, Italy (approval number 4701; April 29, 2022). Before their study enrolment, the participants signed a written informed consent form based on a paper-and-pencil form, agreeing to participate in all the study sessions.

They were informed that (1) their data would be confidential, (2) they could omit any information they did not wish to provide, and (3) they could withdraw from the study without providing any explanation.

4.3.2 Eligibility, Recruitment of Study Participants, and Randomization

The recruitment phase started in May 2022. Study participants were recruited in Northeast Italy via social networking websites (e.g., Facebook groups) and by providing information on the research during university lectures. Those interested in participating were asked to make an appointment with the investigators to participate in the first assessment phase (T0), in which the inclusion and exclusion criteria were evaluated, written informed consent was obtained, and a baseline evaluation was made. Eligible participants were adults from the general population (18 years or older), native Italian speakers, owning a PC, and able to use a PC and smartphone. Participants were excluded from the study if they had been diagnosed with a severe mental disorder or medical conditions that could hinder their participation in the study (e.g., neuromuscular disorders, severe psychiatric or neurological disorders, and assumption of drugs that could interfere with heart rate assessment and the subjective relaxation state), or if a psychotherapeutic treatment was ongoing. Eligible participants were randomly allocated to one of three experimental conditions based on a simple blinded randomization via an Excel (Microsoft Inc.) file. Two experimenters, trained in cognitive and behavioral psychotherapy, conducted the relaxation sessions, each administering to 50% of the sample of each group to control for possible biases related to the therapist’s personality and competence. The two therapists who administered the experimental procedure received the same PMR training and were supervised by a senior researcher and psychotherapist supervisors.

4.3.3 Study Design

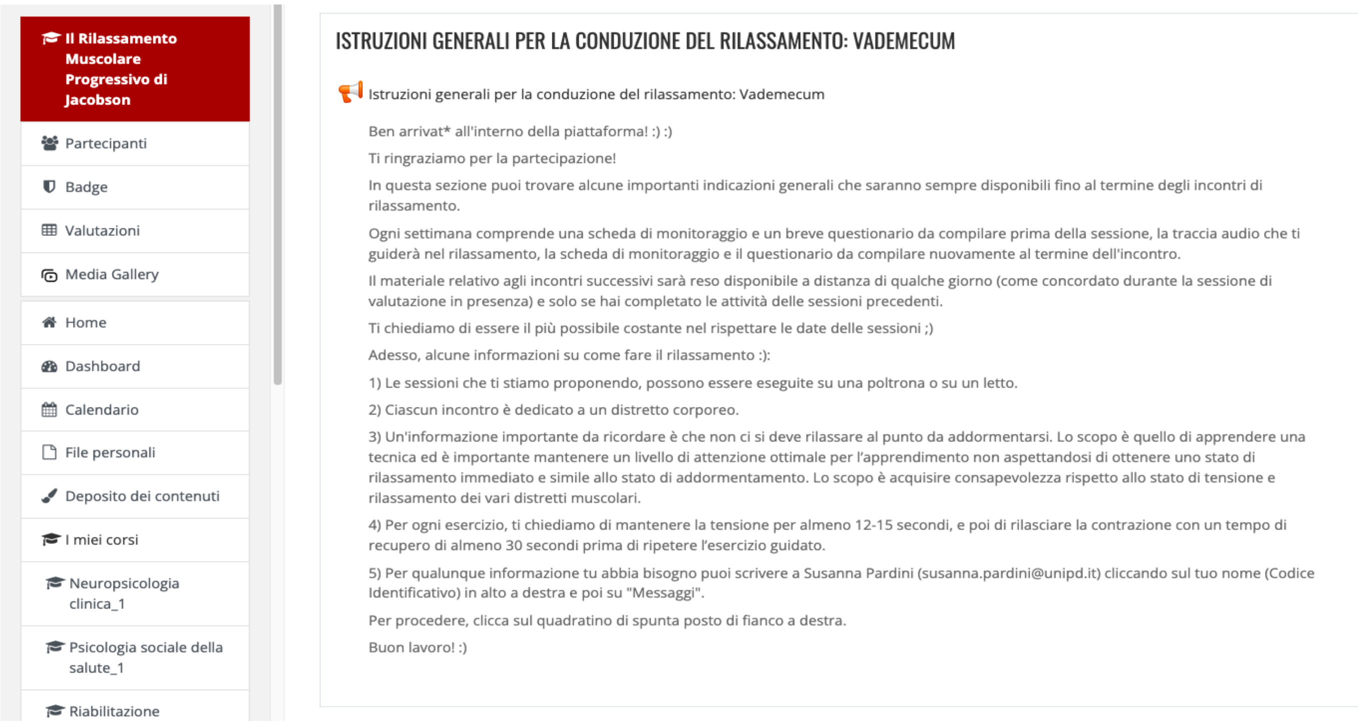
The present study is a longitudinal, between-subjects, 3-armed randomized controlled trial aiming to compare three treatment conditions:

1. *Zoom & Guided Imagery* (Active Comparator condition), consisting of deploying the PMR training via Zoom and GI exposure. It consists of the following steps:
- a standard behavioral intervention based on four individual PMR sessions via Zoom (s1-s4);
- an in vivo PMR relaxing session and GI conducted by a psychotherapist (T1) after a week from the baseline assessment (T0);
- a follow-up phase (T2) after two weeks, consisting in recovering the GI relaxing scenario and PMR session.

2. *Zoom & Virtual Reality* (Intervention A) is an experimental condition in which the complementary intervention comprises the PMR administered via Zoom integrated with a customized VR exposure deployed by a head-mounted display (Oculus Quest 2). It is composed of:
- four individual PMR sessions via Zoom (s1-s4);
- an in vivo PMR relaxing session integrated with a customized exposure in a virtual scenario (T1) after a week from T0;
- a follow-up phase with the same activities as the first condition.

3. *Audio-track & Virtual Reality* (Intervention B) is an experimental condition in which the complementary intervention comprises PMR administered through an audio-track integrated with the same customized VR exposure setup in the Zoom & Virtual Reality condition. It consisted of the following components:
- four individual PMR sessions via an audio-track delivered on the Moodle platform (t1-t4) (see Figure 3);
- an in vivo PMR relaxing session with a customized VR exposure (T1) after a week from T0;
- a follow-up phase characterized by the same activities as the other two conditions.

Figure 3. Example of one of the pages in the Moodle platform used by all three groups to fill out self-reported questionnaires and used by participants in the "Audio & VR" group to complete the PMR training sessions (t1-t4).



The assessment phases took place at baseline (T0; Session 1), before and after the four PMR sessions (administered on Zoom or audio-track), at the fifth in-presence session (T1; Session 6), and a week later, the exposure in one of the two complementary relaxation strategies (T2; Session 7).

★ The *T0 (Baseline; Session 1)* assessment phase has a duration of approximately 37 minutes, is the same for all participants, and is administered at the Virtual Reality Laboratory (A10-A11), Department of General Psychology, University of Padova (Italy). In this phase, the following measures are administered:

- a *demographic schedule* (addressing age, gender, nationality, mother tongue, marital status, years of school attendance, employment status, psychological problems or disorders, ongoing psychological treatment, drug use, medical conditions, neuromuscular issues, previous injuries, previous experiences in relaxation practice or anxiety management training, or with Virtual Reality deployed with a head-mounted display), and also, refraining from smoking, intense physical exercise, consuming caffeine for at least 1 hour before testing, and consuming alcohol for at least 6 hours before testing [64];

- a series of *self-report questionnaires* investigating depression, anxiety, stress, quality of life, and distress coping strategies (STAI-Y, DASS-21, PGWBI, and COPE-NVI);
- resting heart rate detection with a Mi Band 2 sensor.

★ At each of the *four training sessions (t1-t4; Sessions 2-5)*, to check that there were no potential adverse effects related to contracting and releasing the muscles before and after each relaxation session (t1-t4), the personal level of tension is assessed by using a *Visual Analog Scale (VAS)* from 0 (no tension) to 10 (extreme tension level). The state-anxiety level is evaluated based on the STAI-Y1. The four relaxation sessions are administered 2 to 3 days apart from each other for all three groups. The assessment phase is administered through Moodle, an e-learning platform used for data collection.

★ The *T1 phase (at Session 6)* required approximately 60 minutes. Before and after the relaxation session, states of tension and anxiety are assessed using a 0 (no tension) to 10 (extreme tension level) scale, and the state-anxiety level is evaluated based on the STAI-Y1. Then, participants are exposed to a PMR session merged with a VR or a GI procedure. Since the ability to generate vivid visual images is positively associated with the capacity to feel present in a virtual world [259], to control this construct, before the GI or the VR experience, all the participants fill out the *VVIQ* and the *TVIC*. Moreover, at the end of the T1 phase, the VR group filled out the *VRSQ* to monitor VR-related side effects (e.g., sickness), and the *ITC-SOPI* to assess the Sense of Presence, Engagement, Ecological Validity, and Negative Effects experienced to the exposure in the VR or the GI conditions. The Mi Band 2 sensor is used during the entire T1 phase administration to detect resting heart rate activity. This assessment phase is administered through the Moodle e-learning platform.

★ The *T2 phase (at Session 7)* is deployed for approximately 45 minutes. The state-anxiety level is evaluated based on the STAI-Y1. All the users are exposed to a self-GI experience in which those who were part of the VR group are asked to recall the customized VR scenario experienced during the T1 phase. Instead, the GI group retrieved the image participants had used in association with the PMR during the T1 phase. Moreover, at the end of the T2 phase, the VR group only filled out the STAI-Y2, the DASS-21, the PGWBI, the COPE-NVI, and the ITC-SOPI. This assessment phase is administered based on the Moodle e-learning platform. The Mi Band 2 sensor is used during the entire T2 phase administration to detect resting heart rate activity.

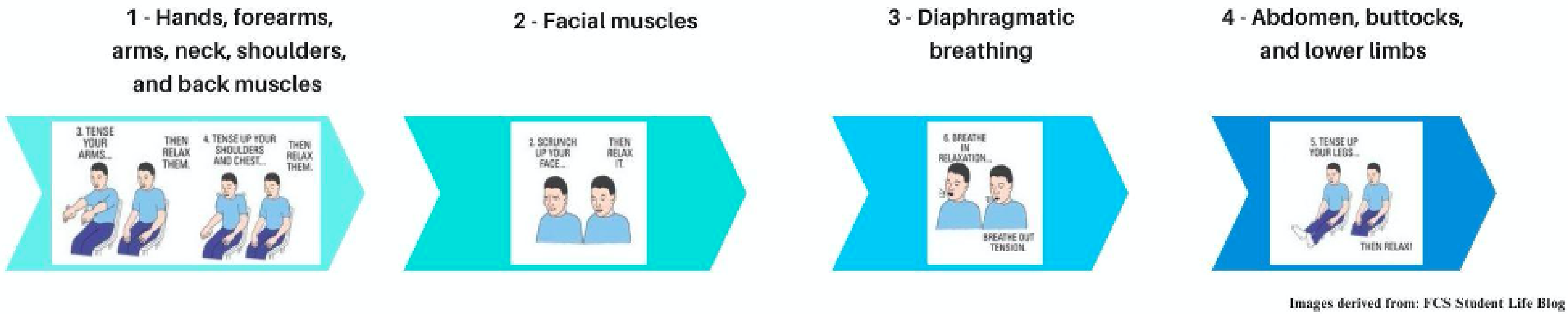
4.3.4 The Integrated PMR and Virtual Environment Design

The virtual environment design and the hardware and software equipment are described in Chapter 3, in the context of the first study in which the aim was to investigate the user experience, preferences, and engagement of the exposure to customized, natural, and realistic VR scenarios. Specifically, we adapted the procedure that Baird and Sands [17] introduced to propose an integrated intervention using different new technologies.

The protocol concerns the learning of the adapted abbreviated PMR (inspired by [55]) in five sessions delivered two times a week, as follows:

• Four sessions of active PMR, in which participants are required to perceptively learn the differences between the tension and relaxation of different muscle sections of the body (see Figure 4). Each session has a duration of approximately 25 minutes. The first session is dedicated to the hands, forearms, arms, neck, shoulders, and back; the second to the facial muscles; the third to the diaphragmatic breathing; and the fourth to the abdomen, buttocks, and lower limbs. These sessions are conducted via the Zoom platform and are conducted by a cognitive-behavioral psychotherapist. Each Zoom session consisted of measuring the relaxation state based on measures filled out using the Moodle e-learning platform, sharing general standardized instructions for conducting relaxation and the rationale of the PMR; guided relaxation aimed at relaxation of a dedicated body site, and filling out the same measures administered at the beginning of the session. A profile was created for each participant to access the Moodle platform. All sessions were self-managed within the Moodle platform for the participants in condition "Audio-track & VR" who participated in the four PMR sessions through the audio-track. Various activities have been scheduled based on the beginning of the training and the end of the activities planned in previous sessions.

Figure 4. Illustrative examples of the relaxation exercises during the four web-based active PMRs sessions.



• The fifth VR session is administered at the University of Padova Laboratory. All participants are asked to wear a smartwatch for heart rate detection. Five measurements (one per minute) are made before the VR experience, 12 during the entire exposure in the virtual environment, and five after the experience in the virtual context. Approximately 12 minutes have been established for the VR experience to avoid potential cybersickness symptoms during the virtual experience. This brief relaxation session is practiced by inexperienced individuals allowing for a decrease in anxiety and negative mood [285, 286].

For an overview of the enrolment, interventions, and assessment phases, see Figures 5-9.

Figure 5. SPIRIT diagram. SPIRIT, Standard Protocol Items: Recommendations for Interventional Trials. Overview of the enrolment, interventions, and assessment phases.

	STUDY PERIOD								
	Enrolment	Allocation	Post-allocation						Close-out
TIMEPOINT	*$-t_1$*	*T0*	*t_1*	*t_2*	*t_3*	*t_4*	*T1*	*T2*	*1 years ± 3 months*
ENROLMENT:									
Eligibility screen	X								
Informed consent	X								
[List other procedures]	X								
Allocation		X							
INTERVENTIONS:									
[Active Comparator]			◀	—	—	—	—	▶	
[Intervention A]			◀	—	—	—	—	▶	
[Intervention B]			◀	—	—	—	—	▶	
ASSESSMENTS:			◀	—	—	—	—	▶	
[List baseline variables]	X	X	◀	—	—	—	—	▶	
[List outcome variables]			◀	—	—	—	—	▶	X

Figure 6. Consolidated Standards of Reporting Trials 2010 flowchart. GI: guided imagery; PMR: progressive muscle relaxation technique; VR: virtual reality.

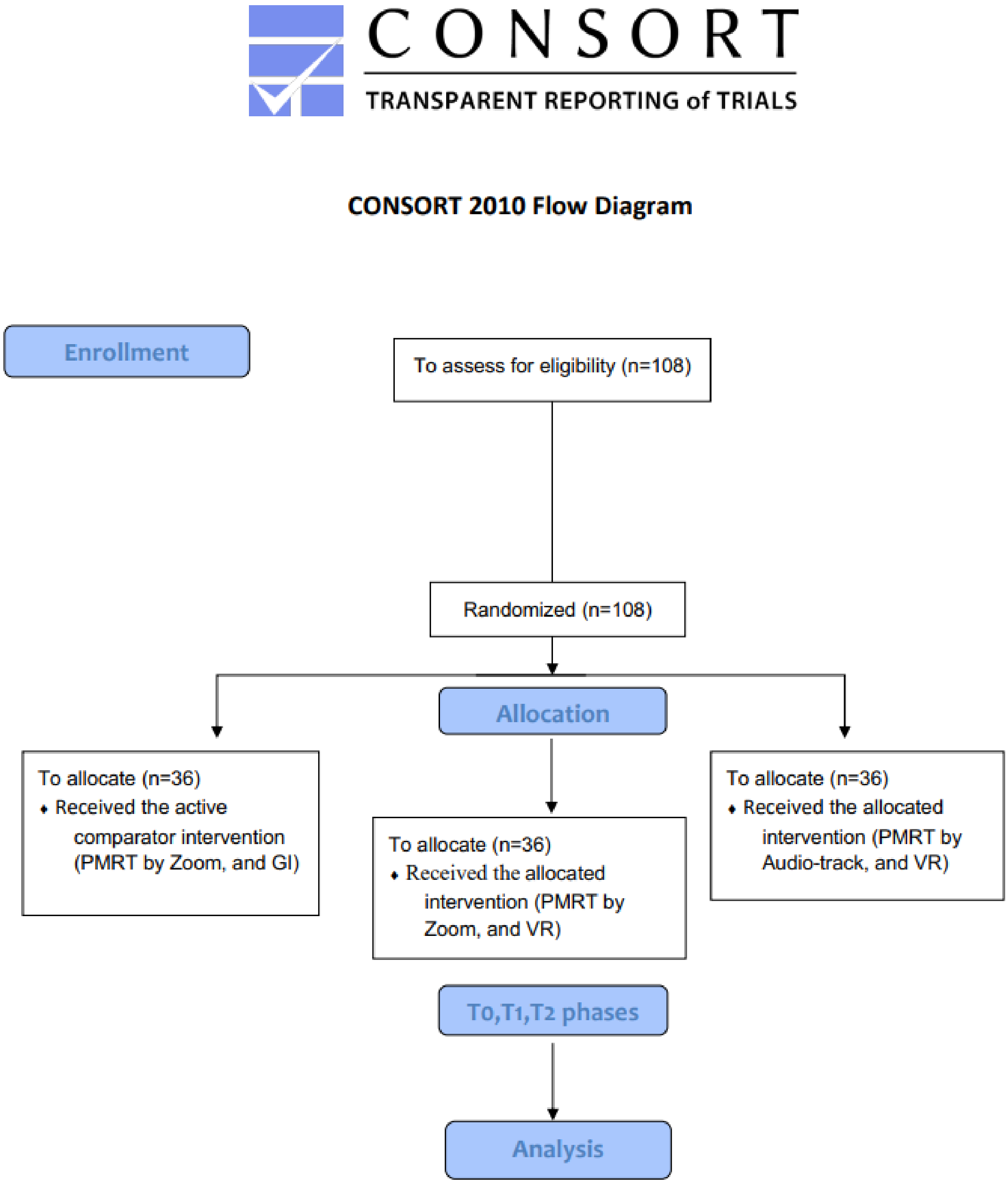


Figure 7. Graphical description of the activities carried out during the Active Comparator condition: PMR training via Zoom and GI exposure.

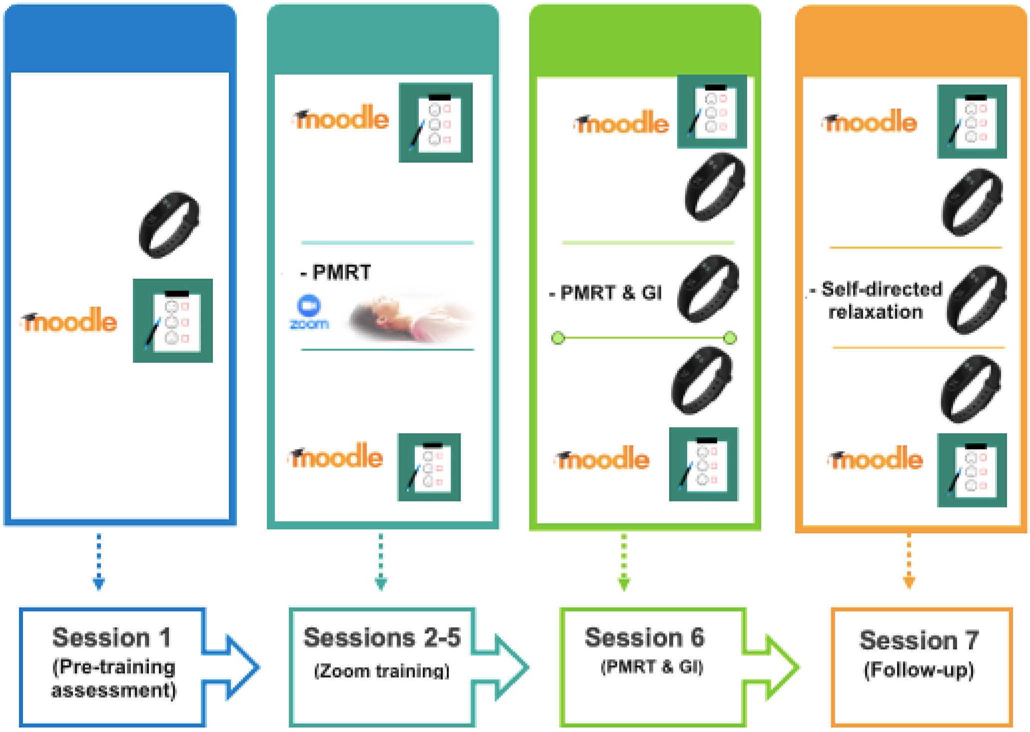


Figure 8. Graphical description of the activities carried out during Intervention A: PMR training administered via Zoom integrated with a customized virtual reality exposure deployed by wearing a head-mounted display (Oculus Quest 2). GI: Guided Imagery; PMR: Progressive Muscle Relaxation Technique.

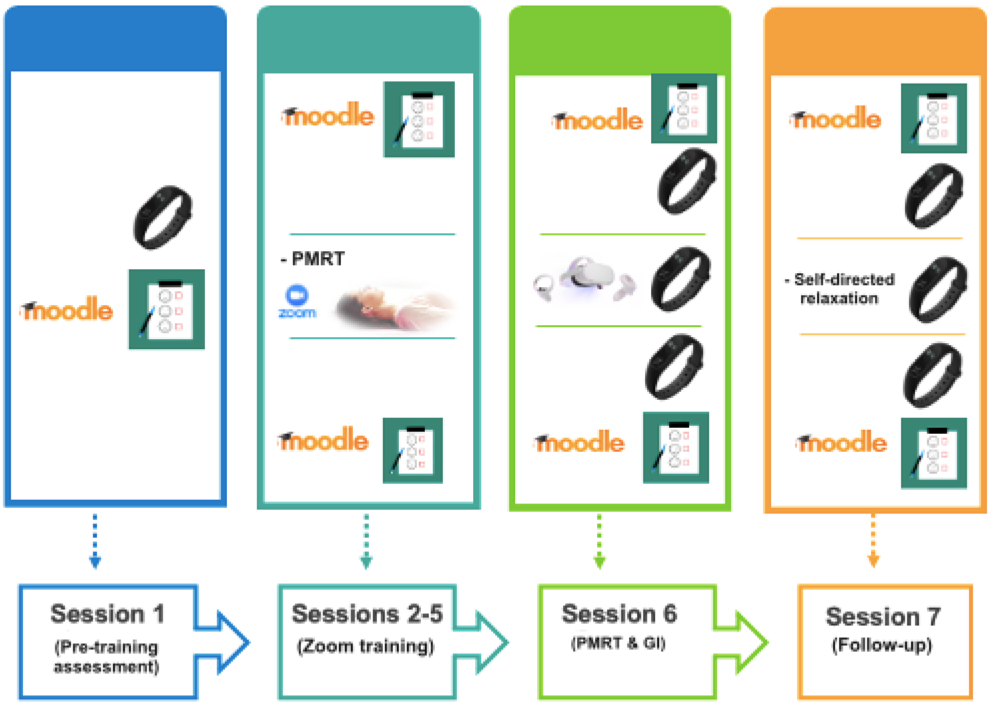
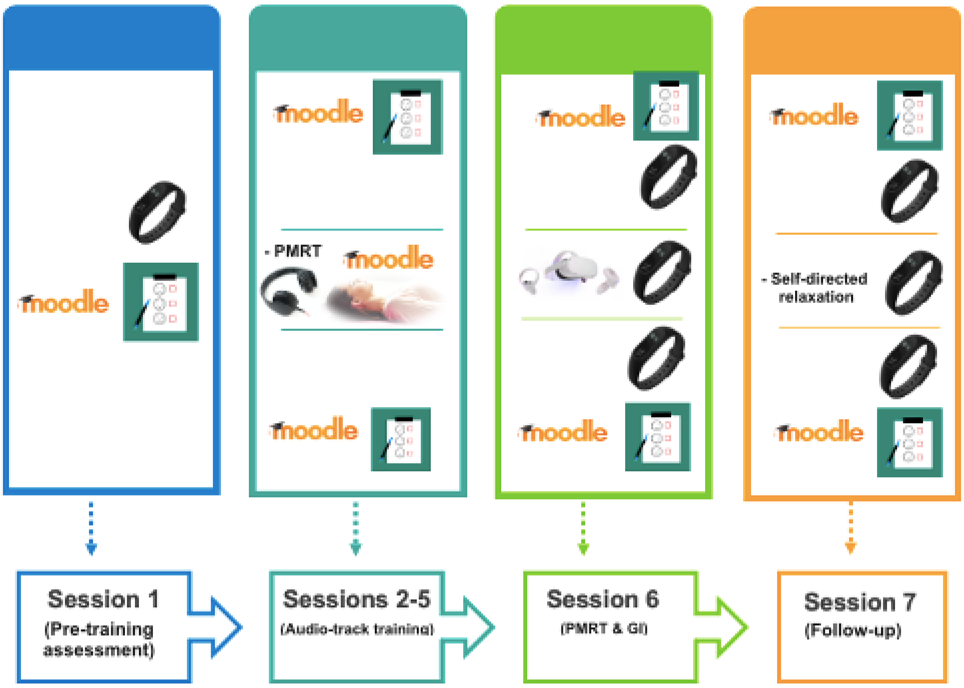


Figure 9. Graphical description of the activities carried out during Intervention B: PMR training administered through the Moodle platform via an audio-track integrated with a customized virtual reality exposure deployed by wearing a head-mounted display (Oculus Quest 2). GI: Guided Imagery; PMR: Progressive Muscle Relaxation Technique.



4.3.5 Power Calculation

Sample size estimation was computed with G*Power 3.1 software (Heinrich Heine Universität Düsseldorf) [287]. As a statistical test, ANOVA repeated-measures between-within factors and interaction have been considered. The effect size was set as 0.25, the α as .05, and the Power (1β error probability) as 0.80. We estimated having to recruit at least 36 participants for each of the three groups. Moreover, sample size was confirmed using the *General Linear Mixed Model Power and Sample Size* program [288].

4.3.6 Data Collection, Storage, and Security

Based on informed consent, participants were informed about the experimental procedure; how data were collected, transmitted, and stored; and who had access to the data. Any digital data, such as responses to web-based questionnaires, were uploaded and saved to a secure server. Any hard-copy documents were stored in a locked cabinet. Both digital data and hard copy documents are retained for ten years after the end of the study and then securely destroyed.

4.3.7 Outcomes measures

Data collection. Measures were administered before and after the relaxation sessions. The heart rate frequency was recorded based on the XIAOMI MiBand2 before the sessions at T1 (Session 6) and T2 (Session 7), to have Baseline data, other than during and after relaxation sessions.

-A *Socio-demographic schedule* was filled in to obtain information about gender, age, mother tongue, marital status, years of education, occupation, psychological, medical, and neuromuscular problems, and use of drugs if participants had relaxation training experience or used virtual reality devices in the past.

- The *State-Trait Anxiety Inventory - Y (STAI-Y)* [245, 246] is a self-report questionnaire that allows investigating the state and trait anxiety with 40 items on a four-point Likert scale. Items are grouped into two scales focused on how subjects generally feel (trait anxiety) or what they experience at particular times (state anxiety). The reliability and validity properties of the STAI-Y are good in the Italian sample. The internal consistency outcomes are in Table 1.

- The *Depressive Anxiety Stress Scale-21 (DASS-21)* [247, 248] is a self-report questionnaire based on 21 items that provide information about anxiety, depression, and stress symptomatology on a four-point Likert scale from 0 to 3. Internal consistency and convergent, divergent, and criterion-oriented validity are adequate in the original and Italian versions. The internal consistency outcomes are in Table 1.

- The *Coping Orientation to Problems Experienced-Nuova Versione Italiana* (COPE-NVI) [282] is a 60 items self-report questionnaire on a five-point Likert scale that investigates how often people use certain coping strategies with stressful or difficult events. Items are grouped into five subscales referring to different coping strategies: Social Support, Avoidance Strategies, Positive Attitude, Problem-Solving, and Turning to Religion. The present tool is psychometrically valid to measure coping styles in the Italian context. The internal consistency outcomes are in Table 1.

-The *Vividness of Visual Imagery Questionnaire (VVIQ)* [283, 284] is composed of 16 items on a five-point Likert scale and investigates individual differences regarding the ability to imagine visual contexts vividly. The participant is asked to generate four mental images and evaluate their vividness. The internal consistency outcomes are in Table 1.

-The *Test of Visual Imagery Control (TVIC)* [283, 284] is a measure that evaluates individual differences in the ability to intentionally control and modify mental images. For example, participants are asked to mentally visualize a car and then transform the image according to 10 different descriptions. Responses are recorded. The internal consistency outcomes are in Table 1.

-The *ITC-Sense of Presence Inventory (ITC-SOPI)* [169, 199] is a questionnaire of 42 items on a five-point Likert scale that allows for investigating the sense of presence experienced in a virtual reality contest. It comprises four subscales investigating the sense of physical space, the level of engagement experience in the virtual context, the Ecological Validity, and the negative effects of exposure. The internal consistency outcomes are in Table 1.

-The *Psychological General Well-Being Index (PGWBI)* [289, 291] is a self-report questionnaire of 22 items that provides a general subjective assessment of psychological well-being. It comprises six sub-scales: Anxiety, Depression, Positivity and Well-being, Self-control, General Health, and Vitality. The scores for all sub-scales can be summarized to provide a summary score, which reaches a maximum of 110 points, representing the best achievable "well-being". The tool's psychometric properties are good for the original version and Italian validation. Considering our sample, an acceptable internal consistency emerged for the total The internal consistency outcomes are in Table 1.

-The *Virtual Reality Symptom Questionnaire (VRSQ)* [249, 292] assesses the general and eye-related physical symptoms of exposure to a virtual reality environment. The score assigned to each item ranges from 0 to 6, with a maximum total score of 84 (48 for general symptoms and 36 for eye symptoms). Higher scores represent worse symptoms, with 0 corresponding to no adverse effects and 84 to serious adverse effects.

Table 1. Demographic features and comparisons considering psychological constructs.

	MEASURE	CRONBACH'S ALPHA	95% CONFIDENCE INTERVAL	
			Lower Bound	Higher Bound
T0	STAI-Y2	0.83	0.76	0.88
	DASS-21- Depression	0.89	0.83	0.90
	DASS-21- Anxiety	0.65	0.62	0.68
	DASS-21- Stress	0.84	0.79	0.88
	PGWBI-Total	0.73	0.68	0.76
	COPE-NVI-Social Support	0.86	0.81	0.90
	COPE-NVI-Avoidance	0.75	0.67	0.84
	COPE-NVI-Positive Attitude	0.79	0.71	0.84
	COPE-NVI-Problem Solving	0.80	0.74	0.84
	COPE-NVI-Trascendental Orientation	0.75	0.70	0.81
T1	STAI-Y2	0.83	0.77	0.87
	STAI-Y1 (before)	0.83	0.75	0.87
	STAI-Y1 (after)	0.80	0.72	0.86
	DASS-21- Depression	0.80	0.73	0.88
	DASS-21- Anxiety	0.62	0.60	0.64
	DASS-21- Stress	0.72	0.64	0.80
	VVIQ	0.90	0.88	0.93
	TVIC	0.86	0.82	0.88
	ITC-SOPI-Presence	0.79	0.70	0.86
	ITC-SOPI-Engagement	0.78	0.70	0.84
	ITC-SOPI-Ecol validity	0.72	0.66	0.81
	ITC-SOPI-Negative effects	0.73	0.64	0.83
T2	STAI-Y2	0.88	0.81	0.91
	DASS-21- Depression	0.79	0.76	0.83
	DASS-21- Anxiety	0.64	0.62	0.66
	DASS-21- Stress	0.70	0.63	0.77
	PGWBI-TOTAL	0.76	0.68	0.85
	COPE-NVI-Social Support	0.87	0.83	0.90
	COPE-NVI-Avoidance	0.79	0.71	0.84
	COPE-NVI-Positive Attitude	0.77	0.71	0.85
	COPE-NVI-Problem Solving	0.80	0.75	0.85
	COPE-NVI-Trascendental Orientation	0.74	0.65	0.81
	ITC-SOPI-Presence	0.93	0.90	0.95
	ITC-SOPI-Engagement	0.92	0.86	0.95
	ITC-SOPI-Ecol validity	0.89	0.84	0.93
	ITC-SOPI-Negative effects	0.81	0.74	0.85

4.4 Results

4.4.1 Statistical Procedure and Data Analysis

Statistical analyses were performed using SPSS (version 29.0; IBM Corp) [293], RStudio 1.4.1717 [294], and the following packages: *tidyverse* [295], *dplyr* [296], *lsmeans* [297], *lmerTest* [298], *LMERConvenienceFunctions* [299] and *ggplot2* [300]. Linear mixed-effects (LME) models were then applied to the data, with Group, Block (pre/post), and Session as predictors and a random intercept for each subject to account for repeated measures. LME models represent an advantageous statistical approach that is more flexible than classic

ANOVA [301, 302], and since they allow the possibility to include both fixed effects and random effects, which represent variables that are not explicitly manipulated by the experimenter, but that contribute to the characteristics of the observed data, such as individual variability in within-subject designs [303]. On the LME models computed in the current study, we additionally performed an *F-test* using the *Satterthwaite approximation for degrees of freedom* [304] to assess the significance of each predictor. Multiple comparisons were corrected with *False Discovery Rate* (FDR). The total score was compared between the groups with a *Welch's t-test* [305]. Pairwise Comparisons with Bonferroni's confidence interval adjustment were calculated to compare differences between and within groups based on SPSS [293]. To investigate the values of Cohen's d and the effect-size correlation r, using the means and standard deviations of groups, the Effect size calculators by the University of Colorado-Colorado Springs (lbecker.uccs.edu) have been used.

To investigate the normal data distributions of the dependent variables, ranges of skewness and kurtosis are determined (±2) [253, 306, 307]. The Kolmogorov-Smirnov and the Shapiro-Wilk tests are performed to evaluate the distributions' statistical significance (*p-value*>.05) and normality. The normality distribution has been investigated for all the dependent variables considered in the study assessed at different times and for the three groups individually, and the collected data follows a normal distribution. Frequencies, means, and standard deviations were measured to explore sociodemographic features. In addition, to assess the internal consistency of all the measures administered at T0, T1, and T2, Cronbach's alpha reliability measure and Confidence intervals (95% CI for reliability) have been executed. Multiple linear regression analyses were performed to investigate if the sense of presence, engagement, and realistic perception of the scenario can predict the state anxiety level experienced after the virtual reality exposure.

4.4.2 Socio-demographic features and comparison

The socio-demographic features of the study sample are outlined in Table 2. Since socio-demographic features (e.g., gender) can play a role in the way VR is experienced [e.g., 308-310], a multivariate ANOVA was conducted to investigate whether groups differed in socio-demographic and psychological characteristics before the relaxation training. A difference between groups was found for age, school years, marital status, and for the "Social Support" and "Transcendental Orientation" subscales of the COPE-NVI (see Table 2). To control for the possible impact baseline differences could have on the research outcomes, the effects of these variables were controlled for in the subsequent analyses. Fifteen individuals (41.7%) in the "Zoom & VR group", twelve participants (33.3%) in the "Zoom & GI group", and thirteen (36.1%) in the "Audio-track & VR group" referred to have an anxiety problem. Seven (19.4%), five (13.89%), and 4 (11.1%) participants respectively in the "Zoom & VR", "Zoom & GI", and "Audio-track & VR" groups referred to feeling anxiety related more to specific activities (mainly about university exams). Based on what participants referred to in the T0 assessment, psychological problems were related to the following themes: 1) problematic relationships with parents, 2) low self-esteem, 3) worries about university tests, 4) worries about economic problems, 5) anxiety symptoms experienced in stressful situations, and 6) relational problems. Moreover, the VRSQ was administered to individuals in the two VR groups to assess the possible collateral effects of VR exposure-related nausea. On average, individuals showed light susceptibility to general and eye-related motion sickness levels (see Table 2).

Table 2. Demographic features and comparisons considering psychological constructs.

	Zoom & VR N=36	Zoom & GI N=36	Audio-track & VR N=36	$F_{(2,107)}$	$\chi 2$	Partial $\eta 2$
Gender (Women) (%)	28 (77.8%)	27 (75.0%)	28 (77.8%)		0.10	0.00
Age M (SD)	**23.83 (6.10)**	**30.42 (8.36)**	**29.86 (8.46)**	**8.05*****		**0.13**
School years M (SD)	**16.81 (1.31)**	**18.25 (2.60)**	**17.72 (2.12)**	**4.45***		**0.08**
Marital Status						
single (%)	**18 (50.0%)**	**16 (44.4%)**	**17 (47.2%)**		**11.70***	**0.07**
fiancé non-cohabiting (%)	**17 (47.2%)**	**10 (27.8%)**	**16 (44.4%)**			
married/cohabiting (%)	**1 (2.8%)**	**10 (27.8%)**	**3 (8.3%)**			
Medication Yes (%)	8 (22.2%)	5 (13.9%)	10 (27.8%)		2.10	0.06
Psychological Problems Yes (%)	15 (41.7%)	12 (33.3%)	13 (36.1%)		0.56	0.05
Medical Problems Yes (%)	6 (16.7%)	10 (27.8%)	10 (27.8%)		1.62	0.11
Relaxation training in the past Yes (%)	8 (22.2%)	3 (8.3%)	9 (25%)		3.81	0.03
VR in the past Yes (%)	10 (27.8%)	8 (22.2%)	13 (36.1%)		1.72	0.08
STAI-Y2-Total M (SD)	48.06 (3.78)	47.56 (3.56)	45.33 (7.50)	2.73		0.05
DASS-21- Depressive M (SD)	8.89 (8.08)	10.89 (7.34)	10.22 (9.71)	0.53		0.01
DASS-21- Anxiety M (SD)	9.06 (3.15)	9.33 (3.61)	9.06 (5.77)	0.05		0.01
DASS-21-Stress M (SD)	17.39 (7.42)	15.56 (6.01)	15.94 (8.01)	0.65		0.01
COPE-NVI-Social Support M (SD)	**34.92 (6.36)**	**32.11 (6.47)**	**31.19 (6.02)**	**3.43***		**0.06**
COPE-NVI-Avoidance M (SD)	22.83 (4.91)	23.00 (4.04)	24.67 (5.60)	1.55		0.03
COPE-NVI-Positive Attitude M (SD)	30.78 (5.03)	30.72 (5.26)	29.56 (5.03)	0.66		0.01
COPE-NVI-Problem solving orientation M (SD)	31.97 (5.03)	31.69 (5.27)	33.28 (5.43)	0.93		0.02
COPE-NVI-Trascendental orientation M (SD)	**17.44 (3.49)**	**17.31 (3.47)**	**13.08 (3.64)**	**17.69*****		**0.25**
PGWBI-22-Total M (SD)	60.94 (4.20)	63.22 (3.27)	61.75 (4.49)	2.97		0.035
VVIQ-Total M (SD)	58.53 (9.37)	58.39 (11.21)	63.06 (9.52)	2.50		0.05
VIC-Total M (SD)	41.56 (5.58)	43.44 (5.32)	42.97 (4.61)	1.29		0.02
VRSQ- General Physical Symptoms M (SD)	1.39 (1.32)	N/A	1.06 (1.33)	1.14		0.02
VRSQ- Eyes-Related Symptoms M (SD)	1.56 (1.32)	N/A	1.03 (0.91)	3.91		0.05

Notes: [a]M=Mean; [b]SD=Standard Deviation; Zoom & VR=Zoom & Virtual Reality Group; Zoom & GI=Zoom & Guided Imagery group; Audio-track & VR=Audio-track & Virtual Reality Group; STAI-Y1=State-Trait Anxiety Inventory (Y2-Trait Anxiety); DASS-21=Depressive, Anxiety, Stress Symptoms Scale-21; COPE-NVI=Coping Orientation to the Problems Experiences-New Italian Version; PGWBI=Psychological General Well-being Index; VVIQ=Vividness of Visual Imagery Questionnaire; TVIC=Test of Visual Imagery Control; VRSQ=Virtual Reality Symptom Questionnaire.

4.4.3 Aim n.1: Investigate if a customized, relaxing scenario in VR can be more effective in reducing state anxiety and heart rate frequency comparing the three groups.

To investigate the differences in state anxiety scores (STAI-Y1) between the three groups before and after the complementary relaxation experience in Session 6 (T1) and Session 7 (T2), a GLM model-based R has been deployed using "group", "block (before/after assessment based on STAI-Y1)", and "session" (T1 and T2) as predictors and a random intercept for each subject to account for repeated measures. In Table 3 are the descriptive analyses for group differences.

Table 3. Descriptive analysis (Mean and Standard Deviation) related to the STAI-Y1 score assessed for each group before and after Session 6 (T1) and Session 7 after one week (T2).

Dependent Variables	**Time**	**Group**	**M[a] (SD)[b]**
STAI-Y1 (T1)	**before**	Zoom & VR	48.06 (3.52)
		Zoom & GI	50.16 (5.16)
		Audio-track & VR	45.33 (5.24)
	after	Zoom & VR	31.17 (4.54)
		Zoom & GI	40.00 (4.28)
		Audio-track & VR	27.83 (5.43)
	before	Zoom & VR	48.89 (3.04)
		Zoom & GI	51.78 (3.99)

STAI-Y1 (T2)		Audio-track & VR	47.61 (4.15)
	after	Zoom & VR	32.39 (4.33)
		Zoom & GI	40.75 (4.74)
		Audio-track & VR	32.00 (4.76)

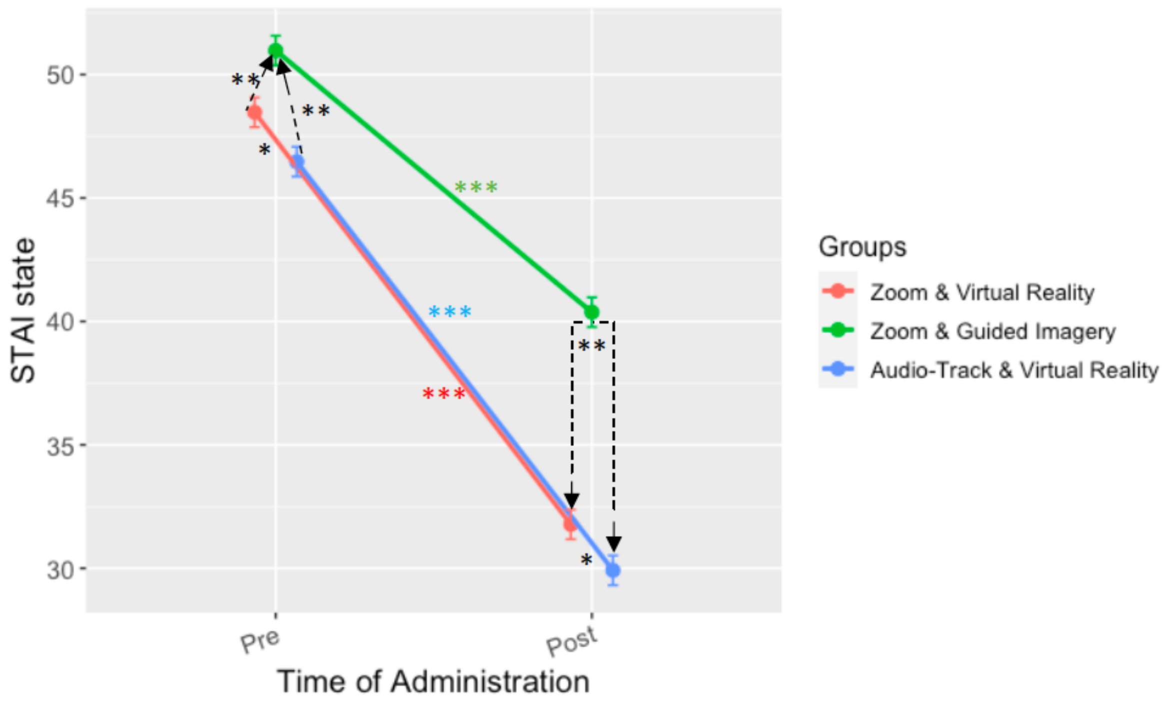
Notes: [a]M=Mean; [b]SD= Standard Deviation; VR= Virtual Reality; GI= Guided Imagery; STAI-Y1= State-Trait Anxiety Inventory (Y1-State Anxiety).

Results showed significant Group main effect ($F_{(2,105)}$=54.95, *p-value*<.001), Block main effect ($F_{(1,315)}$=1835.04; *p-value*<.001), and Session main effect ($F_{(1,315)}$=28.15; *p-value*<.001), as well as significant Block*Group interaction ($F_{(2,315)}$=34.69; *p-value*<.001), (Figure 10), and Session*Group interaction ($F_{(2,315)}$=4.30; *p-value*<.01) (Figure 12).

Pairwise post-hoc contrast of the Group main effect showed that the "Audio-track & VR" group had lower scores than both the "Zoom & VR" (β=1.93; SE=0.74; $t_{(1,105)}$=2.61; *p-value*<.05), and the "Zoom & GI" groups (β=7.48; SE=0.74; $t_{(1,105)}$=10.10; *p-value*<.001). The "Zoom & VR" group obtained lower state anxiety scores than the "Zoom & GI" group (β=-5.55; SE=0.74; $t_{(1,105)}$=-7.49; *p-value*<.001).

Looking at the within-subjects effect from the pairwise post-hoc comparisons of the Block (pre/post)*Group, all the group obtained a decrease in state anxiety after the relaxation sessions ("Zoom & VR": β=16.69; SE=0.59; $t_{(1,315)}$=28.25; *p-value*<.001; "Zoom & GI": β=10.60; SE=0.59; $t_{(1,315)}$=17.93; *p-value*<.001; "Audio-track & VR": β=16.56; SE=0.59; $t_{(1,315)}$=28.01; *p-value*<.001) (see Figure 7). Considering the between-subject effects, individuals in the "Audio-track & VR" group had lower state anxiety scores before starting the relaxation session than the "Zoom & VR" (β=-2; SE=0.85; $t_{(1,177)}$=-2.35; *p-value*<.05), and the "Zoom & GI" group (β=-4.50; SE=0.85; $t_{(1,177)}$=-5.29; *p-value*<.01). Moreover, before starting with the relaxation session, the "GI & VR" group had higher anxiety scores than the "Zoom & VR" (β=2.50; SE=0.85; $t_{(1,177)}$=2.94; *p-value*<.01). After the relaxation sessions, the "Zoom & VR" group had lower anxiety scores than the "Zoom & GI" (β=-8.60; SE=0.85; $t_{(1,177)}$=-10.11; *p-value*<.001), but higher if compared with the "Audio-track & VR" condition (β=1.86; SE=0.85; $t_{(1,177)}$=2.19; *p-value*<.05). The "Audio-track & VR" group had lower scores in anxiety after relaxation also than the "Zoom & GI" group (β=-10.46; SE=0.85; $t_{(1,177)}$=-12.30; *p-value*<.001).

Figure 10. Plot about the interaction between Block (Time of Administration: Pre/Post)*Group.



__Note:__ STAI state Block*Group interaction results. The black asterisk represents *between-group* differences, while asterisks of the same colour as the lines represent *within-group* differences. **; *p-value*<.01; ***: *p-value*<.001. Bars represent the Standard Error. STAI state=State anxiety is assessed based on the State-Trait Anxiety Inventory (Y1-State Anxiety); Pre=Assessment before the relaxation exposure; Post=Assessment after the relaxation exposure.

Other than the "Audio-track & VR" group had lower score in state anxiety before Session 6 (T1), the fact that the *d-Cohen* index and the *effect size* of the differences between the "Zoom & GI" group and the "Audio-track & VR" group were significantly higher after the relaxation experience permits to hypothesize a greater reduction of state anxiety in the "Audio-track & VR" group than the "Zoom & GI" one after T1 (Table 5). After the relaxation session at T2, the "Zoom & VR" group obtained a greater significant reduction of the perceived state anxiety than the "Zoom & GI" groups (Table 5). Compared with the other two groups, individuals in the "Audio-track & VR" group obtained lower scores before the relaxation session at Session 7 (T2). But, also in this case, the greater difference between the "Audio-track & VR" group and the "Zoom & GI" group recorded after the relaxation at T2 can be described as a greater reduction of state anxiety in the "Audio-track & VR" group than the "Zoom & GI" one after T2 (Table 5). Otherwise, no differences emerged after Session 6 (T1) and Session 7 (T2) between the level of state anxiety of the two groups that were previously exposed to the virtual environment (Table 5). For a graphical representation of data, see Figures 11A and 11B.

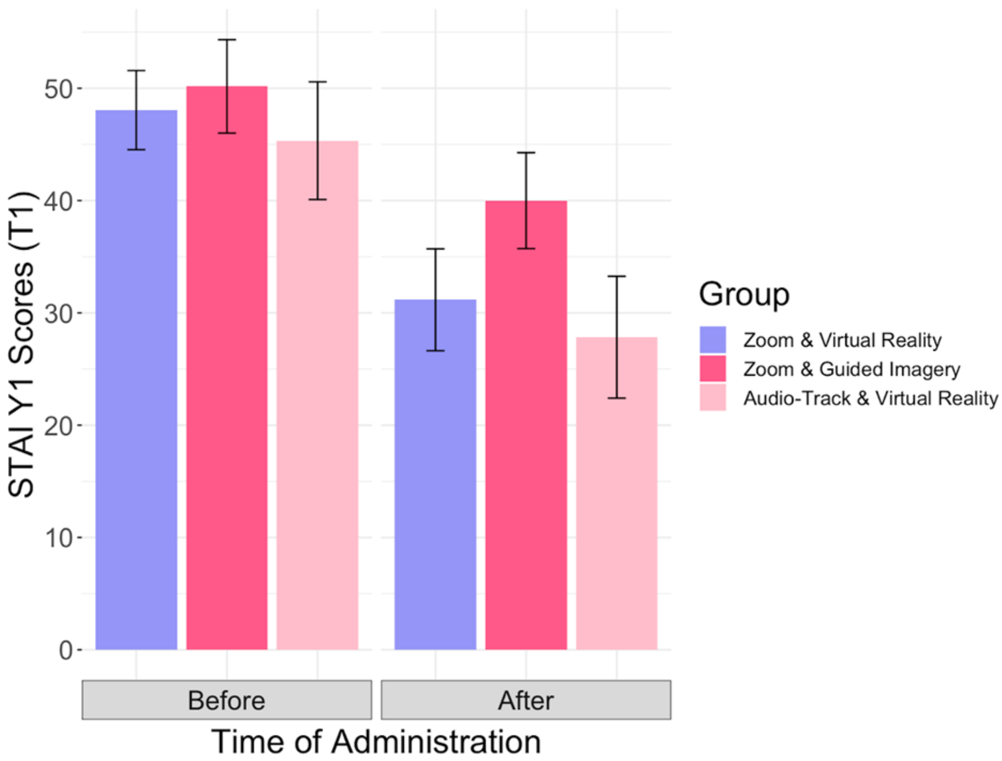
Table 5. Pairwise Comparisons between Groups about differences in state anxiety recorded before and after exposures at T1 and T2 (Confidence interval adjustment: Bonferroni).

Dependent Variables	Groups		Time	Mean Difference (Before - After)	Std. Error	t-test	d-Cohen	effect-size r
STAI-Y1 (T1)	Zoom & VR	Zoom & GI	Before	-2.02	1.05	-1.92	-0.48	-0.23
		Audio-track & VR		2.99	1.24	2.41	0.61	0.29
	Audio-track & VR	Zoom & GI		**-5.18*** **	**1.19**	**-4.35**	**0.93**	**0.42**
	Zoom & VR	Zoom & GI	After	**-9.23*** **	**1.18**	**-7.82**	**-2.00**	**0.71**
		Audio-track & VR		2.63	1.36	1.93	0.67	-0.32
	Audio-track & VR	Zoom & GI		**-12.09*** **	**1.31**	**-9.23**	**2.49**	**0.78**
STAI-Y1 (T2)	Zoom & VR	Zoom & GI	Before	**-2.53* **	**0.96**	**-2.64**	**-0.81**	**-0.38**
		Audio-track & VR		**2.63* **	**1.06**	**2.48**	**0.35**	**0.17**
	Audio-track & VR	Zoom & GI		**-5.08*** **	**1.02**	**-4.98**	**1.02**	**0.45**
	Zoom & VR	Zoom & GI	After	**-8.77*** **	**1.21**	**-7.25**	**-1.84**	**0.68**
		Audio-track & VR		0.08	1.34	0.06	0.09	-0-04
	Audio-track & VR	Zoom & GI		-8.86***	1.28	-6.92	1.84	**0.68**

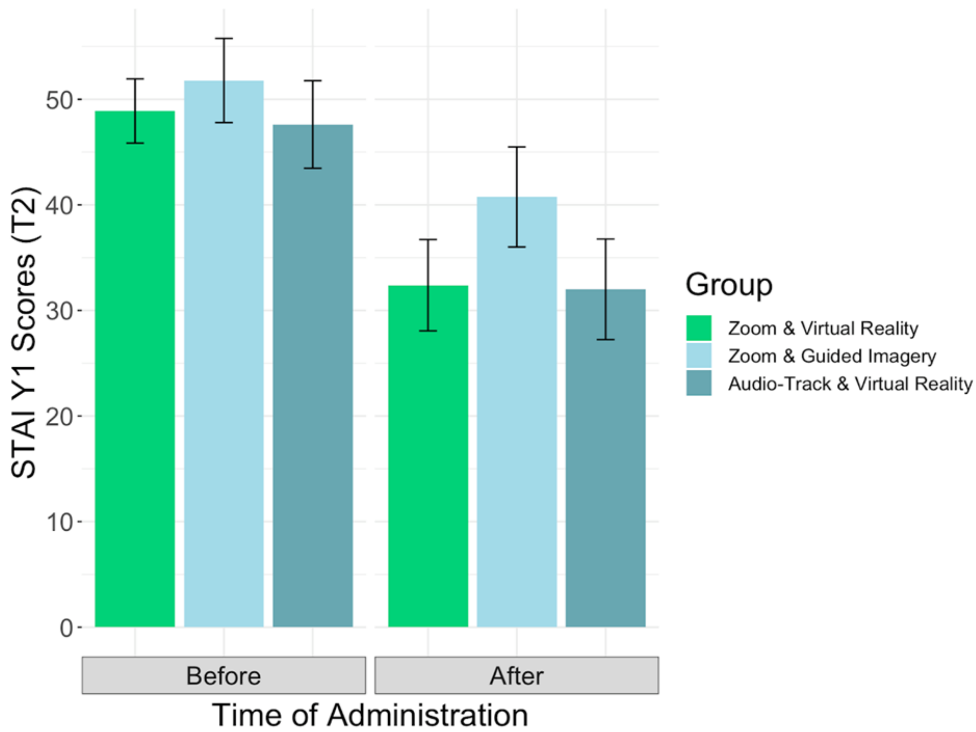
<u>**Notes**</u>: *=*p-value*<.05; **=*p-value*<.01; ***=*p-value*<.001; VR=Virtual Reality; GI=Guided Imagery; STAI-Y1=State-Trait Anxiety Inventory (Y1-State Anxiety).

Figure 11. (A) Graphical description of the differences between and within subjects considering the STAI-Y1 administered before and after the relaxation session at T1. **(B).** Graphical description of the differences between and within subjects considering the STAI-Y1 administered before and after the relaxation session at T2.

(A)



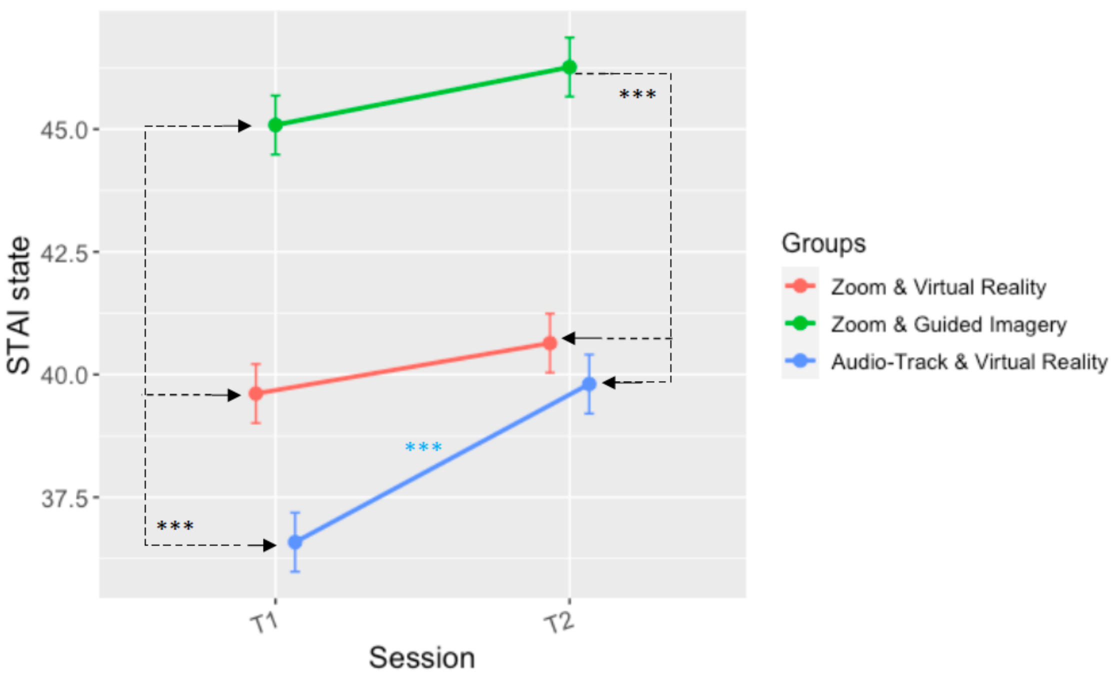
(B)



Pairwise post-hoc comparisons of the Session*Group interaction showed that the "Audio-track & VR" group had lower state anxiety scores at T1 rather than T2 (β=-3.22; SE=0.59; $t_{(1,315)}$=-

5.45; *p-value*<.001). No differences between T1 and T2 have been revealed for the "Zoom & VR" (β=-1.03; SE=0.59; $t_{(1,315)}$=-1.74; *p-value*>.05) and the "Zoom & GI" groups (β=-1.18; SE=0.59; $t_{(1,315)}$=-1.99; *p-value*>.05), showing global maintenance of state anxiety levels comparing the two sessions (Figure 12). Looking at the between-subjects effect, the "Zoom & GI" group obtained higher state anxiety scores than the other two groups at T1 ("Zoom & GI" vs. "Zoom & VR": β=5.47; SE=0.85; $t_{(1,177)}$=6.43; *p-value*<.001; "Zoom & GI" vs. "Audio-track & VR": β=-8.50; SE=0.85; $t_{(1,177)}$=9.99; *p-value*<.001), as well as at T2 ("Zoom & GI" vs. "Zoom & VR": β=5.63; SE=0.85; $t_{(1,177)}$=6.61; *p-value*<.001; "Zoom & GI" vs. "Audio-track & VR": β=6.46; SE=0.85; $t_{(1,177)}$=7.59; *p-value*<.001). The "Zoom & VR" group had higher state anxiety scores than the "Audio-track & VR" group at T1 (β=3.03; SE=0.85; $t_{(1,177)}$=3.56; *p-value*<.001) (Figure 12).

Figure 12. Plot about Session (T1/T2)* Group interaction.



Note: STAI state Session*Group interaction results. The black asterisk represents *between-group* differences, while asterisks of the same color as the lines represent *within-group* differences. *:*p-value*<.05; **:*p-value*<.01; ***:*p-value*<.001. Bars represent the Standard Error. STAI state=State anxiety is assessed based on the State-Trait Anxiety Inventory (Y1-State Anxiety); T1=Session 6; T2=Session 7.

Heart rate

Differences in heart rate have been investigated between the "Zoom & VR", the "Zoom & GI" and the "Audio-track & VR" groups before, during, and after the complementary relaxation experience in Session 6 (T1) and Session 7 (T2). A GLM model has been deployed using "group", "block (before/during/after)", and "session" as predictors and a random intercept for each subject to account for repeated measures. In Table 6 are the descriptive analysis of group differences.

Table 6. Descriptive analysis (Mean and Standard Deviation) related to Heart Rate (HR) assessed for each group before and after Session 6 (T1), and Session 7 (T2).

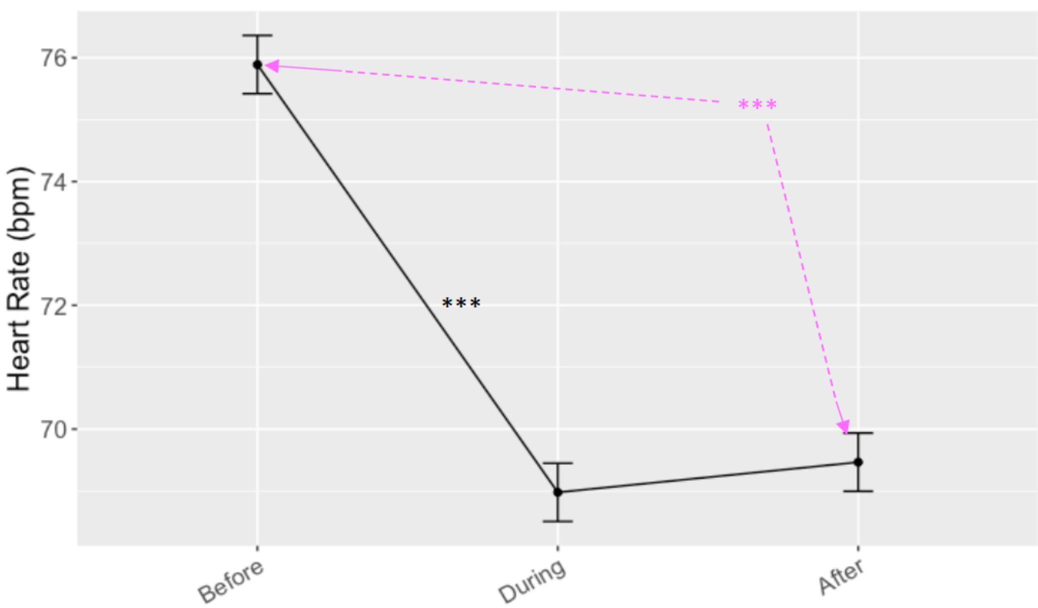
Dependent Variables	Time	Group	M[a] (SD)[b]
HR (T1)	**before**	Zoom & VR	75.02 (5.66)
		Zoom & GI	77.07 (5.64)
		Audio-track & VR	74.02 (7.22)
	during	Zoom & VR	68.26 (5.49)
		Zoom & GI	72.86 (5.23)
		Audio-track & VR	64.48 (5.24)
	after	Zoom & VR	69.11 (4.98)
		Zoom & GI	72.22 (4.73)
		Audio-track & VR	63.53 (6.36)
HR (T2)	**before**	Zoom & VR	77.91 (6.28)
		Zoom & GI	77.55 (5.04)
		Audio-track & VR	73.77 (6.66)
	during	Zoom & VR	70.63 (5.45)
		Zoom & GI	71.87 (5.47)
		Audio-track & VR	65.76 (6.07)
	after	Zoom & VR	73.64 (5.77)
		Zoom & GI	72.80 (5.40)
		Audio-track & VR	65.49 (5.58)

Notes: [a]M=Mean; [b]SD=Standard Deviation; VR=Virtual Reality; GI=Guided Imagery; HR=Heart Rate; T1=Session 6; T2= Session 7.

Heart rate was found to have a significant main effect considering "group" ($F_{(2,105)}$=20.71; *p-value*<.001), "block" ($F_{(2,525)}$=183.64; *p-value*<.001) (Figure 13), and "session" ($F_{(1,525)}$=18.87; *p-value*<.001). Significant Block*Group interaction ($F_{(4,525)}$=8.20; *p-value*<.001) (Figure 14), and Session*Group interaction ($F_{(2,525)}$=8.53; *p-value*<.01) (Figure 16).

Pairwise post-hoc contrast of the Group main effect showed that the "Audio-track & VR" group had lower scores than both the "Zoom & VR" group (β=-4.59; SE=1; $t_{(1,105)}$=-4.58; *p-value*<.001), and the "Zoom & GI" group (β=-6.22; SE=1; $t_{(1,105)}$=-6.21; *p-value*<.001). Data about "session" as a significant main effect are coherent with what emerged for state anxiety, highlighting a general increase in heart rate when data from Session 6 (T1) and Session 7 (T2) are compared. Pairwise post-hoc contrast of the Block main effect highlighted a generally lower level of heart rate during and after the relaxation sessions than before (Before-During: β=6.91; SE=0.40; $t_{(1,525)}$=17.17; *p-value*<.001; Before-After: β=-6.43; SE=0.40; $t_{(1,525)}$=-15.96; *p-value*<.001) (see Figure 13). This pattern should also be related to the fact that the baseline heart rate was much higher, and it can also be associated with the white coat effect due to the agitation experienced when a person knows that a professional is detecting their heart rate [e.g., 311]. The heart rate recorded during the relaxation session did not differ significantly if compared to the heart rate detected after the completion of the Sessions (During-After: β=-0.49; SE=0.40; $t_{(1,525)}$=-1.21; *p-value*>.05).

Figure 13. Plot about Block (Time of Administration: Before/During/After) as a main effect.

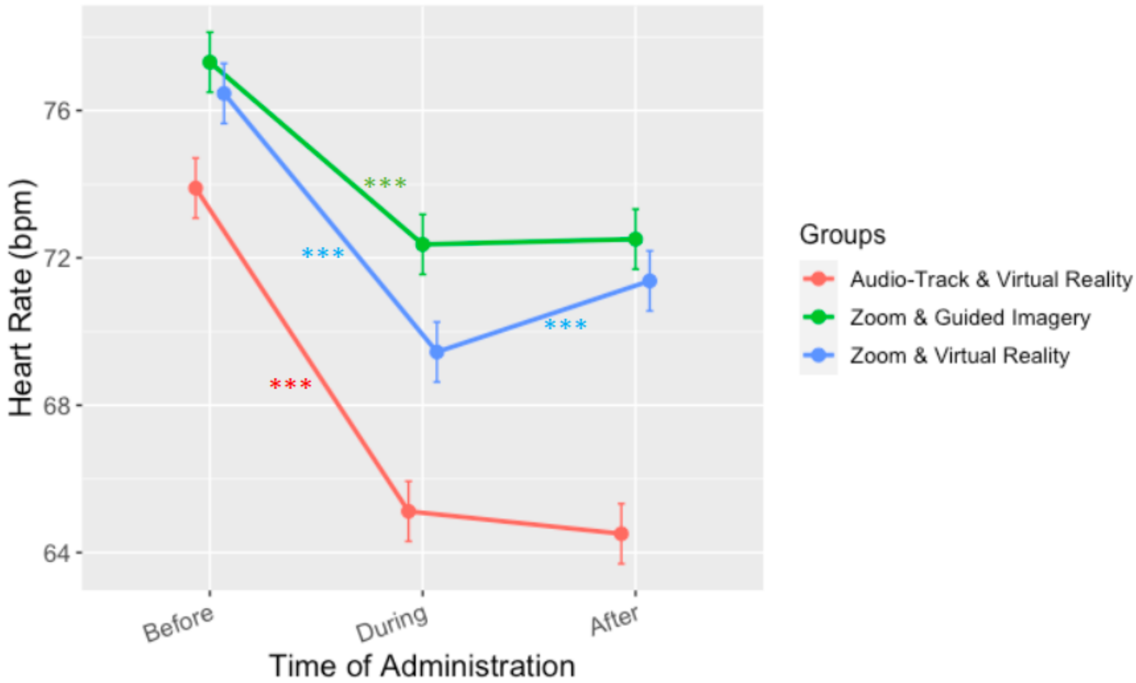


<u>**Note:**</u> Heart Rate Block*Group interaction results. The black asterisk represents the *between-block* difference considering "before" and "during", while the pink asterisk represents the *between-block* difference considering

"before" and "after". ***: *p-value*<.001. Bars represent the Standard Error. Before=Heart rate assessment before the relaxation exposure; During= Heart Rate assessment during the relaxation exposure; After=Heart Rate assessment after the relaxation exposure.

Looking at the within-subjects effect from the pairwise post-hoc comparisons of the block (before/during/after)*group interaction, the "Audio-track & VR" group had a reduction in heart rate during and after the relaxation exposure if compared to the heart rate recorded before the sessions (Before vs. During: β=8.77; SE=0.70; $t_{(1,525)}$=12.58; *p-value*<.001; Before vs. After: β=9.38; SE=0.70; $t_{(1,525)}$=13.46; *p-value*<.001). The same pattern emerged for the "Zoom & GI" group (Before vs During: β=4.95; SE=0.70; $t_{(1,525)}$=7.09; *p-value*>.001; Before vs After: β=4.80; SE=0.70; $t_{(1,525)}$=6.89; *p-value*<.001). Indeed, the "Audio-track & VR" and the "Zoom & GI" groups obtained a significant decrease in HR during the relaxation sessions that persisted and did not change after the relaxation sessions. The HR of the "Zoom & VR" group decreased significantly during the relaxation and showed a small but significant increase once the sessions finished (Before vs. During: β=7.02; SE=0.70; $t_{(1,525)}$=10.07; *p-value*<.001; Before vs. After: β=5.09; SE=0.70; $t_{(1,525)}$=7.30; *p-value*<.001; During vs. After: β=-1.93; SE=0.70; $t_{(1,525)}$=-2.77; *p-value*<.001) (Figure 10). Considering the between-subject effect, individuals in the "Audio-track & VR" group had lower state anxiety scores before starting the relaxation session than the "Zoom & VR" (β=-2.57; SE=1.15; $t_{(1,180)}$=-2.23; *p-value*<.05), and the "Zoom & GI" group (β=-3.42; SE=1.15; $t_{(1,180)}$=-2.96; *p-value*<.05); these differences have been maintained during and after the relaxation sessions (During_ "Audio-track & VR" vs. "Zoom & VR": β=-4.32; SE=1.15; $t_{(1,180)}$=-3.75; *p-value*<.01; "Audio-track & VR" vs "Zoom & GI": β=-7.24; SE=1.15; $t_{(1,180)}$=-6.29; *p-value*<.001; After_ "Audio-track & VR" vs "Zoom & VR": β=-6.86; SE=1.15; $t_{(1,180)}$=-5.96; *p-value*<.001; "Audio-track & VR" vs "Zoom & GI": β=-7.99; SE=1.15; $t_{(1,180)}$=-6.94; *p-value*<.001). Differences between the "Zoom & VR" and the "Zoom & GI" emerged during the relaxation and highlighted a greater decrease in HR for the "Zoom & VR" group (β=-2.92; SE=1.15; $t_{(1,180)}$=-2.53; *p-value*<.05).

Figure 14. Plot about Block (Time of Administration: pre/during/post)*Group interaction.



<u>**Note**</u>**:** Heart Rate Session*Group interaction results. The asterisk of the same color as the lines represents *within-group* differences. ***: *p-value*<.001. Bars represent the Standard Error. Before=Heart rate assessment before the relaxation exposure; During= Heart rate assessment during the relaxation exposure; After= Heart rate assessment after the relaxation exposure.

At Session 6 (T1), "Zoom & VR", and "Audio-track & VR" groups had lower heart rate frequency during the exposure in the virtual environment than individuals in the Guided Imagery condition (Table 7). Moreover, after the exposure a lower heart rate frequency was recorded for the "Audio-track & VR" group, followed by the "Zoom & VR" group, and, lastly by individuals in the "Zoom & GI" condition, that obtain higher heart frequency scores than the participants in the other two VR conditions (Zoom & GI: M=72.22; SD=4.73; Zoom & VR: M=69.11; SD=4.98; Audio-track & VR: M=63.53; SD=6.36) (Table 7).

At Session 7 (T2) individuals in the Audio-track & VR condition had lower scores of heart rate frequency before starting with the relaxation procedure; therefore, it is essential to note that this difference increased during and after the relaxation session (<u>Before Session 7</u>: d-Cohen=0.64; effect size r=0.30; <u>During Session 7</u>: d-Cohen=1.06; effect size r=0.47; <u>After Session 7</u>: d-Cohen=1.33; effect size r=0.65), underlined a higher decrease of heart rate frequency during and following the relaxation session in individuals who in the previous Session 6 (T1) experienced the relaxation in the virtual customized environment (Table 8).

Individuals in the "Audio-track & VR" group obtained lower scores in heart rate frequency during and after the relaxation at Session 7 (T2) than the other two groups. Instead, no differences emerged between the "Zoom & VR" and the "Zoom & GI" groups (see Table 8). In figures 15 A and 15 B are described in a graphical way the differences between groups and the interactions.

Table 7. Pairwise Comparisons between Groups about differences in heart rate recorded before, during and after exposures at T1 (Confidence interval adjustment: Bonferroni).

Dependent Variables	Groups		Time	Mean Difference (Before - After)	Std. Error	t-test	d-Cohen	effect-size r
HR (T1)	Zoom & VR	Zoom & GI	Before	-2.49	1.63	-1.53	-0.36	-0.18
		Audio-track & VR		0.77	1.78	0.43	0.15	0.08
	Audio-track & VR	Zoom & GI		-3.25	1.71	-1.9	0.47	0.23
	Zoom & VR	Zoom & GI	During	**-4.87*** **	**1.39**	**-3.50**	**-0.86**	**-0.39**
		Audio-track & VR		3.19	1.52	2.10	0.70	0.33
	Audio-track & VR	Zoom & GI		**-8.05*** **	**1.46**	**-5.51**	**1.60**	**0.62**
	Zoom & VR	Zoom & GI	After	**-3.62***	**1.42**	**-2.55**	**-0.64**	**-0.30**
		Audio-track & VR		**5.05** **	**1.55**	**3.26**	**0.98**	**0.44**
	Audio-track & VR	Zoom & GI		**-8.67*** **	**1.49**	**-5.82**	**1.55**	**0.61**

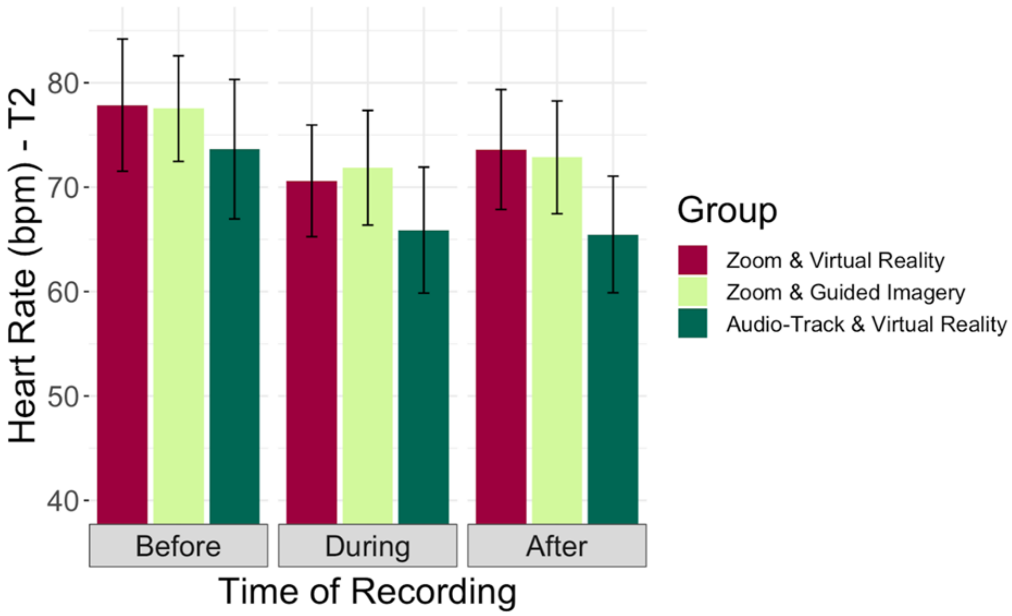
Table 8. Pairwise Comparisons between Groups about differences in heart rate recorded before, during and after exposures at T2 (Confidence interval adjustment: Bonferroni).

Dependent Variables	Groups		Time	Mean Difference (Before - After)	Std. Error	t-test	d-Cohen	effect-size r
HR (T2)	Zoom & VR	Zoom & GI	Before	-0.31	1.59	-0.19	0.06	0.03
		Audio-track & VR		4.14	1.74	2.38	0.64	0.30
	Audio-track & VR	Zoom & GI		**4.45***	**1.66**	**2.68**	**0.64**	**0.30**
	Zoom & VR	Zoom & GI	During	-2.29	1.49	-1.54	-0.23	-0.11
		Audio-track & VR		**4.11***	**1.63**	**2.52**	**0.84**	**0.39**
	Audio-track & VR	Zoom & GI		**-6.40*****	**1.56**	**-4.10**	**1.06**	**0.47**
	Zoom & VR	Zoom & GI	After	-0.23	1.47	-0.16	0.15	0.07
		Audio-track & VR		**7.69*****	**1.60**	**4.81**	**1.44**	**0.58**
	Audio-track & VR	Zoom & GI		**-7.92*****	**1.53**	**-5.18**	**1.33**	**0.55**

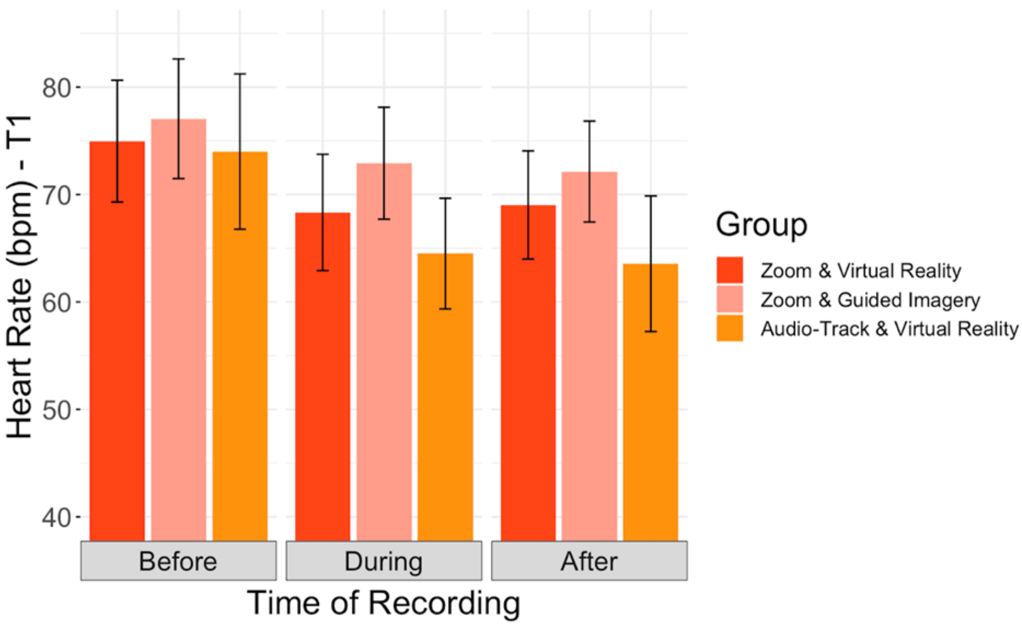
<u>**Notes**</u>: * = p-value <.05; ** = p-value <.01; *** = p-value <.001; VR= Virtual Reality; GI= Guided Imagery; HR= Heart rate frequency.

Figure 15. (A) Graphical description of the differences between and within subjects considering the HR administered before and after the relaxation session at T1. **(B).** Graphical description of the differences between and within subjects considering the HR administered before and after the relaxation session at T2.

(A)



(B)

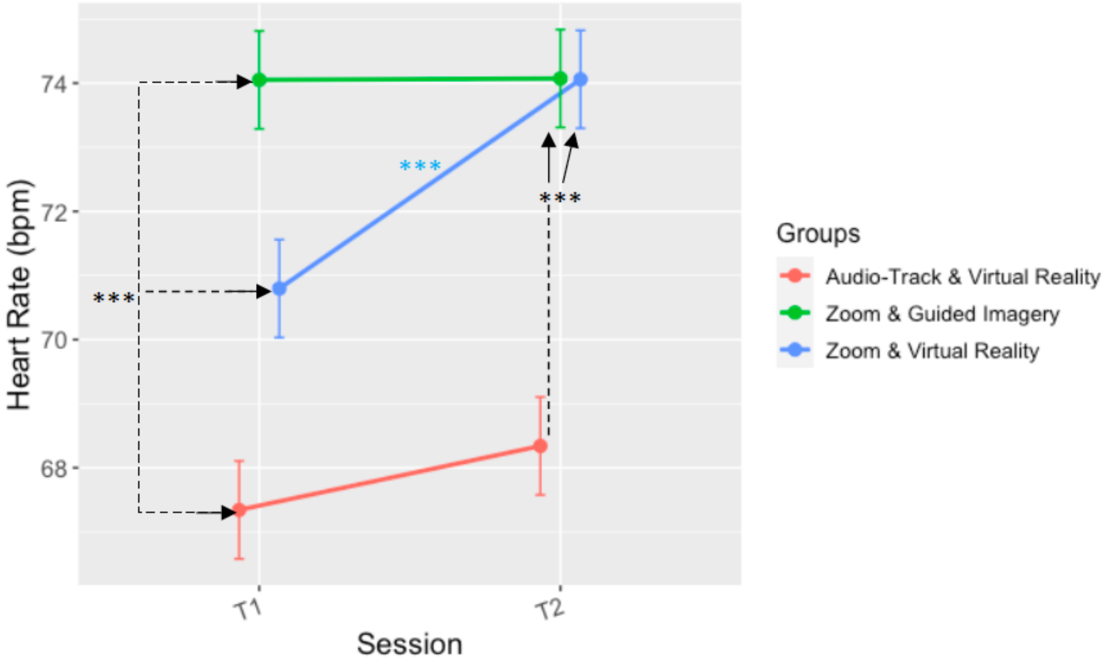


Pairwise post-hoc comparisons of the Session*Group interaction showed no differences in heart rate between T1 and T2 for the "Audio-track & VR" group (β=-0.99; SE=1.08; $t_{(1,525)}$=-1.75; *p-value*>.05), and the "Zoom & GI" group (β=-0.02; SE=1.08; $t_{(1,525)}$=-0.04; *p-*

value>.05). Instead, a global increased in heart rate emerged comparing the assessment at T1 and T2 only for the "Zoom & VR" group (β=-3.26; SE=1.08; $t_{(1,525)}$=-5.73; *p-value*<.001) (Figure 16). Considering the between-subjects effect, the "Zoom & GI" group obtained higher state anxiety scores than the other two groups at T1 (vs. "Audio-track & VR": β=6.71; SE=1.08; $t_{(1,141)}$=6.21; *p-value*>.001; vs. "Zoom & VR": β=3.26; SE=1.08; $t_{(1,141)}$=3.01; *p-value*>.001). Moreover, the "Audio-track & VR" group had a lower heart rate level recorded before the relaxation session than the "Zoom & VR" group (β=-3.45; SE=1.08; $t_{(1,141)}$=-3.20; *p-value*>.001). At T2, the "Audio-track & VR" obtained a lower HR level than both the "Zoom & GI" (β=5.73; SE=1.08; $t_{(1,141)}$=5.31; *p-value*<.001) and the "Zoom & VR" group (β=5.72; SE=1.08; $t_{(1,141)}$=5.30; *p-value*<.001) (Figure 16).

Notably, the greater increase in heart rate obtained by the "Zoom & VR" group from T1 to T2 probably explains the global decrease highlighted, considering "session" as a main effect. Even if the increase is recorded for the "Audio-track & VR" group too, the "Zoom & VR" group seems to be less incisive in promoting relaxation using the strategies learned during the training sessions (s1-s4), and T1, compared to what emerged by data of the "Audio & VR" group. This outcome seems not to be coherent with what is highlighted for STAI-Y1, considering the increase in self-reported state anxiety increase from T1 and T2 but with a lower effect than what is highlighted by the Heart Rate.

Figure 16. Plot about Session (T1/T2)*Group interaction.

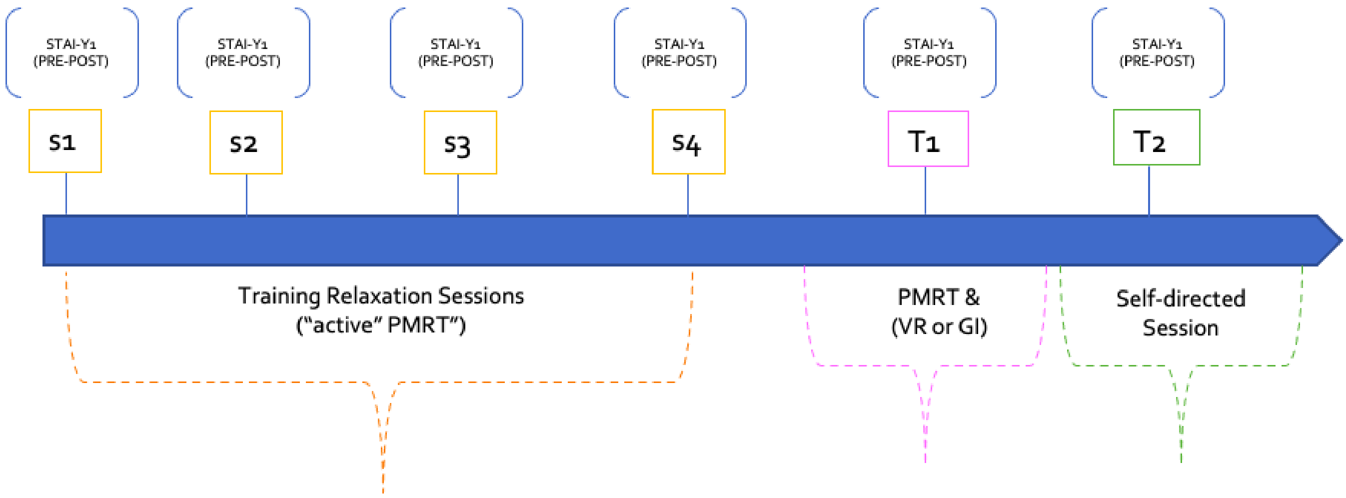


Note: Heart Rate Session*Group interaction results. The black asterisk represents *between-subjects* differences, while the same color as the lines represent *within-group* differences. ***: *p-value*<.001. Bars represent the Standard Error. Before=Heart Rate assessment before the relaxation exposure; During=Heart Rate assessment during the relaxation exposure; After=Heart Rate assessment after the relaxation exposure.

4.4.4 Aim n.2: Investigate the effect of the entire relaxation protocol on state anxiety

To investigate the differences in the STAI-Y1 assessed before and after each of the six PMR training sessions for the "Zoom & VR", "Zoom & GI" and the "Audio-track & VR" groups, a linear mixed-effect model on the scores has been performed, using "group", "block (pre/post assessment based on the STAI-Y1)", and "session" as predictors and a random intercept for each subject to account for repeated measures. For a graphical representation of the STAI-Y1 assessment's phases, see Figure 17. In Table 5 are the descriptive analysis of STAI-Y1 filled out before and after the training sessions (descriptive statistics of the STAI-Y1 assessed at T1 and T2 are in Table 3).

Figure 17. A flowchart about relaxation sessions in which the participants of the three groups filled out the STAI-Y1.



Notes: VR= Virtual Reality; GI= Guided Imagery; STAI-Y1= State-Trait Anxiety Inventory (Y1-State Anxiety); s1-4= Sessions from 1 to 4; T1= Session 6; T2 (Session 7); PMR= Progressive Muscle Relaxation Technique.

Table 5. Descriptive analysis (Mean and Standard Deviation) related to the STAI-Y1 score assessed for each group before and after each training session (s1-s4), Session 6 (T1), and Session 7 (T2).

Dependent Variables	Time	Group	M^a (SD)^b
STAI-Y1 (s1)	before	Zoom & VR	48.19 (5.32)
		Zoom & GI	48.06 (4.14)
		Audio-track & VR	45.61 (9.91)
	after	Zoom & VR	42.49 (4.23)

		Zoom & GI	42.81 (3.82)
		Audio-track & VR	34.50 (7.17)
STAI-Y1 (s2)	**before**	Zoom & VR	48.57 (4.09)
		Zoom & GI	45.89 (4.30)
		Audio-track & VR	45.17 (6.42)
	after	Zoom & VR	41.23 (3.04)
		Zoom & GI	41.31 (3.76)
		Audio-track & VR	33.53 (7.88)
STAI-Y1 (s3)	**before**	Zoom & VR	44.77 (3.40)
		Zoom & GI	43.69 (4.92)
		Audio-track & VR	42.17 (7.93)
		Zoom & VR	42.57 (3.10)

	after	Zoom & GI	40.97 (3.89)
		Audio-track & VR	33.58 (6.39)
STAI-Y1 (s4)	**before**	Zoom & VR	45.74 (4.46)
		Zoom & GI	43.92 (5.27)
		Audio-track & VR	42.31 (9.18)
	after	Zoom & VR	44.14 (4.07)
		Zoom & GI	41.33 (4.62)
		Audio-track & VR	34.19 (7.95)

Notes: [a]M=Mean; [b]SD= Standard Deviation; VR= Virtual Reality; GI= Guided Imagery; STAI-Y1= State-Trait Anxiety Inventory (Y1-State Anxiety); s1-4= sessions from 1 to 4.

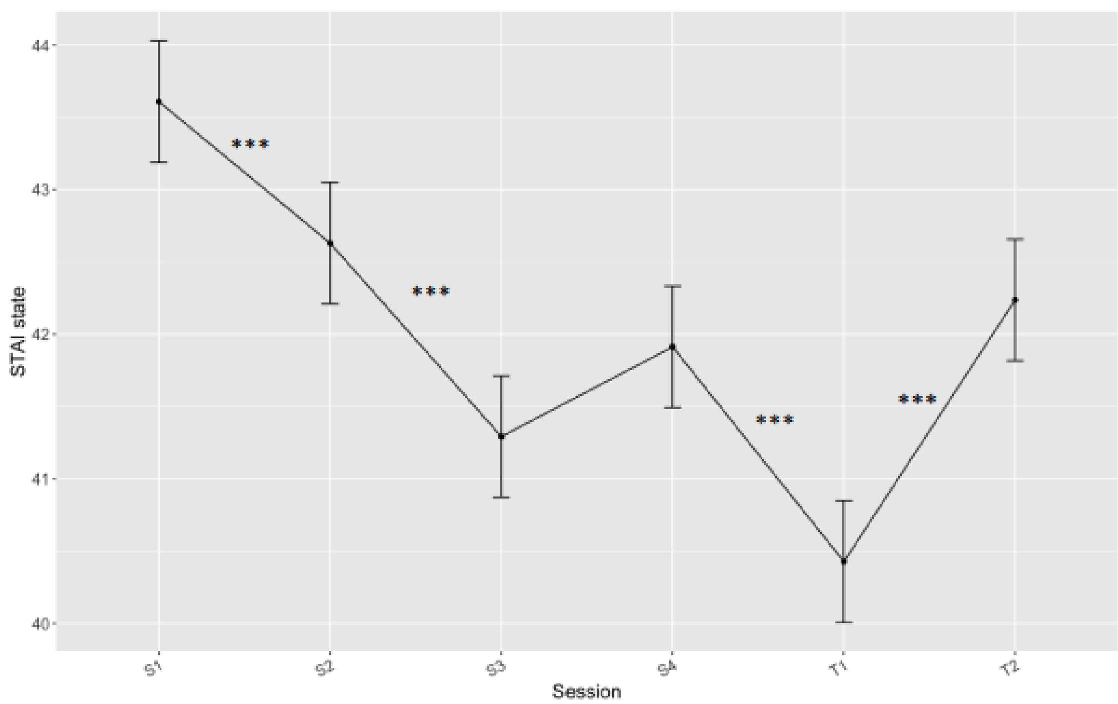
Results showed significant “group” ($F_{(2,105)}$=27.55; *p-value*<.001), “block” ($F_{(1,1154)}$=1383.46; *p-value*<.001), and “session” main effects ($F_{(5,1154)}$=14.21; *p-value*<.001) (Figure 18), as well as significant Block*Session ($F_{(5,1154)}$=65.86; *p-value*<.001), Block*Group ($F_{(2,1154)}$=54.49; *p-value*<.001), Session*Group ($F_{(10,1154)}$=13.21; *p-value*<.001) (Figure 19), and Session*Block*Group interactions ($F_{(10,1154)}$=3.55; *p-value*<.001) (Figure 20).

Pairwise post-hoc contrast of “group” as main effect showed that the “Audio-track & VR” group had lower scores than both the “Zoom & VR” (β=-4.51; SE=0.80; $t_{(1,105)}$=-5.65; *p-value*<.001), and the “Zoom & GI” group (β=-5.58; SE=0.80; $t_{(1,105)}$=-6.99; *p-value*<.001).

Pairwise post-hoc contrast of "session" as main effect showed differences between Session 1 and 2 (β=0.98; SE=0.41; $t_{(1,1154)}$=2.38; *p-value*<.05), Session 2 and 3 (β=1.34; SE=0.41; $t_{(1,1154)}$=3.25; *p-value*<.01), highlighting a decrease in state anxiety which reaches its peak at Session 3, and remain stable until the end of Session 4 that correspond to the last PMR training session (β=-0.62; SE=0.41; $t_{(1,1154)}$=-1.51; *p-value*>.05). A further noteworthy decrease in anxiety is between Session 4 and T1 (β=3.18; SE=0.41; $t_{(1,1154)}$=7.73; *p-value*<.001), shed in light an additional decrease in anxiety once participants complete the Relaxation session complementary to the exposure in the VR or GI scenario (T1). Once participants are exposed to the self-directed relaxation session at T2, they globally obtain state anxiety levels comparable to what they reported after the second training session (Session 2) (*p-value*>.05).

Moreover, as stated before, the statistically significant difference related to "block" revealed a general decrease in state anxiety from the STAI-Y1 score administered before and after each session. This pattern characterized each group separately, based on the significance of the block*group interaction (Pre/Post "Audio-track & VR": β=12.09; SE=0.41; $t_{(1,1154)}$=29.39; *p-value*<.001; Pre/Post "Zoom & VR": β=8.35; SE=0.41; $t_{(1,1154)}$=20.26; *p-value*<.001; Pre/Post "Zoom & GI": β=6.08; SE=0.41; $t_{(1,1154)}$=14.77; *p-value*<.001).

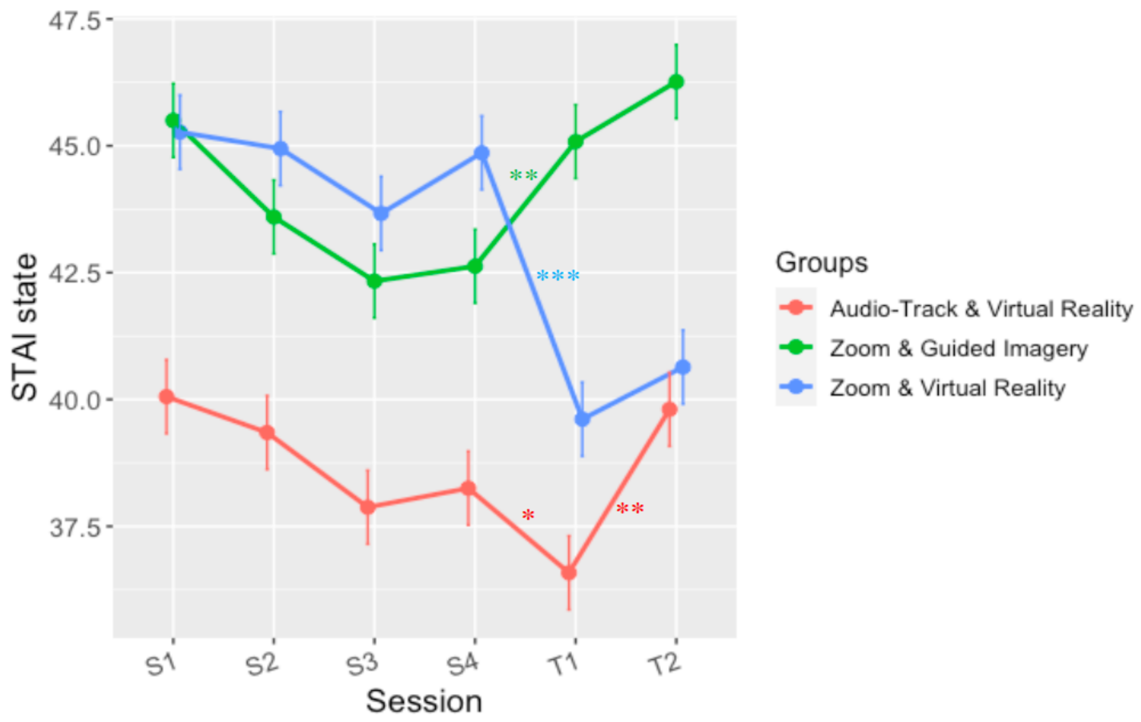
Figure 18. Plot about Session (s1-s4 and T1-T2) as a main effect.



Notes: STAI state Session*Group interaction results. The black asterisks represent the main *within-sessions* differences. ***: *p-value* <.001. Bars represent the Standard Error. s1-s4= the four PMR training sessions; T1= Session 6; T2= Session 7.

The Session*Group interaction is more interesting than what can be seen from the Session main effect since it shows that the maximum decrease between s4 and T1 that emerged from the main effect is due to the decrease in anxiety scores obtained by the "Zoom & VR" group (β=5.25; SE=0.71; $t_{(1,1154)}$=7.37; *p-value*<.001), and, partly, by the "Audio-track & VR" group (β=1.67; SE=0.71; $t_{(1,1154)}$=2.34; *p-value*<.05). It is also notable that the "Zoom & GI" group has an opposite trend as anxiety at T1 had already started to decrease compared to the training sessions (β=-2.46; SE=0.71; $t_{(1,1154)}$=-3.45; *p-value*<.01). The increase at T2 seems to be pushed by the "Audio-track & VR" group (β=-3.22; SE=0.71; $t_{(1,1154)}$=-4.52; *p-value*<.001), while in the groups that were previously exposed to the Zoom relaxation training the level of anxiety is almost equal (*p-value*>.05) (Figure 19).

Figure 19. Plot about Session*Group interaction.

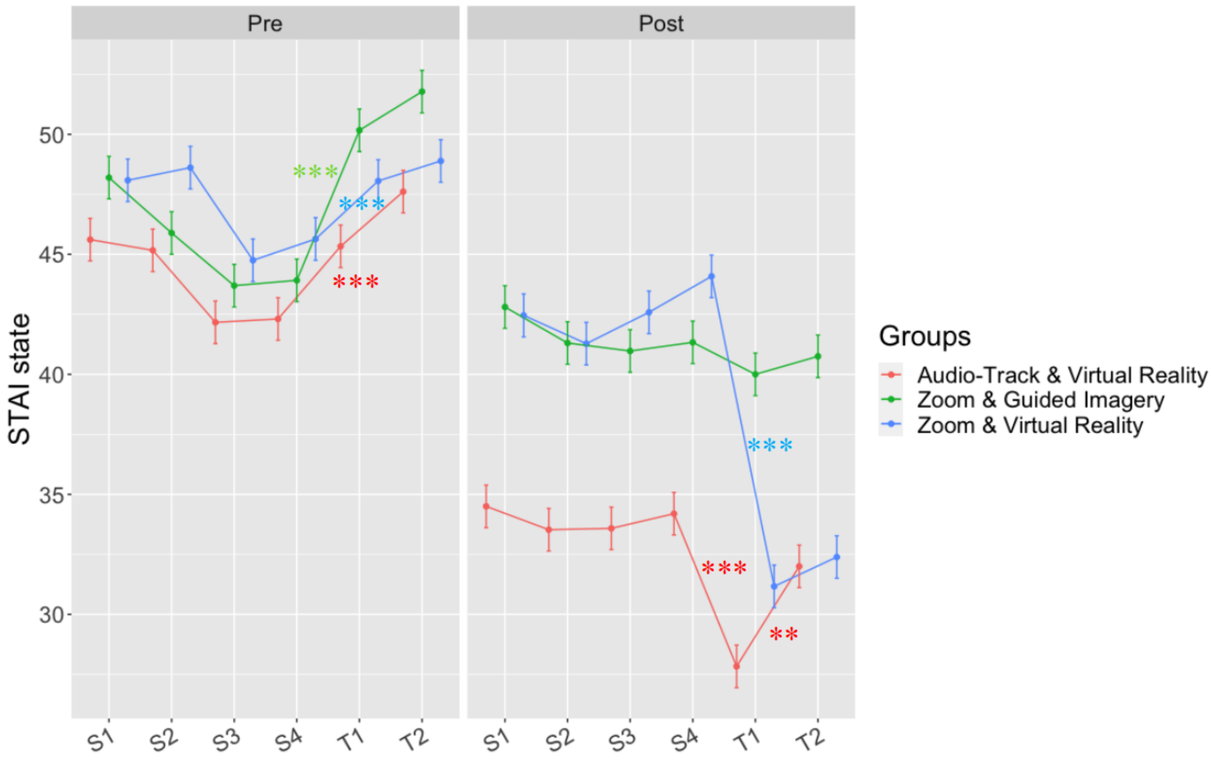


Notes: The asterisks of the same colour as the lines represent *within-group* differences. *:*p-value*<.05; **:*p-value*<.01; ***:*p-value*<.001. Bars represent the Standard Error. STAI state=State anxiety is assessed based on the State-Trait Anxiety Inventory (Y1-State Anxiety); s1-s4= the four training sessions by Zoom or Audio-track; T1=Session 6; T2=Session 7.

Considering the Block*Session*Group interaction, interesting is that the state anxiety felt by the "Zoom & GI" group, recorded before and after every single session (from s1 to T2), shows a constant decrease but remains relatively stable once participants are exposed to the Guided Imagery scenario (*p-value*>0.05). This does not happen in other groups: in the "Audio-track & VR" group, state anxiety undergoes a large reduction at T1 (β=6.36; SE=1.02; $t_{(1,1154)}$=6.31; *p-value*<.001), and then increases at T2 (β=-4.17; SE=1.01; $t_{(1,1154)}$=4.13; *p-value*<.01). At the same time, in the "Zoom & VR" group, anxiety decreases from s4 and T1 (β=12.92; SE=1.01; $t_{(1,1154)}$=12.82; *p-value*<.001), and remains down without changing from T1 and T2 (*p-value*<.05), showing how the latter seems to be the best condition to promote a decrease in anxiety. As was the case for all groups, the GI group greatly increased state anxiety before the in-presence sessions if comparing anxiety recorded before at s4 and T1 (β=-4.14; SE=1.25; $t_{(1,533)}$=3.31; *p-value*<.01). But, unlike evidenced by the groups exposed to virtual reality, the "Zoom & GI" group has not reached a subsequent sharp decrease. The increase in anxiety experienced before the in-presence sessions (at T1 and T2) and the reduced decrease recorded immediately after helps to explain the overall increase in anxiety experienced by the "Zoom & GI" group, if compared to the general level obtained during the training sessions. Instead, the decrease in anxiety after the exposure to VR was so significant that it was evident, even if, as for the group "Zoom & GI", subjects exposed to the VR conditions had a much higher level of state anxiety before the in-presence sessions than the anxiety recorded before the training sessions done by Zoom (Figure 20).

Moreover, it is interesting to note how, from the third training session, individuals of all groups experienced lower anxiety levels before the training than what they experienced before s2 (*p-value* >.01), (Figure 20); it could be outlined that already after two web-based sessions, the participants began to get used and be more confident with the relaxation procedure and it is related with the above-mentioned decrease in state anxiety which reaches its peak at Session 3 revealed by considering "session" as the main effect (Figure 18).

Figure 20. The plot about Block*Session*Group interaction.



<u>Notes</u>: The asterisks of the same color as the lines represent *within-group* differences. *:*p-value*<.05; **:*p-value*<.01; ***:*p-value*<.001. Bars represent the Standard Error. STAI state=State anxiety is assessed based on the State-Trait Anxiety Inventory (Y1-State Anxiety); s1-s4= the four training sessions by Zoom or Audio-track; T1=Session 6; T2=Session 7.

4.4.5 Aim n. 3: Understand if VR promotes a better sense of presence and engagement in the scenario compared to GI after Session 6 (T1) and if it helps to recall the image and be immersed in the relaxing scenario in Session 7 (T2)

To investigate the second aim of the current study, a GLM model is used for each of the ITC-SOPI subscales. In Table 6 are the descriptive statistics.

Table 6. Descriptive analysis (Mean and Standard Deviation) related to the ITC-SOPI subscales scores assessed for each group after Session 6 (T1), and Session 7 (T2).

Dependent Variables	Group	M (SD)
	Zoom & VR	60.06 (8.64)

ITC-SOPI Sense of Physical space (presence) (T1)	**Zoom & GI**	57.00 (8.99)
	Audio-track & VR	62.69 (7.68)
ITC-SOPI Engagement (T1)	**Zoom & VR**	46.61 (4.66)
	Zoom & GI	42.42 (5.71)
	Audio-track & VR	50.81 (3.65)
ITC-SOPI Ecological Validity (T1)	**Zoom & VR**	19.92 (2.12)
	Zoom & GI	17.67 (2.75)
	Audio-track & VR	19.31 (2.58)
ITC-SOPI Negative Effects (T1)	**Zoom & VR**	13.14 (5.17)
	Zoom & GI	12.08 (1.86)
	Audio-track & VR	9.86 (4.47)
ITC-SOPI Sense of Presence (T2)	**Zoom & VR**	50.06 (11.88)
	Zoom & GI	41.22 (19.81)
	Audio-track & VR	53.50 (7.88)
ITC-SOPI Engagement (T2)	**Zoom & VR**	40.50 (6.88)
	Zoom & GI	40.36 (6.16)
	Audio-track & VR	42.47 (5.46)
ITC-SOPI Ecological Validity (T2)	**Zoom & VR**	17.44 (3.85)
	Zoom & GI	14.17 (4.06)
	Audio-track & VR	16.89 (3.16)
ITC-SOPI Negative Effects (T2)	**Zoom & VR**	10.89 (2.42)
	Zoom & GI	10.89 (2.82)

Audio-track & VR	9.64 (2.63)

Notes: M=Mean; SD= Standard Deviation; VR= Virtual Reality; GI= Guided Imagery.

ITC-SOPI "Sense of Physical Space"

Considering the ITC-SOPI "Sense of Physical Space" subscale, significant main effects between and within subjects were found considering "group" ($F_{(2,210)}$=11.14; *p-value*<.001), and "session" ($F_{(2,210)}$=54.37; *p-value*<.001). In general, scores related to the perception of "being immersed" in the scenario decreased independently of the group once participants experienced the self-directed relaxation session at T2.

About "group" as main effect, the "Zoom & GI" group experienced a lower sense of presence in the relaxing scenario rather than the other two groups in which individuals were exposed in a virtual environment ("Zoom & GI" vs. "Zoom & VR": β=-5.94; SE=1.94; $t_{(1,105)}$=-3.07; *p-value*<.01; "Zoom & GI" vs. "Audio-track & VR": β=-8.99; SE=1.94; $t_{(1,105)}$=-4.64; *p-value*<.001).

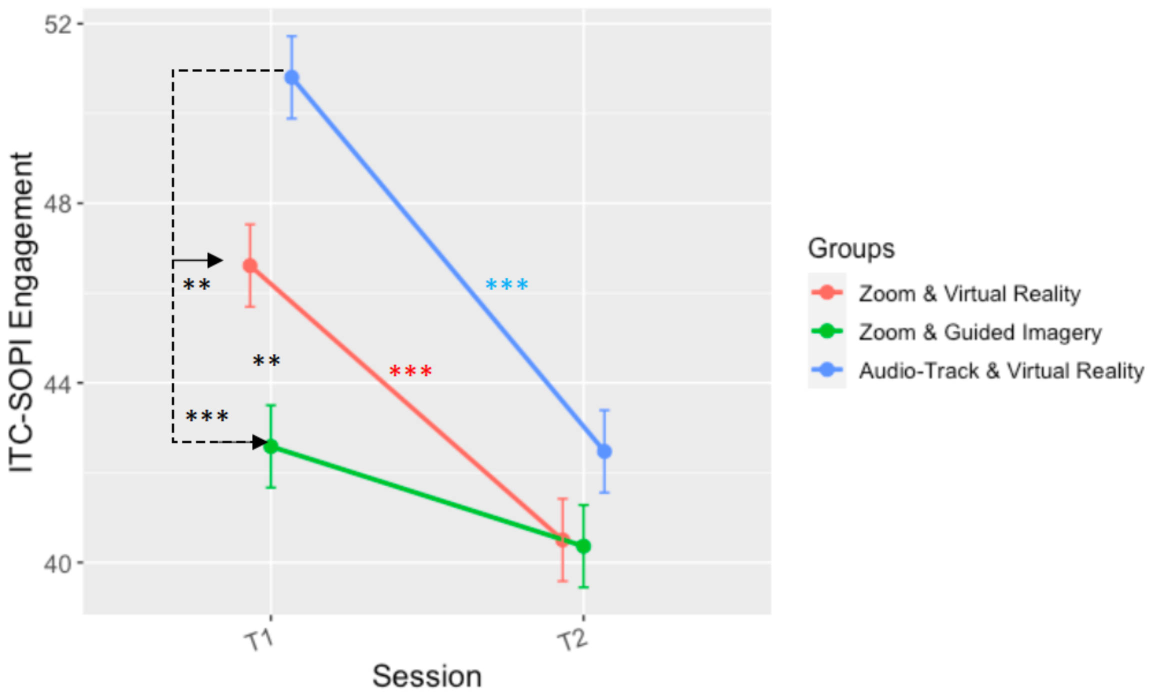
ITC-SOPI "Engagement"

Considering the ITC-SOPI "Engagement" subscale, significant main effects between and within subjects were found considering "group" ($F_{(2,210)}$=16.07; *p-value*<.001), and "session" ($F_{(1,210)}$=55.04; *p-value*<.001). Moreover, the Session*Group interaction was revealed ($F_{(2,210)}$=5.69; *p-value*<.001) (Figure 21).

The "Zoom & GI" group experienced lower engagement in the relaxing scenario rather than groups exposed to a virtual environment ("Zoom & GI" vs. "Zoom & VR": β=-2.08; SE=0.92; $t_{(1,105)}$=-2.27; *p-value*<.05; "Zoom & GI" vs. "Audio-track & VR": β=-5.17; SE=0.92; $t_{(1,105)}$=-5.63; *p-value*<.001). Moreover, the "Audio-track & VR" group showed higher engagement in the VR context than the "Zoom & VR" group (β=3.08; SE=0.92; $t_{(1,105)}$=3.36; *p-value*<.01). As for the "Physical Space" subscale, engagement in the scenario decreased once participants experienced the self-directed relaxation session at T2.

Pairwise post-hoc comparisons of the Session*Group interaction showed that the two VR groups had higher engagement in the experience at T1 rather than T2 ("Zoom & VR": β=6.11; SE=1.30; $t_{(1,105)}$=4.71; *p-value*<.01; "Audio-track & VR": β=8.33; SE=1.30; $t_{(1,105)}$=6.42; *p-value*<.001). No differences emerged for the "Zoom & GI" group (β=2.22; SE=1.30; $t_{(1,105)}$=1.71; *p-value*<.001). Looking at between-subjects effect, "Audio-track & VR" group was more engaged in the experience than the other two groups at T1 ("Audio-track & VR" vs. "Zoom & VR": β=4.19; SE=1.30; $t_{(1,210)}$=3.23; *p-value*<.01; "Audio-track & VR" vs. "Zoom & GI": β=8.22; SE=1.30; $t_{(1,210)}$=6.34; *p-value*<.001), but not at T2, were no differences have been highlighted if comparing groups with each other (*p-value*>.05). The "Zoom & VR" group had a higher score in the engagement scale than the "Zoom & GI" group at T1 (β=4.03; SE=1.30; $t_{(1,210)}$=3.11; *p-value*<.01). An interesting information from the outcome is that no differences in engagement emerged from T1 and T2 for the "Zoom & GI" group, further highlighting the importance of having made the experience in a more immersive context in VR on the sense of engagement felt during the exposure.

Figure 21. Plot about Session (T1/T2)*Group interaction.



<u>Note</u>: ITC-SOPI Engagement Session*Group interaction results. The black asterisk represents *between-subjects* differences, while the same color as the lines represent *within-group* differences. **; *p-value*<.01; ***: *p-value*<.001. Bars represent the Standard Error. T1=Session 6; T2= Session 7.

ITC-SOPI "Ecological Validity"

Considering the ITC-SOPI "Ecological Validity" subscale, significant main effects between and within subjects were found considering "group" ($F_{(2,105)}$=11.69; *p-value*<.001), and "session" ($F_{(1,105)}$=60.95; *p-value*<.001).

The “Zoom & GI” group perceived their imagined environment less credible when they have to refer to the level of realism of the scenario’s content rather than groups exposed in a virtual environment (“Zoom & GI” vs. “Zoom & VR”: β=-2.76; SE=0.60; $t_{(1,105)}$=-4.59; *p-value*<.001; “Zoom & GI” vs. “Audio-track & VR”: β=-2.18; SE=0.60; $t_{(1,105)}$=-3.62; *p-value*<.01). Switching the attention on the “session” main effect, it is revealed that the perception of realism about the scenario in which individuals were exposed, decreased once participants experienced the self-directed relaxation session at T2.

ITC-SOPI “Negative Effects”

Considering the ITC-SOPI “Negative Effects” subscale, significant main effects between and within subjects were found considering “group” ($F_{(2,105)}$=8.00; *p-value*<.001) and “session” ($F_{(1,105)}$=7.33; *p-value*<.001).

As expected, considering that the participants exposed to the imagined scenarios had not to wear the headset, it was found that the “GI & VR” group experienced fewer symptoms (e.g., eye discomfort) than the other two groups (“Zoom & GI” vs. “Zoom & VR”: β=-2.26; SE=0.59; $t_{(1,105)}$=-3.82; *p-value*<.01; “Zoom & GI” vs. “Audio-track & VR”: β=-2.69; SE=1.30; $t_{(1,105)}$=-3.97; *p-value*<.01). In relation to the significance of the “session” as a main effect, the perception of discomfort experienced when individuals had to wear the headset was higher at T1 and decreased at T2, when subjects have just to recall the virtual scenarios that they experienced in the previous session.

4.4.6 Aim n.4: Can the sense of presence, engagement, and the perception that the scenario is realistic to predict a more significant reduction in state anxiety after the virtual reality experience?

A linear regression analysis was conducted on the “Zoom & VR” and the “Zoom & GI” groups data to investigate whether the sense of presence, engagement, and the perception of a realistic scenario predicted a more significant reduction in state anxiety after the relaxation experiences. We considered three ITC-SOPI scales (Sense of Presence, Engagement, and Ecological Validity) as predictors and the STAI-Y1 scores recorded after the VR experience or the GI experience as dependent variables. For the Virtual Reality group, data showed that the factors considered in the model are related to the state anxiety level after the VR experience (Adjusted R Square=0.17; $F_{(3,35)}$=3.32; *p-value*<.05). The data indicates that engagement (ITC-SOPI Engagement) is predictive of state anxiety levels (STAI-Y1) experienced after VR (see Table

7). In the GI group, there are no effects observed after the experience in relation to state anxiety level (Adjusted R Square=0.008; $F_{(3,35)}$=1.10; *p-value*>.05) (see Table 8).

The same investigation has been executed at T2. As for T1, considering the VR group, data showed that the factors considered in the model are related to the state anxiety level after the VR experience (Adjusted R Square= 0.173; $F_{(3,35)}$=3.45; *p-value*<.05). Data evidenced that ecological validity (ITC-SOPI Ecological Validity) is predictive of the state anxiety levels (STAI-Y1) experienced after the relaxation session seven at T2 (see Table 7). No significant effects were observed for the GI group (Adjusted R Square= -0.05; $F_{(3,35)}$=0.42; *p-value* >.05) (see Table 8).

Table 7. Linear regression models related to the Virtual Reality group.

Predictors	**State anxiety level after the VR experience (T1)**	**State anxiety level after the session 7 (T2)**
	β (t)	**β (t)**
ITC-SOPI Sense of Presence	0.04 (.34)	0.16 (1.34)
ITC-SOPI Engagement	**-0.52 (-2.67*)**	-0.19 (-1.31)
ITC-SOPI Ecological Validity	-0.05 (0.15)	**-0.77 (-2.54*)**

<u>**Notes**</u>:
*= *p-value* <.05.

Table 8. Linear regression models related to the Guided Imagery group.

Predictors	**State anxiety level after the VR experience (T1)**	**State anxiety level after the session 7 (T2)**
	β (t)	**β (t)**
ITC-SOPI Sense of Presence	-0.32 (-1.31)	-0.14 (-1.06)

ITC-SOPI Engagement	0.05 (0.22)	0.10 (0.54)
ITC-SOPI Ecological Validity	0.14 (0.83)	0.30 (0.98)

4.4.7 Aim n.5: Investigate group differences regarding trait anxiety, stress, depression, and coping strategies.

STAI-Y2-Trait Anxiety

To investigate the differences in trait anxiety using the STAI-Y2 between the three groups at baseline (T0) and after Session 7 (T2), we applied a GLM model using random intercepts. Significant main effects of "group" ($F_{(2,105)}$=11.01; *p-value*<.001) and "session" ($F_{(1,105)}$=43.83; *p-value*<.001) have been revealed, as well as a significant interaction between the variables "time of assessment" and "group" factors ($F_{(2,105)}$=11.62; *p-value*<.001) emerged. In Table 9 are the descriptive statistics of STAI-Y2 filled out at T0 and T2.

Table 9. Descriptive analysis (Mean and Standard Deviation) related to the STAI-Y2 score assessed for each group at T0 and after Session 7 (T2).

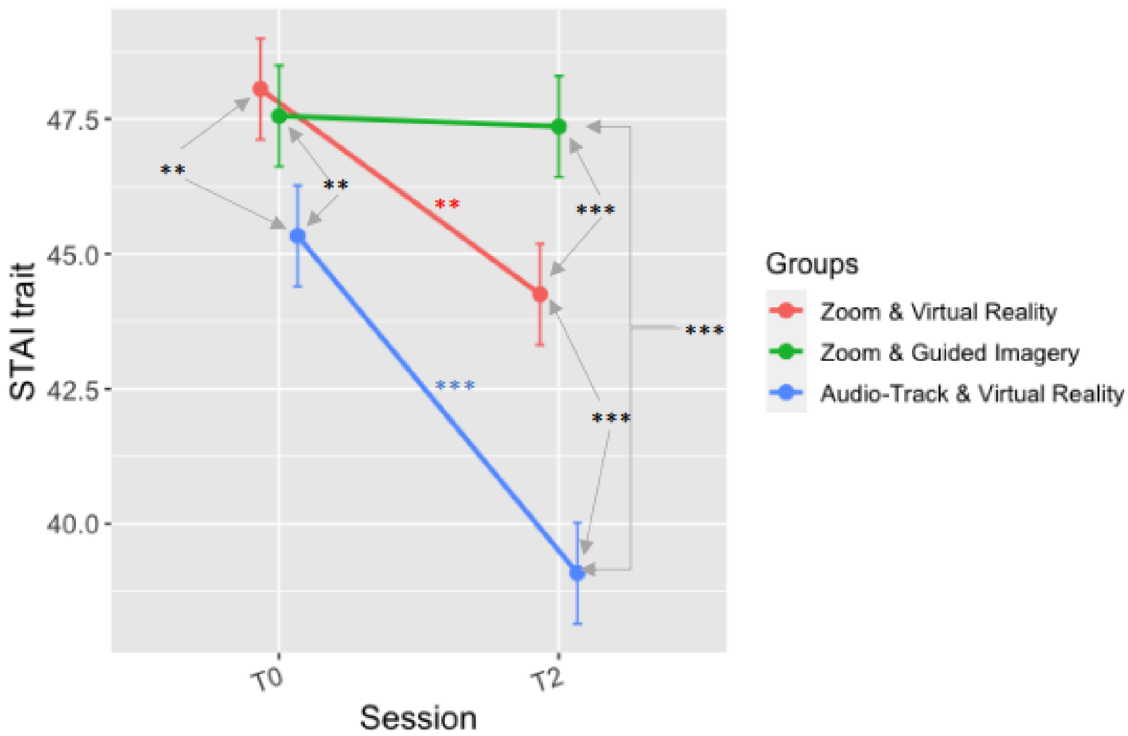
Dependent Variables	Time	Group type	M[a] (SD)[b]
STAI-Y2	T0	Zoom & VR	48.06 (3.78)
		Zoom & GI	47.56 (3.56)
		Audio-track & VR	45.33 (7.50)
	T2	Zoom & VR	44.25 (4.07)
		Zoom & GI	47.36 (4.29)
		Audio-track & VR	39.08 (8.46)

Notes: [a]M=Mean; [b]SD= Standard Deviation; VR= Virtual Reality; GI= Guided Imagery.

In general, the "Audio-track & VR" group had lower scores in trait anxiety than the other groups, with a greater difference if compared with the "Zoom & GI" group ("Audio-track & VR" vs. "Zoom & GI": β=-5.25; SE=1.17; $t_{(1,105)}$=-4.51; *p-value*<.001; "Audio-track & VR" vs "Zoom & VR": β=-3.94; SE=1.17; $t_{(1,105)}$=-3.39; *p-value*<.01). Turning the focus on within-subjects effect, trait anxiety had a greater decrease when assessed at the end of the entire relaxation protocol (T2) than at T0.

It was interesting to observe that once the Session*Group interaction is analyzed, no significant changes in anxiety were recorded from T0 and T2 for the group that had the relaxation experience in the Guided Imagery condition (*p-value*>.05) (Figure 22). Since both the VR groups obtained a reduction in anxiety over time, a positive impact of the use of a more realistic, customized, and immersive virtual environment could have promoted a stronger reduction of anxiety ("Zoom & VR": β=3.81; SE=0.89; $t_{(1,105)}$=4.26; *p-value*<.001; "Audio-track & VR": β=6.25; SE=0.89; $t_{(1,105)}$=6.99; *p-value*<.001). Otherwise, the greater differences between the "Audio-track & VR" and the "Zoom & VR" groups at T2 (β=3.11; SE=1.33; $t_{(1,162)}$=2.35; *p-value*<.05) lead to consider also the empowered impact of the relaxation training (sessions t1-t4) by Audio-track in the anxiety reduction.

Figure 22. Plot about Session*Group interaction.



Note: STAI trait Session*Group interaction results. The black asterisk represents *between-subjects* differences, while the same color as the lines represent *within-group* differences. *: *p-value*<.05; **; *p-value*<.01; ***: *p-value*<.001. Bars represent the Standard Error. T0= Assessment at Baseline; T2= Session 7.

DASS-21-Depressive, Anxiety, Stress Symptoms Scale-21

We investigated differences in depressive, anxiety, and stress symptomatology using the DASS-21 between and within the "Zoom & VR", the "Zoom & GI" and the "Audio-track & VR" groups before and after the complementary relaxation experience in Session 6 (T1) and Session 7 (T2). As for the previous comparisons, a GLM model has been deployed with "group", "block (pre/post assessment based on DASS-21 subscales score)", and "session" as predictors and a random intercept for each subject to account for repeated measures. In Table 10 are the descriptive statistics of the DASS-21 subscales filled out by participants of all groups at T0 and T2.

Table 10. Descriptive analysis (Mean and Standard Deviation) related to the DASS-21 score assessed for each group at T0 and after Session 7 (T2).

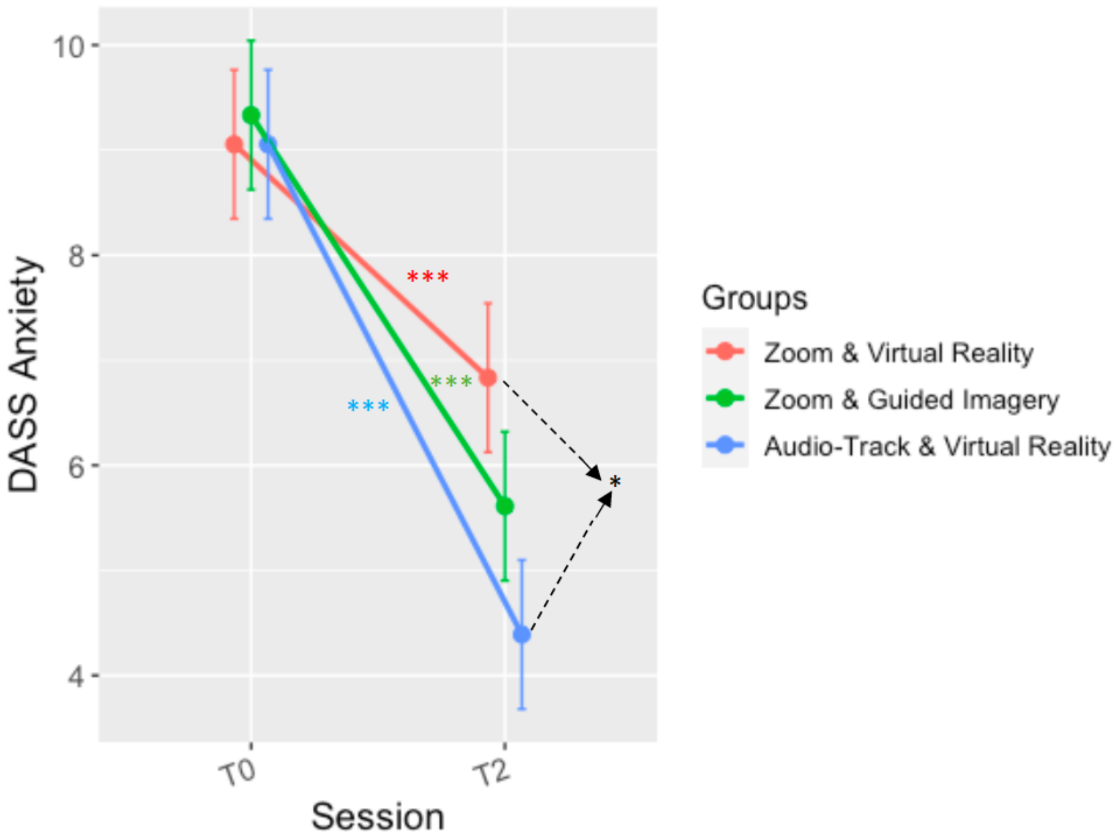
Dependent Variables	Time	Group	M[a] (SD)[b]
DASS-21 - Depressive	**T0**	**Zoom & VR**	8.89 (8.08)
		Zoom & GI	10.89 (7.33)
		Audio-track & VR	10.22 (9.71)
	T2	**Zoom & VR**	8.39 (3.94)
		Zoom & GI	10.56 (6.23)
		Audio-track & VR	6.89 (6.97)

DASS-21 - Anxiety	**T0**	**Zoom & VR**	9.06 (3.15)
		Zoom & GI	9.33 (3.61)
		Audio-track & VR	9.06 (5.77)
	T2	**Zoom & VR**	6.83 (3.95)
		Zoom & GI	5.61 (3.85)
		Audio-track & VR	4.39 (4.68)
DASS-21 - Stress	**T0**	**Zoom & VR**	17.39 (7.42)
		Zoom & GI	15.56 (6.01)
		Audio-track & VR	15.94 (8.01)
	T2	**Zoom & VR**	13.56 (4.14)
		Zoom & GI	12.67 (4.99)
		Audio-track & VR	12.72 (4.93)

Notes: [a]M=Mean; [b]SD= Standard Deviation; VR= Virtual Reality; GI= Guided Imagery; T0=Baseline Session; T2=Session 7.

Considering the DASS-21 - Depressive Scale, "session" as a main effect was significant ($F_{(1,105)}$=5.84; *p-value*<.01), which outlined a decrease of depressive symptomatology comparing T0 and T2. Coherently with what emerged from the STAI-Y2, the DASS-21 "Anxiety" scores decreased from T0 and T1 ($F_{(1,105)}$=93.86; *p-value*<.001). Moreover, a significant interaction Session*Group is highlighted ($F_{(2,105)}$=3.80; *p-value*<.05) (Figure 23). Precisely, for all three groups a decrease in anxiety was revealed ("Zoom & VR": β=2.22; SE=0.63; $t_{(1,105)}$=3.51; *p-value*<.001; "Audio-track & VR": β=4.67; SE=1.00; $t_{(1,154)}$=4.65; *p-value*<.001; "Zoom & GI": β=3.44; SE=1.00; $t_{(1,154)}$=3.44; *p-value*<.001). About the between-subjects comparisons, no differences emerged at T0 (Baseline assessment) (*p-value*>.05). Differently, at T2, the "Audio-track & VR" group obtained a larger decrease in anxiety symptoms than the "Zoom & VR" group (β=2.44; SE=1.00; $t_{(1,154)}$=2.44; *p-value*<.05). The DASS-21 - Stress Scale was significantly only for "session" as a main effect ($F_{(1,105)}$=48.36; *p-value*<.001), highlighting a decrease in stress symptomatology from T0 to T2.

Figure 23. Plot about Session(T0/T2)*Group interaction.



Note: DASS-21 Anxiety Session*Group interaction results. The black asterisk represents *between-subjects* differences, while the same color as the lines represent *within-group* differences. *: p < .05; **; p < .01; ***: p < .001. Bars represent the Standard Error. T0= Assessment at Baseline; T2= Session 7.

PGWBI-Psychological General Well-being

To investigate the differences in psychological well-being within and between the "Zoom & VR", the "Zoom & GI" and the "Audio-track & VR" groups at T0 (Baseline assessment), and Session 7 (T2), a GLM model has been deployed using "group", "block (pre/post assessment based on PGWBI total score)", and "session" as predictors and a random intercept for each subject to account for repeated measures. In Table 10 are the descriptive statistics of the PGWBI filled out at T0 and T2.

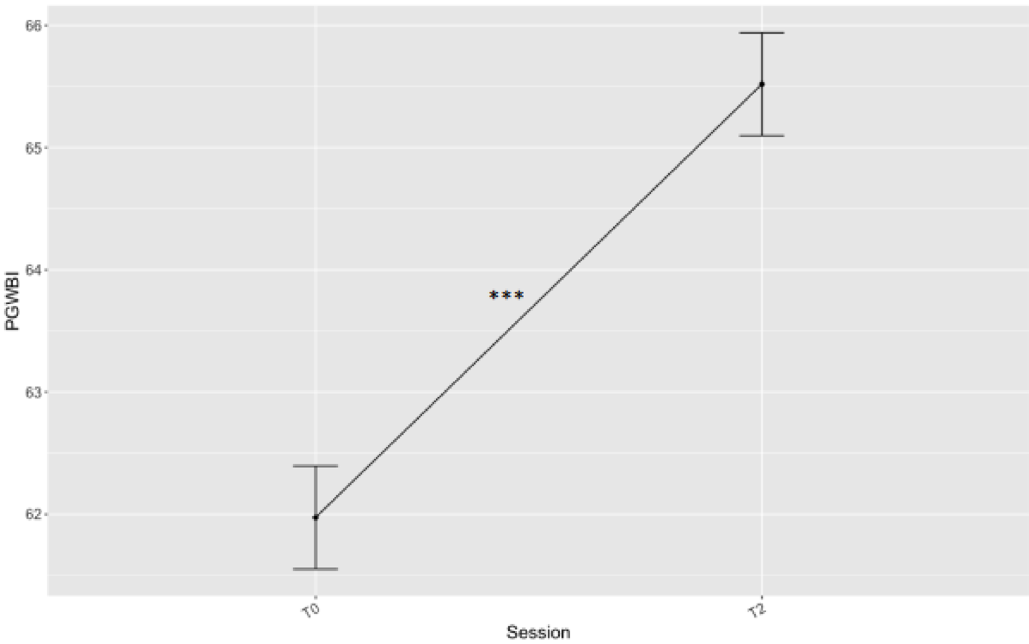
Table 10. Descriptive analysis (Mean and Standard Deviation) related to the PGWBI total score assessed for each group at T0 and after Session 7 (T2).

Dependent Variables	Time	Group type	M[a] (SD)[b]
PGWBI-Total	T0	Zoom & VR	60.94 (4.20)
		Zoom & GI	63.22 (3.27)
		Audio-track & VR	61.75 (4.49)
	T2	Zoom & VR	60.86 (6.97)
		Zoom & GI	63.53 (9.48)
		Audio-track & VR	62.61 (3.89)

Notes: [a]M=Mean; [b]SD= Standard Deviation.

A significant "session" as a main effect ($F_{(1,105)}=43.83$; *p-value*<.001) has been revealed, outlining an increase in the global psychological well-being condition for all the groups (see Figure 24).

Figure 24. Plot about Session (T0/T2) as a main effect.



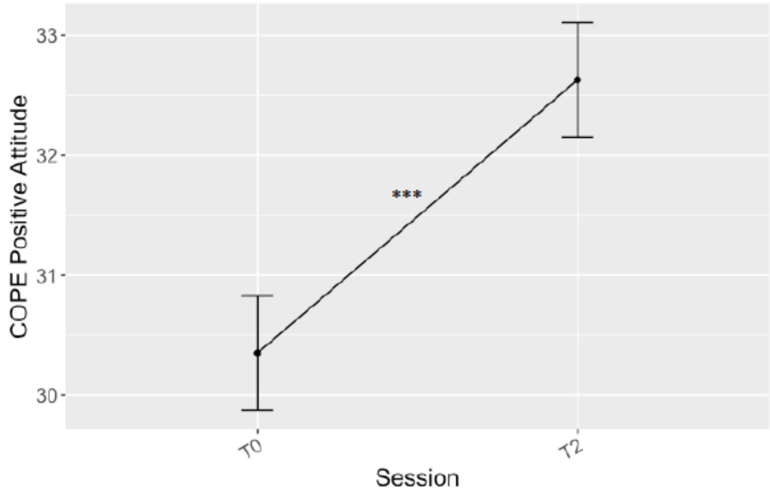
Note: PGWBI Session as a main effect results. The black asterisk represents *between-session* differences. ***: *p-value* <.001. Bars represent the Standard Error. T0= Assessment at Baseline; T2= Session 7.

COPE-NVI - Coping Orientation to Problems Experienced-Nuova Versione Italiana

We investigated differences in strategies people used to cope with problems or stress based on the COPE-NVI between and within the "Zoom & VR", the "Zoom & GI" and the "Audio-track & VR" groups at T0 (Baseline assessment) and Session 7 (T2). A GLM model has been deployed with "group", "block (pre/post assessment based on the COPE-NVI subscales score)", and "session" as predictors and a random intercept for each subject to account for repeated measures. In Table 11 are the descriptive statistics of the COPE-NVI subscales filled out by participants of all groups at T0 and T2.

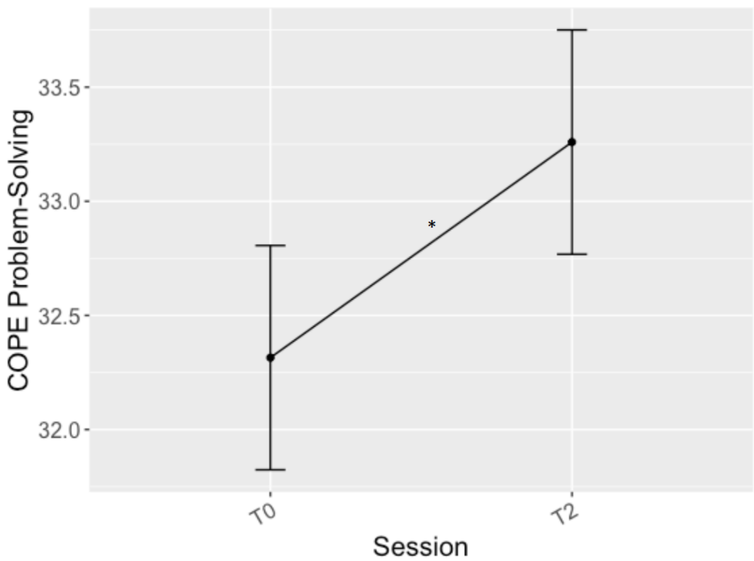
For the COPE-NVI "Positive Attitude" subscale, a significant "Session" effect emerged ($F_{(1,105)}$=37.17; *p-value*<.001) (Figure 25). As it is possible to observe in Figure 21, a general increase in the attitude of acceptance and restructuring beliefs, turning them into a more positive valence, is observed at T2 (T0: Mean= 30.35, Standard Deviation=5.09; T2: Mean= 32.63, Standard Deviation=4.80).

Figure 25. Plot about Session (T0/T2)*Group as a main effect.



Differences between groups emerged based on the significance of the "group" factor as a main effect ($F_{(2,105)}$=3.64; *p-value*<.05). The trend observed in the "Zoom & VR" group was to use more social support to deal with problems than what is revealed from the usual coping strategies of the other groups ("Zoom & VR" vs. "Zoom & GI": β=3.39; SE=1.42; $t_{(1,105)}$=2.39; *p-value*<.05; "Zoom & VR" vs. "Audio-track & VR": β=3.24; SE=1.42; $t_{(1,105)}$=2.28; *p-value*<.05). An interesting data emerged for the "Problem-Solving" subscale; indeed, individuals tended to use more active, focused to the problem, and planning strategies at the end of the entire relaxation protocol assessed at T2, rather than what participants reported during the T0 assessment (Baseline), ($F_{(1,105)}$=5.84; *p-value*<.05) (Figure 26).

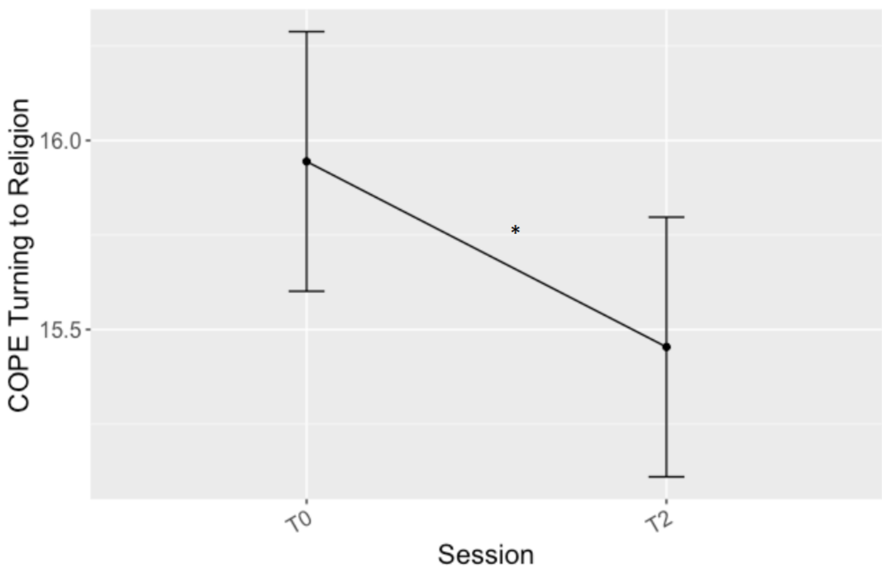
Figure 26. Plot about Session (T0/T2) as a main effect.



Note: COPE Problem-Solving Session as a main effect results. The black asterisk represents *between-session* differences. *: *p-value*<.05; **; *p-value*<.01; ***: *p-value*<.001. Bars represent the Standard Error. T0= Assessment at Baseline; T2= Session 7.

Significant differences were found between "session" ($F_{(1,105)}$= 4.87; *p-value*<.05) (Figure 27), and "group" ($F_{(2,105)}$=20.32; *p-value*<.001) as main effects for the COPE-NVI "Transcendental Orientation" subscale, showing that the "Audio-track & VR" group make less use of a transcendental approach, using religion than the other two groups (vs. "Zoom & VR": β=4.21; SE=0.80; $t_{(1,105)}$=5.29; *p-value*<.001; vs. "Zoom & GI": β=4.56; SE=0.80; $t_{(1,105)}$=5.73; *p-value*<.001). Moreover, independently of what kind of training participants experienced, a reduction from T0 to T2 in using religion to cope with problems has been revealed.

Figure 27. Plot about Session (T0/T2) as a main effect.



Note: COPE Turning to Religion session as a main effect results. The black asterisk represents *between-session* differences. *: *p-value*<.05. Bars represent the Standard Error. T0= Assessment at Baseline; T2= Session 7.

4.4.8 Satisfaction feedback by participants

No differences in terms of utility ($F_{(2,105)}$=1.21; *p-value*>.05) and positive feedback emerged from groups ($F_{(2,105)}$=0.56; *p-value*>.05). On a scale investigating the valence of the general experience considering the entire procedure (from 1=the experience was generally negative for me; to 5=the experience was generally positive for me), individuals expressed positive feedback with a mean score of 4.44 (0.78). Moreover, on a scale from 1 (useless experience) to 5 (helpful experience), participants reported that the relaxation protocol is applicable based on a mean score of 4.35 (0.77). Interesting qualitative feedback, to be considered in the implementation of further studies, emerged from participants and are summarized in Table 11. Four main themes are derived from the qualitative feedback. They are, for the most part, about 1) the advantages of using VR, 2) the importance of adding more sessions and time to learn the relaxation techniques deeply, 3) Considerations of the opportunity to deploy the procedure in settings more similar to daily life, and 4) Suggestions and considerations to improve on the following studies.

Table 11. Qualitative feedback by participants about the entire relaxation experience.

Main themes from qualitative feedback	"Zoom & VR"	"Audio-track & VR"	"Zoom & GI"
Advantages of using VR	*"I think it's an excellent implementation of relaxation techniques. With the headset, I tried a more intense and, therefore, more relaxing experience. I think I've reached a deeper relaxation in that condition"* *"During the follow-up meeting, imagining the environment I had chosen in VR was very helpful to immerse myself in the situation and facilitate relaxation. Focusing on the most detailed re-enactment of the place had helped me free myself from intrusive and unnecessary thoughts"*	*"Having done all the training on the bed, changing in the last sessions was not immediate. In my opinion, the relaxation worked better when I was inside Oculus with the guide"* *"The session with Oculus was where I seemed to relax better"* *"I was excited about the VR experience. Choosing and customizing the environment to my liking was essential because I felt more comfortable and involved in the experiment."* *"One evening, I couldn't sleep. I spontaneously thought of the VR image that had been proposed to me during the*	N/A

		penultimate meeting, which helped me to relax"	
More sessions and time	*"More relaxation sessions to acquire better the PMR technique"*	*"More sessions would be useful, especially with virtual reality"* *"Maybe more meetings with Oculus could be planned. As for me, the one with the oculus was the most relaxing experience. It would also be useful to use the image better when you are not wearing the headset."*	*"Sessions I would have preferred to last longer, especially those mid-way, as it is the time when you start to acquire more awareness"* *"The training via Zoom should last at least two to three more sessions to familiarize yourself with the technique better and use it in a more proper way during meetings in the presence and also in everyday life"* *"I would like to have the opportunity to do more Zoom sessions"*
Relaxation procedures in a more ecological environment	*"I would love to try the virtual reality session at my home, on the bed. I think it would help even more"*	*"It would be interesting to use personal environments and better investigate the impact of the sense of familiarity on immersivity"*	*"I suggest allowing people to sit or lie down as they wish during lab sessions. This would also help to make the setting more ecological (in addition to facilitating relaxation)"*
Suggestions and considerations to improve on the following studies	*"For boring audio tracks, better to vary the contents. Beneficial immersion in the chosen virtual scenario"* *"I recommend providing a bed in the laboratory session because the lying position facilitates relaxation. The experience with Oculus was positive and immersive, but I don't think I had more benefits than the meetings on Zoom. Connecting on Zoom helped my willingness to*	*"As I had done the relaxation sessions on the bed, I found it difficult to apply relaxation to the lab chair"*	*"During the self-directed session, I used the therapist's suggestions in the Zoom training"* *"During the last session it was difficult to use the imagined scenario. Otherwise, I think the Zoom meetings helped me a lot in obtaining relaxation"* *"I appreciated both*

	participate because it helped me relax. With those meetings, I have learned a technique that I try to use even in everyday life"		*the Zoom and the GI experiences"*

4.5 Discussion

4.5.1 Principal Findings

The research on deploying customized VR scenarios for promoting relaxation is growing. Still, few definitive conclusions on its effectiveness have been achieved. Even less is known about the usefulness of integrating standardized and evidence-based relaxation techniques with new technologies that could provide an advantage in promoting autonomous adoption and self-empowerment by users and potential savings of treatment delivery costs (e.g., 215). As stated above, the possibility to customize audio and visual stimuli in the VR environment is a promising approach for meeting users' preferences and needs [e.g., 3], and it has shown encouraging results regarding both feasibility and potential impact on psychological well-being [e.g., 1].

The primary aim of this study was to evaluate the impact of alternative, complementary relaxation training composed of web-based PMR training and exposure to a customized, relaxing scenario in VR aimed to reduce anxiety and promote relaxation considering a sample of university students.

Before starting with the core results discussion, it is essential to note that participants in the VR groups reported no serious motion sickness effects. The most common symptoms were eye-related (e.g., discomfort or slight burning in the eyes once Oculus was removed). Even when experienced, symptoms were defined as not so impactful to ending the experience or not getting pleasure and involvement during the exposure to the virtual environment. As will be outlined in Chapter 5, our outcomes align with previous work that reported that static scenes and a constant speed during movement could prevent cybersickness symptoms (e.g., 312, 313). It is possible that our technological design, and the aim to promote relaxation, reduced the likelihood of occurrence of VR-related motion-sickness symptoms; indeed, the VR design and apparatus used in this study are labelled as static scenarios with only slight visual oscillations (e.g., seawater and oscillation of plants due to the action of the wind), but without any rapid movement.

The first objective of our research was to investigate differences in state anxiety between and within groups. The former being when participants were directly exposed to a virtual or imaginative relaxation session (T1) and the latter using a self-directed relaxation session based on what they learned during the entire procedure (T2).

Although a reduction in state anxiety was observed in all groups at T1 and T2, our results highlighted how being in a customized virtual scenario promoted a greater reduction of the self-perceived state anxiety than in the imaginative condition, when individuals were directly exposed to the VR or GI experience (at T1), and when they have to recall the strategies learned during the relaxation protocol (T2). Indeed, when groups were asked to self-direct the relaxation session, which consisted of recalling the customized image they experienced in VR or GI at T1, those previously exposed to the customized VR scenario obtained lower state anxiety scores than those in the other group after Session 7 at T2. These results are in line with the literature and our first hypothesis since, independently of the type of web-based relaxation training administered before, VR is more effective than in-imagination exposure in allowing a subjective reduction of the state of tension and worry felt (measured based on the STAI-Y1) (e.g., 277-279, 292). Our outcomes are coherent with studies showing how VR could be a valuable tool in reducing stress and promoting relaxation, resulting from an assessment based on self-reported measures [314]. Moreover, although Hoag et al. study [315] target users' sample was composed of children and young adults with acute and chronic illness, our outcomes align with it, showing a significant decline in state anxiety from pre- to post-VR exposure. Our data support the role of VR in facilitating a powerful distraction effect on users reducing their focus on thoughts and external events that would elicit anxiety responses [198, 316]. Regarding the collected data on heart rate activity, findings showed a generally lower heart rate level during and after the relaxation sessions than before for all groups. This outcome is coherent with the self-reported data on state anxiety. But it is important to consider that this pattern may also be related to the fact that the baseline heart rate was much higher and potentially associated with the white coat effect due to the agitation experienced when a person knows that a professional is detecting their heart rate. Considering T1, data are coherent with what has been observed for self-reported anxiety. Indeed, a greater decrease in heart rate frequency was revealed for the two VR groups rather than for the GI group. Our data supporting previous studies' outcomes highlighted the impact of VR relaxing scenarios in maintaining lower levels of heart rate frequency (e.g., 314). Still, additional research is needed to deeply investigate whether and how naturalistic and relaxing VR scenarios induce relaxation and stress reduction by providing feedback on detected changes, such as in heart rate frequency and variability, respiration rate, or skin conductance.

Differently, at T2, no difference emerged between groups previously exposed to the Zoom web-based training, with an increase in heart rate from T1 to T2 for the “Zoom & VR” group. Notably, only the “Audio-track & VR” group obtained a decrease in heart rate levels at T2 comparable to those they achieved in the VR session at T1.

Results tell us that the experience in VR was more impacting on heart rate reduction maintenance than in the condition in which individuals had to recall the immersive image without the HMD support. It is possible that the fact of having learned relaxation based on the audio-track during all the sessions, without the presence of the experimenter, allowed them to generalize the relaxation learned in a more autonomous condition, without the experimenter's presence.

On the other hand, different patterns emerged for self-reported state anxiety. Indeed, once asked participants to report their subjective perception of state anxiety, the “Zoom & VR” group was the only one that, at T2, showed maintenance of the decrease in anxiety previously obtained at T1. Otherwise, the “Audio-track & VR” group had an increase in subjective anxiety levels comparing assessments at T1 and T2.

If we consider the overall performance during all the relaxation sessions, we can say that all groups have shown a reduction in state anxiety. Still, the group exposed to the audio-track condition obtained the most significant decrease during the training phase. Moreover, while the “Zoom & GI” group maintained the level of anxiety reached during the training sessions in the following sessions (T1 and T2), the two VR groups reached a further anxiety reduction compared to the state-anxiety scores in the training phases. The audio-track group has been shown to have achieved the most significant relaxation during training and exposure to VR. This group has most likely benefited from more factors: the fact of having carried out the sessions independently, in a family context without the presence, albeit remotely, of the therapist, and considering the possibility of being exposed to the audio track (which provided for the same modality of the training sessions) when they were also exposed to virtual reality. The fact that there has not been the maintenance of anxiety at T2 shows a possible difficulty of these participants in generalizing relaxation if the self-reported information about the anxiety level is considered. At the same time, the "Zoom & VR" group seems to generalize more based on the STAI-Y1 scores. This leads us to hypothesize that the therapist's presence during the sessions, and the booster effect of VR, seem to have helped more in the learning process of the relaxation procedure. In addition, the environmental situation experienced by this group during the session in the presence was perceived as more like that expected by the therapist during the training phase. This may have affected the greater ability to generalize relaxation in the "Zoom & VR" group during the self-managed laboratory experience. It is possible that the group "Audio-track" perceived the session in the laboratory as more complex than during the training phase, in which the participants of the "Audio-track" group could choose more flexibly and autonomously the places and times to relax, and it is possible that this affected their perceived anxiety level. In general, discrepancies between subjective and psychophysiological measures emerged. This may be due to the fact that cognitive processes were more stressed during the training in the condition with the experimenter (Zoom & VR group). Otherwise, data show that the group trained based on the "Audio-track" gave more attention to the psychophysiological aspect. In any case, only a longer-term evaluation with the most consistent psychophysiological measures collection would provide us with more accurate information about the impact of these two web-based training interventions on anxiety.

The study's objective to understand the impact of VR on the sense of presence, realism, and engagement if compared with the standard guided imagery strategy, outcomes revealed that all groups experience a greater sense of being immersed in the scenarios, higher level of engagement, and sense of realism once they were in the VR or GI conditions than in the self-directed condition (T2). It is also revealed that the Guided Imagery condition allowed participants to experience a lower sense of presence and realism in the scenario than what individuals felt in the VR environment. This result is coherent with studies that showed how the properties of VR in facilitating interaction and converging people's attention allow individuals to experience a greater sense of presence than can be achieved in a context to be imagined, which also requires more cognitive resources from the person (e.g., 257).

Data also showed how virtual reality in the current study promoted a higher level of engagement in the relaxing scenario, especially for those who had completed the training phase in the audio-track condition. As stated before, it is possible that participants exposed to the audio-track condition were more familiar with the audio-track listened to during the VR exposure, and there is a chance that this facilitated further the engagement in the VR scenario. Indeed, it is plausible that the participants who received the entire training sessions guided by the therapist in the "Zoom & VR" group had more difficulty feeling involved as they were not confident with the audio instruction as the users who had done the whole training in the audio-track supported condition.

Our data highlighted how engagement with VR scenarios contributes to reducing perceived anxiety after the VR experience. Indeed, it seems that exposure to the VR scenario, instead of the imaginative one, facilitates the reduction of anxiety levels after the relaxation session. Even if our results need to be further investigated with larger user samples, they are aligned with previous studies, which underlined the potential benefit of using pleasant, relaxing, and immersive VR scenarios for facilitating relaxation and engagement in individuals from the general population [184, 233, 242]. Regarding the sense of presence, engagement, and sense of realism assessment, a point of strength of the current experimental design is the preliminary evaluation of the impact that the ability to control and vividly imagine mental images may have. Since we have not found differences between the two groups on these abilities before the exposure to the relaxation session at T1, we can support the hypothesis of a positive effect that exposure to a VR context can have on reducing anxiety.

The VR group's participants perceived the recalled scenario at T2 as more realistic than individuals in the GI group. Our data showed that the realism that characterized the imagined scenarios, derived from the immersive virtual scenario experienced in the previous T1 session, partially explains the state of anxiety levels felt after the T2 session by the participants in the VR condition. Moreover, participants in the VR group obtained additional benefits in terms of relaxation and state anxiety reduction related to a more realistic sensorial experience that played a substantial role in facilitating the visualization of the scenario and enabled users to focalize their attention on the relaxation activities. Coherently with other studies [184, 198, 242], this core outcome supports the role of immersive VR in promoting relaxation through visualization, engagement, and immersion processes. The prominent impact of being exposed to realistic scenarios in VR on the enhanced visualization at T2 is a key contribution of our study, shedding light on the impact that exposure to VR may have in more ecological everyday settings, such as when people are not wearing the Head-Mounted Display (HMD) but have the chance to transfer the relaxation skills learned in VR to real-world situations.

Our data are coherent with studies that show that a 3D representation of a scenario is more effective in the retention and recall processes than an imaginative representation [317, 318]. Even if the aim was to compare VR scenarios versus a scene on a PC desktop, our outcome aligns with Krokos et al. study [319], highlighting the prominent impact of VR scenarios on memory recall ability. The hypothesis of the current and the Krokos et al. studies [319] are anchored on classical studies in cognitive psychology based on the method of loci [320], and the context-dependent memory theory [321]. These theories imply the essential role of learning and mnemonic processes in creating an association between the mnemonic content and a mental frame of scenarios and then recalling contents by mentally visualizing the scenarios in which the learning and memorization processes occurred [319]. Since that presence, immersion, and engagement in the VR scenarios implies sensorimotor contingencies similar to the real world [322], and the way we create and recall mental constructs is influenced by perception and action in the environment [323, 324], our data coherently confirm the possibility of immersive, virtual environments in enhancing learning and recalling for the intervention of vestibular and sensorimotor inputs [325].

An interesting result is also related to differences within and between groups on trait psychopathological constructs. In general, an increase in the global psychological well-being condition for all the groups has been evidenced, other than a reduction in trait anxiety, depression, and stress symptomatology once assessed at the end of the entire relaxation protocol (T2) than at T0. It was interesting to observe that the significant changes in anxiety were due to the groups exposed to VR since no differences from T0 and T2 were revealed for the group that had the relaxation experience in the GI condition. Specifically, our data showed how participants in the "Audio-track & VR" group obtained lower scores in trait anxiety than the other groups, with a greater difference if compared with the "Zoom & GI" group. It emerged that the audio-track relaxation training, with the booster contribution of VR, significantly reduced anxiety over time. Future studies should investigate this aspect more deeply, introducing an experimental design composed of more than one exposure in VR. Indeed, in this case, we are talking of a more stable manifestation of anxiety, and it is possible that other uncontrolled variables contributed to the final outcome. In any case, these results are promising and support the claim that VR plays a key role in amplifying the effectiveness of already validated interventions, maintaining their effects over time.

Based on the COPE-NVI subscales, the coping strategies, too, seemed to be modified during the relaxation training protocol. Independently on the type of relaxation strategy experienced, participants have started to use a more strategy focused on accepting and restructuring their beliefs when facing stressful or anxious situations.

Moreover, at the end of the entire relaxation protocol, individuals tended to use more strategies to focus on the resolution of the problem and reduced the habits of using religion to cope with problems.

4.5.2 Strengths, limitations, and future perspectives

The current study is the first to examine whether customized virtual reality scenarios work better than guided imagery in improving relaxation and decreasing anxiety when integrated with PMR as a complementary relaxing method. Moreover, this contribution adds new knowledge on the importance of customizing and customizing digital interventions according to the user's perspective, needs, and preferences [3]. Another point of strength of the current experimental design is the assessment of the impact that the ability to control and vividly imagine mental images may have. The outcomes are gathered from a well-designed pilot randomized controlled trial involving three selected groups of 108 university students whose socio-demographic and psychological characteristics have been controlled to balance their effect on the investigated variables. The experimental procedure adopted supports the reliability and validity of the results and the conclusions presented.

Our study also has some limitations that could be overcome by future studies. Our results cannot be generalized to the whole non-clinical population, as our sample consisted of university students carried out in a single university. To further generalize and validate our results' effectiveness, the involvement of participants belonging to clinical and non-clinical populations, stratified according to different socio-demographic characteristics, should be considered [262]. The following studies should consider structuring the relaxation protocol with more VR sessions to better understand the impact of a virtual scenario on relaxation. It should also be useful to introduce other follow-up sessions to investigate the impact of a web-based intervention with VR over time. Another aspect to be considered in further experimental design is introducing a control group that received the training session with the physical presence of the therapist. Given the promising results in studies characterized by partially different experimental designs, it would be helpful to introduce the structuring of virtual web-based contexts in which an avatar guides the learning of relaxation and visually shows how to perform PMR exercises remotely without the therapist. This may potentially facilitate the learning of the training as well as the transfer of the learned techniques in other more ecological contexts where it is not planned to wear the headset (e.g., before an exam). Considering the impact of customization on anxiety and for engaging users in the virtual scenarios, another important aspect that also needs to be considered is the opportunity to introduce in the virtual environment customized stimuli based on the personal life experience of each participant. As an example, introducing olfactory stimuli could be another essential aspect to enhance the sense of realism, immersiveness and presence in the virtual scenarios (e.g., 326-328).

In our study, the prominent data are derived from self-reported questionnaires. Considering the importance of psychophysiological assessment in evaluating tension and other anxiety and arousal measures (e.g., 329), future studies should include in the assessment procedure other more objective measures such as a photoplethysmography (PPG) to record the pulse rate changes comparing data collected before and after the relaxation sessions (Lee et al., 2020: Leong et al., 2022), and electroencephalogram (EEG) to assess the alpha and theta waves related with anxiety [330].

Finally, it is important to consider that seven participants in the “Audio-track & VR” condition dropped the intervention during the training sessions. This informed us about the importance of introducing, in future studies, rewarding strategies to maintain high levels of motivation of participants, especially in individuals that have to administer the training in a more autonomous manner. In future studies, it should also be interesting to obtain more information about the dispositional and personality traits of participants who drop out of the training to predispose the most optimal condition to promote compliance with the interventions.

To conclude, the main objective of psychological interventions, in general, is to offer people the possibility to learn strategies to manage their daily life more constructively and in a self-directed way. The opportunity to deploy VR for promoting self-management of state anxiety also in real-world situations constitutes an interesting line of investigation to be further explored by future studies involving larger non-clinical and clinical populations (e.g., chronic pain patients) to validate and standardize relaxation protocols integrated with new VR tools.

CHAPTER 5.

EXPLORING THE ROLE OF CUSTOMIZED VIRTUAL REALITY SCENARIOS FOR RELAXATION AND ANXIETY MANAGEMENT IN PATIENTS WITH MEDICAL CONDITIONS

The present chapter provides an overview of the third study of the Ph.D. program. The current version is under review by the *Nature - Scientific Reports* (Collection "Virtual Reality in Psychological Research"). The current research is registered as a clinical trial in a publically accessible primary register that participates in the WHO International Clinical Trial Registry Platform (National Institute of Health (NIH) U.S. National Library of Medicine, ClinicalTrials.gov NCT05863065; 17/05/2023).

The research has been conducted in collaboration with Prof. Lora Appel (York University, Toronto, Canada; University Heath Network, Toronto, Canada).

Being immersed in a natural context has a beneficial and pervasive impact on well-being, it is strongly related to the self-perceived and the physiological reduction of stress, relaxation, and the sense of restoration, and it is helpful in regulating mood [331]. In long-term care settings, allowing older adults to enjoy recreational experiences in natural environments can be beneficial, especially if they have cognitive and physical impairments. Despite this, it is essential to reflect on how obstacles (e.g., reduced motor skills and fear of injury during movement) may hinder and limit participation in organized outdoor activities. Virtual Reality (VR) can help expose people to naturalistic scenarios virtually, overcoming obstacles that prevent them from visiting real natural environments. VR could also increase engagement and relaxation in older adults with and without cognitive impairment. Growing evidence supports the claim that immersive virtual reality scenarios: 1) provide innovative strategies for overcoming these obstacles, 2) improve the quality of life in older adults' healthcare facilities, 3) have a positive impact on behavioral and psychological symptoms, and 4) promote engagement and relaxation. Considering the promising outcomes of recent empirical investigations and the need for more depth and breadth studies to have VR interventions adopted by mainstream healthcare, the current presentation aims to describe the results of a Proof-of-Concept and Mixed-Methods study. The research is mainly focused on investigating the feasibility of a customized naturalistic VR scenario by assessing motion-sickness effects, engagement, pleasantness, and emotions related to exposure to a VR context of 23 individuals living in a long-term care home diagnosed with cognitive impairment. The measures administered were self-reported and observational to obtain information from users and seven healthcare staff professionals who attended the VR sessions. At the end of the experimental phase, a focus group session was conducted with the healthcare staff to acquire additional information, mainly on strengths, weaknesses, future perspectives, and risks that are associated with using VR in a long-term care setting.

Feasibility and acceptability were proved to be satisfactory since users' VR experience was well-tolerated, and no adverse side effects were reported or observed. Moreover, preliminary outcomes showed that more than half of the participants were engaged, pleased, and calm most of the time during the virtual activity, showing decreased state anxiety during and after the experience. The current study's key leading innovation is its contribution to advancing knowledge on the role of customized VR scenarios and their impact on the acceptability and potential clinical efficacy of their usage with frail older adults.

STUDY 3. CUSTOMIZED VIRTUAL REALITY NATURALISTIC SCENARIOS PROMOTING ENGAGEMENT AND RELAXATION IN PATIENTS WITH COGNITIVE IMPAIRMENT: A PROOF-OF-CONCEPT MIXED-METHODS STUDY

5.1 Theoretical background

There is growing evidence of the positive impact of being immersed in natural environments on physical and mental health [27-29]. Natural contexts increase the perception of positive emotions, reduce fear, anxiety, anger, and sadness, and play an essential role in regulating heart rate, blood pressure, muscle tension, and brain electrical activity [87].

In healthcare facilities, allowing older adults to have recreational and pleasant experiences in natural environments, especially if they have a cognitive and physical impairment, although challenging, can be beneficial [30]. Participating in organized outdoor activities may be limited by reduced motor ability, cognitive impairment of the patients, the fear of injury during movement, as a side effect of medication, and weather conditions. In addition, outdoor spaces could not always be available. Overall, evidence shows that even if unable to engage directly in a natural environment, visible exposure to nature scenes can be beneficial, reducing hospital length-of-stay and drug consumption [30-33]. Based on these findings, it is desirable to identify alternative strategies for providing older adults with exposure to natural scenes while accounting for barriers to mobility, autonomy, and safety concerns.

A potential innovative method helpful in overcoming these obstacles could be the deployment of Virtual Reality (VR). Indeed, VR technologies have been demonstrated to reduce isolation and increase engagement across several populations [34]. VR systems consist of technologies that provide the user with multiple sensory inputs through, for example, visual and auditory displays and can have varying degrees of immersion generally conveyed through displays, where the interface allows exposure to content that can be explored in 360-degrees, as with head-mounted displays (HMD).

VR-based interventions have been successfully deployed for addressing a myriad of clinical conditions such as specific phobia, social anxiety, panic disorder, post-traumatic stress disorder, and depressive disorders [332, 333].

Evidence suggests that immersive virtual scenarios can improve the quality of life in older adults' healthcare facilities, highlighting a positive impact on behavioral and psychological symptoms. VR was also found to overcome some barriers that can hinder participation in recreational activities, such as the difficulty of moving in the environment [37, 219, 334]. A study by Brimelow et al. [219] demonstrated how immersive scenarios can positively impact users with heterogeneous cognitive impairment levels living in a long-term care home with minimal negative effects.

Patients with cognitive decline may benefit from improving cognitive, emotional, and physical fitness functions if exposed to multisensory VR contexts characterized by quasi-naturalistic and realistic stimuli [335-339]. To our knowledge, few studies have investigated the feasibility and effectiveness of using immersive virtual environments for managing anxiety and promoting a state of relaxation in populations of elderly individuals with impaired physical and cognitive functions [219, 336, 340, 341]. Moreover, there is a lack of research on customizing virtual scenarios for therapeutic purposes.

Some published research has highlighted how using VR HMD promotes the management of depressive and anxious symptoms in older people [3, 221]. Appel et al. [36] investigated the relationship between relaxing, positive environments and both positive and negative emotions based on a sample of older adults with varying (mild to severe) cognitive and physical impairment levels. The participants were exposed through an HMD for an average variable period of 8 minutes to a relaxing environment in which realistic natural scenarios were depicted. Qualitatively, positive feedback is associated with the experience and the perception of a higher state of relaxation. Additionally, there has been an increase in the intensity and frequency of positive emotions experienced and a reduction in the levels of some negative emotions [36]. The authors concluded that exposure of people with cognitive and physical impairments to realistic and natural immersive scenarios in virtual reality through an HMD is safe and feasible. These findings encourage future studies to investigate the role of virtual reality scenarios' customization.

Additional research by Moyle et al. [221] exposed individuals with dementia living in care facilities to a visual and auditory interactive virtual experience with the aim of improving the quality of life by obtaining information about users' moods, apathy, and engagement. The exposure involved observing a screen, without using an HMD, in which a natural scenario was represented. During the exposure, participants were able to select seasons (spring and autumn) and different types of virtual objects through hand and arm movements. Residents, family members, and staff have received positive feedback globally. Participants experienced higher levels of engagement, pleasure, activation, and fear during the exposure to the virtual forest than the control sample. Of note, the authors stated that differences in users' preferences should be considered as a main factor limiting the versatility of the VR Forest.

Research on the effect of customizing VR-scenarios has grown in recent years [3, 233], uncovering benefits such as an increased sense of presence and engagement in the virtual environment. A relaxing and customizable VR environment implies an *a priori* identification of conditions that can be pleasant and relaxing based on the user's needs, allowing the management of any interfering environmental factors that might also be present in the real context [3, 5, 228]. This person-centered approach is precious for those living with cognitive impairment as it also provides a sense of familiarity and security within the VR context [233], but additional investigations are still needed to obtain more consistent data on its feasibility and effectiveness in this population.

5.2 Aims

Considering the promising outcomes of recent studies (e.g., 36, 37, 221) and the recognition that more depth (through rigorous research), and more breadth (encompassing new elements of design, e.g., customization) are needed for VR-interventions to be adopted by mainstream healthcare, we designed a proof-of-concept study, with the following goals:

- The primary objective is to evaluate the impact of VR on self-reported and observational levels of motion-sickness, engagement, and pleasantness in older adults living with cognitive impairment and residing in long term care.
- Based on our knowledge, distinct from most studies in this field, the current study intended to provide customization of visual and audio stimuli over and above, offering a select number of outdoor settings. For this reason, the secondary aim is to investigate if personalized, relaxing virtual environments can be acceptable to

the target group, as well as positively impact feelings and state anxiety, at least in the framework of a proof-of-concept study. Indeed, the current study is part of a continuum of research on the requirements and effects of VR customization for different target populations. The study leveraged on the positive results of VR customization collected in a previous study we conducted [221] involving non clinical population and it intended to further explore the feasibility of different customization options.

- A third goal is to investigate the usability of the VR apparatus from the perspective of health staff working in long-term care to better understand the acceptance and potential adoption of the proposed solution in these clinical settings.

5.3 Methodology

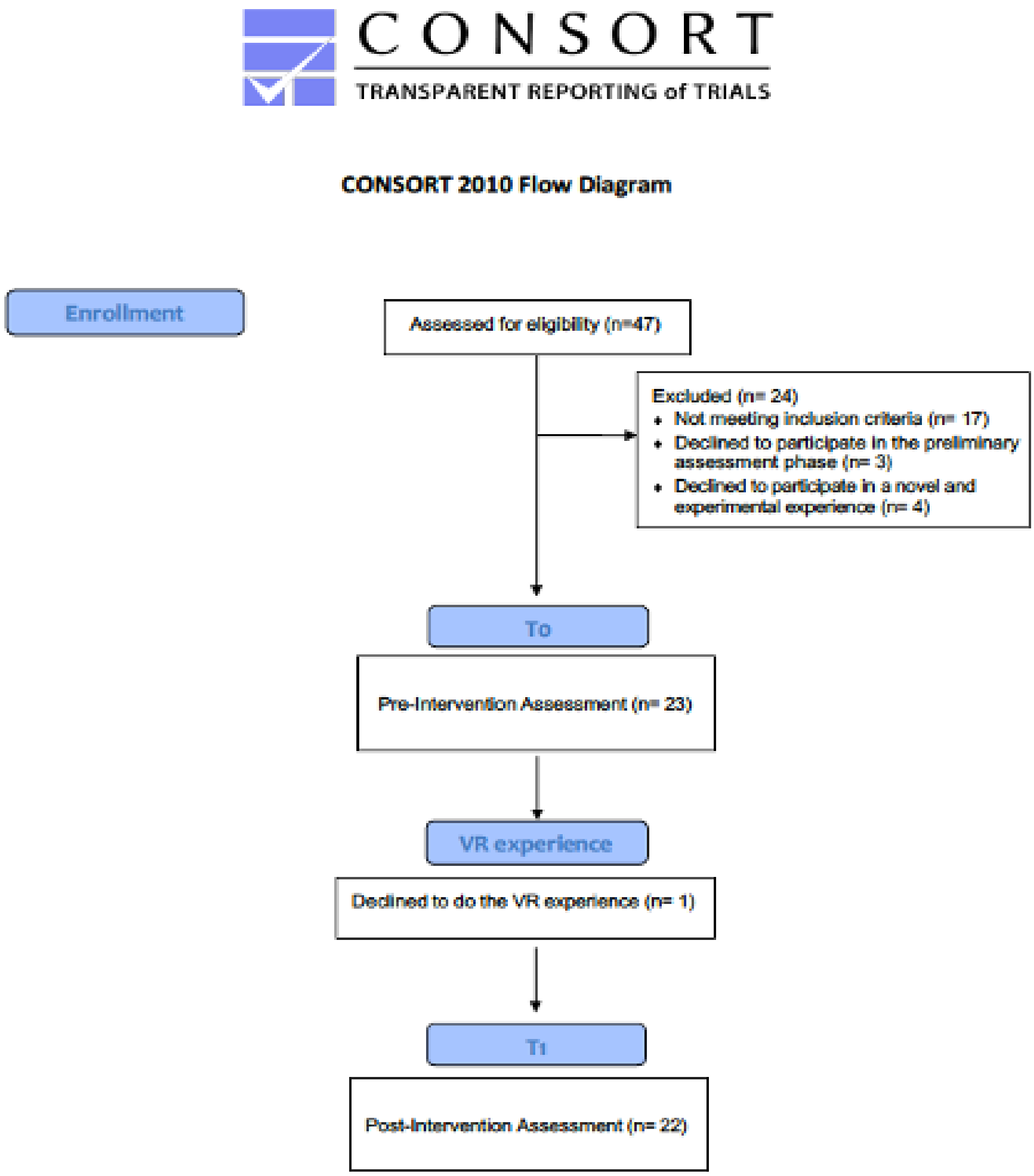
The current proof-of-concept and feasibility study is a one-session single-centre trial conducted at the *Azienda Pubblica di Servizi alla Persona (APSP) "Margherita Grazioli*", a long-term care home in Trento (Italy) in collaboration with the Department of General Psychology – University of Padova (Italy) and the Centre for Health and Wellbeing-Fondazione Bruno Kessler (Italy). The proposed study protocol was approved by the Ethical Committee for Clinical Experimentation - *Azienda Provinciale per i Servizi Sanitari - Provincia Autonoma di Trento* (Italy), (Nr: A827, 10/2022, Rep. Int. 20298 11/22/2022). The research complies with the relevant ethical regulations of the Declaration of Helsinki.

The study design is based on a mixed-methods approach inspired by the Obesity-Related Behavioral Intervention Trials (ORBIT) framework [241] for the design (Phase Ib) of digital interventions and their preliminary testing (Phase IIa). At the current stage, a sample is usually selected from accessible individuals to understand if the intervention deserves an increased depth of analysis, improvement, and future testing.

5.3.1 Participants

An APSP healthcare professional (*Educatrice socio-assistenziale*) identified individuals eligible for the study based on an ad hoc schedule and obtained informed consent. Written informed consent was collected from all participants or their Substitute Decision Makers (SDMs). In addition, authorization by the primary care physician was also requested. Patients over 18, Italian mother tongue, and with mild, moderate, or severe cognitive impairment were eligible for participation. Exclusion criteria were: 1) palliative care; 2) diagnosis of psychosis; 3) severe neurological damage; 4) a positive diagnosis of epilepsy or having first-degree relatives diagnosed with epilepsy; 5) cardiac pacemaker or other metal devices; 6) infectious or gastrointestinal disorders; 7) the presence of open wounds at the level of the face; 8) motor or visual dysfunctions and neuromuscular pain that prevent the use of Oculus. Participants did not receive remuneration upon completion of the study. Overall, 47 users were considered for participation in the study. Of these, 24/47 did not participate for different reasons: 1) 17/47 did not meet all the criteria of inclusion/exclusion; 2) 3/47 did not agree to make the preliminary assessment phase; 3) 4/47 did not want to participate because they did not want to try a new experience that needed to be further studied to better understand the effects. The final sample was composed of 23/47 users, one of whom was not exposed to Oculus for fear of wearing the HMD (see Figure 1).

Figure 1. Trial flow chart.



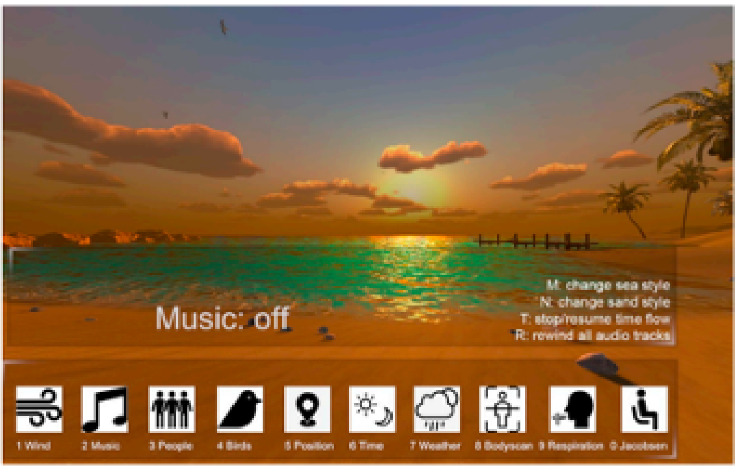
5.3.2 Intervention

5.3.2.1 Hardware and software equipment

A commercially available VR HMD (Oculus Quest 2, Meta Quest) [342], Alienware m15 Ryzen Edition R5" workstation, and a link cable were used. The virtual scenarios were developed in the Unity framework by using the C# programming language (source of assets: https://freesound.org/; Unity; Polyhaven; HDRIhaven). The code was versioned via GitLab. The protocol for the virtual environment design in the current study has been outlined by

Pardini et al. [233]. The individual sessions were video-recorded to allow for triangulation, including nonverbal behavior. Most of the experimental sessions were conducted in the dedicated music-therapy room at the APSP. All of the sessions were administered and evaluated by the same assessor. Health workers accompanied and passively assisted the procedure as observers to get information on the feasibility and usefulness of the procedure and to inform subsequent studies and system design with their requirements. Observations from health professionals were obtained based on self-reported questionnaires and by a Focus Group session. To manage problems related to physical movements and fear of going into an unfamiliar context, two individual sessions were administered in a more commonplace setting, and for one participant, the procedure was administered in their private room. Each session lasted approximately 50 minutes. For safety reasons, VR was always administered when participants were seated safely in a chair or wheelchair. To allow individuals to explore the virtual context, the experimenter and the health care professional who assisted the patient during the procedure helped the participants to rotate their heads and move their chair or wheelchair.

Figure 2. The PC's interface with icons related to the different customizable variables (e.g., music, wind, weather conditions, time of day, and presence of people) [233].



A brief baseline assessment (T0) investigating the ability to move head and body, the use of visual and auditory aids, and the general emotional state were conducted based on an ad hoc measure and a modified version of the *State-Trait Anxiety Inventory- Y1* (STAI-Y1) inspired to the version developed by Appel et al. [36, 37]. At least 2 minutes of VR exposure were conducted before the trial to familiarize patients with the virtual context. Users were invited to choose one of three realistic VR scenarios: a mountain, marine, or countryside environment.

With technical operator support, participants could select and customize all the audio and video stimuli (see Figure 2). A specific range of customization options was chosen as appropriate for the target group of the study, also relying on results of previous studies [40]. Participants had the possibility to visualise the different options and to ask the researchers to modify specific characteristics of the environment. The technical operator and the experimenter could customize virtual scenarios based on a PC's dashboard interface connected to Oculus Quest 2 via a cable. Specifically, the interface presented a series of icons related to the different customizable variables (Figure 2) such as music, wind, weather conditions, time of day, and presence of people). The connection between the PC and the viewer allowed the operator to see what the participant was observing during the experience. Participants had the possibility to visualise the different options and to ask the researchers to modify specific characteristics of the environment. The technical operator and the experimenter could customize virtual scenarios based on a PC's dashboard interface connected to Oculus Quest 2 via a cable. Specifically, the interface presented a series of icons related to the different customizable variables (Figure 2) (such as music, wind, weather conditions, time of day, and presence of people). The connection between the PC and the viewer allowed the operator to monitor in real time what the participant observed during the experience. At any time during the session, participants had the possibility to visualise the different options and to ask the researchers to modify specific characteristics of the environment. Then, the participant was told they could remove the HMD when desired. Throughout the VR session, the experimenter took notes of the participants' verbal and non-verbal communication based on the *Observed Emotion Rating Scale* (OERS), and an *Ad Hoc Observation Form*. Post the intervention phase (T2), the following measures were collected: emotional state, motion-sickness symptoms, usability, engagement, and pleasantness experienced during the activity. Considering the difficulties participants with cognitive impairment could have in peculiar situations, and moments of the day (e.g., negative symptoms relating to the sundowning syndrome), each VR session was arranged based on the participants' and health staff's needs and preferences—Figures 3a and 3b present pictures of two users during their VR experience.

At the end of the entire experimental phase an assessment based on self-report questionnaires of all participants was made and a focus group was conducted with the health staff professionals that observed and assisted the older adult participants during the VR experience.

Figure 3. A participant during the experimental phase with Virtual Reality. Written, informed consent was obtained from the individual or their SDMs to publish these images. Fondazione Bruno Kessler and TrentinoSalute4.0 have the copyright, and permission must be obtained for use in other sources.

5.3.3 Outcome measures

Data collection. Measures are administered in the form of interviews or as observation administered before, during, and after the VR experience. Questionnaires were administered verbally, and participants were asked to respond when they could. Information about the participant's current mental and physical conditions were extrapolated from their medical record.

A *Socio-demographic questionnaire* was administered by the health care professional to obtain information about gender, age, marital status, past occupation, degree level, proneness to motion sickness symptoms, hearing and vision impairments, mobility limitations or use of physical aids, previous experience with VR, and years of stay at the APSP facility. Moreover, the health care professional obtained information about the cognitive impairment level and psychological symptoms from the medical record (e.g., *Mini-Mental State Examination score*-MMSE [343, 344], and the *U.C.L.A. Neuropsychiatric Inventory-NPI* [345]). The inclusion and exclusion criteria evaluation were performed with the demographic schedule.

The modified version of the *State-Trait Anxiety Inventory-Y1 (STAI-Y1)*, inspired by Appel et al. [36, 37], was administered in this study to obtain information on the state-anxiety level and other types of emotions individuals experienced before and after the VR session. The current study specifically investigates relaxation, worry/anxiety, sadness, tightness, annoyance, and anger. The scale was administered as an interview based on a 5-point Likert scale from 1 (not at all) to 5 (a lot). Cronbach's α displayed an adequate consistency for the total score recorded at T0 (Cronbach's $\alpha = 0.75$) and at T1 (Cronbach's $\alpha = 0.71$).

The experimenter used the *Observed Emotion Rating Scale (OERS)* during the VR session. It was adapted from the original version of Lawton et al. [346] and used as an observation tool to assess the presence and frequency of negative emotions (fear, anxiety, anger, and sadness) and positive (pleasure) feelings experienced during the session based on a scale from 1 to 5 (1: "undetected emotion"; 2: "emotion observed for less than 16 seconds"; 3: "emotion observed for 16-59 seconds"; 4: "emotion observed for 1-5 minutes"; 5: "emotion observed for more than 5 minutes").

During the VR session, the *Ad Hoc Observation Form* was also completed to record the type and frequency of vocalizations, phrases, facial expressions, body movements, reminiscences, and pleasant memories elicited during the VR exposure.

The *Virtual Reality Symptom Questionnaire (VRSQ)* [249, 292] assesses the general and eye-related physical symptoms of exposure to a virtual reality environment. The score assigned to each item ranges from 0 to 6, with a maximum total score of 84 (48 for general symptoms and 36 for eye symptoms). Higher scores represent worse symptoms, with 0 corresponding to no adverse effects, and 84 to serious adverse effects.

The VR experience tolerability, acceptance and wearability was primarily estimated based on the frequency of time spent in the VR context, on positive and negative emotion expressed (such as boredom, joy) and the weight of the HMD. Finally, the usability, engagement, pleasantness, and satisfaction experienced in using the VR apparatus were inspired by a measure developed and described by Appel et al. [36, 37], composed of both self-reported questions and other queries that the experimenter answered by observing the participant's behaviors during the experience and characterized by a series of items based on a 5 points Likert scale (Questions about Level of interest, awareness, engagement, and enjoyment observed: 1="very much", 5="not at all"; questions on other information in relation to the VR experience: 1= "strongly disagree", 5= "strongly agree"), and six open-ended questions focalized in obtaining additional information, where possible, about: 1) what participants liked best and least; 2) what participants would like to see; 3) if participants would like to repeat the experience; 4) if participants would recommend the experience to a friend.

To obtain information from health professionals working in the APSP about usability and the perceived quality rating of the VR set-up deployed, the *Adapting-Mobile App Rating Scale (A-MARS)-Subjective Quality Scale* [347], and the *System Usability Scale (SUS)* [348-350] were filled in by operators who participated during the VR sessions. Questionnaires' administration was performed after the administration of the experimental procedure. At the end of the experimental phase, a focus group was conducted with the health professionals that assisted users during the VR experience. Issues discussed during the focus group were the strengths and weaknesses associated with using virtual reality, the future perspectives, and the risks associated with using virtual reality with users affected by cognitive impairment.

5.3.4 Sample size estimation

Sample size calculations were performed to have more rigorous information for interpreting in a more conservative way quantitative data. This permits to estimate the sample size needed to detect a significant difference based on the administration of the STAI. An a priori power analysis has been executed determining an expected medium standardized effect size (effect size = .65), with a power of 80%. Considering a non-normal distribution of the STAI, sample size was calculated with G-Power for non-parametric tests (Kruskal-Wallis Test, Wilcoxon test). Results suggest that a sample of at least 22 patients have to be enrolled. Sample size and Power for non-parametric tests (Kruskal-Wallis Test, Wilcoxon test) were calculated with G-Power. Results suggest that, with a non-normal distribution, 22 patients have to be enrolled. If parametric statistics are conducted (assuming the normal distribution), the sample should instead consist of n = 21 users with Bonferroni correction (*alpha* = 0.05), an effect size equal to .65, and a power of 80%. Considering the current sample was not normally distributed based on the STAI, a sample of at least 22 patients is enrolled.

5.3.5 Data analysis

Continuous data are presented as mean ± standard deviation. Categorical data are presented as numbers with percentages. The statements made by participants during the VR experience were analyzed by SP and SO using thematic analysis and reported as frequencies. Data were analyzed thematically following an inductive, data-driven approach [351]. Data codes were generated systematically, collated into themes, and applied to the data set to generate frequencies. For a comparison of non-normally distributed continuous variables before and after the VR intervention, the Wilcoxon signed-rank test is used for each intervention separately. A two-sided p-value <.05 is considered significant. Statistical analyses were undertaken using SPSS® version 29 [293]. Moreover, qualitative responses were transcribed before, during, and after the VR exposure. In order to analyze data obtained by the audio-recorded focus group, the micro interlocutor analysis method has been applied [352]. The present method is helpful in obtaining information on participants' attitudes, points of view on the use of VR, and permits to have quantitative data on participant grouping. Data were analyzed based on descriptive statistics.

5.4 Results

5.4.1 Demographic analysis

Twenty-three older adults were recruited from the APSP "Margherita Grazioli". Demographics and clinical features of the study sample are described in Tables 1 and 2.
It is important to specify that twenty individuals (87%) could move their heads without difficulty, and only 5 (34.8%) were able to move autonomously in the environment, but with supervision. Eleven participants were in a wheelchair during the VR experience (47.8%), and twelve (52.2%) used the chair provided by researchers.

Table 1. Demographic features of the entire sample.

Demographic features	**Sample Group N=23**
Gender	**N (%)**
Women	19 (82.6%)
Age	**Mean (SD)**
	86.6 (5.12)
Marital Status	**N (%)**
Single	1 (4.3%)
Married	5 (21.7%)
Divorced	2 (8.4%)
Widowed	15 (65.2%)

Education	N (%)
Primary school	13 (56.5%)
Middle school	3 (13%)
High school	3 (13%)
Employability training certificate	4 (17.4%)
Past employment	**N (%)**
Housekeeper	11 (47.8%)
Worker	7 (30.4%)
Clerical worker	3 (13%)
Teacher	2 (8.6%)
Aids	**N (%)**
Wearing glasses	12 (52.2%)
Hearing problems	6 (26.1%)
Wheelchair user	11 (47.8%)
Walking aid	6 (26.1%)
Multifunctional highchair	1 (4.3%)
Walking stick	1 (4.3%)
No aids	1 (4.3%)
Dizziness experienced during movement of transportation	**N (%)**
Yes	None
Sickness experienced while traveling	**N (%)**
Yes	0
Sometimes	6 (26.1%)
No	17 (73.9%)
Feel involved in watching television	**N (%)**
Yes	13 (56.5%)
A little	5 (21.7%)
No	5 (21.7%)
Aware of what VR is	**N (%)**
Yes	2 (8.7%)
No	21 (91.3%)
Past experiences with VR	
Yes	None

Favourite actual pleasant activities	N (%)
Listen to music	2 (8.7%)
Reading	2 (8.7%)
Walking	6 (26.1%)
Dancing	1 (4.3%)
Talking with friends	2 (8.7%)
Painting	1 (4.3%)
Playing card games	1 (4.3%)
Doing crossword puzzles	1 (4.3%)
Watching TV	6 (26.1%)
Outdoor activities	1 (4.3%)

Activities to cope with anxiety (in the past)	N (%)
	1 (4.3%)
Painting	14 (60.9%)
Outdoor activities	2 (8.7%)
Knitting	1 (4.3%)
Reading	1 (4.3%)
Listen to music	2 (8.7%)
Spending time with family and friends	1 (4.3%)
Singing	1 (4.3%)
To pray	

Table 2. Clinical features of the entire sample (N=23).

Mini-Mental State Examination (MMSE)	
Cognitive Impairment Levels (range)	**N (%)**
Mild (18-26) **(n, %)**	11 (47.8%)
Moderate (10-17) **(n, %)**	9 (39.2%)
Severe (<10) **(n, %)**	3 (13%)

Neuropsychiatric Inventory (NPI)		
Clinical features	**N (%)**	**(Frequency x Severity) Mean (SD)**
Delusions	0	0

Hallucinations	0	0
Agitation/Aggression	2 (8.7%)	0.43 (1.47)
Depression/Dysphoria	7 (30.4%)	1.52 (3.12)
Anxiety	9 (39.2%)	2.57 (4.09)
Elation/Euphoria	0	0
Apathy/Indifference	4 (17.4%)	1.22 (3.45)
Disinhibition	3 (13%)	0.91 (2.94)
Irritability/Lability	7 (30.4%)	1.30 (2.98)
Aberrant motor behavior	5 (21.7%)	1.61 (3.81)
Sleep and Nighttime Behavior Disorders	5 (21.7%)	1.30 (3.11)
Appetite and Eating Disorders	2 (8.7%)	0.87 (2.94)

In order to control the potential relationship between the presence of neuropsychiatric symptoms and the cognitive impairment level, Kendall's tau rank and Spearman's rho correlations between the MMSE and the NPI total score were executed considering the entire sample. No relationship between neuropsychiatric symptoms and the cognitive impairment level emerged (Kendall's tau rank = -0.23; p-value > .05; Spearman's rho = -0.29; p-value > .05).

5.4.2 1^ Objective: Investigation of tolerability, motion-sickness effects, engagement, and pleasantness associated with the VR experience.

VR tolerability was operationalized as the frequency of time spent in the VR context that is also related to the emotions felt during the experience and the wearability of the HMD. On average, participants spent 9.91 minutes exposed to the VR scenario (SD=4.78; minimum =1 minute; maximum = 17 minutes). Fifteen users (68.19%) spent at least 9 minutes of time in the VR context (SD=4.78; minimum =1 minute; maximum = 17 minutes). None of the users referred to experiencing a general condition of discomfort, drowsiness, headache, sweating, claustrophobia or disorientation, and nausea during the VR experience. Three participants 3/22 (13.1%) felt a slight fatigue state, 1/22 (4.3%) experienced boredom, 10/22 (43.5%) reported that their eyes were slightly tired and irritated during the VR exposure, 2/22 (8.7%) experienced a slightly blurred vision, and 3/22 (13%) reported having had slight difficulty focusing. Ten (43.5%) participants experienced discomfort due to wearing the HMD (two participants said: "*these special glasses are heavy*"), and one participant completed only the T0 assessment but decided not to try the VR since he was worried about wearing the HMD.

Table 3 summarizes the responses assessed on a 5-point Likert scale, from 1 (very much) to 5 (not at all), related to the interest, awareness, engagement, and enjoyment shown during the VR experience highlighting how the VR activity, on average, was appreciated by participants.

Table 3. Level of interest, awareness, engagement, and enjoyment observed.

Interest and awareness	**Mean (SD)**
General interest in the visual and auditory stimuli of the VR scenario	1.85 (0.75)
Awareness during the experience (based on posture and facial expression)	1.85 (0.67)
Engagement	**Mean (SD)**
Engagement (based on verbal feedback)	1.95 (0.83)
Reminiscences	2.20 (1.20)
Enjoyment	**Mean (SD)**
Enjoyment (based on posture and facial expression)	1.20 (0.41)

Some of the verbal feedback (direct quotes) about engagement in VR were: "*beautiful", "I would like to add other flowers", "I am feeling good here", and "It is marvellous"*. Two users

said, *"the experience was good, but it should be useful for younger people"*, and *"not bad (...), but I prefer to do other things"*.
During and after the experience, 11/22 participants (50%) reported that the VR scenario triggered memories by saying, for example: *"When I was younger, I went to Sicily with my babies", "It is different (but) I am thinking about the picnic at the mountain with friends"*. Moreover, post-intervention, a participant said that the experience allowed her not to think about negative things for a while. In general, 16/22 users (72.7%) expressed their desire to be exposed to VR scenarios in the future and would recommend the experience to their loved ones and friends.

Overall, seven main themes were identified based on what participants verbally shared during the experience (see Table 4): (1) reminiscence (11/22 participants; 47.8%); (2) aesthetic appreciation of the virtual context (8/22 participants; 34.7%); (3) realism (6/22 participants; 26.1%); (4) sense of safeness and protection in the virtual environment (4/22 participants; 17.4%); (5) suggestions for improving the VR scenarios (2/22 participants; 8.4%); (6) lack of interest (2/22 participants; 8.4%); (7) appreciation of the new experience (1/22 participants; 4.3%).

Table 4. Themes and quotes by participants.

Main Theme	User Quotes
"Reminiscence"	"(...) there is also my mom, she is old now (...) we went together to the see (...)" (**Participant 2**). "I was with my dad at the sea - I went to the sea" (**Participant 2**). " (...) my mountain (...)" (**Participant 3**). "I walked a lot in my mountains" (**Participant 4**). "We went there with the children" (**Participant 6**). "We used to play on a field like this" (**Participant 6**). "When I could walk in the mountains (...) melancholy" (**Participant 5**) (then she cocked up by remembering what she is no longer able to do). "I went to the sea in Jesolo, good memories. Now the children go alone" (**Participant 9**). "(...) in Sardinia, this sea reminds me of my happy time" (**Participant 10**). "I took care of my garden" (**Participant 20**). "I went many times in Sicily with children" (**Participant 15**). "How I liked to walk in the mountains" (**Participant 14**). " (...) I remember lots of things (...)" (**Participant 22**).
"Aesthetic appreciation of the virtual context"	"We went to the mountains with blankets (...) and everyone sang the mountain songs" (**Participant 16**). " (...) beautiful here" (**Participant 3**).

	“Suddenly a beautiful snowfall (...) the trees are beautiful (...) there are little animals and butterflies that go around (...) is beautiful (...) beautiful trees and the river that moves split in two - the effect is more positive than negative” (**Participant 4**). “Beautiful” (**Participant 12**). “Beautiful place” (**Participant 13**). “Wow(...) how beautiful (...) what beautiful streams” (**Participant 14**). “Beautiful, beautiful (...) that wonder” (**Participant 15**). “Beautiful, the sea is immense, what a wonder, I see clouds” (**Participant 22**). “Beautiful that stuff (...) how did you do, beautiful, but is there such a place?” (**Participant 22**).
“Realism”	“There’s a wad there that’s gone because I touched it” (**Participant 7**). “Touch the water of the sea (laughs) (..) oh maria looks at the beautiful trees (..) just bathe the water” (**Participant 10**). “I can't see well what it looks like, it seems cloudy but it is clear they are not” (**Participant 18**). “They seem like the *Cascata delle Marmore*” (**Participant 15**). “Does not increase the wind that takes me away” (**Participant 15**). “(...) seem like scarecrows that make blue flowers” (**Participant 15**). “Now comes the water, (...) it makes me feel good - but is it true? - look how much water that comes” (**Participant 16**). “Some things don’t seem true (...) plant shadows don’t move (...)” (**Participant 13**).
“Sense of safeness and protection in the virtual environment”	“I feel calm here” (**Participant 2**). “I feel good” (**Participant 5**). “I feel safe” (**Participant 8**). “The sea is the place that makes me feel good and safe even in reality” (**Participant 16**).
“Lack of interest“	„I’d rather go back to my room (...) I saw that birds pass by and that’s it, I like all the tools (annoyed), I’m fine everything it’s nice but nothing more, I want to go back to my room“ (**Participant 1**). “I don’t care so much today, I’m old, a little heavy (referred to the HMD)” (**Participant 19**).
“Suggestions”	“Beautiful, but I would like more people here” (**Participant 7**). “Plants must be better arranged” (**Participant 9**).
“Appreciation of the new experience”	“Nice to see new things” (**Participant 8**).

5.4.3 2^ Objective: Preliminary investigation of the customized VR scenarios on emotional states investigated before, during, and after the virtual exposure.

Based on the modified version of the STAI-Y1, a Wilcoxon Signed Ranks Test revealed that scores related to a state of relaxation were significantly higher after the VR experience (Md = 3, n = 22) than before (Md = 2, n = 22), z = 2.29, *p-value* = .022. Moreover, levels of manifested anxiety and worry significantly decreased after the experience (Md = 1, n = 22) if compared to levels found before the virtual exposure (Md = 2, n=22), z = -3.13, *p-value* = .002. No differences were found for sadness, tightness, annoyance, and anger (-1.73 < z < -0.88; *p-value* > .05) (see Table 5).

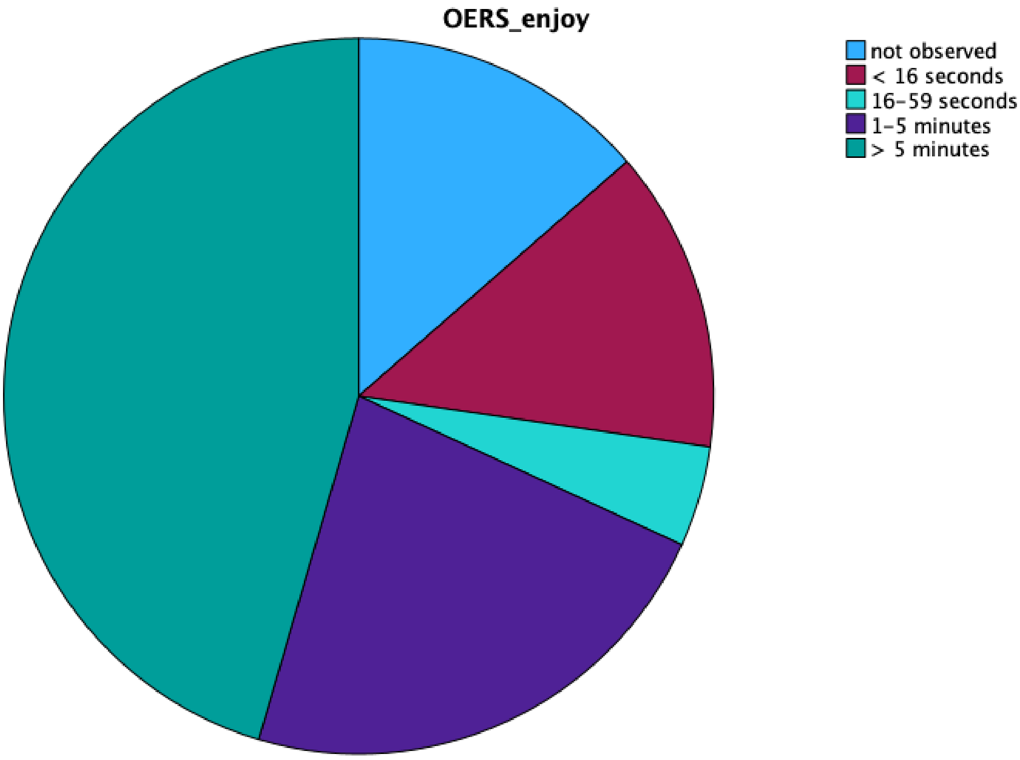
Table 5. State emotions comparisons.

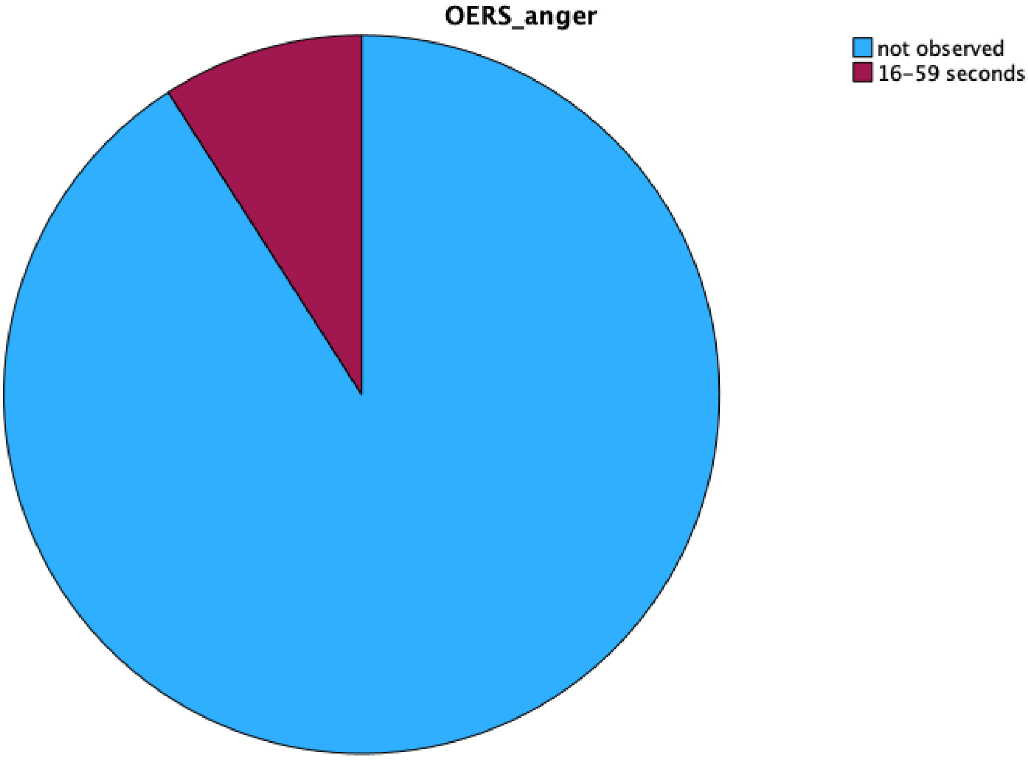
	T0 (before VR)			T1 (after VR)		
	25th percentile	**50th percentile (Median)**	**75th percentile**	**25th percentile**	**50th percentile (Median)**	**75th percentile**
Relaxed	**2**	**2**	**3**	**2**	**3**	**4**
Sad	1	1	1.25	1	1	2
Uptight	1	2	3	1	1	2.25
Annoyed or upset	1	1	2	1	1	1.25
Worried/Anxiety state	**1**	**2**	**3**	**1**	**1**	**2**

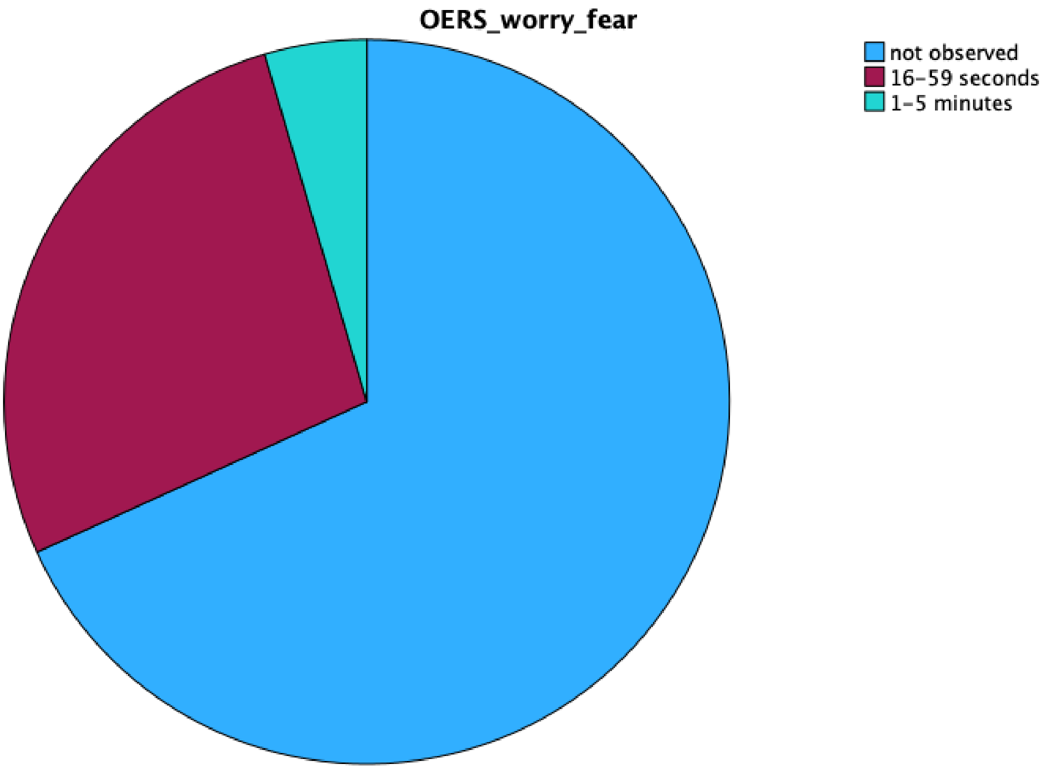
More than half of participants (12/22; 52.2%) expressed being engaged and involved in the virtual environment. During the VR experience, it was observed that 10/22 (43.5%) participants felt a state of pleasantness for more than 5 minutes, 5/22 (21.7%) seemed to enjoy the activity for a period between 1 and 5 minutes, 1/22 (4.3%) for at least a minute, 3/22 (13%) less than 16 seconds and a minority, 3/22 (13%), reported no enjoyable manifestations (see Figure 4).
Only two participants (8.7%) showed a state of annoyance for at least a minute, six users (26.1%) showed to be worried during the virtual activity for at least a minute, and 1/22 (4.3%)

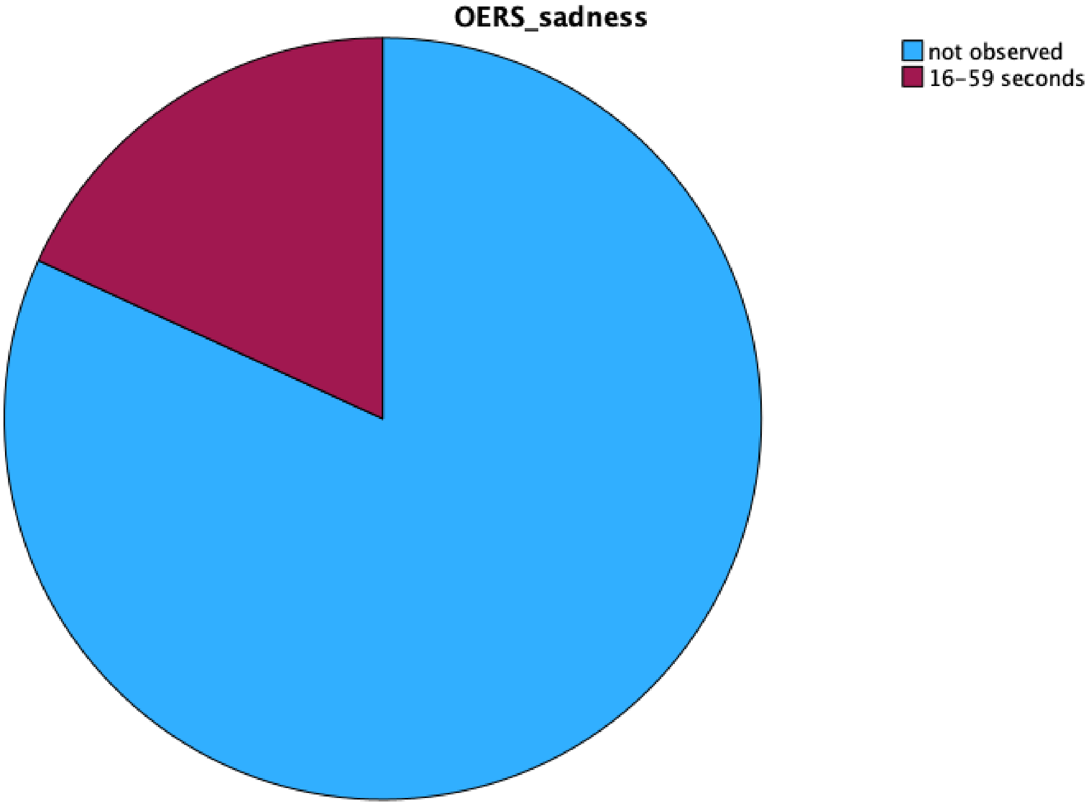
for at least two minutes. Four participants (17.4%) expressed sadness for no more than a minute (see Figure 4).

Figure 4. Pie charts related to the frequency of emotional states recorded with the OERS.




OERS_anger
not observed
16-59 seconds


OERS_worry_fear
not observed
16-59 seconds
1-5 minutes



5.4.4 3^ objective: Preliminary investigation of the usability of the VR procedure and apparatus as perceived by the health staff.

Seven individuals from the health staff provided assistance during the VR sessions (at least two VR sessions each). At the end of the entire VR experimental procedure with participants, 5/7 health staff operators took part in a dedicated assessment phase focused on assessing the VR procedure's usability from their individual perspectives and in a Focus Group.

Based on the SUS questionnaire, all participating staff rated the technology is equal to or above 67.5 with an average score of 69 (Standard Deviation=2.24; min.=67.5; max.=72.5), which corresponds to a level of "marginal" acceptability and usability, defined as "OK" [355, 356].

The score is associated with the fact that the health staff participants stressed that the support of a technical person would be needed to ensure the successful implementation of the VR-scenarios, especially due to the role the PC plays in customizing the environments. In general, the low SUS score regards the technical difficulties expected by operators in administering it independently.

The A-MARS - Section E scale was used to assess the subjective quality rating of the VR apparatus. All the health staff individuals reported that they would recommend the VR apparatus to several people that could obtain benefit from its use. Most of the staff respondents (3/5) were willing to use the VR solution at least 10-50 times in a year, and participants were willing to pay for such a product. When requested to evaluate the overall experience they had with the VR solution, healthcare staff participants expressed an average score of 3.5 points on a scale from 1 ("*One of the worst e-tools I've used*") to 5 ("*One of the best e-tools I've used*"). Finally, all healthcare staff said that they thought the use of VR was useful in facilitating relaxation, especially in patients with mild cognitive impairment, since people with more severe impairment may find additional obstacles in experiencing VR (e.g., related to the difficulty in understanding what objects represented).

The focus group was aimed at investigating five main themes related to the VR apparatus usage. For each theme, at least two questions were asked, and the following themes were derived:

- **Theme 1: Strengths and advantages of VR use**

(1.1: "*According to your experience, are there strengths and advantages in using virtual reality as a pleasant activity to promote relaxation in people with cognitive impairment?";* 1.2: *"What are they all about?*").

All the participants agreed in judging the VR apparatus and procedure as a simple activity to do with users since it does not require particular cognitive or motor skills. Health staff individuals thought it was a valuable activity for promoting pleasant and potentially relaxing experiences in older people with various levels of cognitive impairment. Another advantage observed was the capacity VR can allow hospitalized people to see places they can no longer experience. Another strength from the health staff's point of view is the possibility of exploring a different kind of virtual context and choosing the preferred scenarios according to the users' preferences and needs.

- **Theme 2: Weaknesses and disadvantages of using VR**

(2.1: "*Based on your experience, are there disadvantages and weaknesses in using virtual reality as a pleasant activity for promoting relaxation in people with cognitive impairment?";* 2.2: *"What are they all about?*").

All participants agreed that the heaviness and wearability of the Oculus quest-2 HMD, or the need to wear it, was the main obstacle in the VR procedure and the primary reason why some people refused to participate in the activity. According to 3/5 health staff professionals, the structured device was seen as unsafe, especially for people with higher cognitive impairment or concerned about their safety.

- **Theme 3: Future perspectives and what to change for continuing the use of VR with the health facility's users**

(3.1: *"Based on your experience, should the virtual reality procedure be modified to continue to be used with people with cognitive impairment?";* 3.2: *"How?"*).

All health staff individuals agreed in suggesting to change the type of HMD, going for models that are lighter and more wearable. For people with higher cognitive impairment, it would be difficult to understand the reason for wearing the HMD, and this may also elicit some anxiety. A less invasive HMD may likely help to overcome these difficulties. A suggestion was to consider exposing users that perceive higher anxiety levels in wearing the HMD, and greater difficulty understanding the activity, in a virtual setup that does not require to wear the HMD (e.g., a Cave Automatic Virtual Environment).

All participants agreed to actively involve the health staff in the VR deployment with users to make the context even more familiar.

Another element to consider for the future is to expand the number of virtual reality experiences to familiarize the person with the equipment and the virtual context.

Three health staff suggested creating other VR environments and making natural contexts more realistic. Another suggestion for future investigation was to deploy the procedure without using the PC with the aim of facilitating the intervention's administration.

- **Theme 4: Facilitating factors of the VR procedure deployment**

(4.1: "*Based on your experience, are there any factors that have facilitated the use of virtual reality?;* 4.2: *"What are they all about?"*).

All participants said that a facilitating factor could be the deployment of the VR procedure in a familiar setting to facilitate users' perception of safety.

One health staff member added that, regardless of the severity of the cognitive impairment, having peculiar personality characteristics (e.g., being predisposed to new experiences) could be another facilitating factor. From a general perspective, health staff participants agreed in considering low levels of cognitive decline as a condition that might decrease the benefit provided by the VR intervention (e.g., for issues related to understanding the intervention's aim, and for the difficulty in expressing and understanding if the activity is really appreciated).

However, they reported that the most important human factor to consider when inviting to a VR session is related to the individual personality characteristics, since they observed how two participants - despite a critical level of cognitive impairment - were calm and positive during the VR exposure.

- **Theme 5: Risks in using virtual reality**

(5.1: "*Based on your experience, are there risks in applying this technology the way it was done in this research?"*; 5.2: *"What are they all about?"*).

The most significant risk encountered is eliciting intense emotions, not only positive, that must be contained even after exposure to virtual reality. They also considered this a potential point of strength of the solution since it allows people to be exposed to their feelings and memories. Based on the experience gained during the VR sessions, they did not believe there were any further risks as the procedure was assisted.

From the focus group transcript, information on the frequency of agreement and disagreement expressed directly or through examples from each participant was collected for questions 1.1, 2.1, 3.1, 4.1, and 5.1 and was systematically described in Table 6 following the example of previous studies [352, 353].

Table 6. Frequencies related to the agreement/disagreement expressed by the health care staff participants to the main themes of the focus group.

Question	**Type of Response**					
	A	**SE**	**NR**	**D**	**SD**	**AR**
1.1 *Are there strengths and advantages in using VR as a pleasant activity for promoting relaxation in people with cognitive impairment?*	4	1	0	0	0	0
2.1 *Are there disadvantages and weaknesses in using VR as a pleasant activity for promoting relaxation in people with cognitive impairment?*	5	5	0	0	0	0
3.1 *Can the VR procedure be modified to continue to be used with people with cognitive impairment?*	3	2	0	0	0	0
4.1 *Are there any factors that have facilitated the use of VR?*	1	3	1	0	0	0

5.1 *Are there risks in applying this technology the way it was done in this research?*	3	1	1	0	0	0

Notes: A: Explicit agreement; **SE**: Provided example suggesting agreement; **NR**: Did not indicate agreement or dissent (e.g., nonresponse or did not know); **D**: Indicated dissent; **SD**: Provided significant example suggesting dissent; **AR**: Ambivalent response.

5.5 Discussion

The main aim of the current study was to assess the feasibility of and potential benefit of VR exposure in a target of older adults living in long-term care. Feasibility and acceptance proved to be satisfactory, in line with previous research (e.g., 36, 37): the exposure to the VR apparatus was well-tolerated, and no severe or notable adverse side effects (such as nausea, dizziness, or confusion) were reported. The most frequently reported symptoms by only those who wore the VR apparatus for more than five minutes were a slight sensation of fatigue and eye discomfort limited to the period of exposure in the HMD. It is relevant to note that the VR environments used in this study are defined as static scenarios with only slight visual oscillations (e.g., seawater and oscillation of plants due to the action of the wind), but without any rapid movement. This was an intentional design consideration, given that previous work reported that static scenes and a constant speed during movement could prevent cybersickness symptoms (e.g., 354-357).

The main difficulty referred to by nearly half of the participants (both patients and healthcare staff) was the weight and wearability of the HMD. This issue has been previously reported, for instance, in Kalantari et al. study [218] but differs slightly from older studies (e.g., 36) where the model of HMD used (Samsung Gear VR) only weighed 318 grams, while Oculus quest 2, used here, weighs 503 grams. Even if a larger sample is necessary to consider these results representative of the target population, our sample was entirely composed of older adults, individuals with a slender physique and weak muscle mass, which undoubtedly contributes to the perception of heaviness. Despite this limitation, the perceived weight of the device by the participants did not significantly affect the overall experience of the virtual context or withdrawal from the study.

Similar to other studies (e.g., 36, 37, 218), participants expressed verbally or manifested with nonverbal behavior a general state of interest, awareness, engagement, and enjoyment during the VR exposure showing appreciation of the experience. Reports collected during the intervention showed that the exposure to a realistic, natural, and above all, customized virtual environment adapted to users' preferences and needs, prompted reactions, such as reminiscence of melancholic memories, the aesthetic appreciation of what they were seeing, the sense of safeness and protection in an appreciated context. Interestingly given the research context, participants also expressed feelings of self-realization and "being useful" by providing opinions and suggestions to the experimenters on how to improve the virtual scenarios.

Moreover, more than 70% of the participants stated that they would recommend VR to a friend, confirming the potential benefits of the VR experience in users with cognitive impairment.

The general increased relaxation state and the reduction in worry/anxiety post-VR, both self-reported and observed, are consistent with prior findings (e.g., 36, 37, 358), supporting the hypothesis that VR can serve as a restorative or stress-reducing experience.

A set of core constructs emerged from the focus groups conducted with healthcare professionals. In line with data reported by older adult participants involved in the study, one healthcare staff perceived the HMD to be too difficult and heavy for older adults. Even if corrective measures could be taken to improve comfort when wearing the HMD, novel and lightweight HMD might further facilitate acceptance and ease of use, especially for those in a more fragile state.

A second constraint is related to the difficulty of properly assessing a patient's VR experience in case of severe cognitive impairment. In this case, the collection of bio-physiological parameters could be added as part of the experimental procedure, to better assess the experience of the patient and triangulate different sources of information (e.g., heart rate, skin conductance, etc.).

Finally, the collection of informed consent was reported as a problematic - albeit necessary - task: signing (pen-and-paper) a form was *per se* not well accepted by older adults, whilst other approaches of collecting informed consent might be more suitable and easy-to-deploy (e.g., verbal consent). It is, however, important to add that this step is essential for the deployment of a research project, but it is expected it would not impact the implementation of a therapy program.

Considering the major (perceived) advantages of using VR for patients, focus group participants highlighted the possibilities to deploy environments patients are not able to experience anymore (e.g., seascapes, mountainscapes), because of clinical and/or logistical issues.

Given the feedback provided by staff during the focus group and the results from patient participants using VR, we provide several recommendations to inform future developments and improvements of the solutions, both from a methodological viewpoint and an operational perspective.

From an operational perspective, the HMD proved to be generally acceptable but a lighter-weight HMD might improve usability, particularly for this target group. In addition, to mitigate discomfort and potential anxiety, identifying customized time and space could be beneficial to meet patients' needs. For instance, certain times of day (e.g., sundown syndrome) and locations (unfamiliar rooms) may trigger anxiety and behaviours, which should be avoided when necessary. Finally, preparatory procedures should include a targeted and careful assessment of physical condition, including hearing aids, glasses, and mobility devices, although, in the current research, no major problems were reported.

From a methodological perspective, enriching the VR experience with additional audio and video details could further improve the impact of the VR intervention, considering that patients might be more familiar with some environments (e.g., mountain scenery) over others, and thus paying more attention and wanting to explore specific details. In terms of customization, this option appeared to be appropriate and viable for the target group. In fact, the core objective was to explore the feasibility of the entire procedure (including the availability of certain degrees of customization), as this option could potentially be neither viable nor acceptable for this context.

Adding psycho-physiological measures (e.g., heart rate variability, skin conductance, etc.) could greatly improve the assessment of anxiety/relaxation, particularly in patients with severe cognitive impairment, where there may be challenges in communicating. It is important to acknowledge that participant anxiety levels in this study may have been higher than expected because patients were exposed to VR for the first time and in an unfamiliar room (which was dedicated to this study). An additional methodological issue is related to participants' sample inclusion criteria. In the large majority of studies, measures that evaluate the cognitive decline level (e.g., the MMSE) are used as reference (e.g., 36). In our study we demonstrate that individuals of all ranges of cognition are able to benefit from VR. Preliminary data from the Focus group suggests that personality traits might play a role in reinforcing efficacy of these interventions. Indeed, some specific traits (like willingness to try new experiences) could be a reliable proxy of potential success, therefore these characteristics should be considered (perhaps weighted even more) than cognitive abilities in future studies to properly assess their impact and role in the process.

Another important outcome of this study highlights the potential of VR customization. In terms of acceptance, personal-adaptation refers to the ability to tailor environments and features to users' preferences (e.g., removing personal triggers for anxiety related to peculiar visual and auditory stimuli that could characterize the VR scenarios). For efficacy, adaptation implies the opportunity to facilitate a stronger connection between the virtual context and a personal history or narrative. In other words, linking the virtual environment with personal constructs/meanings could facilitate the emergence of viable and sustainable "therapeutic" experiences, where the patient is involved somewhere in between the area of elaboration, even considering the reminiscence, that can emerge during the exposure and may contribute to decreasing anxiety (e.g., 359).

5.5.1 Limitations

While promising, it is important to keep in mind several potential limitations that may have introduced bias in the present study. Given the small sample size and recruitment from a single long-term care facility, generalizability of the results should be taken with caution. Moreover, evidence on gender differences in VR's user experience, presence, and usability are still debated in the literature [e.g., 308, 360]. For this reason, future studies should stratify the samples to control the effect of gender other than various socio-demographic variables.

Additional bias could be introduced through subjective researchers' observations, and the lack of triangulation of self-reports with more objective measures, such as biophysiological data.

Authors cannot exclude that an increased level of interaction (e.g., combining metaverse and game mechanics) - not included in this study - could have an impact on the potential acceptance of the proposed experience. In addition, a limitation could be represented by the lack of neural networks to further analyze the different sources of data: this would be possible only with large datasets, and this limitation is directly linked to the purpose of the study and the related sample size.

An additional limitation is linked to the relatively limited range of customization options made available: they were limited as this range was deemed appropriate for the target group of the study, but could be appropriate to suggest more focused stimuli very close to the personal life, interest, values and needs of each user.

Finally, because we used an adapted version of the STAY questionnaire (to suit our population of interest) [36, 37], we cannot ensure the validity of the tool.

5.5.2 Future Directions

Future research should compare different HMDs (e.g., PICO 4 HMD) [361] and weights (among other features - more easily applied to vision glasses, etc.) to see if this has a noticeable impact on tolerability by older adults. VR-content should also be enriched with added audio and video details.

In the future, the focus could shift towards expanding the range of customization options in virtual scenarios and measuring their impact while also extending the contribution and knowledge provided by our study.

Studies should assess the impact of multiple exposures, both in terms of acceptance and the clinical effect on anxiety. With this approach, healthcare professionals could administer VR sessions several times to the same individuals, which may decrease feelings of fear, anxiety, and prejudice related to the unfamiliar technology [358]. It also allows researchers to evaluate the potential impact of the intervention at different moments of the day [40].

Considering the emotional impact VR sessions could evoke, future interventions should design pre- and post-strategies to help mitigate or manage emotional reactions potentially triggered by the VR. For example, the introduction of listening spaces or dedicated space to contain emotional states. A more focused analysis of the specific diseases would be useful to better understand if, for example, some but not other visual and auditory problems prevent ease-of-use of the HMD. Stratifying the sample according to the severity of cognitive deterioration to better assess if the VR apparatus deployed could be more effective for some groups over others, as well as to investigate the possible changes to the virtual context in relation to users' preferences and needs. Moreover, following studies should recruit a larger sample size and include objective psycho-physiological assessments.

5.5 Conclusions

This study builds on the growing body of literature empirically evaluating the acceptance and potential impact of immersive VR in long-term care settings, with specific considerations for older adults with varying degrees of cognitive, sensory, and mobility impairments. Based on our knowledge, unique to other work, we took into account the effect of customizing the VR-experience. This represents a valuable step-forward compared to the standard "one-size-fits-all" approach adopted in the majority of the studies in the field of VR [359]. At the same time, while customization could improve acceptance by accommodating and tailoring the VR environment in light of patients' preferences (e.g., 3, 5, 233) it might lead to potential challenges in its deployment. This factor may significantly impact either enhancing or hindering the experience. To our knowledge, this is one of the few studies that have explored customization as an option for this type of population.

Since user-centred approaches need more effort by those responsible for administering the therapy, it is also critical that we seek their input on the design of interventions if we want to encourage their adoption and sustainability (e.g., 359).

The current research took into account the viewpoints of the healthcare staff which brought valuable insight into the patient's previous history and usual emotional patterns and reactions. In addition, feedback from health staff participants gave us the opportunity to consider alternative way in administering the procedure. Indeed, the following study that we will carry out operators will administer the procedure directly to patients and will involve the use of an easy-to-use smartphone interface for customizing the VR environments without the support of a technician.

Moreover, we were able to correlate feedback between patient and staff groups, and across the multiple data collection methods.

Despite limitations, this research contributes to advancing knowledge related to the customization of VR experiences and their related impact on acceptance and potential clinical efficacy in older adults. Given the recognition that current interventions are not satisfactory and that the number of older adults with cognitive decline will only increase, we need to dedicate resources to the co-design and evaluation of novel therapies for this population. VR presents a relatively cost-effective and customizable solution that can be deployed in long term care contexts, offering new hope for personalized-care.

PART 3

⊣⊢

GENERAL DISCUSSION AND FUTURE PERSPECTIVES

CHAPTER 6

GENERAL CONCLUSIONS AND FUTURE PERSPECTIVES

6.1 Summary of results

Virtual Reality (VR) is extensively deployed in the clinical psychology and psychotherapy fields. It is used to manage different mental health problems, such as anxiety disorders. The application of VR is also growing to improve the effectiveness and flexibility of various relaxation techniques or is used alone to promote a state of calm and anxiety reduction. Indeed, literature shows that VR scenarios representing, for instance, visual and auditory elements of natural relaxing environments can facilitate the learning of relaxation techniques, such as Body Scan and Progressive Muscle Relaxation Training (PMR). Moreover, the opportunity for customization of the VR scenarios could be an element that further facilitates relaxation, allowing participants to experience more realistic emotional conditions, increasing relaxation, sense of presence, and perception of security in the virtual reality. The current Ph.D. project aimed to investigate customized, relaxing VR scenarios, used alone or in association with specific relaxation training protocols, to support the management of anxiety and other related psychological constructs. Three studies characterized by mixed methodologies have been conducted to reach this goal:

- STUDY 1: The first study (Chapter 3) investigated anxiety symptoms, user experience, and individual preferences regarding exposure to customized and non-customized relaxing VR environments combined with a Body Scan audio guiding track. The study was based on an exploratory crossover experimental design mixed-method approach on a non-clinical population. Findings revealed that customized scenarios could enhance the subjective perception of relaxation, immersivity, and pleasure compared to non-customized virtual settings. These findings expand on the impact of customized VR environments, suggesting the role of customization as a promising component in facilitating engagement and promoting a higher perceived state of relaxation. The study was in the preliminary phases based on the Obesity-Related Behavioural Intervention Trial (ORBIT) model [241], specifically the design (Phase Ib) of digital interventions and their preliminary testing (Phase IIa). The results of this study allowed the subsequent works to be conducted in which the next phases of the ORBIT model were implemented to evaluate the preliminary efficacy of the customized relaxation intervention with a pilot study (Chapter 4) and the feasibility of the one-shot VR procedure on a clinical sample (Chapter 5).

- STUDY 2: The knowledge about the importance of validating innovative and more flexible interventions and the results from the first study informed and led us to deploy a second pilot study, reported in Chapter 4, which investigated the impact that exposure to a customized context in VR can have on anxiety, stress, depression, coping strategies, quality of life, and other variables related to engagement and the sense of presence, compared to a standard treatment that involves the application of guided imagination. In this case, the virtual or imagined scenarios were administered with an abbreviated PMR, and the main aim was to understand if VR can have the potential to overcome possible limitations of the "as usual" Guided Imagery treatment. The focus was on assessing the impact on state anxiety of PMR associated with a customized-relaxing scenario in VR and the role of virtual scenarios in facilitating the recall of relaxing images and the sense of presence. Moreover, this research was interested in understanding the impact of two web-based interventions used to administer the PMR. To investigate the research's aims, the sample was composed of 108 university students randomly assigned to one of three different experimental conditions: 1) PMR Training sessions by Zoom and VR exposure; 2) PMR Training sessions by Audio-track and VR exposure; 3) PMR Training sessions by Zoom and Guided Imagery exposure. The study is novel and imbued with innovative aspects based on the new challenges in validating psychological treatments for relaxation that allow them to be administered online and with the help of customized, immersive techniques supported by virtual reality. The results highlighted how being in a customized virtual scenario promoted a greater reduction of the self-perceived state anxiety than in the imaginative condition, when individuals were directly exposed to the VR or GI experience and when they had to recall the strategies learned during the relaxation protocol. Independently of the type of web-based relaxation training administered before, VR is more effective than in-imagination exposure in allowing a subjective reduction of the state of tension and worry felt (e.g., 277-279, 292). The audio-track group achieved the most significant relaxation during training and exposure to VR. At the same time, it was revealed that the therapist's presence during the training sessions, and the booster effect of VR, helped more in learning the relaxation procedure.

- STUDY 3: Considering the importance of assessing customized VR environments to reduce arousal and anxiety in clinical groups, a *third proof-of-concept study*, reported in Chapter 5, was conducted involving a sample of older adults diagnosed with dementia. This research topic is part of a new line of research investigating usability and the possible impact on reducing activation, anxiety, and negative emotions that can be experienced frequently in the ordinary day of people living in healthcare facilities. To add useful and innovative components starting from what already exists and driven by the indication of Appel et al. [361] and Moyle et al. [221], the customization aspect was added to the current experimental design as well as the healthcare professionals' point of view was investigated to obtain useful feedback to inform future studies that our research group is going to implement in the next months. Previous studies showed how VR could increase engagement and relaxation in older adults with and without cognitive impairment. The main aim of this study was to investigate the feasibility of customized naturalistic VR scenarios by assessing motion-sickness effects, engagement, pleasantness, and emotions related to exposure in the virtual context. Feasibility and acceptability have proved satisfactory, considering that the VR experience was well-tolerated and no adverse side effects have been reported. Regarding the output from the focus group and overall research analysis, different recommendations were listed in Chapter 5 to inform future developments and improvements of the solution, both from a methodological and operational perspective. From an operational perspective, HMD has proved to be generally acceptable. At the same time, lightweight HMD might improve usability, particularly for this target group. In addition, to mitigate discomfort and potential anxiety, identifying personalized time slots and dedicated familiar rooms could be beneficial to meet patients' needs. For instance, researchers should offer different settings for VR exposure (e.g., patient's room rather than less familiar locations). From a methodological perspective, enriching the VR experience with additional audio and video elements could further improve the efficacy of a VR intervention, considering patients familiarity with some environments and therefore paying more attention to specific details. As previously mentioned, adding psycho-physiological measures (e.g., heart rate variability, skin conductance, etc.) could largely improve the assessment of anxiety/relaxation patterns, particularly in patients with high levels of cognitive impairment. From this perspective, it cannot be excluded that the reported levels in terms of anxiety are somehow linked to the fact that patients were exposed to VR for the first time, within a unique timeslot, and in a dedicated (albeit not familiar to patients) room. Future research could assess the impact of multi-session interventions in terms of acceptability and effect on anxiety patterns and the impact of multi-sessions embedded in therapeutic intervention. Considering the emotional impact and the personal experiences a VR session could evoke, it might be worth identifying strategies to create pre- and post-VR dedicated sessions. This is in light of managing cognitive/emotional reactions that could emerge from the VR experience and supporting patients. An additional methodological issue is related to patients' selection. In most studies, measures that evaluate the cognitive decline level (e.g., the MMSE) are used as reference (e.g., 36). The present study suggests that regardless of their cognitive decline scores or clinical issues, patients with specific personality profiles could benefit from VR, particularly those more prone to experiment with novel approaches.

6.2 Take-home messages and future perspectives

The current studies highlighted the importance of personalizing and customizing VR environments from feasibility and efficacy perspectives.

The current Ph.D. project introduced a novel therapeutic approach to promote relaxation, structuring evidence from the literature on the features of relaxing natural scenarios and using standardized relaxation training administered with alternative tools (e.g., Zoom platform, audio-track, immersive VR tool).

Indeed, inspired by Recchia et al. [362], we used elements of evidence-based therapies described in the literature and introduced new technological tools to administer the interventions tested. We started by obtaining qualitative and quantitative information to build the software and procedure apparatus based on the personal experience of convenience samples. This pre-clinical development phase provided as an output a combination of digital active ingredients and digital platforms suitable for the best use.

The acceptance and preliminary efficacy of the interventions were tested with promising results. In other words, customizing the virtual environments could promote an experience closer to users' needs and preferences, potentially providing greater efficacy than non-customized ones. Moreover, exposure to virtual scenarios was found as a better way to reduce anxiety than the standard modality consisting in the deployment of the guided imagery technique.

In general, these preliminary results assist in planning future studies on the effect of relaxation training in customized VR environments on large-scale clinical and non-clinical samples. They examined the feasibility and preliminary effectiveness that is indicated in the ORBIT model framework as a key objective of the pre-clinical assessment of interventions. Based on subsequent randomized clinical trials that will have to investigate the digitalized relaxation protocol introduced with the present thesis on large clinical samples, our solutions could represent future digital therapies to be delivered in the ecological situations of the real-world context, in which health professionals, family members, or users by themselves can use virtual reality as a treatment excipient for delivering evidence-based interventions for mental health and well-being based on cognitive and behavioral therapy (e.g., [362]).

This speculation is also based on one of the crucial take-home messages of the presented studies about the prominent impact of being exposed to realistic and customized scenarios in VR. Specifically, the effects that exposure to VR may have in more ecological everyday settings are supported by the results of the study presented in Chapter 4, showing the benefit for individuals to transfer the relaxation skills learned in VR to real-world situations. Considering the positive outcomes found in the above-reported studies, future research may explore using VR during the training sessions with customizable avatars that guide users in learning relaxation techniques more interactively, based on Artificial Intelligence (AI) empowered solutions fitting the users' needs. One planned study of our research group will go in this direction, considering both user samples from the non-clinical population and individuals that suffer from chronic pain and oncological diseases. Indeed, the aim will be to use complemented relaxation strategies guided by a virtual therapist to learn how to manage chronic pain based on individuals with heterogeneous diseases and to reduce state-anxiety before and after surgical procedures with breast cancer patients.

The fact that evaluating web-based training without the support of virtual reality has allowed us to achieve promising results also suggests the opportunity of studying the delivery of standardized relaxation training by using alternative technological solutions, including the use of Chatbots, a computing program that uses AI and Natural Language Processing (NLP) to understand customer questions and automate their answers, simulating human conversation [363]. Chatbots may be deployed as virtual assistants, interacting with users, and providing specific support in case of problems during training. Using chatbots to support the delivery of relaxation interventions may help to overcome the criticalities of remote access and interaction with the therapist, providing interactive support without invading the individual's personal space during relaxation. Chatbots may also overcome the possible limitations of using the audio-track guided relaxation as they are more interactive and potentially engaging solutions that could reduce the risk of drop-out and allow the person to resolve any doubts associated with certain activities during the training phase.

From the perspective of the Stepped Care Model [364], we can hypothesize that the different investigated relaxation strategies and means for delivering a relaxation treatment could be administered in the future as stand-alone or complementary strategies according to the goals, the target problems and the population considered. Indeed, for example:

- A web-based delivery mode deployed autonomously without the presence of a therapist could be used to reach the needs of the entire population to acquire a technique useful to prevent or manage bearable and not invalidated anxiety and stress problems;
- A chatbot-based approach could be a more tailored mode of delivering mental well-being interventions that also provide specific information based on the type of problem affecting the target user;
- An approach in which the remote therapist is guiding the relaxation training could be a suitable modality for people who are doing treatment with a professional but do not need a strictly personalized support during the training phase;
- The use of VR could be more appropriate for interventions to be delivered in clinical and healthcare facilities where it is necessary to provide healthcare services to several people at the same time, but where limitations in personnel resources may complicate the service delivery.

Each intervention can be adequate in different contexts, and it is essential to be investigated with rigorous studies on the most effective protocols best fitting the different target populations.

Another aspect that future studies should better address is the deployment of more ecological experimental designs. For example, healthcare professionals can administer the experimental procedure several times to stem the potential obstacle of a “one shot” intervention with VR. This would potentially increase the positive effect on anxiety and the generalization of what has been learned from the virtual experience to other real-world contexts (e.g., facing an exam at the university) and also decrease feelings of fear and anxiety related to the non-familiarity with the VR apparatus, as is the case of people with a diagnosis of dementia.

Moreover, the thesis’s studies informed on the possibility of introducing other improvements to overcome limitations during the administration procedures:

- The use of proper software to personalize and customize virtual scenarios by smartphone. Future applications of VR should be easily administered autonomously by users or healthcare professionals without peculiar expertise in the technology field.

Considering this, one of the difficulties of the current studies was using the PC to customize scenarios. Indeed, sometimes software updating operations occur, and we noticed that this would make it more difficult the procedures' administration by therapists or users not able to cope with unexpected events, mainly due to technical issues. For this reason, in our next studies a dedicated software by Smartphone will be deployed to customize virtual scenarios more easily by non-expert administrators and users, connected to the HMD without a link cable.

- Introducing more scenarios and stimuli that users can select to customize their relaxing virtual experience.
- The integration of the virtual reality software with a virtual avatar, AI powered chatbots, web-based audio-track, and assessment measures in public, embraceable, and familiar Personal Health Record - PHR platform (e.g., the Trentino Citizens Clinical Record-TReC platform), accessible to the population of communities living in specific region or country to promote an Integrated Care Model for patients' empowerment and data repository [365], and to facilitate improved communication and quality of the services delivered with advantages for both health care staff and citizens/patients [366].
- The deployment of customization of virtual reality scenarios more dynamically during exposure to respond to users' needs and preferences based on their emotional responses, monitored continuously with psycho-physiological cues, self-reported information, body movements, facial expressions, eye tracking, and brain signals. AI techniques (e.g., machine learning, deep learning, and natural language processing) provide computers with reasoning and analytical capabilities, and the possibility of merging AI and customized VR experiences has yet to be fully realized and studied (e.g., 3, 5).
- Despite the advantages of personalized VR in offering an intervention based on user's needs and preferences, future research is also needed to overcome possible obstacles, such as the difficulty of integrating complex technological and personalized systems in healthcare facilities [3, 367, 368].

To conclude, the introduction of VR and web-based training could positively impact the reduction of therapy sessions and their cost, as it allows partial self-management of the treatment. If the combined administration of a personalized and customized VR relaxation scenario and the deployment of a standardized and validated relaxation protocol effectively obtain a better subjective perception of relaxation than the standard procedure, it could offer a valuable opportunity for users to do relaxation with greater autonomy. For this reason, assessing the efficacy of a validated relaxation intervention in additional VR-based settings could extend the treatment administration options, creating interesting opportunities for introducing innovative interventions in situations where the standard procedure is more challenging to be effectively deployed.

The results and limitations of these studies will be the basis for the design and implementation of future research, currently in progress at the Bruno Kessler Foundation Digital Health research unit, that will involve the validation of VR-based relaxation solutions with different clinical populations, such as individuals with cognitive deterioration, cancer, chronic pain, and palliative care.

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ABBREVIATIONS

VR	Virtual Reality
PMR	Progressive Muscle Relaxation
GI	Guided Imagery
HMDs	Head Mounted Displays
ART	Attention Restoration Theory
APA	American Psychological Association
SRT	Stress Reduction Theory
PFA	Perceptual Fluency Account
CAVE	Cave Automatic Virtual Environment
PQ	Presence Questionnaire
ITC-SOPI	ITC- Sense of Presence Inventory
MAUVE	Multi-criteria Assessment of Usability for Virtual Environments
ORBIT	Obesity-Related Behavioral Intervention Trials
FBK	Fondazione Bruno Kessler
STAI	State-Trait Anxiety Inventory
DASS-21	Depressive Anxiety Stress Scale-21
VREs	Virtual Reality Environments
SAM	Self-Assessment Manikin
VAS	Visual Analogue Scale
VRSQ	Virtual Reality Symptom Questionnaire
cVRE	customized Virtual Reality Environment
ANOVA	Analysis of Variance
COPE-NVI	Coping Orientation to the Problems Experienced-New Italian Version
VVIQ	Vividness of Visual Imagery Questionnaire
TVIC	Test of Visual Imagery Control
PGWBI	Psychological General Well-Being Index
LME	Linear Mixed-Effects
FDR	False Discovery Rate
HR	Heart Rate
SDMs	Substitute Decision Makers
APSP	Azienda Pubblica di Servizi alla Persona
OERS	Observed Emotion Rating Scale
MMSE	Mini-Mental State Examination
NPI	U.C.L.A. Neuropsychiatric Inventory-NPI
A-MARS	Adapting-Mobile App Rating Scale
SUS	System Usability Scale
TReC	Trentino Citizens Clinical Record

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