Virtual Reality (2025) 29:147
https://doi.org/10.1007/s10055-025-01218-w

ORIGINAL ARTICLE

# The potential of virtual reality for enhancing the efficacy and acceptability of mindfulness training in non-clinical adults: a pilot randomised controlled trial

Marta Modrego-Alarcón[1,2,3] · Yolanda López-Del-Hoyo[1,2,3] · María Beltrán-Ruiz[1,3] · Javier García-Campayo[1,2,3,4] · Jesus Montero-Marin[5,6,7]

Received: 26 November 2024 / Accepted: 11 August 2025


**Abstract**
Mindfulness-based programmes (MBPs) have proven effective in enhancing mental health outcomes among non-clinical populations, yet they face significant attrition rates. The role of virtual reality (VR) in improving engagement and effectiveness within this context remains uncertain. To explore the potential acceptability and effectiveness of VR-based mindfulness interventions for mental health outcomes in non-clinical adults, we conducted a pilot randomised controlled trial (RCT) with pre-treatment and post-treatment measures, alongside pre-post VR session assessments. A total of 51 participants were randomly assigned to three groups: "MBP" alone ($n=15$), "MBP+VR" ($n=20$) and "Relaxation" therapy ($n=16$), the latter serving as the control condition. We utilised the innovative technology of the MK360 immersive experiences system, offering auditory and visual stimuli that allowed participants to immerse themselves in a virtual world. "MBP+VR" demonstrated greater acceptability compared to "Relaxation" but equal acceptability to "MBP" alone. All study conditions showed significant reductions in psychological distress, the primary outcome. Notably, "MBP+VR" outperformed "Relaxation" in reducing psychological distress ($p=.0.015$), with large effects. Both MBP and MBP+VR showed superior results compared to the Relaxation group. MBP demonstrated greater improvements in depressive symptoms (DASS-21), positive affect (PANAS), the Observing facet of mindfulness (FFMQ), and several self-compassion measures (total SCS, Self-Kindness, lower Self-Judgment, and Mindfulness subscale). MBP+VR was superior in the total FFMQ score, the Observing facet, and the SCS Mindfulness subscale. Participants in the "MBP+VR" group experienced significant improvements in state mindfulness (across six short sessions in mindfulness-based VR environments) and emotional states (relaxation in all VR environments, reduced sadness in VR-environment 3, increased surprise in VR-environment 5, and decreased anxiety in VR-environment 6). They reported an intermediate sense of presence in each of the VR environments. Despite these promising results, further research in this area is warranted.

**Keywords** Psychological distress · Mindfulness-based programme · Virtual reality · Non-clinical · Randomised controlled trial

✉ Yolanda López-Del-Hoyo
yolandal@unizar.es

1 Institute for Health Research Aragon (IIS Aragón), Zaragoza, Spain

2 Primary Care Prevention and Health Promotion Network (redIAPP), Zaragoza, Spain

3 Departamento de Psicología y Sociología, Faculty of Social and Labor Sciences, Universidad de Zaragoza, San Juan Bosco, 13, 50009 Zaragoza, Spain

4 Hospital Universitario Miguel Servet, Zaragoza, Spain

5 Teaching, Research and Innovation Unit, Parc Sanitari Sant Joan de Déu, Sant Boi de Llobregat, Spain

6 Department of Psychiatry, Warneford Hospital, University of Oxford, Oxford, UK

7 Consortium for Biomedical Research in Epidemiology and Public Health (CIBER Epidemiology and Public Health - CIBERESP), 28029 Madrid, Spain

Published online: 05 September 2025

## 1 Introduction

Mindfulness is defined as paying attention to the present moment (Kabat-Zinn 2003). This involves maintaining awareness of the flow of experiences in the present moment—for example, the sensation of breathing, interoceptive and proprioceptive body signals, ongoing thoughts, and affective tones—while adopting an attitude of curiosity and acceptance (Bishop et al. 2004; Shapiro et al. 2006). Mindfulness-based programmes (MBPs), such as Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT), are structured interventions that combine meditation practices, psychoeducational content and experiential inquiry. MBPs are a popular approach to improving mental health and well-being in non-clinical populations and have demonstrated their effectiveness (Enkema et al. 2020; Goldberg et al. 2021; Khoury et al. 2015). Their beneficial effects are thought to arise through several mechanisms, including attentional regulation, enhanced present-moment awareness, decentering from internal experiences, and improved emotion regulation (Hölzel et al. 2011; Gu et al. 2015). However, adherence remains a challenge: cumulative attrition averages approximately 19% in traditional MBPs and exceeds 24% in digital settings (Lam et al. 2022; Linardon et al. 2023).

There is growing interest in exploring the possibilities of virtual reality (VR) in psychology and, more particularly, mindfulness. VR is described as a collection of technologies that allow people to interact efficiently with three-dimensional (3D) computerised databases in real time by using their natural senses and skills (McCloy and Stone 2001). Virtual reality environments offer visual cues, including 3D animations that effectively illustrate skills and processes, thereby facilitating the training of users in real-world tasks and procedures. This is particularly beneficial for overcoming challenges associated with tasks that may be perceived as unengaging or lacking intuitive clarity (Xie et al. 2021).

The literature regarding the efficacy of VR-based mindfulness interventions on psychological and physiological health is in its infancy (Failla et al. 2022; Wieczorek et al. 2024; Zhang et al. 2021). Most studies have evaluated the effects of a single meditation experience using VR, finding increases in the state mindfulness of participants (Navarro-Haro et al. 2017; Seabrook et al. 2020; Yildirim and O'Grady 2020) and improvements in their emotional states (e.g. decreased anxiety, anger and depression; increased relaxation, surprise and joy) (Kaplan-Rakowski et al. 2021; Navarro-Haro et al. 2017; Seabrook et al. 2020; Tarrant et al. 2018, 2022; Waller et al. 2021). Moreover, mindfulness practitioners have shown good acceptance of VR (Flores et al. 2018; Gomez et al. 2017; Navarro-Haro et al. 2017). However, other studies have not found significant improvements in the investigated outcomes when using mindfulness interventions delivered through virtual reality compared to mindfulness interventions based on other delivery modalities, such as traditional guided meditation (Olasz et al. 2024) or computer-guided meditation (Poetar et al. 2023). The literature also encompasses studies that evaluate the efficacy of MBPs complemented with VR. In the study conducted by Navarro-Haro et al. (2019), 42 patients with Generalized Anxiety Disorder (GAD) were randomly assigned to MBP or MBP complemented with VR (MBP + VR). Results showed significant reductions in general anxiety in both groups, as well as improvements in depression, emotion regulation and several aspects of mindfulness skills and interoceptive awareness. Interestingly, patients in the MBP + VR group were significantly more adherent to treatment than those receiving standard MBP. This increased adherence was also found in the study by Modrego-Alarcón et al. (2021) comprising 280 university students, where both MBP conditions (MBP and MBP + VR) were also found to be more effective than relaxation therapy in reducing perceived stress post-intervention, with effects maintained at six-month follow-up. This supports the idea that combining VR with mindfulness training may be more appealing and generate a synergistic effect that produces better outcomes (Zhang et al. 2021).

Despite growing interest in this field of study, the current evidence base shows serious limitations: (i) only a small number of RCTs have been completed; (ii) most studies use single-session or short-duration protocols; and (iii) multi-session, group-delivered, non-HMD formats are scarce (Arpaia et al. 2022; Wieczorek et al. 2024). The present study addresses these gaps by testing a multi-session MBP delivered in a shared, projection-based immersive environment (MK360) with a non-clinical sample. Specifically, the objectives of this study were a) to ascertain the acceptability of an MBP complemented by six VR sessions, b) to assess its effectiveness in enhancing the mental health of non-clinical adults, and c) to evaluate its impacts on mindfulness, emotional states and the level of immersion within the VR environments.

## 2 Materials and methods

### 2.1 Design

A 6-week parallel randomised controlled trial (RCT) was conducted involving three arms: Mindfulness-Based Program (MBP) alone, MBP combined with Virtual Reality (MBP + VR) and a Relaxation group. The MBP and MBP + VR groups served as the experimental interventions, while the Relaxation group functioned as the control condition. Assessments were carried out at pre-treatment and post-treatment. Additionally, participants in the MBP+VR condition completed questionnaires immediately before and immediately after each short VR session. A total of six short sessions in mindfulness-based VR environments were evaluated. The Consolidated Standards of Reporting Trials (CONSORT) guidelines were followed (Schulz et al. 2010).

## 2.2 Participants

Fifty-one participants were recruited. The inclusion criteria were (1) aged 18–65 years, (2) informed written consent, and (3) perfect understanding of spoken and written Spanish. The exclusion criteria were as (1) taking drugs that affect the central nervous system, (2) having practised mindfulness in the previous 6 months, and (3) having physical or psychological disorders that prevented participation in the intervention. Table 1 provides a detailed description of socio-demographic information by group.

This study was conceived as a pilot randomized controlled trial, with the primary aim of assessing the feasibility, acceptability, and preliminary effects of the intervention, rather than testing specific hypotheses with adequate statistical power. Accordingly, no formal power analysis was performed, in line with recommendations for pilot studies (Julious 2005; Leon et al. 2011; Billingham et al. 2013). The total sample size (N = 51) was determined based on practical considerations, including recruitment capacity and resource availability—particularly regarding the limited access to immersive VR equipment—while also aligning with

**Table 1** Baseline characteristics of participants by group

| | MBP (n = 15) | MBP + VR (n = 20) | Relaxation (n = 16) | *p* |
|---|---|---|---|---|
| *Socio-demographic characteristics* | | | | |
| Age, M (SD) | 49.27 (12.81) | 46.75 (10.08) | 51.31 (8.24) | 0.430 |
| Sex, females, n (%) | 13 (86.7%) | 15 (78.9%) | 12 (75%) | 0.712 |
| Civil status, married, n (%) | 12 (80%) | 17 (85%) | 10 (62.5%) | 0.266 |
| Level of studies, university, n (%) | 12 (80%) | 11 (55%) | 11 (68.8%) | 0.431 |
| Job status, employed, n (%) | 11 (73.3%) | 15 (75%) | 11 (68.8%) | 0.914 |
| *Previous experience* | | | | |
| Relaxation training, yes, n (%) | 5 (33.3%) | 12 (60%) | 6 (37.5%) | 0.223 |
| Mindfulness training, yes, n (%) | 2 (13.3%) | 4 (20%) | 3 (18.8%) | 0.869 |
| Virtual reality training, yes, n (%) | 0 (0%) | 2 (10%) | 0 (0%) | 0.199 |
| Experience with computers, M (SD) [0–3] | 1.53 (0.74) | 1.75 (0.72) | 1.56 (0.73) | 0.626 |
| Knowledge on 3D images, M (SD) [0–3] | 0.20 (0.41) | 0.60 (0.82) | 0.47 (0.64) | 0.222 |
| Frequency of videogaming, M (SD) [0–3] | 0.53 (0.92) | 0.79 (0.98) | 0.33 (0.62) | 0.312 |
| Knowledge on VR, M (SD) [0–3] | 0.27 (0.46) | 0.85 (0.88) | 0.63 (0.62) | 0.058 |
| *Clinical/psychological characteristics* | | | | |
| GHQ12, M (SD) | 14.07 (5.65) | 17.05 (5.56) | 14.31 (7.39) | 0.284 |
| SF12 Physical, M (SD) | 42.08 (8.04) | 44.08 (7.91) | 40.16 (6.82) | 0.317 |
| SF12 Mental, M (SD) | 38.10 (7.76) | 34.74 (6.23) | 39.68 (7.78) | 0.119 |
| DASS-21 Total, M (SD) | 23.80 (14.50) | 23.53 (9.56) | 21.94 (13.64) | 0.905 |
| DASS-21 Depression, M (SD) | 7.00 (5.66) | 6.68 (3.33) | 7.06 (5.93) | 0.971 |
| DASS-21 Anxiety, M (SD) | 6.40 (5.37) | 6.16 (4.56) | 5.50 (4.23) | 0.858 |
| DASS-21 Stress, M (SD) | 10.40 (4.41) | 10.21 (3.38) | 9.38 (5.02) | 0.771 |
| PANAS Positive, M (SD) | 29.60 (7.84) | 30.79 (6.29) | 30.19 (8.64) | 0.901 |
| PANAS Negative, M (SD) | 24.60 (6.85) | 29.85 (6.98) | 25.31 (9.21) | 0.095 |
| FFMQ Total, M (SD) | 114.20 (18.30) | 112.44 (28.22) | 119.13 (22.47) | 0.703 |
| FFMQ Observing, M (SD) | 22.60 (7.07) | 24.05 (6.56) | 23.69 (5.68) | 0.799 |
| FFMQ Describing, M (SD) | 25.93 (5.27) | 27.25 (9.21) | 27.06 (7.44) | 0.870 |
| FFMQ Awareness, M (SD) | 24.07 (6.66) | 21.39 (5.30) | 24.88 (8.13) | 0.295 |
| FFMQ Nonjudging, M (SD) | 22.20 (6.35) | 22.65 (8.56) | 24.44 (8.77) | 0.710 |
| FFMQ Nonreacting, M (SD) | 19.40 (4.53) | 17.90 (5.12) | 19.06 (5.01) | 0.634 |
| SCS Total, M (SD) | 72.15 (19.51) | 73.74 (20.05) | 77.27 (17.69) | 0.766 |
| SCS Self-kindness, M (SD) | 28.07 (7.56) | 28.26 (8.51) | 29.47 (8.17) | 0.875 |
| SCS Self-judgement, M (SD) | 12.87 (4.17) | 13.75 (4.69) | 14.20 (5.13) | 0.730 |
| SCS Common humanity, M (SD) | 23.79 (6.68) | 23.15 (5.12) | 23.63 (4.30) | 0.936 |
| SCS Isolation, M (SD) | 11.14 (3.82) | 11.80 (3.24) | 12.06 (4.31) | 0.792 |
| SCS Mindfulness, M (SD) | 12.20 (3.51) | 12.30 (3.56) | 13.31 (3.16) | 0.594 |
| SCS Overidentification, M (SD) | 10.07 (3.34) | 9.95 (3.73) | 10.31 (4.11) | 0.959 |

n, frequencies; %, percentages; p, *p value*; M, mean; SD, standard deviation; MBP, Mindfulness-based programme; MBP + VR, Mindfulness-based programme + immersive virtual environments; GHQ12, General Health Questionnaire; SF12, SF-12 Health Survey; DASS-21 = Depression Anxiety and Stress Scales; PANAS, The Positive and Negative Affect: Schedule; FFMQ, Five Facet Mindfulness Questionnaire; SCS, Self-Compassion Scale established guidelines for pilot trials suggesting 12–30 participants per arm (Julious 2005; Teare et al. 2014). Insights from this pilot will guide the design and power calculations of a subsequent fully powered trial.

Figure 1 shows the flow of participants in the study. The total sampling universe consisted of 60 participants. Of these, 9 were excluded and 51 were eligible to participate. They were randomly assigned to the MBP group (n = 15), the MBP + VR group (n = 20), or the Relaxation group (n = 16). Participants were middle-aged, and most were women (see Table 1 for more details).

### 2.3 Procedure

Access to potential participants was established via two methods: advertisements placed in the media and social media platforms such as Facebook and X. Individuals who made email contact received information at a meeting held by a research team member, during which the study was explained and an information sheet containing an informed consent document was provided. During the initial meeting, the study was explained to participants, and an information sheet along with the informed consent document was provided. Pre-intervention assessments were conducted one week before the intervention. Subsequently, subjects were randomly assigned into one of three groups – MBP, MBP + VR or Relaxation – by an independent researcher using a computer-generated random sequence. Each group then engaged in its respective six-week intervention programme. Post-intervention assessments were conducted one week after the completion of the intervention. Due to the nature of the intervention, neither participants nor those delivering the intervention were blinded to group allocation. However, outcome assessments — including pre- and post-intervention— were conducted by a member of the research team who was blinded to group assignments, in order to minimize detection bias. Additionally, throughout the course of the intervention, participants in the MBP + VR

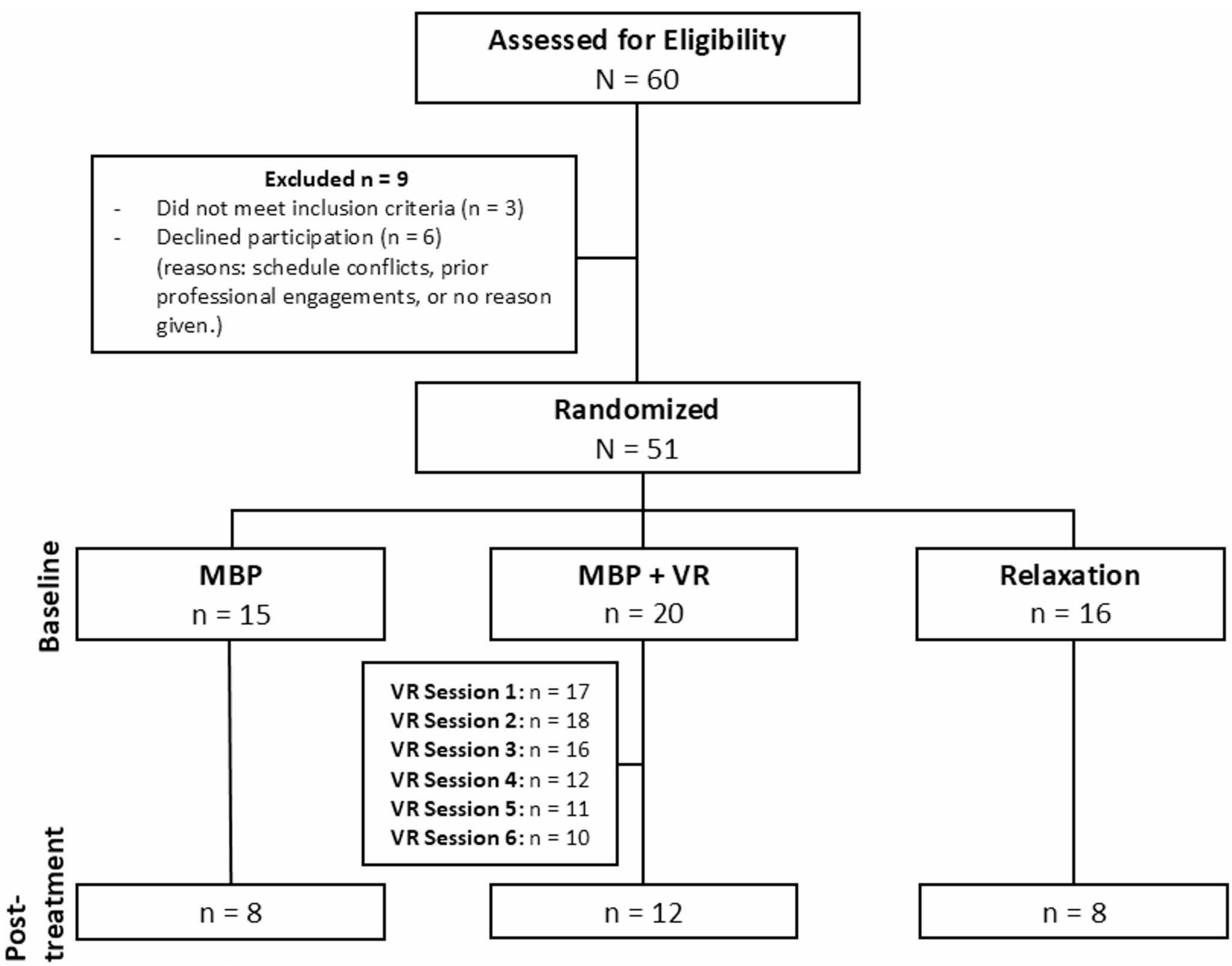


**Fig. 1** Flow chart of participants in the randomized controlled trial

group were also evaluated immediately before and after each short VR session by a different member of the research team. Given the visible use of VR equipment during these specific assessments, full blinding could not be maintained. Prior to the use of VR, the clinical psychologist responsible for delivering the virtual environments conducted a health screening of the participants. Immersive virtual reality is generally contraindicated for pregnant women; individuals with hypertension, ear infections, epilepsy, or vertigo; patients who have recently undergone surgery; and those with cardiovascular disease, psychosis, or severe mental illness. Accordingly, the psychologist ensured that none of the participants presented any of these conditions before proceeding with the intervention. All the group sessions were held in a classroom in the Faculty of Social and Occupational Sciences at the University of Zaragoza. No incentives were provided to the participants in compensation for their participation in the study.

This study was approved by the Ethics Committee of the corresponding regional authority (CEICA Aragón, PI21/429). Written informed consent was obtained from all participants.

#### 2.3.1 Mindfulness-based programme (MBP)

Participants in MBP completed the mindfulness programme developed by Garcia-Campayo and Demarzo (2015), which was adapted to contain six group sessions. Each session had a theoretical-practical duration of 90 min and was held once a week over 6 weeks. The contents and timeline of this programme are detailed in Supplement 1. MBP was led by a clinical psychologist specifically trained in the application of the mindfulness programme.

#### 2.3.2 Mindfulness-based programme + immersive virtual environments (MBP + VR)

This condition was equivalent to MBP except for the shorter session duration (reduced from 90 to 80 min), meaning that its content was also slightly shortened. The 10-min difference was devoted to a VR session either before or after the mindfulness session.

The VR sessions comprised mindfulness and self-compassion exercises derived from the core practices of the MBP group (mindfulness-based programme developed by Garcia-Campayo and Demarzo, 2015), which were carefully adapted to the virtual reality format. The structure of the programme followed a progressive sequence: the first session focused on breathing practice; the second on the metaphor of the mind; the third introduced the body scan; the fourth incorporated mindful movements; the fifth explored walking meditation; and the sixth and final session concluded with the Metta (loving-kindness) practice. A detailed description of each practice is provided in Table 2, while Fig. 2 visually presents the corresponding virtual environments.

The content of these brief VR sessions was conceptualized and scripted by three of the manuscript's authors, each of whom has between 10 and 30 years of meditation experience. They collaborated closely with the technical team at Broomx, who were responsible for all technical components—including programming, graphic design, sound design, and user experience—necessary to bring the VR environments to life.

From a technical standpoint, the sessions were delivered using the Broomx MK360 immersive projection system (https://broomx.com/), a device designed to create 3D, m ultisensory, and interactive experiences that can be shared by multiple users simultaneously without the need for head-mounted displays. Its advanced optical system projects images across three walls and the ceiling, adapting to a wide range of indoor environments. The unit integrates a projection module, CPU, GPU, built-in speaker, WiFi hotspot, and multiple connectivity options. It is operated via a dedicated smartphone application developed by Broomx, which allows for seamless control and navigation. This technology has been previously used in various research settings (Cano et al. 2024; Sultana et al. 2021). For further details and example content, see: https://broomx.com/content/collections/health-care. The VR sessions were administered by a clinical psychologist who underwent brief training provided by Broomx, the supplier of the VR system. This psychologist was responsible for initiating the virtual environments and remained present throughout the session to ensure its proper development and to attend to any technical issues, participants' needs, or potential adverse effects that might arise during the experience.

The VR sessions were delivered in a room adjacent to the one that was used for the MBP session and adequately equipped for the correct visualization of the different VR environments.

#### 2.3.3 Relaxation therapy (relaxation)

This condition also consisted of 90-min group sessions held once a week over 6 weeks. This programme was an adapted version of progressive muscle relaxation therapy (Bernstein and Borkovec 1973) and involved the training of 16 muscle groups during the initial sessions, 7 muscle groups during the intermediate sessions, 4 muscle groups in the later stage, and only relaxation through recall in the final session. The programme was complemented with visualizations, as originally proposed by Jacobson (Jacobson 1938). This same adapted version was employed by Modrego-Alarcón

**Table 2** Brief mindfulness-based VR environments

| Practices | VR environment | Duration |
|---|---|---|
| 1. Breathing practice | Participants are asked to focus attention on the breath. The scenario is set in a dark maritime scenery, with a full moon, where the waves move simulating the rhythm of breathing. The auditory stimuli consist of the gentle sound of waves and calming music, accompanied by instructions delivered in a male voice to redirect attention to the breath, guiding each inhalation and exhalation like waves coming and going | 10′25″ |
| 2. Practice of the metaphor of the mind | This practice presents the concept of distancing oneself from thoughts. The visualization features a three-dimensional room filled with inflated balloons, symbolizing how the mind becomes cluttered with thoughts to which we cling. A male voice, accompanied by very calming music, explains that by training our attention, we can gradually clear the mind of these balloons. From time to time, balloons (thoughts) will appear; we observe them mindfully and let them pass without attachment | 10′05″ |
| 3. Body scan practice | This exercise consists of a guided body scan with visual support. A female voice, accompanied by calming music, guides participants to become aware of each area of the body, while the corresponding regions are simultaneously highlighted on the body silhouette | 10′16″ |
| 4. Mindful movements practice | Participants are instructed, through a female voice accompanied by gentle music, to focus attention on the body movements with the support of a virtual human figure performing a series of five conscious movements to be repeated by the participants | 9′19″ |
| 5. Walking meditation practice | This exercise consists of a guided mindful walking led by a gentle female voice, accompanied by soothing, tranquil music. The scenario is set in a sandy desert where participants have the sensation of walking slowly and consciously, fully present with each step | 10′01″ |
| 6. Metta practice | This exercise consists of a practice of sending good wishes to others and to oneself, led by a gentle female voice with peaceful, soothing music playing softly in the background. The setting is set in a spring landscape that contains a tree that grows as good wishes are sent | 9′57″ |

Top row (from left to right): VR-environment 1 (breathing practice); VR-environment 2 (Metaphor of the mind practice); VR-environment 3 (body scan practice). Bottom row (from left to right): VR-environment 4 (mindful movements practice); VR-environment 5: (walking meditation practice); VR-environment 6 (metta practice)

et al. (2021) as an active control condition in comparison to MBPs, which comprised the experimental groups. Similar adaptations of progressive muscle relaxation have also been utilized in previous studies (Kyrios et al. 2018; Schröder et al. 2013). This group was led by a clinical psychologist specially trained in the application of relaxation therapy, who was different from the clinical psychologist leading the MBPs.

## 2.4 Measures

Figure 3 contains the assessment timeline.

### 2.4.1 Socio-demographics and previous experience

This information was collected at pre-intervention through a bespoke questionnaire and consisted of age, sex, nationality, relationship status, studies, employment and previous experience with relaxation, mindfulness/compassion and immersive VR environments. Experience with the use of technologies was measured by four items of a brief version of the Independent Television Company Sense of Presence Inventory (ITC-SOPI; (Lessiter et al. 2001; Baños et al. 2004). This scale has demonstrated adequate psychometrics properties (Baños et al. 2004).

### 2.4.2 Acceptability

Participant expectations and satisfaction with the intervention were evaluated through a revised Credibility/Expectancy Scale (Borkovec and Nau 1972). Items assessed the logic, satisfaction, recommendability, usefulness and aversiveness of the intervention. This adaptation has been used in previous studies, with good psychometric properties (Modrego-Alarcón et al. 2025; Navarro-Haro et al. 2019).

### 2.4.3 Primary outcome measure

The primary outcome was psychological distress at post-treatment as measured by the General Health Questionnaire (GHQ-12). The GHQ-12 is a 12-ítem self-report instrument of psychological distress. Each item is scored using a Likert-type 4-point response scale (corresponding to symptoms present, from ‘not at all’ = 0 to ‘much more than usual’ = 3. Higher scores represent higher levels of distress. The GHQ-12 displays adequate reliability and validity for use in the Spanish population (Sánchez-López and Dresch 2008).

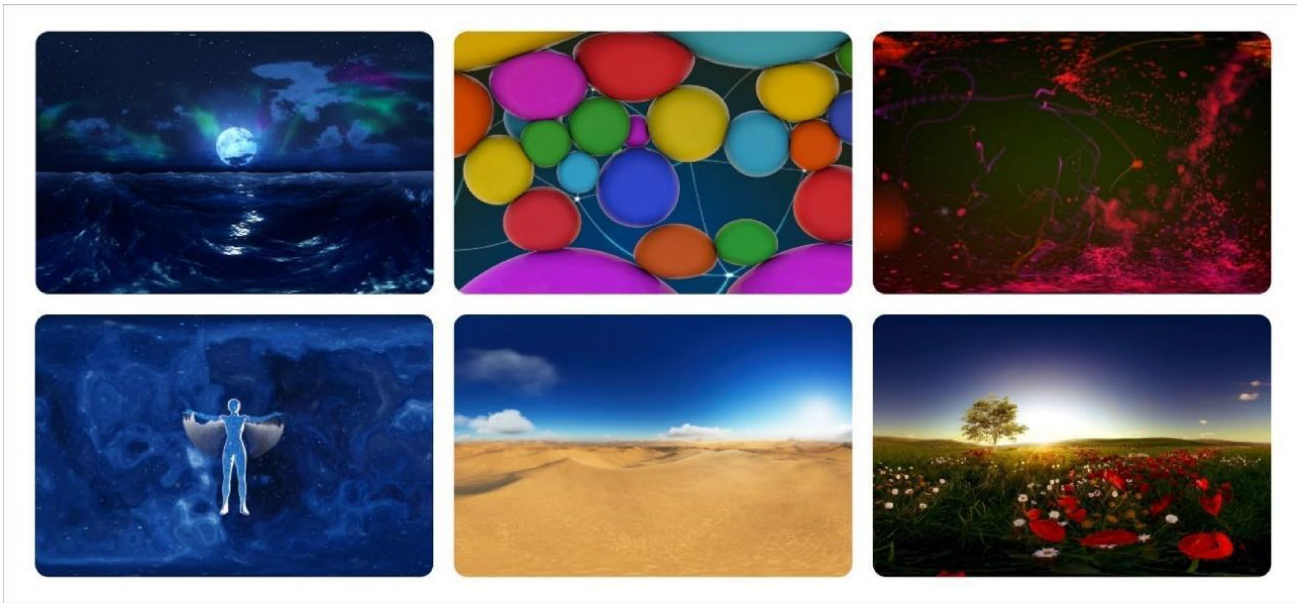

**Fig. 2** Screenshot from the six virtual reality environments

#### 2.4.4 Secondary outcomes measures

- The SF-12 Health Survey (Ware et al. 1996) assesses how health affects an individual's daily life. It measures both physical and mental aspects, ranging from 0 (worst possible health) to 100 (best possible health). The SF-12 has been validated in Spain, yielding robust psychometric results (Gandek et al. 1998).
- The Depression Anxiety and Stress Scales (DASS-21) (Lovibond and Lovibond 1995) is a self-report measure in which participants rate the frequency and severity of their negative emotional states of depression, anxiety and stress over the previous week. Each subscale has seven items, ranging from 0 to 21 points (a total score is also calculated). Psychometric indices of the Spanish version of DASS-21 are good (Daza et al. 2002).
- The Positive and Negative Affect: Schedule (PANAS) (Watson et al. 1988) measures both positive and negative affectivity. The psychometric characteristics of the Spanish PANAS are appropriate (Sandín et al. 1999).

#### 2.4.5 Process measures

- The Five Facet Mindfulness Questionnaire (FFMQ) (Baer et al. 2006) is a measure of mindfulness consisting of 39 items grouped into five subscales: observing, describing, acting with awareness, non-judging of and non-reactivity to inner experience. The subscales can be combined to generate a total score. The Spanish version shows good psychometric properties (Soler et al. 2012).
- The Self-Compassion Scale (SCS) (Neff 2003) evaluates self-compassion through the components of self-kindness, common humanity and mindfulness. It also provides a total score. The Spanish version of the SCS is a valid and reliable instrument (Garcia-Campayo et al. 2014).

#### 2.4.6 Virtual reality assessments

- An adaptation of the Mindful Attention Awareness Scale (MAAS) (Brown and Ryan 2003) was used to measure state mindfulness. Higher scores reflect lower levels of state mindfulness. This shorter scale has been used in previous studies with Spanish samples with good internal consistency (Navarro-Haro et al. 2017, 2019)
- A brief version of the visual analogue scale (VAS) (Gross and Levenson, 1995) was used to assess the participants' emotional state. This scale comprises seven items (happiness, sadness, anger, surprise, anxiety, relaxation/calm, vigour/energy). This shorter scale has been used in previous studies with Spanish samples with good internal consistency (Navarro-Haro et al. 2017, 2019).
- Three items from the Slater-Usoh-Steed Questionnaire (SUS) (Slater et al. 1994) were used to assess the sense of presence immediately after each VR session: 1) Rate your sense of being in the virtual reality environment; 2) To what extent were there times during the experience when the computer-generated world became the 'reality' for you, and you almost forgot about the 'real world'

| | | PRE | INTERVENTION | | | | | | | | | | | | POST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outcome variables | **Measures** | | **Sessions VR** | | | | | | | | | | | | |
| | | | **S1** | | **S2** | | **S3** | | **S4** | | **S5** | | **S6** | | |
| | | | Pre | Post | Pre | Post | Pre | Post | Pre | Post | Pre | Post | Pre | Post | |
| **Demographic information** | Custom demographic questionnaire | X | | | | | | | | | | | | | |
| **Technology experience** | ITC-SOPI | X | | | | | | | | | | | | | |
| **Intervention expectations and satisfaction** | Credibility/ Expectancy Scale | X | | | | | | | | | | | | | X |
| **Psychological distress** | General Health Questionnaire (GHQ) | X | | | | | | | | | | | | | X |
| **Health-related quality of life** | SF-12 Health Survey (SF-12) | X | | | | | | | | | | | | | X |
| **Depression, anxiety, and stress levels** | Abbreviated version of the Depression Anxiety and Stress Scales (DASS-21) | X | | | | | | | | | | | | | X |
| **Affectivity** | Positive and Negative Affect Schedule (PANAS) | X | | | | | | | | | | | | | X |
| **Mindfulness** | The Five Facet Mindfulness Questionnaire (FFMQ) | X | | | | | | | | | | | | | X |
| **Compassion** | Self-Compassion Scale (SCS) | X | | | | | | | | | | | | | X |
| **State mindfulness** | MAAS-State | | X | X | X | X | X | X | X | X | X | X | X | X | |
| **Emotional states** | VAS | | X | X | X | X | X | X | X | X | X | X | X | X | |
| **Sense of presence** | Slater-Usoh-Steed Questionnaire (SUS) | | | X | | X | | X | | X | | X | | X | |

**Fig. 3** Timeline of assessments

outside?; 3) When you think back to the experience, do you think of the virtual reality environment more as images that you saw or more as somewhere you visited? The Spanish version has been used with adequate psychometrics (Navarro-Haro et al. 2017, 2019).

### 2.5 Statistical analyses

The socio-demographic and clinical characteristics were described using means (SDs), and frequencies (percentages), according to their distribution. Comparisons were conducted using t and $\chi^2$ tests to ensure there were no baseline differences. Analysis of covariance (ANCOVA) was performed following the intention-to-treat (ITT) principle. ANCOVA was applied to post-intervention scores, with baseline values included as covariates to examine potential differences within and between groups after the intervention. Effect sizes were interpreted according to the following conventional thresholds for partial eta-squared ($\eta^2$): small ($0.01 \leq \eta^2 < 0.06$), medium ($0.06 \leq \eta^2 < 0.14$), and large ($\eta^2 \geq 0.14$), following Cohen's guidelines (Cohen 1988). Contrasts between pre and post VR sessions were conducted using the corresponding t test. The significance level was $\alpha < 0.05$. The SPSS-29 package was used for the analyses.

## 3 Results

Table 1 shows the participants' baseline characteristics by group. There were no significant between-group differences for any of the socio-demographic or psychological outcomes.

Attendance was higher in MBP (M = 5.58; SD = 0.79) and MBP + VR (M = 5.71; SD = 0.49), compared to the control condition (M = 4.78; SD = 1.09), with no significant differences between the two mindfulness groups (Table 3).

There were no significant between-group differences in terms of expectations, with intermediate-to-high scores in all but the aversive item, which showed low values (Table 3). After the intervention, significantly higher satisfaction scores were obtained in both MBP conditions compared to Relaxation, which showed intermediate-to-high values (Table 3). Low scores for the aversive item were obtained in all the groups, with no significant differences. Participants in MBP + VR reported moderately high perceived usefulness of VR for practising mindfulness (M = 7.25; SD = 2.90).

As shown in Table 4, we identified several significant between-group differences. First, there were significant reductions in psychological distress (primary outcome) in all the study conditions. However, there were only significant between-group differences when comparing the

**Table 3** Session attendance, treatment expectancies, and credibility

| | Mindfulness | Mindfulness + VR | Control | F(df) | *p* | $\eta^2$ | Comp (p) |
|---|---|---|---|---|---|---|---|
| Attendance, M (SD) [0–6] | 5.71 (0.49) | 5.58 (0.79) | 4.78 (1.09) | 3.16(2) | 0.060 | 0.20 | M vs C (.038); M + VR vs C (.041); M + VR vs M (.748) |
| *Expectancies (pre-), M (SD) [0–10]* | | | | | | | |
| This intervention seems logical | 7.93 (1.44) | 8.45 (1.47) | 7.69 (1.70) | 1.17(2) | 0.320 | 0.05 | M vs C (.525); M + VR vs C (.146); M + VR vs M (.748) |
| I feel satisfied about this intervention | 8.20 (1.32) | 8.00 (1.49) | 7.63 (1.63) | 0.60(2) | 0.550 | 0.03 | M vs C (.287); M + VR vs C (.456); M + VR vs M (.696) |
| I would recommend this to a friend | 8.60 (1.45) | 8.35 (1.60) | 7.88 (1.82) | 0.80(2) | 0.456 | 0.03 | M vs C (.223); M + VR vs C (.390); M + VR vs M (.656) |
| It could be useful for other problems | 8.73 (1.49) | 8.05 (1.61) | 8.06 (1.88) | 0.88(2) | 0.422 | 0.04 | M vs C (.267); M + VR vs C (.982); M + VR vs M (.235) |
| I think it will be helpful for me | 7.93 (1.39) | 8.00 (1.62) | 7.25 (1.92) | 1.04(2) | 0.359 | 0.04 | M vs C (.257); M + VR vs C (.184); M + VR vs M (.907) |
| This intervention could be aversive | 1.80 (2.31) | 1.75 (2.36) | 0.81 (1.22) | 1.20(2) | 0.310 | 0.05 | M vs C (.187); M + VR vs C (.180); M + VR vs M (.943) |
| *Credibility (post-), M (SD) [0–10]* | | | | | | | |
| This intervention was logical | 9.50 (0.55) | 9.25 (1.07) | 7.78 (1.09) | 7.60(2) | 0.003 | 0.39 | M vs C (.003); M + VR vs C (.002); M + VR vs M (.617) |
| I feel satisfied about this intervention | 9.83 (0.41) | 8.83 (1.75) | 7.78 (1.20) | 4.06(2) | 0.030 | 0.25 | M vs C (.010); M + VR vs C (.097); M + VR vs M (.162) |
| I would recommend this to a friend | 9.83 (0.41) | 9.58 (0.79) | 7.67 (1.87) | 8.14(2) | 0.002 | 0.40 | M vs C (.003); M + VR vs C (.002); M + VR vs M (.686) |
| VR could be useful for mindfulness | – | 7.25 (2.90) | – | – | – | – | - |
| I think it was helpful for me | 9.33 (1.21) | 8.58 (2.28 | 6.33 (3.08) | 3.40(2) | 0.050 | 0.22 | M vs C (.027); M + VR vs C (.045); M + VR vs M (.541) |
| This intervention was aversive | 0.00 (0.00) | 0.92 (2.31) | 0.67 (1.00) | 0.61(2) | 0.554 | 0.05 | M vs C (.456); M + VR vs C (.737); M + VR vs M (.283) |

M, mean; SD, standard deviation; *p*, *p value*; mindfulness, mindfulness-based programme; mindfulness + VR, mindfulness-based programme + immersive virtual environments; C, control, control group

**Table 4** Within- and between-group analyses of primary and secondary mental health and process outcomes

| | Mindfulness (n = 7) | | | Mindfulness + VR (n = 12) | | | Control (n = 9) | | | ANCOVA | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre- | Post- | *p* | Pre- | Post- | *p* | Pre- | Post- | *p* | F(df) | *p* | $\eta^2$ | Comp (p) |
| GHQ12 | 13.71 (4.65) | 7.14 (2.73) | **0.028** | 16.09 (5.39) | 6.55 (2.38) | **< 0.001** | 12.89 (6.07) | 9.33 (3.16) | **.034** | 3.55(2) | **0.045** | 0.24 | M vs C (.101); **M + VR vs C (.015)**; M + VR vs M (.477) |
| SF12 physical | 46.76 (8.30) | 37.22 (6.96) | 0.345 | 42.48 (9.35) | 40.22 (6.71) | 0.260 | 41.73 (6.08) | 44.02 (7.34) | .508 | 3.15(2) | 0.062 | 0.22 | **M vs C (.020)**; M + VR vs C (.163); M + VR vs M (.175) |
| SF12 mental | 38.69 (3.79) | 43.61 (4.41) | 0.170 | 35.28 (6.99) | 38.60 (5.22) | 0.087 | 41.08 (7.63) | 38.52 (9.08) | .438 | 1.73(2) | 0.200 | 0.13 | M vs C (.076); M + VR vs C (.431); M + VR vs M (.241) |
| DASS-21 total | 24.29 (15.53) | 11.29 (6.92) | **0.049** | 25.50 (9.87) | 17.30 (9.09) | **0.014** | 21.22 (13.89) | 14.89 (7.99) | .162 | 1.30(2) | 0.292 | 0.11 | M vs C (.234); M + VR vs C (.749); M + VR vs M (.133) |
| DASS-21 depression | 6.43 (5.91) | 1.43 (1.81) | 0.064 | 7.73 (3.29) | 4.36 (3.11) | **< 0.001** | 7.11 (5.42) | 5.11 (4.62) | .192 | 2.75(2) | 0.085 | 0.19 | **M vs C (.030)**; M + VR vs C (.457); M + VR vs M (.104) |
| DASS-21 anxiety | 6.71 (6.60) | 3.71 (3.77) | 0.124 | 6.36 (4.93) | 4.27 (4.29) | 0.151 | 4.67 (4.27) | 3.33 (1.80) | .377 | 0.11(2) | 0.893 | 0.01 | M vs C (.806); M + VR vs C (.822); M + VR vs M (.639) |
| DASS-21 stress | 11.14 (4.18) | 6.14 (2.48) | **0.034** | 10.42 (3.87) | 7.67 (3.11) | 0.007 | 9.44 (5.53) | 6.44 (3.21) | .110 | 0.93(2) | 0.408 | 0.07 | M vs C (.565); M + VR vs C (.450); M + VR vs M (.193) |
| PANAS positive | 30.14 (10.14) | 38.71 (6.60) | **0.013** | 29.36 (5.73) | 32.45 (6.98) | 0.071 | 33.56 (8.59) | 31.33 (6.56) | .468 | 5.08(2) | **0.015** | 0.31 | **M vs C (.004)**; M + VR vs C (.233); **M + VR vs M (.041)** |
| PANAS negative | 26.43 (6.53) | 21.14 (3.13) | 0.060 | 30.33 (7.75) | 24.75 (6.89) | **0.013** | 25.78 (10.06) | 24.44 (9.02) | .582 | 0.91(2) | 0.415 | 0.07 | M vs C (.197); M + VR vs C (.389); M + VR vs M (.583) |
| FFMQ total | 114.29 (18.80) | 124.14 (22.69) | 0.086 | 105.70 (35.76) | 125.50 (28.88) | **0.002** | 122.44 (23.06) | 123.11 (24.15) | .798 | 4.65(2) | **0.021** | 0.30 | M vs C (.185); **M + VR vs C (.006)**; M + VR vs M (.143) |
| FFMQ observing | 25.43 (8.46) | 29.00 (6.00) | 0.128 | 23.00 (7.34) | 28.33 (5.91) | **<0.001** | 24.33 (4.95) | 23.67 (5.66) | .622 | 6.03(2) | **0.008** | 0.34 | **M vs C (.022)**; **M + VR vs C (.003)**; M + VR vs M (.612) |
| FFMQ describing | 27.00 (6.33) | 28.00 (9.22) | 0.711 | 25.92 (10.88) | 28.92 (8.89) | 0.098 | 27.22 (8.77) | 28.33 (7.47) | .308 | 0.38(2) | 0.689 | 0.03 | M vs C (.948); M + VR vs C (.480); M + VR vs M (.469) |
| FFMQ awareness | 23.86 (6.84) | 23.71 (4.39) | 0.927 | 20.90 (6.05) | 24.10 (4.46) | 0.076 | 26.78 (8.14) | 25.11 (7.49) | .139 | 1.59(2) | 0.226 | 0.13 | M vs C (.776); M + VR vs C (.109); M + VR vs M (.193) |
| FFMQ nonjudging | 19.14 (5.76) | 22.43 (6.16) | 0.083 | 21.75 (10.66) | 25.33 (9.41) | 0.093 | 23.78 (9.55) | 25.22 (8.72) | .472 | 0.23(2) | 0.797 | 0.02 | M vs C (.851); M + VR vs C (.518); M + VR vs M (.193) |
| FFFMQ nonreacting | 18.86 (5.27) | 21.00 (4.83) | 0.057 | 16.50 (6.01) | 19.67 (5.42) | **0.003** | 20.33 (4.58) | 20.78 (5.59) | .578 | 1.83(2) | 0.182 | 0.13 | M vs C (.561); M + VR vs C (.070); M + VR vs M (.252) |
| SCS Total | 71.43 (16.98) | 83.29 (18.69) | 0.028 | 70.91 (23.59) | 77.36 (20.95) | **0.042** | 76.67 (20.11) | 76.89 (23.05) | .942 | 2.68(2) | 0.090 | 0.19 | **M vs C (.031)**; M + VR vs C (.201); M + VR vs M (.249) |
| SCS self-kindness | 25.71 (5.88) | 30.86 (5.15) | **.017** | 28.00 (10.02) | 29.00 (9.87) | 0.337 | 29.00 (9.58) | 29.67 (9.98) | .659 | 2.74(2) | 0.085 | 0.19 | **M vs C (.047)**; M + VR vs C (.894); M + VR vs M (.894) |
| SCS self-judgement (lack of) | 10.71 (2.93) | 14.43 (2.57) | **0.010** | 13.92 (5.27) | 13.42 (4.93) | 0.455 | 13.78 (5.83) | 14.44 (5.22) | .397 | 5.66(2) | **0.010** | 0.32 | **M vs C (.039)**; M + VR vs C (.246); **M + VR vs M (.003)** |
| SCS common humanity | 24.29 (7.04) | 27.14 (7.73) | 0.172 | 22.25 (5.64) | 24.25 (5.97) | 0.086 | 23.33 (4.12) | 23.89 (6.15) | .657 | 0.48(2) | 0.627 | 0.04 | M vs C (.348); M + VR vs C (.545); M + VR vs M (.662) |
| SCS isolation (lack of) | 11.50 (3.56) | 12.00 (3.89) | 0.606 | 11.50 (3.56) | 12.00 (3.89) | **0.032** | 11.89 (4.51) | 4.74 (1.58) | .884 | 0.51(2) | 0.604 | 0.04 | M vs C (.321); M + VR vs C (.628); M + VR vs M (.541) |

**Table 4** (continued)

| | Mindfulness (n = 7) | | | Mindfulness + VR (n = 12) | | | Control (n = 9) | | | ANCOVA | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre- | Post- | *p* | Pre- | Post- | *p* | Pre- | Post- | *p* | F(df) | *p* | $\eta^2$ | Comp (p) |
| SCS mindfulness | 21.43 (4.86) | 25.29 (6.37) | **0.011** | 20.75 (7.93) | 23.17 (1.88) | 0.086 | 24.33 (8.23) | 23.33 (8.65) | .371 | 5.58(2) | **0.010** | 0.32 | **M vs C (.005); M + VR vs C (.013)**; M + VR vs M (.448) |
| SCS overidentification (lack of) | 8.43 (3.55) | 11.29 (3.45) | **0.026** | 9.25 (4.33) | 10.25 (3.39) | 0.305 | 10.33 (5.05) | 10.56 (5.50) | .738 | 0.71(2) | 0.502 | 0.06 | M vs C (.247); M + VR vs C (.612); M + VR vs M (.441) |

n, frequencies; p, *p value*; M, mean; mindfulness, mindfulness-based programme; mindfulness + VR, mindfulness-based programme + immersive virtual environments; GHQ12, general health questionnaire; SF12, SF-12 Health Survey; DASS-21, depression anxiety and stress scales; PANAS, the positive and negative affect: schedule; FFMQ, five facet mindfulness questionnaire; SCS, self-compassion scale; Bold indicates statistically significant values ($\alpha$<0.05)

MBP+VR to controls, favouring MBP+VR ($p$=0.015). Furthermore, MBP showed better results in positive affect compared to both Relaxation ($p$=0.004) and MBP+VR ($p$=0.004). Additionally, the MBP+VR group showed a significant improvement in overall mindfulness, as reflected by the total FFMQ score, compared to the Relaxation group ($p$=0.006). Significant differences were also observed in the observing mindfulness facet when comparing MBP to the Relaxation group ($p$=0.022) and MBP+VR to the Relaxation group ($p$=0.003), both favouring the mindfulness groups. Similarly, both MBP and MBP+VR displayed significant differences in the mindfulness self-compassion facet compared to Relaxation ($p$=0.005 and $p$=0.013, respectively), again in favour of the mindfulness groups. Lastly, significant between-group differences were found in the self-compassion facet of (lack of) self-judgement when comparing MBP to Relaxation ($p$=0.039) and MBP to MBP+VR ($p$=0.003), favouring MBP. Between-group, non-significant effects were also observed in physical and mental quality of life (SF-12), negative emotional states and depression (DASS21-total and DASS21-depression), and the mindfulness facets of awareness and non-reacting (see Table 4 for more details).

Of the 20 participants allocated to the MBP+VR condition, the number of participants completing each VR session was as follows: VR-environment 1 (n=17), VR-environment 2 (n=18), VR-environment 3 (n=16), VR-environment 4 (n=12), VR-environment 5 (n=11), VR-environment 6 (n=10). It is important to note that participants were not required to complete all six sessions, which explains the variation in the number of participants across sessions. Table 5 shows the pre-post comparisons for each VR session for state mindfulness and emotional state. Significant pre-post improvements in mindfulness state were obtained in all VR environments except for VR-environment 1. There were significant pre-post improvements in state of relaxation in all the VR environments.

In addition, we observed significant pre-post reductions in sadness in VR-environment 3, increments in surprise in VR-environment 5, and reductions in anxiety in VR-environment 6. Finally, intermediate average scores in the sense of presence were observed in all environments, ranging from 3.50 to 4.73 (Table 5).

## 4 Discussion

Recent advances in VR technology have made it more available, affordable and popular for a variety of applications in today's society (Xie et al. 2021). The main aim of this study was to explore the possibilities of VR for mindfulness in a non-clinical sample.

**Table 5** Contrasts between pre- and post- individual VR sessions

| | Session 1 (n=17) | Session 2 (n=18) | Session 3 (n=16) | Session 4 (n=12) | Session 5 (n=11) | Session 6 (n=10) |
|---|---|---|---|---|---|---|
| *VAS joy, M (SD)* | | | | | | |
| Pre-session | 4.24 (1.03) | 3.67 (1.19) | 3.63 (1.20) | 4.00 (1.04) | 3.82 (1.08) | 4.30 (1.06) |
| Post-session | 4.18 (1.29) | 3.94 (1.39) | 3.75 (1.24) | 4.08 (1.31) | 3.78 (1.72) | 4.50 (1.58) |
| (*p*) | (0.813) | (0.320) | (0.438) | (0.763) | (0.999) | (0.615) |
| *VAS Sadness, M (SD)* | | | | | | |
| Pre-session | 2.76 (1.52) | 2.11 (0.96) | 2.94 (1.44) | 2.33 (1.30) | 2.90 (1.66) | 2.20 (1.23) |
| Post-session | 2.18 (1.47) | 1.78 (1.00) | 1.88 (1.26) | 1.92 (1.17) | 2.22 (1.09) | 1.80 (1.03) |
| (*p*) | (0.149) | (0.124) | **(0.008)** | (0.096) | (0.276) | (0.305) |
| *VAS anger, M (SD)* | | | | | | |
| Pre-session | 1.65 (1.06) | 1.72 (0.90) | 2.25 (1.65) | 2.08 (1.17) | 1.55 (0.69) | 1.40 (0.52) |
| Post-session | 1.35 (0.70) | 1.56 (0.092) | 2.19 (1.64) | 1.83 (1.19) | 1.44 (0.73) | 1.20 (0.42) |
| (*p*) | (0.096) | (0.317) | (0.763) | (0.180) | (0.705) | (0.157) |
| *VAS surprise, M (SD)* | | | | | | |
| Pre-session | 3.47 (1.59) | 2.56 (1.20) | 2.37 (1.20) | 2.08 (1.38) | 2.00 (1.18) | 2.40 (1.43) |
| Post-session | 2.81 (1.42) | 3.06 (1.39) | 2.19 (1.11) | 2.25 (1.29) | 2.89 (1.62) | 3.10 (1.66) |
| (*p*) | (0.168) | (0.248) | (0.666) | (0.589) | (0.023) | (0.268) |
| *VAS anxiety, M (SD)* | | | | | | |
| Pre-session | 3.35 (1.77) | 2.56 (1.58) | 3.06 (1.44) | 2.67 (1.78) | 3.27 (1.27) | 2.90 (1.37) |
| Post-session | 2.71 (1.61) | 2.33 (1.53) | 2.56 (1.55) | 2.08 (1.38) | 2.44 (1.59) | 2.10 (1.60) |
| (p) | (0.166) | (0.260) | (0.064) | (0.068) | (0.202) | (0.033) |
| *VAS relaxation, M (SD)* | | | | | | |
| Pre-session | 3.24 (1.48) | 3.67 (1.24) | 3.56 (1.37) | 3.50 (1.00) | 3.55 (1.04) | 4.40 (1.43) |
| Post-session | 4.76 (1.39) | 4.78 (1.35) | 4.47 (1.25) | 5.00 (1.41) | 4.67 (1.23) | 5.10 (1.45) |
| (*p*) | **(0.003)** | **(0.002)** | **(0.013)** | **(0.004)** | **(0.047)** | **(0.008)** |
| *VAS energy, M (SD)* | | | | | | |
| Pre-session | 3.76 (1.30) | 3.29 (1.26) | 3.63 (0.96) | 3.25 (1.14) | 3.55 (0.69) | 3.70 (1.06) |
| Post-session | 3.81 (1.33) | 3.78 (1.11) | 3.69 (1.45) | 3.92 (1.38) | 3.56 (1.01) | 3.56 (1.24) |
| (*p*) | (0.809) | (0.188) | (0.886) | (0.071) | (0.705) | (0.739) |
| *MAAS, M (SD)* | | | | | | |
| Pre-session | 3.33 (1.44) | 3.20 (1.20) | 2.61 (1.50) | 2.93 (1.17) | 3.12 (1.11) | 3.14 (1.23) |
| Post-session | 2.61 (1.24) | 2.36 (1.51) | 1.48 (1.27) | 2.18 (1.15) | 1.64 (0.99) | 1.38 (1.07) |
| (*p*) | (0.120) | **(0.010)** | **(0.009)** | **(0.036)** | **(0.038)** | **(0.012)** |
| SUS, M (SD) | 3.69 (1.42) | 3.87 (1.13) | 3.55 (1.78) | 3.50 (1.70) | 3.57 (1.81) | 4.73 (1.53) |

M, mean; SD = standard deviation; *p*, *p value*; VAS, brief version of the visual analogue scale composed of seven items (happiness, sadness, anger, surprise, anxiety, relaxation/calm, vigour/energy). Participants chose responses ranging from 1 (not feeling the emotion at all) to 7 (feeling the emotion extremely); MAAS, mindful attention awareness scale; SUS, Slater-Usoh-Steed questionnaire; Bold indicates statistically significant values ($\alpha < 0.05$)

Contrary to our expectations, MBP+VR showed no significant improvements in attendance compared to MBP alone. However, both MBP and MBP+VR had higher attendance levels compared to the Relaxation control group. Similarly, our results were positive in terms of satisfaction regarding the intervention, with participants reporting high levels of enjoyment and perceived improvement in both MBP conditions, while lower scores were found in the Relaxation group. Regarding psychological measures, while all three study conditions (MBP, MBP+VR, and Relaxation) achieved significant reductions in psychological distress, these reductions were only statistically significant when comparing MBP+VR to the Relaxation group. These findings could be considered an added benefit of incorporating virtual reality into mindfulness programs, suggesting that VR may enhance the effectiveness of mindfulness interventions in reducing psychological distress beyond what is achieved through traditional methods alone. Additionally, MBP+VR demonstrated significantly better outcomes than Relaxation on the overall mindfulness level, measured through the total FFMQ score. However, these advantages favouring the MBP+VR condition were not observed in other secondary variables, such as positive affect or the variable of (lack of) self-judgement, where MBP alone achieved better outcomes compared to the other two groups. Regarding this last variable, research shows that mindfulness training can significantly reduce self-judgment (Joss et al. 2025; Willard et al. 2022) which could explain the improvements seen compared to a relaxation control group. However, further investigation is needed to clarify why MBP alone also outperformed the MBP+VR group in this respect. Taken together, the lack of advantages in attendance to MBP+VR compared to MBP, the similar levels of satisfaction, as well as contradictory results regarding the efficacy of MBP and MBP+VR based on the psychological variables evaluated, make further research necessary regarding the added effects of integrating virtual reality into mindfulness programme. One possible reason for this observed limited benefit of VR in our study could be attributed to the age of the participants, whose average age was close to fifty years. Adults tend to show greater reluctance and require more support to adopt new technologies compared to younger individuals (Mitzner et al. 2010; Heart and Kalderon 2013). However, while some studies in the field of mindfulness and VR have demonstrated beneficial effects of VR-based mindfulness interventions among younger participants (Modrego-Alarcon et al. 2021; Yildirim and O'Grady 2020), other studies have documented contradictory results; for example, Olasz et al. (2024) reported no significant benefits of virtual reality in a similarly young population. These contradictory findings highlight the need for more detailed research that thoroughly examines whether demographic differences may be an important factor to consider when evaluating the effectiveness of mindfulness interventions supplemented with VR.

Similar to other studies (Navarro-Haro et al. 2017; Seabrook et al. 2020; Yildirim and O'Grady 2020), significant increases in state mindfulness were observed in all the VR sessions, except for the session corresponding to VR Environment 1. In this session, participants were shown a seascape. The audio guide invited them to focus on their breathing, adapting each inhalation and exhalation to the movement of the waves. We suggest that this externally controlled guidance may not have aligned with each participant's natural pattern, potentially reducing the session's effectiveness. These findings, in general, underscore the potential of VR to enhance participants' state mindfulness, which may in turn lead to improvements in trait mindfulness, as we observed at post-intervention (Kiken et al. 2015). We observed significant increases in state of relaxation across all VR sessions, consistent with previous studies (Navarro-Haro et al. 2017, 2019; Tarrant et al. 2022; Waller et al. 2021). Additionally, body scan (VR-environment 3) led to significant decreases in sadness, similar to findings by Tarrant et al. (Tarrant et al. 2022), indicating that VR-based body scans may have the potential for reducing negative mood states. This finding aligns with evidence that audio-guided body-scans can acutely reduce negative mood in chronic-pain patients (Ussher et al. 2014) and with meta-analytic data showing consistent affective benefits across populations (Gan et al. 2022), suggesting that VR may enhance a pre-existing effect rather than introduce a novel one. Significant increases in surprise were noted during the walking meditation practice (VR-environment 5), possibly due to the novelty of changing positions from sitting to walking during the session. Finally, the Metta (compassion) practice (VR-environment 6) achieved significant reductions in anxiety. Further research employing compassion practices through VR is needed to better understand this finding. In terms of sense of presence, intermediate scores were observed in all environments, except for VR-environment 6, where higher levels were found, possibly due to the more generative and immersive nature of the Metta practice.

Our research applied innovative technology through the MK360 immersive experiences system, which provides auditory and visual stimuli to enable participants to navigate within a virtual world. Although this technology had been utilised in previous studies (Cano et al. 2024; Sultana et al. 2021), this marks the first instance where the virtual environments offered by this technology are rooted in mindfulness practices. Using this system addresses certain practical limitations associated with head-mounted VR experiences. For instance, in Chandrasiri et al. (2019), an Oculus Rift head-mounted display (HMD) was employed for the mindfulness VR experience, after which most participants reported discomfort wearing the HMD. Utilising 3D environments enables us to elicit a sense of presence in participants without the need for devices that may disrupt the user experience. The use of 3D environments also facilitates collective implementation, offering potential advantages over individual VR sessions (e.g. social identification, motivation, behavioural adaptation, cohesion, trust and constructive feedback) (Borek and Abraham 2018). Nevertheless, current evidence on the benefits of individual versus group mindfulness delivery remains limited (Hutchinson et al. 2021). While some research suggests a general equivalence between the two formats (Schroevers et al. 2016; Matiz et al. 2018), other studies highlight specific advantages of group settings, including increased levels of mindfulness and social connection (Hanley et al. 2022), as well as improved executive function (Millett et al. 2021)—emphasising the need for future research to disentangle the unique contribution of co-presence, whether physical or virtual. In this context, we recommend that future studies incorporate evaluation tools capable of assessing the specific effects of collective VR implementation. The immersive virtual environments used in our study were developed by our research team to encompass a wide range of the core practices in MBPs. This represents a strength of our study compared to others that evaluate the effects of a single VR practice (Failla et al. 2022). Future studies should analyse the potential differential effects of different mindfulness practices. Generative practices like Metta may hold particular promise in this domain.

Although these findings are encouraging, this study has important limitations. First, it was designed as a pilot study with a small sample size, substantial attrition and a predominantly female participant group, which may restrict the generalisability of our results. Several factors might have contributed to the relatively high attrition rate. One possible explanation is that participants were drawn from a non-clinical population, where intrinsic motivation to complete the programme may be lower than in clinical or help-seeking samples. Additionally, the protocol included multiple in-person sessions over several weeks, which may have posed logistical barriers such as scheduling conflicts or reduced novelty. Future studies should prospectively assess dropout reasons to clarify how best to improve retention in VR-supported mindfulness interventions. The study solely relied on self-report measures, and the assessed variables were not tracked over time. To gain a deeper understanding of the effects of VR, it would be beneficial to incorporate neurophysiological measurements into the experimental procedure and conduct follow-up assessments after the conclusion of treatment (Failla et al. 2022). Additionally, only 20 subjects participated in the MBP+VR condition, further limiting the generalisability of results, particularly concerning VR-specific outcomes. Moreover, since our design did not include a non-immersive electronic comparison (e.g., 2-D video or desktop delivery), it remains unclear whether the observed benefits are unique to immersive VR or could be replicated using simpler digital formats. Future trials should therefore directly compare VR with matched 2-D implementations to isolate the specific contribution of immersion (Yildirim and O'Grady 2020). On the other hand, data collection regarding potential adverse effects—such as discomfort associated with the use of immersive technologies (e.g., cybersickness)—was not systematized. Although no serious adverse events were reported, the information was primarily derived from spontaneous comments made by participants to the psychologist present during the intervention, which may have limited the formal detection and documentation of such effects. Future research should include standardized procedures for the systematic assessment of potential adverse reactions. Finally, another important limitation of the present study concerns the use of different facilitators across conditions. Specifically, the relaxation control group was led by a clinical psychologist distinct from the one delivering the MBP interventions. This introduces the possibility of therapist-related variability, i.e., differences in delivery style, interpersonal factors, or participant suggestibility, which may have influenced the outcomes independently of the intervention content.

Given the limited existing research, our study represents a promising step forward in the application of VR in the field of mindfulness. We recommend that future research should endeavour to explore the potential of VR in this domain.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s10055-025-01218-w.

**Acknowledgements** JM-M holds a "Miguel Servet" research contract from the ISCIII (CP21/00080), has been funded by mobility grants for the duration of the project (MV22/00022, CAS22/00436) and thanks the Department of Psychiatry at the University of Oxford, United Kingdom, and the CIBER of Epidemiology and Public Health of Spain (CIBERESP CB22/02/00052; ISCIII) for their support. The authors thank the Mental Health Research group (B17_23R) and the Health Research Institute of Aragón (IIS Aragón); the Research Network on Chronicity, Primary Care and Health Promotion (RICAPPS, RD21/0016/0005) and the Carlos III Health Institute. Finally, The authors would like to acknowledge Broomx Technologies – Immersive solutions for supplying intervention materials (hardware and software). Materials can be accessed at https://broomx.com/.

**Author contributions** M.M.A, Y.L.H and J.G.C defined the protocol and designed and conducted the experiment. J.M.M carried out the statistical analyses. M.M.A. and J.M.M contributed to writing the original draft, and all authors, M.M.A, Y.L.H, M.B.R, J.G.C, and J.M.M, corrected, supervised, and approved the manuscript.

**Funding** Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. The project has had the support of the Mental Health research group of the DGA (B17_23R) that is part of the Department of Innovation, Research and University of the Government of Aragon (Spain) and the Health Research Institute of Aragon (IIS Aragón). This work has also been supported by the Research Network on Chronicity, Primary Care and Health Promotion (RICAPPS, RD21/0016/0005) which is part of the Cooperative Networks for Results-Oriented Health Research (RICORS) (Institute of Health Carlos III); Feder finances "Another way of making Europe", NextGeneration EU funds. The funders have no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

**Data availability** The data supporting the results of this study are not published but are available to anyone upon request to the authors.

## Declarations

**Conflict of interest** Conflicts of interest: JM-M. is associated with the Mindfulness Research Centre at the University of Oxford.

## References


Arpaia P, D'Errico G, De Paolis LT, Moccaldi N, Nuccetelli F (2022) A narrative review of mindfulness-based interventions using virtual reality. Mindfulness 13:556–571 https://doi.org/10.1007/s12671-021-01783-6

Baer RA, Smith GT, Hopkins J, Krietemeyer J, Toney L (2006) Using self-report assessment methods to explore facets of mindfulness. Assessment 13(1):27–45. https://doi.org/10.1177/1073191105283504

Baños RM, Botella C, Alcañiz M, Liaño V, Guerrero B, Rey B (2004) Immersion and emotion: their impact on the sense of presence. Cyberpsychol Behav 7(6):734–741. https://doi.org/10.1089/cpb.2004.7.734

Bernstein DA and Borkovec TD (1973) Progressive relaxation training: a manual for the helping professions. Research Press

Billingham SAM, Whitehead AL, Julious SA (2013) An audit of sample sizes for pilot and feasibility trials being undertaken in the United Kingdom registered in the UK clinical research network database. BMC Med Res Methodol 13:104. https://doi.org/10.1186/1471-2288-13-104

Bishop SR, Lau M, Shapiro S, Carlson L, Anderson ND, Carmody J, Segal ZV, Abbey S, Speca M, Velting D, Devins G (2004) Mindfulness: a proposed operational definition. Clin Psychol Sci Pract 11(3):230–241. https://doi.org/10.1093/clipsy.bph077

Borek AJ, Abraham C (2018) How do small groups promote behaviour change? An integrative conceptual review of explanatory mechanisms. Appl Psychol Health Well-Being 10(1):30–61. https://doi.org/10.1111/aphw.12120

Borkovec TD, Nau SD (1972) Credibility of analogue therapy rationales. J Behav Ther Exp Psychiatry 3:257–260

Brown KW, Ryan RM (2003) The benefits of being present: mindfulness and its role in psychological well-being. J Pers Soc Psychol 84(4):822–848. https://doi.org/10.1037/0022-3514.84.4.822

Cano N, Gómez-Hernández J, Ariza M, Mora T, Roche D, Porras-Garcia B, Garolera M (2024) A multimodal group-based immersive virtual reality intervention for improving cognition and mental health in patients with post-covid-19 condition. A quasi-experimental design study. Front Psychol 15:1441018. https://doi.org/10.3389/fpsyg.2024.1441018

Chandrasiri A, Collett J, Fassbender E, De Foe A (2019) A virtual reality approach to mindfulness skills training. Virtual Reality. https://doi.org/10.1007/s10055-019-00380-2

Cohen J (1998) Statistical power analysis for the behavioral sciences. Lawrence Erlbaum Associates. https://doi.org/10.4324/9780203771587

Daza P, Novy DM, Stanley MA, Averill P (2002) The depression anxiety stress scale-21: Spanish translation and validation with a Hispanic sample. J Psychopathol Behav Assess 24(3):195–205. https://doi.org/10.1023/A:1016014818163

Enkema MC, McClain L, Bird ER, Halvorson MA, Larimer ME (2020) Associations between mindfulness and mental health outcomes: a systematic review of ecological momentary assessment research. Mindfulness 11(11):2455–2469. https://doi.org/10.1007/s12671-020-01442-2

Failla C, Marino F, Bernardelli L, Gaggioli A, Doria G, Chilà P, Minutoli R, Mangano R, Torrisi R, Tartarisco G, Bruschetta R, Arcuri F, Cerasa A, Pioggia G (2022) Mediating mindfulness-based interventions with virtual reality in non-clinical populations: the state-of-the-art. Healthcare. https://doi.org/10.3390/healthcare10071220

Flores A, Linehan MM, Todd SR, Hoffman HG (2018) The use of virtual reality to facilitate mindfulness skills training in dialectical behavioral therapy for spinal cord injury: a case study. Front Psychol 9:1–7. https://doi.org/10.3389/fpsyg.2018.00531

Gan R, Zhang L, Chen S (2022) The effects of body-scan meditation: a systematic review and meta-analysis. Appl Psychol Health Well-Being 14(3):1062–1080. https://doi.org/10.1111/aphw.12317

Gandek B, Ware JE, Aaronson NK, Apolone G, Bjorner JB, Brazier JE, Bullinger M, Kaasa S, Leplege A, Prieto L, Sullivan M (1998) Cross-validation of item selection and scoring for the SF-12 health survey in nine countries: results from the IQOLA project. J Clin Epidemiol 51(11):1171–1178. https://doi.org/10.1016/S0895-4356(98)00109-7

García-Campayo J and Demarzo M (2015) Mindfulness y compasión: La nueva revolucion. Siglantana

Garcia-Campayo J, Navarro-Gil M, Andrés E, Montero-Marin J, López-Artal L, Demarzo MMP (2014) Validation of the Spanish versions of the long (26 items) and short (12 items) forms of the self-compassion scale (SCS). Health Qual Life Outcomes 12:1–9. https://doi.org/10.1186/1477-7525-12-4

Goldberg SB, Riordan KM, Sun S, Davidson RJ (2021) The empirical status of mindfulness-based interventions: a systematic review of 44 meta-analyses of randomized controlled trials. Perspect Psychol Sci 17(1):108–130. https://doi.org/10.1177/1745691620968771

Gomez J, Hoffman HG, Bistricky SL, Gonzalez M, Rosenberg L, Sampaio M, Garcia-Palacios A, Navarro-Haro MV, Alhalabi W, Rosenberg M, Meyer WJ, Linehan MM (2017) The use of virtual reality facilitates dialectical behavior therapy® 'observing sounds and visuals' mindfulness skills training exercises for a Latino patient with severe burns: A case study. Front Psychol. https://doi.org/10.3389/fpsyg.2017.01611

Gross JJ, Levenson RW (1995) Emotion elicitation using films. Cogn Emot 9(1):87–108

Gu J, Strauss C, Bond R, Cavanagh K (2015) How do mindfulness-based cognitive therapy and mindfulness-based stress reduction improve mental health and wellbeing? A systematic review and meta-analysis of mediation studies. Clin Psychol Rev 37:1–12. https://doi.org/10.1016/j.cpr.2015.01.006

Hanley AW, Dehili V, Krzanowski D, Barou D, Lecy N, & Garland EL (2022) Effects of Video-Guided Group vs. Solitary Meditation on Mindfulness and Social Connectivity: A Pilot Study. Clin Soc Work J 50:316–324. https://doi.org/10.1007/s10615-021-00812-0

Heart T, Kalderon E (2013) Older adults: are they ready to adopt health-related ICT? Int J Med Inform 82(11):e209–e231. https://doi.org/10.1016/j.ijmedinf.2011.03.002

Hölzel BK, Lazar SW, Gard T et al (2011) How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. Perspect Psychol Sci 6(6):537–559. https://doi.org/10.1177/1745691611419671

Hutchinson JK, Jones F, Griffith G (2021) Group and common factors in mindfulness-based programmes: a selective review and implications for teachers. Mindfulness 12:1582–1596. https://doi.org/10.1007/s12671-021-01596-7

Jacobson E (1938) Progressive relaxation. University of Chicago Press

Joss D, Datko M, Washington CI, Tresvalles MA, Mete M, Lazar SW, Hoge EA (2025) Neural correlates of reduction in self-judgment after mindful self-compassion training: a pilot study with resting state fMRI. J Mood Anxiety Disord 9:100096. https://doi.org/10.1089/jicm.2022.0511

Julious SA (2005) Sample size of 12 per group rule of thumb for a pilot study. Pharm Stat 4(4):287–291. https://doi.org/10.1002/pst.185

Kabat-Zinn J (2003) Mindfulness-based interventions in context: past, present, and future. Clin Psychol Sci Pract 10(2):144–156. https://doi.org/10.1093/clipsy.bpg016

Kaplan-Rakowski R, Johnson KR, Wojdynski T (2021) The impact of virtual reality meditation on college students' exam performance. Smart Learn Environ. https://doi.org/10.1186/s40561-021-00166-7

Khoury B, Sharma M, Rush SE, Fournier C (2015) Mindfulness-based stress reduction for healthy individuals: a meta-analysis. J Psychosom Res 78(6):519–528. https://doi.org/10.1016/j.jpsychores.2015.03.009

Kiken LG, Garland EL, Bluth K, Palsson OS, Gaylord SA (2015) From a state to a trait: Trajectories of state mindfulness in meditation during intervention predict changes in trait mindfulness. Pers Individ Differ 81:41–46. https://doi.org/10.1016/j.paid.2014.12.044

Kyrios M, Ahern C, Fassnacht DB, Nedeljkovic M, Moulding R, Meyer D (2018) Therapist-assisted internet-based cognitive behavioral therapy versus progressive relaxation in obsessive-compulsive disorder: randomized controlled trial. J Med Internet Res 20(8):e242. https://doi.org/10.2196/jmir.9566

Lam SU, Kirvin-Quamme A, Goldberg SB (2022) Overall and differential attrition in mindfulness-based interventions: a meta-analysis. Mindfulness 13(11):2676–2690. https://doi.org/10.1007/s12671-022-01970-z

Leon AC, Davis LL, Kraemer HC (2011) The role and interpretation of pilot studies in clinical research. J Psychiatr Res 45(5):626–629. https://doi.org/10.1016/j.jpsychires.2010.10.008

Lessiter J, Freeman J, Keogh E, Davidoff J (2001) A cross-media presence questionnaire: the ITC-sense of presence inventory. Presence Teleoperators Virtual Environ 10(3):282–297. https://doi.org/10.1162/105474601300343612

Linardon J (2023) Rates of attrition and engagement in randomized controlled trials of mindfulness apps: systematic review and meta-analysis. Behav Res Ther 170:104421. https://doi.org/10.1016/j.brat.2023.104421

Lovibond PF, Lovibond SH (1995) The structure of negative emotional states: comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. Behav Res Ther 33(3):335–343. https://doi.org/10.1016/0005-7967(94)00075-U

Matiz A, Fabbro F, Crescentini C (2018) Single vs. group mindfulness meditation: effects on personality, religiousness/spirituality, and mindfulness skills. Mindfulness 9:1236–1244. https://doi.org/10.1007/s12671-017-0865-0

McCloy R, Stone R (2001) Science, medicine, and the future. Virtual reality in surgery. BMJ 323(7318):912–915. https://doi.org/10.1136/bmj.323.7318.912

Millett G, D'Amico D, Amestoy ME et al (2021) Do group-based mindfulness meditation programs enhance executive functioning? A systematic review and meta-analysis. Conscious Cogn 95:103195. https://doi.org/10.1016/j.concog.2021.103195

Modrego-Alarcón M, Morillo H, Campos D, Navarro-Gil MT, Montero-Marín J, Monreal-Bartolomé A, García-Campayo J, López-Del-Hoyo Y (2025) Effects and acceptability of virtual reality to facilitate mindfulness practice in university students. J Comput High Educ 37(1):273–298. https://doi.org/10.1007/s12528-023-09393-y

Modrego-Alarcón M, López-del-Hoyo Y, García-Campayo J, Pérez-Aranda A, Navarro-Gil M, Beltrán-Ruiz M, Morillo H, Delgado-Suarez I, Oliván-Arévalo R, Montero-Marin J (2021) Efficacy of a mindfulness-based programme with and without virtual reality support to reduce stress in university students: A randomized controlled trial. Behav Res Therapy 142(December 2020):103866. https://doi.org/10.1016/j.brat.2021.103866

Mitzner TL, Boron JB, Fausset CB, Adams AE, Charness N, Czaja SJ, Dijkstra K, Fisk AD, Rogers WA, Sharit J (2010) Older adults talk technology: technology usage and attitudes. Comput Hum Behav 26(6):1710–1721. https://doi.org/10.1016/j.chb.2010.06.020

Navarro-Haro MV, López-del-Hoyo Y, Campos D, Linehan MM, Hoffman HG, García-Palacios A, Modrego-Alarcón M, Borao L, García-Campayo J (2017) Meditation experts try virtual reality mindfulness: a pilot study evaluation of the feasibility and acceptability of virtual reality to facilitate mindfulness practice in people attending a mindfulness conference. PLoS ONE. https://doi.org/10.1371/journal.pone.0187777

Navarro-Haro MV, Modrego-Alarcón M, Hoffman HG, López-Montoyo A, Navarro-Gil M, Montero-Marin J, García-Palacios A, Borao L, García-Campayo J (2019) Evaluation of a mindfulness-based intervention with and without virtual reality dialectical behavior therapy® mindfulness skills training for the treatment of generalized anxiety disorder in primary care: a pilot study. Front Psychol 10:55. https://doi.org/10.3389/fpsyg.2019.00055

Neff KD (2003) The development and validation of a scale to measure self-compassion. Self Identity 2(3):223–250. https://doi.org/10.1080/15298860309027

Olasz O, Erdős S, Horváth K (2024) The effects of virtual reality-based mindfulness exercises on the perception of time, psychological and physiological states of young people: a randomized crossover trial. Mindfulness 15(9):2347–2354. https://doi.org/10.1007/s12671-024-02438-y

Poetar CR, Bradley N, Voinescu A (2023) Immersive virtual reality or computerised mindfulness meditation for improving mood? Preliminary efficacy from a pilot randomised trial. Front Psychol 14:1157469. https://doi.org/10.3389/fpsyg.2023.1157469

Sánchez-López MP, Dresch V (2008) The 12-item general health questionnaire (GHQ-12): reliability, external validity and factor structure in the Spanish population. Psicothema 20(4):839–843

Sandín B, Chorot P, Lostao L, Joiner TE, Santed MA, Valiente RM (1999) Escalas PANAS de afecto positivo y negativo—Validacion factorial y transcultural. Psicothema 11(1):37–51

Schröder A, Heider J, Zaby A, Göllner R (2013) Cognitive behavioral therapy versus progressive muscle relaxation training for multiple somatoform symptoms: results of a randomized controlled trial. Cognit Ther Res 37:296–306. https://doi.org/10.1007/s10608-012-9474-3

Schroevers MJ, Tovote KA, Snippe E, Fleer J (2016) Group and individual mindfulness-based cognitive therapy (MBCT) are both effective: a pilot randomized controlled trial in depressed people with a somatic disease. Mindfulness 7:1339–1346. https://doi.org/10.1007/s12671-016-0575-z

Schulz KF, Altman DG, Moher D (2010) CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. BMJ. https://doi.org/10.1136/bmj.c332

Seabrook E, Kelly R, Foley F, Theiler S, Thomas N, Wadley G, Nedeljkovic M (2020) Understanding how virtual reality can support mindfulness practice: mixed methods study. J Med Internet Res 22(3):e16106. https://doi.org/10.2196/16106

Shapiro SL, Carlson LE, Astin JA, Freedman B (2006) Mechanisms of mindfulness. J Clin Psychol 62(3):373–386. https://doi.org/10.1002/jclp.20237

Slater M, Usoh M, Steed A (1994) Depth of presence in virtual environments. Presence Teleoperators Virtual Environ 3(2):130–144. https://doi.org/10.1162/pres.1994.3.2.130

Soler J, Tejedor R, Feliu-Sol A, Pascual JC, Cebolla A, Soriano J, Alvarez E, Perez V (2012) Propiedades psicométricas de la versión española de la escala mindful attention awareness scale (MAAS). Actas Esp Psiquiatr 40(1):18–25

Sultana M, Campbell K, Jennings M, Montero-Odasso M, Orange JB, Knowlton J, St George A, Bryant D (2021) Virtual reality experience intervention may reduce responsive behaviors in nursing home residents with dementia: a case series. Journal of Alzheimer's Disease : JAD 84(2):883–893. https://doi.org/10.3233/JAD-210010

Tarrant J, Jackson R, Viczko J (2022) A feasibility test of a brief mobile virtual reality meditation for frontline healthcare workers in a hospital setting. Front Virtual Real 3(January):1–12. https://doi.org/10.3389/frvir.2022.764745

Tarrant J, Viczko J, Cope H (2018) Virtual reality for anxiety reduction demonstrated by quantitative EEG: a pilot study. Front Psychol 9:1280. https://doi.org/10.3389/fpsyg.2018.01280

Teare MD, Dimairo M, Shephard N, Hayman A, Whitehead A, Walters SJ (2014) Sample size requirements to estimate key design parameters from external pilot randomised controlled trials: a simulation study. Trials 15:264. https://doi.org/10.1186/1745-6215-15-264

Ussher M, Spatz A, Copland C, Nicolaou A, Cargill A, Amini-Tabrizi N, McCracken LM (2014) Immediate effects of a brief mindfulness-based body-scan on patients with chronic pain. J Behav Med 37(1):127–134. https://doi.org/10.1007/s10865-012-9466-5

Waller M, Mistry D, Jetly R, Frewen P (2021) Meditating in virtual reality 3: 360° video of perceptual presence of instructor. Mindfulness 12(6):1424–1437. https://doi.org/10.1007/s12671-021-01612-w

Ware JJ, Kosinski M, Keller SD (1996) A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. Med Care 34(3):220–233. https://doi.org/10.1097/00005650-199603000-00003

Watson D, Clark LA, Tellegen A (1988) Development and validation of brief measures of positive and negative affect: the PANAS scales. J Pers Soc Psychol 54(6):1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Wieczorek A, Schrank F, Renner K-H, Wagner M (2024) Psychological and physiological health outcomes of virtual reality-based mindfulness interventions: a systematic review and evidence mapping of empirical studies. Digit Health 10:20552076241272604. https://doi.org/10.1177/20552076241272604

Willard R, Possemato K, Ramon A, Bergen-Cico D (2022) Self-compassion and self-judgment: potential mediators of a mindfulness intervention on depression. J Integr Complement Med 28(7):607–609

Xie B, Liu H, Alghofaili R, Zhang Y, Jiang Y, Lobo FD, Li C, Li W, Huang H, Akdere M, Mousas C, Yu L-F (2021) A review on virtual reality skill training applications. Front Virtual Real. https://doi.org/10.3389/frvir.2021.645153

Yildirim C and O'Grady T (2020) The Efficacy of a Virtual Reality-Based Mindfulness Intervention. In: Proceedings - 2020 IEEE International Conference on Artificial Intelligence and Virtual Reality, AIVR 2020, pp 158–165. https://doi.org/10.1109/AIVR50618.2020.00035

Zhang S, Chen M, Yang N, Lu S, Ni S (2021) Effectiveness of VR based mindfulness on psychological and physiological health: a systematic review. Curr Psychol. https://doi.org/10.1007/s12144-021-01777-6