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Advances in Mental Health

Promotion, Prevention and Early Intervention

ISSN: 1838-7357 (Print) 1837-4905 (Online) Journal homepage: www.tandfonline.com/journals/ramh20

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To cite this article: Rafael Martins, Sara de Sousa, João Viana, Rita Fortuna, André Henriques, Alzira Silva & Raquel Simões de Almeida (19 Jan 2026): The impact of virtual reality-based forest therapy in psychiatric inpatient care: a pilot study, Advances in Mental Health, DOI: 10.1080/18387357.2026.2615679

To link to this article: https://doi.org/10.1080/18387357.2026.2615679

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ADVANCES IN MENTAL HEALTH
https://doi.org/10.1080/18387357.2026.2615679

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The impact of virtual reality-based forest therapy in psychiatric inpatient care: a pilot study

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ABSTRACT

Objective: This study evaluated the effectiveness of a Virtual Reality (VR)-based Forest Therapy program in reducing depressive symptoms, anxiety, stress, and physiological distress among psychiatric inpatients.

Method: A quasi-experimental study was conducted with 16 inpatients (mean age: 38) in a clinical setting. Participants engaged in four immersive VR sessions simulating forest environments. Psychometric assessments included the DASS-21 and WHO-5, administered pre- and post-intervention. Autonomic responses were monitored via Heart Rate Variability (HRV) and Electrodermal Activity (EDA).

Results: Following the intervention, participants showed statistically significant improvements in depression, anxiety, stress, and well-being scores ($p < .001$). While changes in physiological indicators (HRV and EDA) were not statistically significant, observed trends suggested increased autonomic stability and relaxation.

Discussion: The findings suggest that VR-based Forest Therapy appears to be a promising, accessible intervention for promoting wellbeing in psychiatric settings with limited nature access. While the results are encouraging, the lack of a control group and follow-up data limits conclusions regarding long-term durability. Further research with larger samples is required to validate these findings.

ARTICLE HISTORY
Received 15 July 2025
Accepted 7 January 2026

KEYWORDS
Virtual reality; forest therapy; mental health; nature based-intervention

1. Introduction

1.1. Theoretical framework

Exposure to nature has been shown to significantly reduce stress levels and improve physical health, psychological well-being, and social well-being (Müller-Riemenschneider et al., 2020; Shanahan et al., 2016). Furthermore, exposure to nature cultivates feelings of hope, inner strength, resilience, and self-worth, all of which are essential for mental recovery (Firby & Raine, 2022; Pálsdóttir et al., 2014). The act of observing and experiencing nature has been associated with increased feeling of happiness, enjoyment and contentment (Mourão et al., 2019; Pálsdóttir et al., 2014).

Additionally, engagement with nature has been shown to restore mental capacities and enhance well-being by fostering feelings of calm, inner quietness, and escapism (Heard et al., 2020). Natural environments play a vital role in stress reduction and relaxation, offering individual a chance to experience a state of 'just being' (Mourão et al., 2019; Wagenfeld et al., 2018), yet it is a matter of considerable concern that urbanisation and challenges of contemporary life are resulting in decreased engagement with the natural environment (Soga & Gaston, 2016). To counter this development, nature-based interventions can facilitate the promotion of nature-based experiences through a structured manner (Shanahan et al., 2019). These interventions encompass programs, activities, or strategies designed to engage individuals in nature-based experiences with the specific aim of enhancing health, well-being (Shanahan et al., 2019), a sense of empowerment and self-efficacy (Drake et al., 2021; James et al., 2021), and a sense of autonomy and control (McIver et al., 2018).

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/18387357.2026.2615679.
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Research shows a positive link between time spent in nature and mental health leading to the inclusion of natural settings in mental health practices (Bratman et al., 2019; Mitchell et al., 2015; Pálsdóttir et al., 2018). Sundara Rajoo et al. (2021) demonstrated that young adults facing anxiety, sadness or stress benefit from outdoor therapeutic exercises. Group activities, such as walks in nature, have also been associated with mental health improvements (Marselle et al., 2019; Pouso et al., 2021). Additionally, nature-based therapies using horticulture and mindfulness have shown benefits in mood, self-awareness, and environmental awareness (Sidenius et al., 2015, 2020).

Physiological benefits from nature-based therapies include reductions in heart rate, blood pressure, and cortisol levels (Lee et al., 2014; Wang et al., 2019). For example, forest walking has been shown to decrease sympathetic nervous activity, while bamboo forest therapy improves oxygen saturation (Lee et al., 2014; Zeng et al., 2020). Nature-based intervention for patients with depression and anxiety have been reported to enhance presence, autonomy, and social interaction, contributing to overall well-being (Adams & Morgan, 2018; Carlson et al., 2020).

One of this interventions is forest-bathing, a nature-based programme involving a slow, mindful experience in natural settings that encourages the opening of senses, potentially enhancing individuals physical and psychological health (Hansen et al., 2017). Evidence suggests that forest bathing reduces stress (Antonelli et al., 2019), anxiety, depression (Kotera et al., 2022), social isolation and rumination (McEwan et al., 2022). Forest Therapy is a structured, intentional approach integrating nature-based interventions with specific therapeutic goals. Unlike Forest Bathing, it is led by trained professionals who intervene in clinical contexts because its focus is on treating or managing specific health conditions (Wang et al., 2019). It engages multiple senses, such as sight, sound, smell, touch, and sometimes taste, to foster a deeper connection with nature (B.-J. Park et al., 2020). Forest Therapy has been shown to reduce stress, improve mood, boost immune function, and lower blood pressure (Lee et al., 2017; Poulsen et al., 2016; Yi et al., 2022). It also helps alleviate symptoms of depression, anxiety, and psychological distress (Alyan et al., 2021; Cheng et al., 2021; Gascon et al., 2015).

Additionally, Mindfulness-Based Interventions (MBIs) have been widely studied over the past four decades and are consistently associated with improvements in stress reduction, emotional regulation, and overall psychological well-being (Creswell, 2017; Kabat-Zinn, 1990). Originally developed in clinical contexts, such as Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT), MBIs have since expanded to diverse populations and settings, showing efficacy not only in symptom reduction but also in promoting resilience, positive affect, and flourishing (Garland & Howard, 2018; Khoury et al., 2013). This growing body of evidence underscores the central role of mindfulness practice as a therapeutic mechanism and justifies its integration as a core component of interventions aimed at enhancing well-being.

The patient-centered approach enhances the effectiveness of nature-based therapy in promoting holistic well-being by prioritising individual needs, goals, and preferences while fostering a supportive environment (James et al., 2021). The incorporation of nature-base activities and experiences facilitates a more engaging and experiential therapeutic process, aligning with the principles of patient-centred care (James et al., 2021). These interventions contribute to personal and self-concept development, increasing individual awareness, acceptance, and optimism (McIver et al., 2018).

Research suggests that virtual nature engagement, including photos, videos, nature sounds, and virtual reality can reduce stress, and increase positive affect and psychological responses, such as skin conductance, relaxation and cardiovascular health (Annerstedt et al., 2013; Browning et al., 2020; Mattila et al., 2020; Tsutsumi et al., 2017). Virtual nature exposure has also been associated with increased relaxation and a sense of adventure (Appel et al., 2020). The application of Virtual Reality in forest therapy demonstrates considerable potential (Soutelo et al., 2024). Evidence suggests that even brief Virtual Reality forest exposure, as short as fifteen minutes, can elicit significant improvements in psychological health and well-being, with effects comparable to those experienced in actual forest environments (Vermeesch et al., 2024). Recent studies on Virtual Reality generated forest environments have reported substantial positive psychological and physiological outcomes, such as reductions in stress, anxiety and depression (Alanazi et al., 2023; Hsieh & Li, 2022). Notably, Virtual Reality has been shown to induce nearly identical psychological and physiological responses as real nature exposure (H. Li, Zhang, et al., 2021).

The utility of Virtual Reality in health interventions, particularly mental health and by occupational therapists, is expanding, with evidence supporting its efficacy as a therapeutic tool(Chen et al., 2022; Freeman et al., 2017). Virtual reality technology is especially effective in creating realistic, immersive natural

environments that reduce stress through heightened realism and presence (Alyan et al., 2021). This immersive quality enables precise delivery of therapeutic stimuli, positioning Virtual Reality as a promising alternative for individuals unable to access natural environments (Benchimol-Elkaim et al., 2024; Maples-Keller et al., 2017). As Virtual Reality technology progresses, it may serve as a safe accessible substitute for natural immersion, expanding therapeutic options to support mental health and well-being (Alanazi et al., 2023; Chan et al., 2023).

Despite growing evidence on the benefits of forest therapy using Virtual Reality, there remains a significant gap in the literature regarding their specific impact on psychiatric inpatients. Therefore, this study aims to assess the impact of a therapeutic programme of forest therapy using Virtual Reality on the well-being and quality of life of individuals in psychiatric inpatient settings.

Based on the preceding theoretical framework and existing literature, the present research postulates the following hypotheses:

H1: Participants will demonstrate an increase in subjective well-being following their engagement in the Virtual Reality-based forest therapy program.

H2: Participants will show a reduction in self-reported levels of anxiety, stress, and depressive symptoms at the end of the Virtual Reality-based forest therapy program.

H3: Participants physiological indicators of stress, specifically Heart Rate Variability (HRV) and Electrodermal Activity (EDA), will exhibit a change consistent with decreased sympathetic nervous system activation after each session of the program.

2. Materials and methods

2.1. Research design

A quasi-experimental study design without a control group was used to evaluate impact of VR-based forest therapy programme on the well-being, and quality of life of individuals in psychiatric inpatients settings. This design is commonly utilised to evaluate the effectiveness of treatments (Chiang et al., 2015). As with other quasi-experimental approaches, randomisation was not implemented in this study (Chiang et al., 2015; Cook & Campbell, 1979), with participants being purposively assigned to the intervention group based on predefined inclusion and exclusion criteria.

2.2. Participants

This study employed a non-probability convenience sample, with participants selected based on predefined inclusion and exclusion criteria. Recruitment was limited to individuals who were available and clinically stabilised during the data collection period. This approach was chosen due to the specific characteristics of the target group, which included individuals already undergoing psychiatric treatment and receiving occupational therapy (OT). The psychiatric service where the sample was collected is characterised predominantly by a population of psychotic patients.

Participants were included if they were adult psychiatric inpatients who had been referred for OT and meets the conditions to sign the informed consent. Participants were excluded they had history of seizures; vision and hearing deficits not rectified by supporting technologies; motor deficits that make it difficult or impossible for them to use the Virtual Reality equipment; cognitive deficits and/or lack of proficiency in Portuguese; been involuntarily or compulsorily hospitalised; or were adults under assisted decision making, law 49/2018, August 14, as published in the Diário da República.

2.3. Data collection

2.3.1. Instruments

2.3.1.1. Demographic questionnaire. Demographic information was collected using a short research-designed questionnaire that included questions about age, gender, marital status, level of education, professional status, diagnosis, visual and upper limb difficulties, admission initiave, seizure episodes,

prior virtual reality experiences, household arrangement and legal framework of the 'Maior Acompanhado' law 49/2018.

2.3.1.2. Portuguese version of the simulator sickness questionnaire (SSQ). Cybersickness refers to unpleasant symptoms experienced during or after a virtual reality session, including nausea, eye strain, and a sense of disorientation (LaViola, 2000). A crucial aspect of advancing virtual reality technology is the standardised identification and measurement of cybersickness symptoms, along with the understanding the factors contributing to them (Gonçalves et al., 2024). This approach helps to ensure user well-being and minimises the likelihood of users abandoning virtual environments (Gonçalves et al., 2024).

The SSQ is a self-report questionnaire designed to evaluate overall cybersickness through sixteen items, focusing on nausea, oculomotor discomfort, disorientation, and general symptoms (Gonçalves et al., 2024). The SSQ evaluates symptoms using a scale of four levels: 'absent', 'mild', 'moderate' and 'severe', which are converted to 0, 1, 2 and 3 respectively (Gonçalves et al., 2024). The values from each subscale are summed and applied to a conversion formula to calculate the final score for each subscale. The total severity score is determined by adding the pre-conversion subscale values and applying them to a specific formula, which provides the overall result for the scale. Higher score indicate a more severe experience of cybersickness symptoms (Gonçalves et al., 2024).

2.3.1.3. Portuguese version of the Igroup presence questionnaire (IPQ). Presence is a multifaceted construct encompassing multiple levels and dimensions (Biocca & Delaney, 1995) and has been assessed through various questionnaires. To quantify this construct, numerous concepts have been proposed, including spatial presence, realism, involvement, self-location, cognitive involvement, naturalness, social actor within the medium, passive social presence, active social presence, engagement, social richness, social realism, and perceptual realism, among others (Vasconcelos-Raposo et al., 2016).

One such instrument is the IPQ, a self-report questionnaire initially developed by (Schubert et al., 2001). In its original version, it was designed to assess the following variables: spatial presence (SP1, SP2, SP3, SP4, and SP5), involvement (INV1, INV2, INV3, and INV4), realism (REAL1, REAL2, REAL3, and REAL4), and overall presence (G1). All items were presented using a five-point Likert scale with varying anchor points (Vasconcelos-Raposo et al., 2016).

2.3.1.4. Portuguese version of the depression, anxiety and stress scale (DASS-21). The DASS-21 (Lovibond et al., 1995) is a set of three self-report subscales based on a 4-point Likert scale. Each subscale consists of seven items designed to assess the emotional states of depression, anxiety, and stress. Participants are asked to indicate the extent to which each statement applied to them over the past week. Responses are rated on a severity or frequency scale ranging from 0 to 3 points, with the final score obtained by summing the responses for the items within each subscale (Apóstolo et al., 2006; Lovibond et al., 1995).

The depression subscale assesses symptoms such as inertia, anhedonia, dysphoria, lack of interest or engagement, self-deprecation, devaluation of life, and hopelessness. The anxiety subscale evaluates autonomic nervous system arousal, musculoskeletal effects, situational anxiety, and subjective experiences of anxiety. Finally, the stress subscale measures difficulty relaxing, nervous arousal, ease of disturbance or agitation, irritability or overreaction, and impatience (Apóstolo et al., 2006; Lovibond et al., 1995). Additionally, the Portuguese version shows Cronbach's alpha values of 0.90 for depression, 0.86 for anxiety, 0.88 for stress and 0.95 for the overall scale (Apóstolo et al., 2006). In the original version, DASS-21 show Cronbach´s alpha values of 0.88 for depression, 0,83 for anxiety, 0,85 for stress and 0.89 for the overall scale (Osman et al., 2012). The DASS-21 shows good psychometric validity and reliability (Taber, 2018).

2.3.1.5. Portuguese version of the World Health Organisation well-being index (WHO-5). The WHO-5 (World Health Organization, 2024) is a self-reported instrument designed to assess mental well-being. It comprises five statements reflecting experiences over the past two weeks, each rated on a 6-point scale, where higher scores indicate greater mental well-being (World Health Organization, 2024). WHO-5 shows a Cronbach's alpha value of 0.80 (Carvalho et al., 2025), which shows good psychometric validity and reliability (Taber, 2018).

2.3.2. Technologies

2.3.2.1. VR set. The Oculus Quest Pro is a next-generation virtual and mixed reality headset developed by Meta, designed to deliver advanced immersion through enhanced sensors, precise tracking, and high-resolution displays, and is increasingly utilised in scientific, educational and professional applications (Meta, 2024).

2.3.2.2. Polar H10 sensor. The Polar H10 Heart Rate Sensor is a heart rate (HR) monitor designed to provide accurate and reliable measurements (Polar, 2017).

2.3.2.3. Plux Biosignals electrodermal activity sensor (EDA). The Plux Biosignals EDA sensor (Plux Biosignals, 2021) accurately measures the electrical properties of the skin, which fluctuate due to changes in sweat secretion and sweat gland activity, resulting from variations in sympathetic nervous system activity. The low-noise signal conditioning and amplification circuitry ensure optimal performance, enabling the detection of even the slightest electrodermal skin response events (Plux Biosignals, 2021).

2.3.3. Procedure

Before the program began, the research team obtained approval from the Ethics Committee São João Local Health Unit (CE-82-25) and met with the inpatient psychiatric team, including the Medical Director, Head Nurse and Occupational Therapist, to present the project. The sample included psychiatric inpatients referred to OT, and participants were selected by the unit Occupational Therapist. After recruitment, they completed a demographic questionnaire covering basic information and inclusion/exclusion criteria.

The programme started with an experimentation session (Session 0) at the Inpatient Unit of the Psychiatric Service of the São João Local Health Unit, where all the sessions would occur, the researcher provided an overview of the programme, VR set and virtual environment (developed by the LabRP research team) (Figure 1) that participants would later experience. During Session 0, participants were asked to sign a consent form, according to the ethical principles outlined in the Helsinki Declaration, a demographic questionnaire and the SSQ.

Before the start of each session, the room in which the intervention would take place, was prepared for the virtual forest immersion, equipment ready to use and temperature set. Before starting the immersion, the Polar H10 sensor and the Plux Biosignals EDA sensor were calibrated and fitted to the participant.

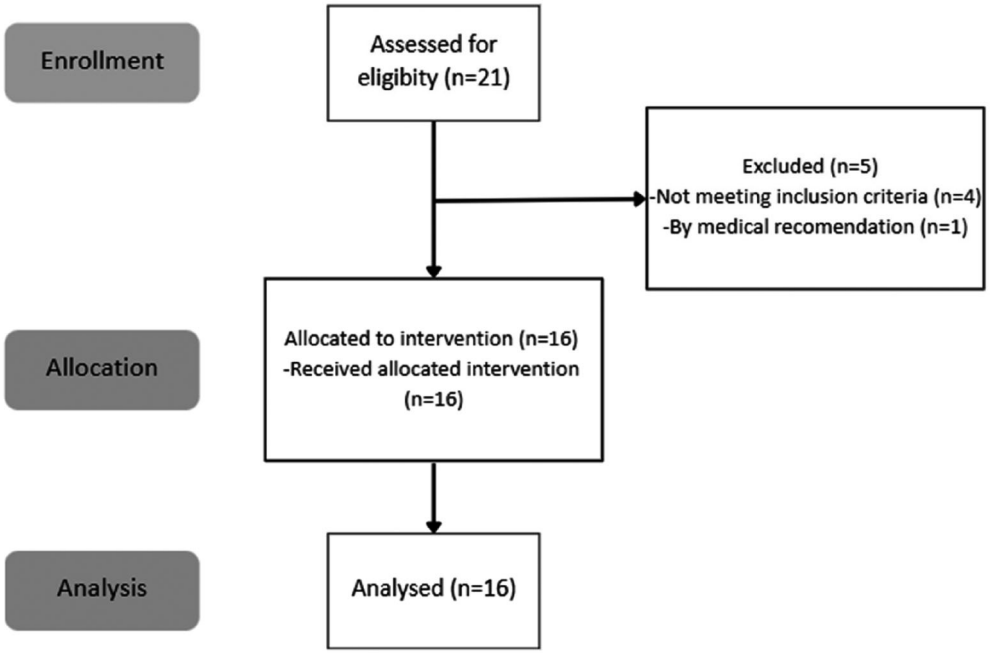


Figure 1. Flow diagram of the sample recruitment.

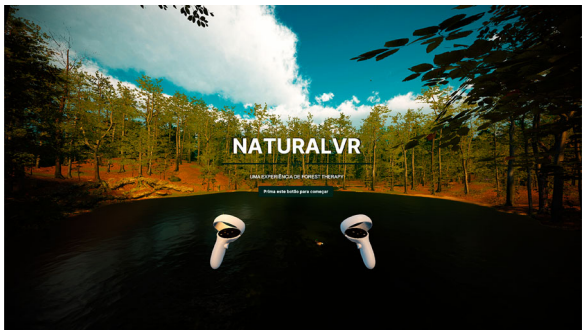


Figure 2. Virtual environment home screen.

The program consisted of four sessions over one week, alternating between two virtual forest environments (Figures 2 and 3). Each session followed a similar three-stage format: pre-exposure, VR immersion, and post-exposure. Session 1 began with completing DASS-21 and WHO-5 questionnaires (see Table 1) and Sessions 2, 3 and 4 with a brief discussion of plan and expectations.

Two distinct virtual forest environments were developed using Unity software, featuring high-resolution 3D modelling and spatialised natural sounds (birdsong, water streams, wind through leaves). Both environments were designed to be non-interactive, with a slow-paced virtual 'walk' along forest paths. Scenarios utilised the same vegetation type, dense temperate woodland, and visual layout but were matched in exposure duration and soundscape composition. All participants experienced both scenarios in alternating sessions; the order was fixed and standardised. A consistent three drops per session lavender essential oil diffusion was used to stimulate olfactory input. Mindfulness segments followed a standardised audio script recorded by a therapist familiar to participants, containing nature-themed guidance, breathing instructions, and sensory anchoring prompts. During mindfulness, participants kept their eyes open to maintain visual immersion. The full script and scenario descriptions are included in Appendix 1 for replication.

During VR immersion, participants took a slow, mindful virtual walk through the forest (3–4 min), guided to observe natural elements and senses. This was followed by a relaxation and sensory meditation exercise (8–10 min), aimed to fostering calmness, presence, and sensory awareness. The sessions ended

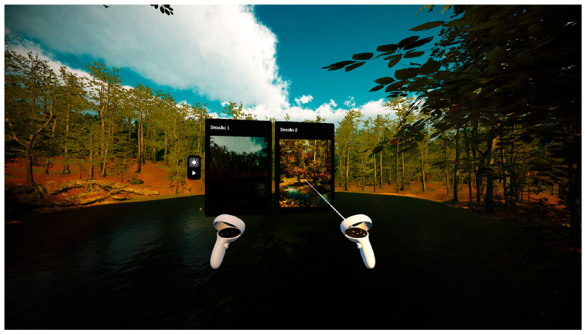


Figure 3. Two options of forest therapy sessions.

Table 1. Timeline for instrument administration.

	S1	S2	S3	S4
DASS-21[a]	X			X
WHO-5[b]	X			X
IPQ[c]	X			X
SSQ[d]	X	X	X	X

[a]Depression, Anxiety and Stress Scale.
[b]World Health Organization Well-Being Index.
[c]Igroup Presence Questionnaire.
[d]Simulator Sickness Questionnaire.

with a virtual walk (Session 1 and 3) or self reflection (Session 2 and 4) (5 min), during which participants were encouraged to identify sensory details, share positive memories, or mentally capture a calming 'nature image'. During the VR immersion, lavender essential oil was diffused in the room to stimulate the sense of smell and enhance the overall immersive experience. At the end of each session, a brief discussion took place and the SSQ questionnaire was completed (see Table 1). Additionally, at the end of Session 1, the IPQ questionnaire was completed (see Table 1). Furthermore, at the end of session 4, participants completed the IPQ, DASS-21 and WHO-5 questionnaires (see Table 1).

2.4. Data analysis and processing

2.4.1. Data analysis

The sample was characterised using descriptive statistical methods. Quantitative variables were summarised through measure of central tendency mean (x) and median (M) and measures of dispersion (standard deviation (SD) and interquartile range (IQR)). Qualitative variables were described using absolute (N) and relative (%) frequencies. A significance level of $\alpha = 0.05$ and 95% confidence interval were adopted for all statistical procedures performed (Marôco, 2018).

The normality of the variables was assessed by the Shapiro–Wilk test. The parametric paired-samples t-test was applied to study the differences in scores for depression, anxiety, stress (DASS-21) and presence (IPQ). Differences in well-being scores (WHO-5) were analyzed using the non-parametric Wilcoxon test. To evaluate the differences in cybersickness scores (SSQ) across sessions, the non-parametric Friedman test was employed. Differences between physiological data of the start and end of each session were analyzed using either the parametric paired-samples *t*-test or the non-parametric Wilcoxon test, depending on the normality of the data distribution. To analyze the physiological data statistically, data processing was required.

2.4.2. EDA data processing

Electrodermal activity (EDA) data were processed using a fully automated Python 3.11.9 pipeline with libraries including pandas, numpy, scipy, and NeuroKit2. Signals were recorded at 1000 Hz using the BiosignalsPlux system and stored as 16-bit digital values. The first and last two minutes of each recording were excluded to remove artifacts related to participant adjustment and movement.

Digital values were converted to skin conductance (μS) via the manufacturer's transfer function and filtered with a 4th-order Butterworth low-pass filter at 5 Hz to eliminate noise, preserving relevant physiological components below 3 Hz. Data were downsampled to 20 Hz, balancing data size reduction with physiological fidelity. Each signal was segmented into two 3-minute blocks – Start and End – enabling intra-session comparisons. Using NeuroKit2's eda_process(), signals were decomposed into tonic (skin conductance level, SCL) and phasic components (skin conductance responses, SCRs). Due to the relaxation protocol, phasic SCRs were mostly absent, so analyses focused on tonic SCL as a marker of sympathetic nervous system activity. Mean SCL values from each block across sessions were used to assess intra-session and intervention-related changes in autonomic arousal. Processed data were exported in Excel format for further analysis.

2.4.3. HRV data processing

Heart rate (HR) data were processed using a fully automated Python 3.11.9 pipeline with libraries such as pandas, numpy, and openpyxl. Raw HR data were recorded via the Polar H10 system at 1 Hz and exported as Excel files. The first and last two minutes of each recording were excluded to avoid artifacts from participant movement and stabilisation.

HR values outside the physiological range of 30 to 220 bpm were filtered out to remove artifacts. Heart rate values were converted into RR intervals (ms) using the formula $RR = 60{,}000 / HR\ (bpm)$ to enable heart rate variability (HRV) analysis. An adaptive artifact filter excluded RR intervals with changes exceeding 20% between consecutive beats. After preprocessing, time-domain HRV metrics were computed, including RR count, mean HR, RMSSD (reflecting parasympathetic activity), SDNN (overall variability), and pNN50 (parasympathetic modulation). Processed data were exported in Excel format for further analysis.

3. Results

The sample was predominantly male (62.5%), aged between 18 and 25 years (31.3%), and single (68.8%)(see Table 2). Most participants had completed high school education (62.5%) and were psychiatric diagnosed primarily with psychotic disorders (62.5%)(see Table 2).

3.1. Depression scale analysis

A comparison of the depression scores before and after the intervention revealed a notable reduction in symptom severity (see Table 3). At the first assessment (Session 1), participants presented a median score of 13 (IQR = 13), with scores ranging from 0 to 21, indicating a moderate to severe depressive symptoms in some cases. At the post-intervention assessment (Session 4), the median score decreased to 5.50 (IQR = 4), with values ranging from 0 to 13, reflecting a general reduction in depressive symptoms, mostly within the mild and normal range.

The paired-samples t-test confirmed that the reduction in the depression scores between the two sessions was statistically significant ($p < .001$).

3.2. Anxiety scale analysis

Anxiety levels demonstrated an improvement from pre to post-intervention (see Table 4). At Session 1, the median anxiety score was 9.50 (IQR = 11), with the individual scores ranging from 0 to 20, suggesting moderate anxiety symptoms in the group. By Session 4, scores had significantly decreased, with a median of 1.00 (IQR = 2), and a maximum value of only 5, indicating that all participants reported normal anxiety levels.

The paired-samples t-test revealed a statically significant reduction in anxiety scores between the two assessments ($p < .001$).

Table 2. Sociodemographic characterisation of the sample.

Variable	*n* (%)
Gender	
Male	10 (62.5%)
Female	6 (37.5%)
Age	
18–25	5 (31.3%)
26–35	4 (25.0%)
36–49	3 (18.8%)
50 or older/to 69	4(25.0%)
Marital Status	
Single	11 (68.8%)
Married	3 (18.8%)
Divorced	2 (12.5%)
Level of education	
4th degree	1 (6.3%)
6th degree	3 (18.8%)
High School	10 (62.5%)
Higher Education	2 (12.5%)
Psychiatric diagnosis	
Psychotic Disorder	10 (62.5%)
Personality Disorder	3 (18.8%)
Mood Disorder	1 (6.3%)
Eating Disorder	1 (6.3%)
Suicidal Ideation	1 (6.3%)

Table 3. Pre-intervention and post-intervention depression scale scores comparison.

Moment of assessment	M ± IQP	$\underline{x}$ ± SD	95% CI LB UB	Min	Max	*p*-value[a]
Session 1	13.00 (±13)	12.31 (±7.16)	8.52 16.10	0	21	.603[a] < .001[b]
Session 4	5.50 (±4)	5.19 (±3.31)	3.41 6.96	0	13	

[a]Shapiro-Wilk test.
[b]Paired Samples *t*-test.

Table 4. Pre-intervention and post-intervention anxiety scale scores comparison.

Moment of assessment	M ± IQR	x̲ ± SD	95%CI LB UB	Min	Max	*p*-Value[a]
Session 1	9.50 (±11)	9.13 (±6.10)	5.88 12.37	0	20	.291[a] < .001[b]
Session 4	1.00 (±2)	1.56(±1.90)	.55 2.57	0	5	

[a]Shapiro-Wilk test.
[b]Paired Samples *t*-test.

3.3. Stress scale analysis

Stress levels also declined considerably following the intervention (see Table 5). In the initial session (Session 1), participants presented a median stress score of 12.50 (IQR = 10), with scores ranging from 4 to 21, indicating a moderate to high stress levels in several participants. At the final session (Session 4), the median score reduced to 5.00 (IQR = 2), with the minimum and maximum values of 1 and 11, suggesting a consistent decrease in perceived stress across the sample.

Through the application of the paired-samples t-test, the reduction observed was statistically significant ($p < .001$).

3.4. WHO-5 scale analysis

Participants well-being scores improved substantially between pre and post-intervention assessments (see Table 6). In Session 1, the median score on the WHO-5 scale was 11.50 (IQR = 10), with scores ranging from 3 to 21, indicating a reduced psychological well-being at baseline. By Session 4, the median score had increased to 20.00 (IQR = 13), with a narrower score range from 14 to 23, reflecting a notable enhancement in participants perceived well-being.

Due to non-normal distribution of the data, confirmed by the Shapiro–Wilk test ($p = 0.009$), the non parametric Wilcoxon signed-rank test was applied. The increased in scores was statistically significant ($p < .001$).

3.5. SSQ scale analysis

Simulator sickness scores were assessed across all four sessions, showing significant variations over time (see Table 7). At Session 1, the median score was 0.00 (IQR = 6.55), with a minimum of 0 and a maximum of 26.18, indicating minimal symptoms initially. In Session 2, scores increased to a median of 7.48 (IQR = 14.03), with a maximum of 48.62, reflecting a rise in simulator sickness symptoms.

The median score further increased to 9.35 (IQR = 18.70) in Session 3, although this change was not statistically significant compared to Session 2 ($p = .103$). By Session 4, the median score decreased to 3.74 (IQR = 14.96), with a maximum of 52.36. Overall, the Friedman test indicated differences across sessions ($p = .006$).

3.6. IPQ scale analysis

Participants reported consistent levels of perceived presence across the sessions (see Table 8). After Session 1, the median presence score was 3.22 (IQR = 0.90), with values ranging from 1.78 to 4.50. Following Session

Table 5. Pre-intervention and post-intervention stress scale scores comparison.

Moment of assessment	M ± IQR	x̲ ± SD	95%CI LB UB	Min	Max	*p*-value[a]
Session 1	12.50 (±10)	12.44(±5.30)	9.61 15.26	4	21	.833[a] < .001[b]
Session 4	5.00 (±2.00)	4.88(±2.47)	3.56 6.19	1	11	

[a]Shapiro-Wilk test.
[b]Paired Samples *t*-test.

Table 6. Pre-intervention and post-intervention well-being scale (WHO-5) scores comparison.

Moment of assessment	M ± IQR	x̲ ± SD	95%CI LB UB	Min	Max	*p*-value[a]
Session 1	11.50 (±10)	12.13 (±5.57)	9.16 15.09	3	21	.009[a] < .001[b]
Session 4	20.00 (±3)	19.38 (±2.31)	18.15 20.60	14	23	

[a]Shapiro-Wilk test.
[b]Wilcoxon test.

Table 7. Simulator sickness scores at each of the four measurements and the comparison between them.

Moment of assessment	M ± IQR	Minimum	Maximum	*p*-value[a]
Session 1	0.00 (±6.55)	0.00	26.18	<.001[a]
Session 2	7.48 (±14.03)	0.00	48.62	.002[a]
				.006[b]
Session 3	9.35 (±18.70)	0.00	29.2	.103[a]
Session 4	3.74 (±14.96)	0.00	52.36	<.001[a]

[a]Shapiro-Wilk test.
[b]Friedman test.

Table 8. Post-session 1 and post- session 4 presence (IPQ) scores and the comparison between them.

Moment of assessment	M ± IQR	Minimum	Maximum	*p*-value[a]
Session 1	3.22 (±0.90)	1.78	4.50	..386[a] < .319[b]
Session 4	3.46 (±1.47)	2.33	4.75	

[a]Shapiro-Wilk test.
[b]Paired-samples *t*-test.

4, the median score slightly increased to 3.46 (IQR = 1.47), with a range from 2.33 to 4.75. The paired-samples t-test revealed no statistically significant difference between sessions ($p = .319$).

3.7. HRV data analysis

RMSSD values, a key indicator of short-term parasympathetic activity and autonomic relaxation, showed no statistically significant differences between the beginning and end of any session (Session 1: $p = .796$; Session 2: $p = .918$; Session 3: $p = .535$; Session 4: $p = .094$), despite some individual variability (see Table 9). For instance, Session 1, median RMSSD rose slightly from 5.55 ms (IQR = 2.28) to 5.80 ms (IQR = 1.59), while other sessions showed similar minor fluctuations without consistent trends.

SDNN values, which reflect overall heart rate variability and are influence by both sympathetic and parasympathetic activity, showed no statistically significant differences between the star and end of any session (all $p > .30$), despite small numerical fluctuations across the sessions (see Table 10). For example, in Session 1, SDNN increased slightly from 19.44 ms (IQR = 14.51) to 21.05 ms (IQR = 5.30), whereas in Session 4 a small decrease was observed from 18.68 ms to 17.00 ms, without reaching statistical significance.

Table 9. RMSSD measurements at the start and end of each session and the comparison between them.

	Start S1	End S1	Start S2	End S2	Start S3	End S3	Start S4	End S4
M ± IQR	5.55 (±2.28)	5.80 (±1.59)	6.61 (±3.96)	6.16 (±4.18)	6.45 (±5.45)	6.49 (±3.96)	5.70 (±2.14)	5.25 (±2.39)
Minimum	2.34	2.74	3.08	2.97	2.76	2.48	2.78	3.16
Maximum	10.08	10.59	10.62	15.09	17.54	10.62	10.48	12.48
p-value[a]	.003[a]		.026[a]		<.001[a]		.372[a]	
	.796[b]		.918[b]		.535[b]		.894[c]	

[a]Shapiro-Wilk test.
[b]Wilcoxon test.
[c]Paired samples *t*-test.

Table 10. SDNN measurements at the start and end of each session and the comparison between them.

	Start S1	End S1	Start S2	End S2	Start S3	End S3	Start S4	End S4
M ± IQR	19.44 (±14,51)	21.05 (±5.30)	27.81 (±20.88)	20.08 (±18.92)	18.99 (±14.25)	21.17 (±12.30)	18.68 (±15.72)	17.00 (±12.67)
Minimum	5.24	7.75	10.02	11.66	7.95	6.90	8.71	11.35
Maximum	36.50	34.28	48.90	45.28	39.03	30.02	46.70	44.62
p-value[a]	.003[a]		.026[a]		<.001[a]		.372[a]	
	.796[b]		.918[b]		.535[b]		.894[c]	

[a]Shapiro-Wilk test.
[b]Wilcoxon test.
[c]Paired Samples *t*-test.

Table 11. pNN50 measurements at the start and end of each session and the comparison between them.

	Start S1	End S1	Start S2	End S2	Start S3	End S3	Start S4	End S4
M ± IQR	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.56)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	1.11	0.56	0.56	2.78	2.22	0.56	0.00	0.00
p-value[a]	<.001[a]		<.001[a]		<.001[a]		.000[a]	
	1.000[b]		.655[b]		.655[b]		.102[b]	

[a]Shapiro-Wilk test.
[b]Wilcoxon test.
[c]Paired samples *t*-test.

Table 12. Mean HR measurements at the start and end of each session and the comparison between them.

	Start S1	End S1	Start S2	End S2	Start S3	End S3	Start S4	End S4
M ± IQR	88.69 (±14.47)	86.34 (±14.00)	82.69 (±11.97)	82.63 (±11.11)	91.22 (±11.08)	87.81 (±10.62)	88.11 (±10.89)	87.13 (±11.11)
Minimum	63.99	64.00	64.31	65.55	70.90	73.07	69.29	70.63
Maximum	114.19	115.31	107.56	107.28	110.87	108.82	113.49	117.93
p-value[a]	.128[a]		.524[a]		.458[a]		.979[a]	
	.038[b]		.909[b]		.011[b]		.289[b]	

[a]Shapiro-Wilk test.
[b]Paired Samples *t*-test.

Table 13. SCL measurements at the start and end of each session and the comparison between them.

	Start S1	End S1	Start S2	End S2	Start S3	End S3	Start S4	End S4
M ± IQR	4.89 (±6.85)	4.02 (±6.39)	4.04 (±5.10)	3,42 (±7.69)	3.69 (±6.72)	3.27 (±8.33)	3.08 (±3.75)	1.99 (±3.56)
Minimum	0.19	0.17	0.37	0.31	0.41	0.33	0.43	0.38
Maximum	12.04	12.40	13.88	13.85	11.12	11.99	8.58	6.26
p-value[a]	.216[a]		.590[a]		.197[a]		.163[a]	
	.883[b]		.814[b]		.976[b]		.244[b]	

[a]Shapiro-Wilk test.
[b]Paired Samples *t*-test.

Table 14. SCR peaks measurement at the start and end of each session and the comparison between them.

	Start S1	End S1	Start S2	End S2	Start S3	End S3	Start S4	End S4
SCR	0	0	0	0	0	0	0	0

pNN50 values, an index of parasympathetic activity representing the percentage of consecutive heartbeats differing by more than 50 ms, remained consistently close to zero across all sessions, both at the beginning and end (see Table 11). No statistically significant differences were observed between timepoint in any session (all $p > .10$), despite minor individual fluctuations.

HR measurements showed a general trend toward reduction from the start to the end of sessions, which may suggest a physiological shift relaxation during the intervention (see Table 12). Statistically significant decreases in HR were observed in Session 1 ($p = .038$) and 3 ($p = .011$), indicating acute reductions in cardiac activation. In Sessions 2 and 4, although no significant changes were found ($p > .28$), the HR remained stable.

3.8. EDA data analysis

SCL, and indicator of tonic sympathetic arousal, showed slight intra-session decreases across all sessions (see Table 13). However, none of these differences reached statistical significance (all $p > .24$).

Throughout all four sessions, no phasic SCR were detected at either the start or end of the recordings (see Table 14). All SCR peak counts remained consistently at zero across sessions.

4. Discussion

This study aimed to assess the impact of a virtual reality based forest therapy programme on the mental well-being, depressive symptoms, anxiety, stress and physiological indicators of psychiatric inpatients.

The main findings indicate that the intervention was associated with statistically significant reductions in depression, anxiety and stress levels, as well as notable perceived well-being. Additionally, physiological indicators such as HRV and EDA showed trends compatible with relaxation or autonomic stability, though most of these changes were not statistically significant. It is important to emphasise that these improvements should be interpreted within the specific context of psychiatric inpatient care. The recruitment strategy targeted inpatients who were clinically stable and actively receiving OT, which ensured safety and feasibility for VR immersion but may also have shaped the observed outcomes. Our cohort's diagnostic profile was skewed toward psychotic disorders (62.5%), with fewer cases of mood or personality disorders. This diagnostic distribution, along with clinical stability at the time of participation, means the findings are most directly applicable to similar inpatient subgroups rather than the broader psychiatric inpatient population. In addition, although baseline psychological measures were collected, variables such as length of stay at enrollment and detailed symptom acuity scores were not systematically recorded, limiting our ability to explore how these factors might have influenced responsiveness. The rapid improvements observed may also reflect the combined effects of the unit overall intervention plan, including pharmacological treatment and non-pharmacological therapies (Kern et al., 2009; Valencia et al., 2013).

As anticipated theoretically, depression, anxiety, and stress levels decreased from the pre to post- intervention assessments. These findings align with the positive effects commonly reported in Forest Therapy practice (Lee et al., 2017; Song et al., 2016; Yeon et al., 2021), and further support the benefits of virtual nature (Alanazi et al., 2023; Alyan et al., 2021; Chan et al., 2023; Hsieh & Li, 2022; Reese, Stahlberg, et al., 2022; Wang et al., 2019).

The significant reductions in DASS-21 scores reflect improvements in emotional distress, while in WHO-5 well-being score suggest a broader effect on subjective psychological quality of life. These results are consistent with findings from Browning et al. (2023), who demonstrated that repeated VR nature exposure led to significant reductions in anxiety in university students, and Li, Dong, et al. (2021), who found that virtual restorative environments improved emotional and cognitive functioning in individual with anxiety and depression.

Similarly, Chan et al. (2023) observed that both young adults and older adults experienced improved mood and reduced stress after VR nature exposure, reinforcing the idea that such interventions can support and induce general well-being. These outcomes align with the World Health Organization definition of mental health, in which emotional balance, coping, and positive affect are essential aspects of health (World Health Organization, 2021).

The affective improvements are consistent with the principles of the Stress Reduction Theory (SRT), which posits that exposure to natural environments facilitates psychophysiological recovery from stress by evoking positive affective responses and reducing sympathetic nervous system activation (Ulrich et al., 1991). The immersive VR nature experience likely triggered similar restorative processes, promoting calmness and emotional relief even in a controlled clinical context.

Additionally, results align with the Attention Restoration Theory (ART) (Kaplan, 1995), which suggests that natural environments replenish depleted cognitive resources by providing a setting that demands effortless attention or 'soft fascination', the sense of 'being away', the sense of extent and compatibility. Also, the Biophilia hypothesis (Wilson, 1984) posits that humans have an innate affinity for nature, and this connection has been shown to support mental health by reducing stress, enhancing emotional well-being, and promoting cognitive restoration. Even in simulated form, nature exposure through VR appears to activate psychological mechanisms of recovery and emotional recalibration, as supported by Bratman et al. (2015) and Mattila et al. (2020). The VR forest environment may have facilitated cognitive restoration, thereby improving subjective well-being as measure by the WHO-5. These theories collectively explain how immersive natural exposure can support both affective and cognitive pathways to enhance mental health in psychiatric patients. Although participants were not formally asked whether they value or regularly seek out natural environments outside of hospitalisation, it is noteworthy that spending time in the hospital garden is among the most appreciated activities by inpatients, yet the garden at São João Local Health Unit was temporarily closed during the intervention period.

While VR forest therapy provides a valuable alternative in contexts where access to outdoor nature is restricted, it cannot fully replicate the embodied and multisensory qualities of real-world nature-based interventions. In particular, the lack of physical interaction, natural movement, fresh air, tactile sensory

input, and exposure to bioactive compounds such as phytoncides distinguishes VR from traditional forest therapy. Phytoncides, volatile organic compounds emitted by trees, have been shown to reduce pro-inflammatory cytokines, lower cortisol, activate natural killer cells, and even increase anticancer protein expression, with effects persisting for at least a week (Chen et al., 2025; Lew & Fleming, 2024; Li, 2023; Park et al., 2021). Their absence in VR-based interventions suggests that digital nature may only partially reproduce the restorative and immunological mechanisms of real-world exposure, as emphasised in theories such as Biophilia, ART and SRT.

Though not uniformly significant, physiological data support the interpretation of autonomic stability and relaxation. In particular, HR decreased significantly in Sessions 1 and 3, mirroring findings by Blum et al. (2019) and Liszio et al. (2018), who reported VR nature induced reductions in HR and increased HRV as indicators of parasympathetic activation. On the other hand, no decrease was observed in Sessions 2 and 4, which may be explained by differences in session structure and immersion duration affecting the magnitude of autonomic changes.

Measures of HRV such as RMSSD and SDNN remained generally stable. While this could be interpreted as a lack of change, it may alternatively suggest the maintenance of a calm physiological state throughout the sessions, which is a desirable outcome in clinical population. Knaust et al. (2021) similarly noted that stable HRV in immersive VR conditions could reflect a sustained parasympathetic state, particularly in low-stimulation environments designed for restoration.

SCL values showed a consistent downward trend, and the absence of SCR peaks across sessions suggests that the intervention did not elicit acute sympathetic responses. These findings are consistent with Annerstedt et al. (2013) and Reese, Mehner, et al. (2022), who found that VR nature environments support physiological stress recovery without inducing arousal.

Although HRV and EDA did not reach statistical significance, whereas psychological outcomes showed clear improvement, this divergence is supported by prior research. Meta-analytic data indicate that stress management interventions produce only small short-term effects on vagally mediated HRV (Gathright et al., 2024). Moreover, experimental work has shown measurable psychological benefits following HRV biofeedback, such as improved working memory and affective states, without concurrent physiological changes in vagal tone (Bahameish & Stockman, 2024). Pilot studies with healthcare professionals likewise reported significant improvements in psychometric measures, accompanied by only non-significant trends in HRV and EDA (Castro Ribeiro et al., 2023). In addition, a recent systematic review of VR-based breathing interventions concluded that evidence for HRV outcomes remains of very low quality due to small samples, methodological heterogeneity, and reliance on surrogate endpoints (Cortez-Vázquez et al., 2024). Taken together, these findings suggest that the absence of significant physiological effects in our study should be interpreted cautiously and does not contradict the observed psychological benefits.

An important observation in this study is the parallel between improvements in psychological outcomes and the physiological trends. The parallel between physiological relaxation and overall reductions in psychological distress may suggest a broader pattern of psychophysiological coherence, whereby emotional and bodily states shift together toward relaxation. Such pattern is well described in the literature on stress recovery and biofeedback (Blum et al., 2019; Thayer et al., 2009).

Similarly, the rise in WHO-5 scores may not only reflect emotional recovery but could also indicate a regulatory capacity at the physiological level. Even though HRV measures did not show strong statistical changes, their stability over time suggests that the participations were not experiencing dysregulation, an encouraging sign in inpatient population where autonomic instability is a common (Lin et al., 2019). The convergence of emotional relief and physiological calm reinforces the evolving view that effective mental health interventions must address both mind and body. In this sense, immersive VR can be considered a multimodal intervention, capable of triggering coordinated psychological and physiological effects.

Satisfaction with the VR environment may have played a role in facilitating engagement and enhancing therapeutic outcomes. Satisfaction and perceived realism are important, as the user perception of space and presence can influence emotional recovery and therapeutic engagement (Alyan et al., 2021; Chen et al., 2023). In designing the forest environment, commonly preferred features were incorporated, such as natural elements that evoke privacy and safety, supporting both immersion and psychological comfort (Chen et al., 2023). The high fidelity offered by VR technology enhances this effect, simulating real-world environments in a way that maximises therapeutic potential (Chan et al., 2023; Maples-Keller et al., 2017).

Additionally, a notable aspect of this intervention was the use of a therapist virtual voice that was familiar to participants and pre-recorded to guide the Forest Therapy sessions. The presence of a familiar voice have had a positive impact by enhancing fellings like safety, comfort and trust within the VR environment. Familiar auditory cues can contribute to emotional regulation and engagement, potentially strengthening the therapeutic effect beyond the immersive virtual experience alone (Rus-Calafell et al., 2020). These factors likely contributed to the post-interventions benefits observed in the programme and may have reinforced autonomic stability.

The consistently high presence scores suggest that participants were emotionally and cognitively engaged with the VR environment. Presence has been shown to enhance the therapeutic potential of virtual interventions (Chirico & Gaggioli, 2019), and its stability in this study likely contributed to the observed outcomes (Vasconcelos-Raposo et al., 2016). Recent evidence further indicates that Presence mediates the restorative effects of VR compared to non-immersive settings (Clemente et al., 2025). In addition, the multidimensional framework proposed by Coelho et al. (2006), which distinguishes between media presence and inner presence, provides a useful lens for interpreting how participants engaged with the intervention. Additionally, the low levels of cybersickness observed in this study, together with the progressive reduction of symptoms across sessions, reinforce the overall feasibility of the intervention (Gonçalves et al., 2024). This habituation pattern has been previously reported in both psychiatric and physically impaired populations (Lakhani et al., 2020; Mostajeran et al., 2021) and suggests that repeated exposure does not lead to symptom accumulation over time. Importantly, no adverse physiological or psychological effects were detected, indicating that the VR component can be safely incorporated into routine psychiatric care. This is of particular relevance for long-term interventions, where sustained adherence is essential, and in clinical settings with limited access to real outdoor environments.

Our findings also resonate with recent systematic reviews of VR-based and traditional forest therapy. A systematic review of VR forest therapy in older adults (Clemente et al., 2024) demonstrated consistent improvements in psychological well-being, suggesting that immersive digital nature can provide benefits across different populations. While that review focused on elderly participants, the present study extends these observations to a psychiatric inpatient setting, underscoring the broader applicability of VR nature-based interventions across clinical groups. More broadly, a systematic review by Rajoo et al. (2020) documented both psychological and physiological benefits of real-world forest therapy, supporting the interpretation that the positive effects observed in VR-based interventions may rely on similar restorative mechanisms.

Furthermore, the structure of the intervention, five consecutive sessions over five days, was intentionally designed to match the typical duration of psychiatric inpatient stays. Given the need of patient stabilisation, this format allowed the intervention to be delivered during a key therapeutic window when patients are more receptive to engagement. Each sessions lasted between 17 and 18 min of immersion, a duration considered optimal to this population, long enough to elicit therapeutic effects while remaining tolerable and preventing cognitive or sensory overload. Based on the outcomes observed, we suggest that this condensed and consecutive format may be particularly well-suited for inpatient psychiatric care.

The evidence from this study contributes to a broader understanding of how immersive, therapeutic VR interventions can influence mental health outcomes through both symptom relief and well-being enhancement, especially in inpatient settings. Previous research has shown that reductions in depression, anxiety, and stress are often followed by subjective well-being, suggesting a cascading effect across emotional domains (Bomyea et al., 2015; Reese, Stahlberg, et al., 2022; Vermeesch et al., 2024; Zeng et al., 2020). The present findings reinforce this pattern, highlighting how targeted psychological intervention within virtual environment can generate widespread benefits, and positioning VR nature as a viable strategy for holistic mental health promotion.

An additional consideration in interpreting the positive outcomes of this study lies in the incorporation of mindfulness and guided meditation components within the virtual environment. These elements were present throughout the sessions, either through ambient auditory guidance or visual cues designed to promote attentional anchoring and present-moment awareness. Forest Therapy, as applied here, can be classified as a mindfulness-based intervention (Zhang et al., 2022). Mindfulness is a process that fosters a non-judgmental awareness of the present moment and has been shown to improve emotional regulation

and reduce reactivity to stressors (Hofmann & Gómez, 2017). Participants were repeatedly exposed to this practice, particularly during the meditation phase of each session.

This sustained exposure raises the possibility of generalisation, the process by which behaviours or strategies learned in one setting are transferred to others (Stokes & Baer, 1977). Generalisation is essential to any intervention to have real-world applicability, and its absence significantly limits long-term utility (Carruthers et al., 2020). Given that participants completed multiple sessions and experienced the guided mindfulness and brief slow-paced breathing consistently, it is plausible that they internalised some of these skills (Pilcher et al., 2025). If this occurred, the benefits observed may extend beyond VR context into daily life, supporting broader improvements in mental health, emotional resilience, and occupational participation.

It is also important to acknowledge that the intervention integrated multiple potentially active elements, including VR-based exposure to natural environments, mindfulness meditation, lavender scent, and the use of a familiar therapist voice. Each of these components has been independently associated with benefits such as reduced stress, anxiety and enhanced emotional regulation (Browning et al., 2020; Goyal et al., 2014; Koulivand et al., 2013; Rus-Calafell et al., 2020). The observed outcomes in this study should therefore be interpreted as reflecting the combined effects of this multimodal package, rather than the isolated contribution of VR immersion. Future dismantling or factorial studies will be needed to disentangle the relative influence of each component.

As a field that increasingly embraces evidence based approaches, the integration of immersive VR nature sessions into mental health practices could offer a novel, engaging, and adaptable modality, particularly in inpatient settings. It would allow clients to learn and rehearse therapeutic strategies, such as relaxation, grounding, and emotional regulation, in a controlled, repeatable and safe virtual environment. If generalisation of these effects occurs beyond the VR context, as the literature suggests is possible, this method could effectively support both symptom management and occupational engagement in real-world settings, further advancing holistic mental health care.

The findings support the incorporation of immersive VR nature into psychiatric treatment programs as a complementary strategy for emotional physiological stabilisation. By enhancing well- being, reducing emotional distress, and maintaining physiological calm, the intervention addresses multiple components of the WHO definition of mental health (World Health Organization, 2021).

5. Limitations

Several limitation must be acknowledged. The limited sample increases the risk of Type II errors, that is, failing to reject the null hypothesis despite the existence of true effects. This is particularly relevant for the physiological variables, where trends suggested potential changes that were not confirmed statistically. Although the preprocessing pipeline for physiological data was carefully designed and relied on validated automatic filtering procedures, no additional manual visual inspection of raw signals was performed. This should be acknowledged, as residual artefacts may still influence HRV and EDA measures, particularly in small samples. The sample size was small and no control group was used, which limits generalisability and attribution of effects. The sample consisted in clinically stable inpatients engaged in OT, and the diagnostic distribution was skewed toward psychotic disorders (62.5%), which constrains generalisability. Length of stay at enrollment and standardised symptom acuity were not recorded, precluding analyses of these potential moderators The short duration of the intervention may not captured long-term changes, and the influence of external variables such as medication, ongoing therapies and circadian rhythms on psychophysiological outcomes cannot be ruled out. Moreover, outcomes were measured only immediately after the intervention, the absence of follow-up limits conclusions regarding the persistence and durability of the observed effects. Furthermore, the lack of qualitative data prevents exploration of subjective perceptions beyond the standardised measures. Finally, it should be noted that all psychometric instruments relied on self-report. Participants completed these measures autonomously but under the supervision of their reference occupational therapist, who provided clarification when needed. Although this ensured feasibility in the inpatient setting, no additional attention checks were implemented. This represents a potential limitation, as response validity could not be independently verified.

Future studies with larger samples may be able to better capture subtler effects and reduce the likelihood of false negatives, particularly in physiological measure where trends not reach statistical significance. Future studies should collect and examine variables like standardised symptom acidity, to better understand

for whom and under what conditions VR-based forest therapy is most effective. Also, further research should use randomised controlled designs, larger and with different types of samples, including follow-ups to assess long-term effects. Direct comparisons between real and virtual nature will help clarify the extent to which digital environments can replicate the benefits of real nature. Personalising VR content or increasing interactivity may further enhance outcomes.

6. Conclusion

The present study aimed to assess the feasibility and therapeutic potential of an immersive VR-based Forest Therapy intervention for psychiatric inpatients. Given the positive outcomes in depressive symptoms, anxiety, stress, well-being, stability of physiological indicator, and the absence of adverse effects, this intervention appears both viable and beneficial within this clinical context. These findings contribute to the growing field of virtual nature therapy and reinforce the potential of adapting Forest Therapy principles to immersive virtual environments. They further support the use of VR as a complementary mental health tool, particularly in setting with limited access to natural spaces.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work has been supported by Fundação para a Ciência e Tecnologia (FCT) through R&D Units funding (UID/05210/2023).

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