Extending the Technology Acceptance Model for the analysis of Virtual Reality mindfulness applications

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Abstract

This paper extends the Technology Acceptance Model (TAM) to evaluate the acceptance of Virtual Reality (VR) for mindfulness practices, focusing on technological usability and therapeutic outcomes. Using a mixed-methods approach, we adapted TAM's core constructs—Perceived Usefulness (PU) and Perceived Ease of Use (PEOU)—to assess mental health benefits (e.g., mood improvement, stress reduction) and VR-specific usability challenges (e.g., hardware comfort, interaction intuitiveness). A pilot study was employed with a sample of university students combining non-parametric statistical analyses (Wilcoxon signed-rank test, effect size calculations) and qualitative thematic exploration. The results showed improved PU and PEOU after VR exposure, including better mood and usability comfort. Qualitative insights highlighted immersion and environmental suitability as critical facilitators of mindfulness, with participants emphasizing VR's capacity to reduce external distractions. The adapted TAM framework integrates therapeutic metrics and VR usability factors, providing a dual perspective on technological acceptance and psychological impact. This study highlights the strengths of mixed-methods designs in pilot research, balancing quantitative precision and qualitative insights. These findings underscore VR's potential as a tool for mental health interventions while identifying key areas for refinement, such as ergonomic design and personalized guidance. Future research should expand participant diversity, incorporate longitudinal physiological measures, and explore environmental variability to optimize VR mindfulness applications.

Keywords

virtual reality, mindfulness, Technology Acceptance Model, mental health, pilot study

1. Introduction

Mental health represents a significant challenge in contemporary society, affecting individuals of all ages and backgrounds [1, 2, 3]. Problems such as stress, anxiety, depression, and burnout are increasingly prevalent, especially among university students [4, 5, 6, 7, 8] and healthcare professionals [9, 10, 11]. These disorders can negatively impact the quality of life, academic and professional performance, and overall well-being. Traditional approaches to mental health treatment, such as therapy and medication, are often limited in terms of accessibility, cost, and effectiveness, which creates the need to explore new solutions [12, 13].

In this context, Virtual Reality (VR) is a promising tool that complements traditional interventions. VR offers the ability to create immersive and interactive environments that can be used to train mindfulness skills. This practice involves focusing on the present moment in a non-judgmental and open way. Regular mindfulness practice has shown benefits in reducing stress, anxiety, and depression,

Interacción '25: XXV International Conference on Human-Computer Interaction, September 03–05, 2025, Valladolid, Spain

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as well as improving emotional regulation, well-being, and attention. According to some studies, VR can improve adherence to mindfulness programs and also increase retention compared to traditional practices [5, 9, 10, 11]. According to the literature, VR-based mindfulness applications can offer several advantages compared to traditional approaches:

- Accessibility: VR can make mindfulness practices more accessible to people who have difficulty travelling to therapy environments or live in remote areas [12, 13].
- Engagement: Immersive virtual environments can increase participant engagement and motivation, making mindfulness practice more interesting and enjoyable [3, 10, 11].
- Control: VR allows for control over the environment and customization of mindfulness practices to meet the individual needs of each person [12, 10, 11].
- Feedback: VR enables using biofeedback and other monitoring forms to provide users with information about their physiological and emotional state, helping them deepen their mindfulness practice [10, 11].
- Versatility: VR can be used in various contexts, including clinics, schools, and even at home [6, 13].
- Overcoming Barriers: Virtual environments can help people with physical difficulties or limitations who would not have access to traditional meditation spaces or outdoor activities [10].

However, the application of VR in mindfulness also presents challenges. User acceptance of the technology is crucial for the success of interventions [13]. Factors such as equipment discomfort, immersion quality, cost, and lack of familiarity with the technology can be barriers to overcome [13].

The Technology Acceptance Model (TAM) is a widely used theoretical framework to understand and predict user acceptance of new technologies [14]. The TAM suggests that technology acceptance is influenced by two main factors: perceived usefulness and perceived ease of use [14]. Applying the TAM in a VR with a mindfulness context can provide valuable insights into how university students perceive and accept this combination of technologies and practices.

This study proposes an extension of TAM that integrates mental health metrics and VR-specific usability factors. Using a mixed-methods approach, i.e. the combination of non-parametric statistical tests and qualitative thematic analysis, we evaluate not only technological acceptance but also the psychological impact of VR on mindfulness practices. By bidding on technological acceptance and therapeutic outcomes, this framework provides a dual perspective to guide the design and evaluation of VR mindfulness interventions.

2. VR and mindfulness for mental health

The combination of VR and mindfulness has shown promise for mental health interventions [1, 2, 3]. VR offers immersive environments that can complement and enhance mindfulness practice, based on complete attention to the present moment [3, 4].

VR can create a sense of presence in relaxing virtual environments and serve as an anchor for attention, reducing distractions. Furthermore, it increases participants' engagement and motivation and can be used in guided practices, combining immersive videos and narrations. Some studies utilize natural scenarios like beaches or forests to create relaxing environments [3, 6]. Others combine mindfulness practice with biofeedback, adding a physiological component [4, 10].

Mindfulness practice, facilitated by VR, can enhance emotional regulation, reduce stress and anxiety, and promote overall well-being [3, 4, 10]. VR enhances mindfulness mechanisms such as decentering, which helps individuals distance themselves from their thoughts and emotions while increasing self-awareness and compassion [3, 10].

Among the various VR-based interventions, studies have explored the use of VR in different contexts, including Mindfulness-Based Stress Reduction (MBSR) programs [1, 2, 10], Dialectical Behavior Therapy (DBT) [3, 12, 10], and treatment of anxiety and pain disorders [3, 4, 10].

According to Wieczorek's systematic review, these interventions can significantly improve mindfulness state, positive affect, and reduce stress and anxiety [10]. VR also seems to improve treatment adherence and retention in mindfulness programs [1]. However, the adoption of VR still raises some controversy, generating debate about the increased effectiveness of mindfulness when using VR compared to traditional practice. Some studies indicate that VR is as effective as traditional practice but does not represent a significant improvement [1]. Additionally, some study participants reported discomfort with VR equipment and video quality issues [4]. Another barrier is the heterogeneity of studies and lack of methodological standardization make it difficult to evaluate effectiveness [10].

Thus, it is necessary to develop standards and best practices for the use of VR in mindfulness [10], as well as longitudinal studies to better understand the mechanisms of action and long-term effectiveness of VR mindfulness interventions [3, 10].

3. Extension to the Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) [15], proposed in 1989, is one of the most widely used theories to understand and predict the acceptance and use of technologies by users. TAM is based on two primary constructs: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). PU refers to the degree to which an individual believes using a specific system will enhance their job performance or overall productivity. PEOU is the degree to which an individual believes that using a system will be free of effort [14].

These constructs are associated with Attitude Towards Use (ATU), i.e., the general attitude of the user towards the use of technology (which can be positive or negative) depending on how they perceive the benefits and ease of the technology, and Behavioral Intention to Use (BI), defined as the user's intention to use the technology, which is directly influenced by PU and indirectly by PEOU, as well as their attitude towards the technology, are determinants in the actual system use.

TAM constructs are interrelated to predict whether a person will adopt a technology. For instance, if someone believes that a technology is useful (PU) and easy to use (PEOU), they are more likely to have a positive attitude (ATU) and, consequently, a greater intention to use it (BI). The Figure 1 shows the original TAM.

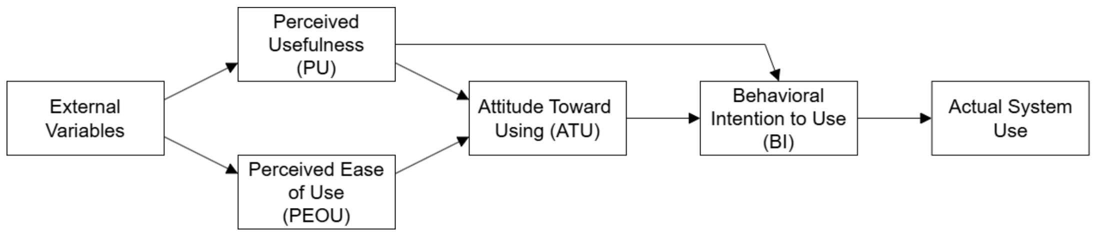

Figure 1: Original TAM. Adapted from Davis (1989)

TAM has been widely applied in various fields, such as healthcare, education, and business, to understand the acceptance of new technologies [16]. The simplicity and effectiveness of the model have made it a valuable tool for researchers and practitioners seeking to implement new technologies effectively. The model helps identify the factors that influence technology acceptance, allowing organizations to develop strategies to improve the adoption of new systems and technological tools [17].

3.1. Adaptation of the TAM for VR mindfulness evaluation

TAM was systematically adapted to address the unique interplay between immersive technology and therapeutic outcomes to evaluate the acceptance of VR for mindfulness interventions. PU and PEOU were refined to align with VR mindfulness contexts, incorporating mental health metrics and VR-specific usability factors.

The original TAM framework emphasizes productivity-oriented utility (e.g., workplace efficiency) [14, 15]. However, VR mindfulness prioritizes therapeutic efficacy, necessitating a shift toward psychological outcomes such as mood regulation and stress reduction [1, 10]. VR's immersive nature introduces usability challenges (e.g., hardware comfort, interaction design) that standard TAM overlooks [18, 16]. This adaptation bridges TAM's theoretical foundations with the demands of VR-mediated mindfulness, ensuring relevance to both technological and therapeutic dimensions.

3.2. Modifications to Perceived Usefulness (PU)

TAM's PU items were redefined to assess VR's capacity to enhance mental well-being, reflecting mindfulness goals. For this construct, we considered three external variables: Mood, Depression Level and the Number of Negative Thoughts. The objective is to measure whether there is a perceived change in PU, denoting that using VR applications focused on mindfulness has proven helpful for users.

Mood (PU1) was chosen because a user's current affective state significantly influences their subjective evaluation of technology. Positive mood states are associated with enhanced cognitive flexibility and increased receptivity to new experiences, which can lead users to perceive the VR mindfulness system as more beneficial for sustaining emotional well-being. Conversely, individuals in a negative mood may be more critical but may also perceive a more significant relative benefit if the intervention improves their attitude.

The second variable, Depression Level (PU2), was selected because depression is typically associated with diminished motivation, negative expectations, and reduced capacity to experience pleasure (anhedonia), which can affect initial perceptions of system usefulness. However, for users experiencing depressive symptoms, even slight improvements in affect or cognitive clarity resulting from VR mindfulness sessions can lead to heightened perceptions of usefulness, particularly when contrasted with their baseline state.

Finally, the Number of Negative Thoughts (PU3) is considered due to the fact that frequent negative automatic thoughts indicate emotional distress and are strongly associated with cognitive overload and impaired well-being. A system that effectively interrupts or alleviates such patterns may benefit users who frequently experience them. This perception is reinforced when the VR experience promotes attentional refocusing or emotional regulation.

These psychological variables influence PU by shaping users' expectations and evaluations of the system's ability to enhance their mental health. In interventions where emotional and cognitive relief are primary goals—as in VR-based mindfulness—these variables are particularly evident predictors of perceived utility, arguably surpassing technical or usability-related factors.

By framing PU around mental health outcomes, the adaptation ensures construct validity for therapeutic contexts, as validated by systematic reviews linking VR to reduced anxiety and improved emotional regulation [10, 11].

3.3. Refinement of Perceived Ease of Use (PEOU)

PEOU construct was expanded to address usability barriers specific to VR, which are critical for mindfulness adherence. In immersive environments such as VR-based mindfulness applications, users' perceptions of system usability are shaped by various experiential and interaction-related variables.

The first variable, Ease of Use (PEOU1), refers to the direct operational simplicity of the system. When users can navigate and operate the VR application with minimal effort, they are more likely to perceive the system as easy to use. This is particularly important in mindfulness contexts, where minimizing cognitive load is essential for fostering engagement and sustained usage.

Another element is Interactivity (PEOU2), which involves high levels of system responsiveness and meaningful interactions. Smooth and interactive VR mindfulness experiences contribute to an uninterrupted user experience, reinforcing the perception that the system is manageable and user-friendly. Conversely, poor interactivity may create discord that negatively affects the perceived ease of use.

Intuitiveness (PEOU3) also plays a fundamental role. A system is considered intuitive when users can operate it without extensive learning or prior experience. In VR applications, intuitiveness allows users to focus on the mindfulness experience itself rather than the interface, which is especially important for individuals less familiar with immersive technologies.

Finally, Comfort of Use (PEOU4) pertains to the physical and ergonomic aspects of the system, such as the weight and fit of the VR headset, freedom of movement, and absence of physical strain or discomfort. In VR contexts, physical comfort is vital for enabling users to engage with the system for the intended duration without distraction or fatigue, thus enhancing their perception of ease of use.

These external variables directly contribute to the PEOU construct by reducing interaction barriers and increasing the system's smoothness and accessibility. In mindfulness, where the goal is to promote relaxation and presence, the perception that the system is easy to use is a foundational element for effective adoption and sustained engagement. Figure 2 shows the proposed TAM with VR-Mindfulness extension.

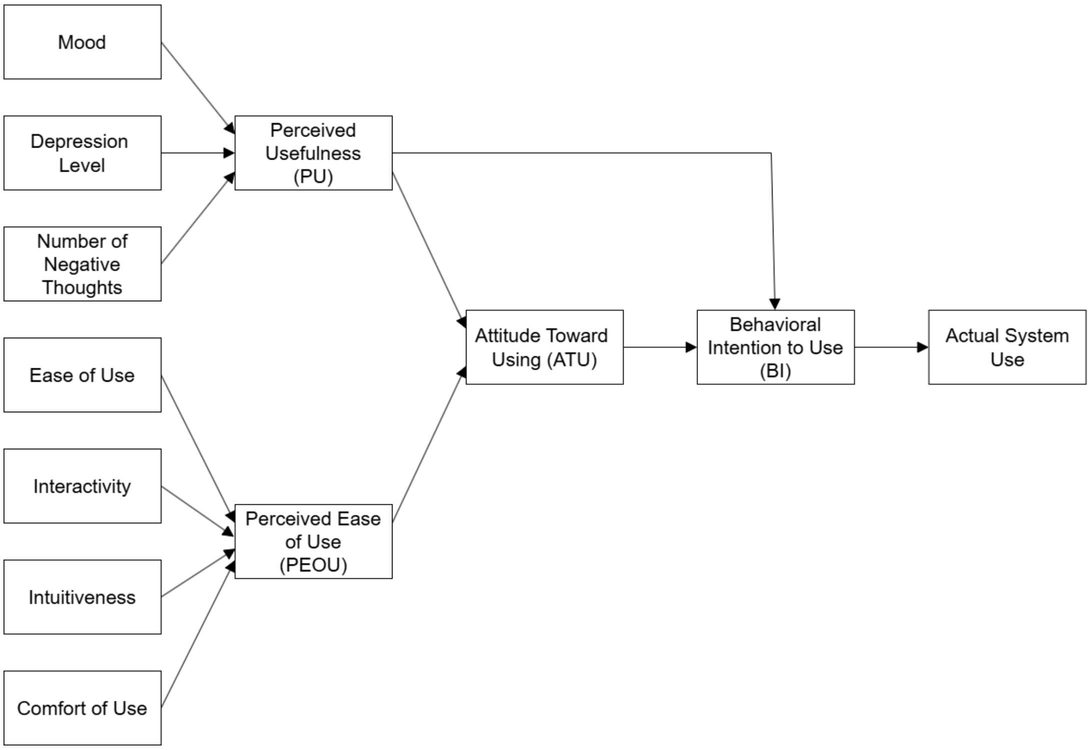

Figure 2: VR - Mindfulness TAM extension.

The rationale behind these items relies on the fact that VR acceptance hinges on both software and hardware usability [18, 16]. By including a comfort-related item (PEOU4), we acknowledge VR's ergonomic demands, a factor underrepresented in traditional TAM but vital for mindfulness interventions requiring sustained engagement [9].

Additionally, we propose incorporating structured scales based on the TAM model and open-ended questions to assess ATU and BI, adopting a hybrid approach which combines descriptive and inferential analyses to examine underlying constructs. Thus, integrating these methods provides a robust strategy for assessing technology acceptance, increasing the reliability and generalizability of the results.

3.4. Methodological enhancements

Pre-Post Design. We propose shifting verb tenses (e.g., "*will be useful*" and "*was useful*") in the questionnaire items to enable longitudinal analysis of how direct VR exposure alters perceptions. This approach aligns with TAM extensions advocating for experiential evaluation in emerging technologies [17].

Qualitative Triangulation. We also suggest using open-ended questions to complement PU/PEOU scores by capturing subjective experiences (e.g., "sense of presence", "post-session mood changes"). This mixed-methods design strengthens validity, as qualitative insights contextualize quantitative trends—a best practice in small-sample studies [19].

This adaptation advances TAM's applicability to immersive health technologies and VR paradigm by:

- **Integrating Mental Health Metrics:** Grounding PU in therapeutic outcomes, as advocated in VR mindfulness literature [3, 10].
- **Addressing Immersive Usability:** Expanding PEOU to include hardware comfort and interaction design, critical for VR adoption [18].
- **Balancing Rigor and Flexibility:** Combining quantitative TAM metrics with qualitative depth, a strategy endorsed for exploratory pilots [19].

In summary, by adapting TAM to the context of VR-based mindfulness, this study proposes a framework for assessing both user acceptance and therapeutic impact. The adjustments made to the model reflect the dual function of VR as an immersive experience and a mental health intervention, offering a valuable guideline for future research in digital therapeutics.

4. The experiment

The experiment involved the use of two different VR headset models: the Meta Quest 3 and the Apple Vision Pro. These devices were selected to ensure compatibility with different mindfulness applications.

4.1. Justification for the pilot study

This study assesses the feasibility of using VR for mindfulness practices using the proposed Extended TAM. Conducting a pilot study was essential for several reasons:

1. **Exploratory Nature and Initial Insights**: Given the innovative intersection of VR and mindfulness, gathering preliminary data before designing large-scale studies is important. The pilot study allows us to explore how users initially perceive VR-based mindfulness and identify key trends that warrant further investigation.
2. **Validation of Methodology and Measurement Instruments**: The pilot study assesses whether the proposed survey instruments effectively capture perceived usefulness (PU) and perceived ease of use (PEOU) in this domain (Immersive VR for mindfulness).
3. **Practical Constraints and Need for a Controlled Environment**: Recruiting a large sample for an emerging technological intervention can be challenging. A small-scale study enables testing the experimental procedure under controlled conditions, ensuring participant safety and comfort while interacting with VR.
4. **Use of Statistical Methods Suitable for Small Samples**: The study employs non-parametric statistical techniques, such as the Wilcoxon signed-rank test and effect size calculations, to derive meaningful insights despite the small sample size. Additionally, qualitative thematic analysis complements the statistical findings, providing a richer understanding of participant experiences.
5. **Guidance for Future Research**: The findings highlight methodological adjustments needed for subsequent studies, such as refining the experimental protocol and enhancing the survey design. These insights will support the development of larger studies with more diverse participant pools.

4.2. VR applications used in the experiment

The study employed four carefully selected VR applications, each offering distinct mindfulness-related experiences. The selection was based on their ability to represent different approaches to VR-mediated mindfulness while covering a spectrum of immersive qualities:

- **Tripp**: A purpose-built mindfulness and meditation application that combines guided sessions with abstract virtual immersive environments (Figure 3). This was included as it represents a direct VR adaptation of traditional mindfulness practices, offering structured breathing exercises and visualizations designed to reduce anxiety and promote relaxation.

Figure 3: Tripp Application Interface. Source: Tripp INC. https://www.tripp.com/

- **Nature Treks VR**: Provides an open exploration of natural environments (forests, beaches, etc.) with minimal interaction requirements. This application was selected as it embodies the "nature exposure" approach to mindfulness, allowing participants to practice attention-focusing in serene virtual landscapes without structured guidance. It offers highly immersive environments and soothing soundtracks, creating an ideal atmosphere for mindfulness practices and stress reduction.
- **The Room VR**: A puzzle-based experience focused on mystery and investigation. The game evokes a sense of suspense and fascination in locations such as a gothic cathedral, a mausoleum, and an enigmatic sanctuary. While not explicitly designed for mindfulness, the game encourages states of concentration and attentiveness by challenging players to focus on solving intricate puzzles and interacting with objects in detail. This application was included to test whether light cognitive engagement could support mindful states through focused attention on problem-solving tasks.
- **Thrill of the Fight**: A boxing simulator with high physical intensity (Figure 4. This unconventional choice was included to contrast with traditional mindfulness applications and evaluate whether physically demanding VR experiences could produce mood-enhancing effects through different mechanisms (e.g., catharsis, physical exertion), promoting an alternative approach to well-being.

Figure 4: Thrill of Fight Interface. Source: Sealost Interactive LLC. https://sealostinteractive.com/

The diversity of applications allowed us to assess different pathways through which VR might support mindfulness and mental well-being, from direct meditation support to more indirect approaches through environmental immersion and physical engagement.

4.3. Participants

The study sample consisted of 6 master's degree students from the University of Granada, aged between 22 and 25 years (mean age = 22.8 years). Among the participants, 5 identified as male and 1 as female. The participants were recruited voluntarily after the experiment was announced to the students. All participants were familiar with VR, but none of them had experienced any VR applications for mindfulness before.

4.4. Methodology

The objective of this study was to evaluate the willingness of participants to use VR applications for mindfulness to reduce anxiety and potential depression. This study utilized the extended TAM to assess the acceptance of this technology.

The experiment was conducted in three main stages:

1. **Profile and Pre-Test Questionnaire (TAM)**: In the initial phase, participants completed a demographic and profile questionnaire and a pre-test based on the TAM. The pre-test used a 7-point Likert scale to evaluate participants' initial perceptions of the VR technology's ease of use (PEOU) and perceived usefulness (PU).
2. **Interaction with VR Applications for Mindfulness**: Participants were invited to use VR headsets with applications focused on mindfulness practices in the second phase. The two different VR headset models were used alternately to optimize the time required for the experiment. These sessions were conducted in a controlled environment to ensure the safety and comfort of the participants.
3. **Post-Test Questionnaire (TAM) and Exploratory Questions**: After the VR interaction, participants completed a post-test TAM using the same 7-point Likert scale to assess changes in their perceptions of ease of use and usefulness. Additionally, they answered exploratory open-ended questions to provide qualitative insights into their experiences.

4.5. Measurement instruments

The extended TAM questionnaires in the pre-test and post-test utilized a 7-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (7). This format allowed for a detailed assessment of participants' perceptions of the technology. For each external variable, we proposed a corresponding question. These questions are presented in Table 1 and Table 2.

Table 1
Perceived Use Questions

#	Pre-Test	Post-Test
PU1	I believe VR can help improve my mood.	I believe VR helped improve my mood.
PU2	VR has the potential to alleviate depression symptoms.	I believe VR would help alleviate depression symptoms.
PU3	Using VR will be useful for distracting me from negative thoughts.	Using VR was useful for distracting me from negative thoughts.

The first item (PU1) refers to mood improvement: "I believe VR can help improve my mood" (Pre-Test) and "I believe VR helped improve my mood" (Post-Test). This item aligns with studies demonstrating VR's efficacy in mood modulation through immersive relaxation [9, 10].

The second item (PU2) focuses on depression symptom alleviation, evaluating VR's perceived clinical value, and addressing mental health applications [1, 12].

The last item (PU3) concerns distraction from negative thoughts, capturing VR's role in redirecting attention, a core mechanism in mindfulness practice [3, 12].

Table 2
Perceived Ease of Use Questions

#	Pre-Test	Post-Test
PEOU1	I believe it will be easy to use the VR during the session.	It seemed easy to use the VR during the session.
PEOU2	Using immersive glasses will be simple and straightforward.	I could move and interact with virtual objects without problems.
PEOU3	I believe interacting with VR will be intuitive and easy to learn.	The usage experience was simple and straightforward.
PEOU4	I believe I will feel comfortable using VR headsets during the session.	I felt comfortable using VR headsets during the treatment.

The PEOU1 concerns the ease of use, contrasting pre-test expectations ("I believe it will be easy to use VR") with post-test experiences ("It seemed easy to use VR"), capturing usability adaptation processes [14].

PEOU2 refers to interaction simplicity and focuses on VR's interaction mechanics, a known barrier for novices [18].

The third item, PEOU3, addresses Intuitiveness, estimating the learning curve, which is critical for minimizing cognitive load during mindfulness sessions [9].

The fourth item, PEOU4, is related to comfort, explicitly assessing hardware ergonomics, a frequent obstacle in prolonged VR use [18].

The questions related to Attitude Toward Use (ATU) and Behavioral Intention (BI) were designed to evaluate critical dimensions of the extended TAM, prioritizing both therapeutic outcomes and the technical feasibility of virtual reality (VR).

The questions in Table 3 (ATU) focused on participants' subjective perceptions of the technology's clinical efficacy, such as their belief in VR's capacity to alleviate depressive symptoms and their willingness to recommend its use to others. These responses captured the redefined Perceived Usefulness (PU), which in this context extends beyond traditional productivity metrics to encompass tangible psychological impacts, such as emotional regulation and reduced negative thought patterns.

Table 3
Exploratory Questions related to ATU

#	Question
ATU1	Do you think VR can be an effective tool for treating depression? Why?
ATU2	Do you have any suggestions for improving the VR experience?
ATU3	How did your expectations about VR change after participating in the experiment?
ATU4	Would you recommend the use of VR to other young university students dealing with depression?
ATU5	Is there anything else you would like to add about your experience with VR and its potential use in treating depression?

The questions in Table 4 (BI) explored practical VR experiences, emphasizing immersion, physical comfort, and interaction smoothness. For instance, participant reflections on the sense of presence in virtual environments and hardware discomfort were adapted to address ergonomic challenges unique to immersive technologies. Questions addressing post-session mood changes and well-being link immersion to core mindfulness therapeutic mechanisms, such as minimizing external distractions.

Table 4
Exploratory Questions related to BI

#	Question
BI1	Describe your experience using the VR headset. What did you like the most, and what didn't you like?
BI2	How would you describe the sensation of being in the virtual environment? Did you feel present and immersed?
BI3	Did you notice any changes in your mood after the VR session? Please describe.
BI4	How would you evaluate the ease of use of the VR headset? Did you experience any difficulties?
BI5	Was there anything about using the VR headset that caused you discomfort?
BI6	How would you describe the overall impact of the VR session on your well-being?

This qualitative approach complemented the quantitative data obtained through the PU and PEOU questionnaires, allowing a deeper analysis of the participants' experiences. The textual responses helped contextualize statistical scores and revealed important nuances about VR acceptance in therapeutic environments.

4.6. Data Analysis

The collected data were analyzed using the following statistical methods:

- **Wilcoxon Signed-Rank Test**: Used to evaluate differences between the pre-test and post-test measurements due to the small sample size and the ordinal nature of the data.
- **Effect Size (Cohen's d)**: Calculated to measure the magnitude of the observed differences between the pre-test and post-test conditions.
- **Sign Test**: Applied to verify the significance of differences in individual responses, complementing the Wilcoxon test analysis.
- **ATU and BI Questions Analysis**: The qualitative responses were analyzed to identify common themes and insights about participants' experiences, perceptions, and suggestions for improving the VR applications.

5. Results and discussion

5.1. Acceptance of VR

This study collected pre-test and post-test data to analyze changes in perceptions following an intervention. The variables analyzed include Perceived Ease of Use (PEOU1, PEOU2, PEOU3, PEOU4) and Perceived Usefulness (PU1, PU2, PU3). The results are shown in Tables 5.1 and 5.1.

Table 5
Pre-Test Descriptive Statistics

	PEOU1	PEOU2	PEOU3	PEOU4	PU1	PU2	PU3
Count	6	6	6	6	6	6	6
Mean	5.50	4.67	6.00	5.83	5.50	5.17	6.17
Std	1.38	1.21	0.63	1.17	0.84	1.17	0.75
Min	4.00	3.00	5.00	4.00	4.00	4.00	5.00
25%	4.25	4.00	6.00	5,25	5.25	4.25	6.00
50%	5.50	4.50	6.00	6.00	6.00	5.00	6.00
75%	6.75	5.75	6.00	6.75	6.00	5.75	6.75
Max	7.00	6.00	7.00	7.00	6.00	7.00	7.00

Table 6
Post-Test Descriptive Statistics

	PEOU1	PEOU2	PEOU3	PEOU4	PU1	PU2	PU3
Count	6	6	6	6	6	6	6
Mean	6.17	6.33	6.33	6.67	6.00	6.33	6.17
Std	1.17	0.82	0.52	0.51	0.63	0.52	1.17
Min	4.00	5.00	6.00	6.00	5.00	6.00	4.00
25%	6.00	6.00	6.00	6.25	6.00	6.00	6.00
50%	6.50	6.50	6.00	7.00	6.00	6.00	6.50
75%	7.00	7.00	6.75	7.00	6.00	6.75	7.00
Max	7.00	7.00	7.00	7.00	7.00	7.00	7.00

The Cronbach's alpha coefficient, widely used in scientific research to assess the internal consistency of measurement instruments, requires a sufficiently large sample to ensure the stability and validity of the results. Some methodological studies recommend using samples of at least 30 participants to obtain reliable estimates of Cronbach's alpha [20]. This recommendation aims to capture response diversity and minimize the impact of random variations.

Therefore, Cronbach's alpha was not calculated for the sample in this pilot test. However, in studies with a larger sample of participants, it is recommended to use some measure of reliability before proceeding with the analysis to obtain precise and meaningful estimates of the instrument's internal consistency.

Table 7
Statistical Test Results (Wilcoxon, Sign Test, Cohen's d)

Variable	W (Wilcoxon)	p-value (Wilcoxon)	p-value (Sign Test)	Cohen's d
PEOU1	2.5	0.3173	0.21875	0.521
PEOU2	1.5	0.0937	0.21875	1.613
PEOU3	1.5	0.4142	0.21875	0.577
PEOU4	2.5	0.1573	0.21875	0.922
PU1	0.0	0.0833	0.03125	0.674
PU2	2.0	0.1290	0.21875	1.290
PU3	5.0	1.0	0.6875	0.000

Despite the differences in the means not being statistically significant according to the Wilcoxon test, the Sign Test results show that PU1 exhibits a statistically significant change. Furthermore, the effect sizes suggest substantial changes in certain variables, particularly PEOU2 and PU2, which showed large effect sizes. The variables PEOU1, PEOU3, and PU1 exhibited medium effect sizes, with Cohen's d values of 0.521, 0.577, and 0.674, respectively, indicating moderate changes. In contrast, the variable PU3 did not present a significant change.

The results also indicate that there were perceived improvements in the ease of use and usefulness of the evaluated technology, as evidenced by the increases in the mean values of the variables. However, the lack of overall statistical significance suggests a larger sample or additional analysis to confirm these findings. The effect size provides insight into the changes' magnitude, highlighting the observed findings' relevance.

5.1.1. Experience impact

The responses from ATU and BI questions indicate that VR can be a promising tool for mindfulness, mainly due to its ability to provide immersion and isolation from external stimuli.

Most participants reported a positive experience with VR, highlighting the high immersion provided by virtual environments. According to some responses, realistic graphics and ambient sounds increased the sense of presence in the virtual world. However, some participants mentioned difficulties with navigation within the environments. Sense of Presence and Immersion Reports indicated that the feeling of being ”inside” the virtual environment was intense for most participants. Some stated that they even forgot they were in a simulated world, especially in experiences exploring natural settings. However, there were variations in the perception of immersion depending on the type of environment explored.

Most participants reported feeling more relaxed after the VR session. In particular, mindfulness within the virtual environment was mentioned as effective in reducing stress and promoting calm. Some participants compared the experience to traditional meditation and indicated that guidance within VR could make the practice more accessible and effective.

Regarding ease of use and comfort, most participants considered the VR headset interface intuitive, although some mentioned the need for initial instruction to understand the controls better. Most reported that the headsets were comfortable, but some participants indicated that the experience could be improved by using headphones for better sound isolation.

Finally, some participants reported that their expectations regarding VR changed after the experiment, highlighting that the technology has broader applications than they had imagined. They recommend VR to other university students dealing with psychological disorders, mainly due to its ability to provide a controlled and safe space for relaxation.

6. Conclusion and future work

This pilot study explored the acceptance of VR for mindfulness practices, using the TAM as an analytical framework. This work advances its theoretical scope beyond traditional productivity-oriented applications by extending TAM to address the unique interplay between immersive technology and mental health outcomes. Specifically, we reframed Perceived Usefulness to prioritize therapeutic benefits (e.g., mood enhancement, stress reduction) and expanded Perceived Ease of Use to encompass VR-specific usability factors, such as hardware comfort and interaction intuitiveness. This adaptation underscores TAM's flexibility in evaluating emerging technologies where psychological and ergonomic compatibility are critical to user acceptance.

Methodologically, the study demonstrates how a mixed-methods approach — combining quantitative TAM metrics with qualitative experiential insights — can enrich technology acceptance research in niche or exploratory contexts. By bridging standardized scales with participant narratives, we captured nuanced drivers of acceptance, such as immersion and environmental suitability, that quantitative metrics might overlook. This dual-lens approach provides a blueprint for adapting TAM to complex, interdisciplinary domains like digital therapeutics.

The results indicate that, despite the limitations of the small sample size, participants reported a predominantly positive experience, highlighting VR's immersion and potential usefulness for mindfulness practice.

Quantitative analysis showed increases in the mean values of PU and PEOU, suggesting a favorable trend toward technology acceptance. However, statistical tests did not identify significant differences in all variables, reinforcing the need for studies with larger samples to validate these findings. Qualitative analysis complemented the quantitative results, revealing that participants perceived VR as a suitable environment for reducing distractions and promoting relaxation, although some technical difficulties were mentioned. Additionally, responses to exploratory questions suggested that using headphones and having greater control over the environment where the experience takes place could enhance immersion and reduce external distractions, emphasizing the importance of a controlled setting for future experiments.

Future research should focus on expanding the sample size and conducting longitudinal studies to assess the long-term impact of VR-based mindfulness interventions. Additionally, exploring variations in experimental conditions — such as different VR environments, integrating biofeedback mechanisms, and including personalized mindfulness guidance — could provide deeper insights into optimizing the user experience.

Another important approach for future work is investigating the role of individual differences, such as prior experience with VR and familiarity with mindfulness practices, in shaping technology acceptance. Conducting studies with diverse populations, including older adults and individuals with specific mental health conditions, would also contribute to a more comprehensive understanding of VR's potential benefits and limitations for mindfulness.

Furthermore, improving experimental design by ensuring a fully controlled environment and refining usability aspects, such as enhancing interaction mechanisms and reducing equipment discomfort, could lead to better engagement and more reliable results. Future studies could also incorporate mixed-method approaches, combining physiological measures (e.g., heart rate variability, EEG) with self-reported data to objectively evaluate VR's effectiveness in mindfulness training.

By addressing these research directions, future work can contribute to a more rigorous and evidence-based understanding of how VR can support mental health interventions and enhance mindfulness practices.

Acknowledgments

This work has been supported by the PLEISAR-Social project, Ref. PID2022-136779OB-C33, funded by the Ministry of Science and Innovation of Spain (MCIN/AEI/10.13039/501100011033, EU), and the C-ING-179-UGR23 project, funded by the Regional Ministry of Universities, Research and Innovation and the FEDER Andalucía 2021-2027 Programme.

Declaration on generative AI

During the preparation of this work, the author(s) used CHAT-GPT-4, Copilot and Grammarly in order to: Grammar and spelling check. After using these tool(s)/service(s), the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

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