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Virtual reality mindfulness training for veterans in residential substance use treatment: Pilot study of feasibility and acceptability

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Abstract

Background: Mindfulness training is effective in recovery from substance use disorders; however, adoption can be difficult due to environmental and personal distractions. Virtual reality (VR) may help overcome these challenges by providing an immersive environment for practicing mindfulness, but there is currently limited knowledge regarding patient and provider perceptions of VR-based tools.

Objective: The present study investigated the feasibility and acceptability of VR mindfulness training for veterans in residential substance use treatment as well as potential benefits of VR mindfulness interventions in this population. We conducted a pilot feasibility/acceptability study as a first step toward conducting a larger randomized controlled trial (RCT).

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Author statement

During the preparation of this work the author(s) did not use generative AI or AI-assisted technologies.

CRediT authorship contribution statement

Natalia Van Doren: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Writing – original draft, Writing – review & editing. **Helen Ng:** Formal analysis, Project administration, Writing – review & editing. **Eshaan Rawat:** Formal analysis, Writing – review & editing. **Kevin R. McKenna:** Conceptualization, Data curation, Project administration, Resources, Supervision. **Daniel Blonigen:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.josat.2024.209315.

Methods: The study recruited participants ($N = 32$) from a 30-day residential substance use program and collected both qualitative and quantitative feedback on the VR mindfulness intervention using a mixed-methods approach. Patients ($n = 20$) and providers ($n = 12$) rated the acceptability, usability, and satisfaction of the intervention. Using a within-subjects design, patients provided pre-post emotion ratings and reported on state mindfulness and VR presence after completing a single-session self-guided VR mindfulness intervention. Patients provided qualitative interview data on their overall impressions, while providers gave the same information via survey.

Results: Both patients and providers reported high satisfaction and confidence in the intervention. Moreover, within subjects *t*-tests showed that patients experienced significant reductions in negative affect and significant increases in positive affect from pre-post, along with high levels of state mindfulness and presence. Results of thematic analysis revealed that the intervention facilitated focused attention on the present moment, induced a state of calm and relaxation, and reduced negative thoughts and emotions. Participants requested improvements such as better integration of audiovisual elements, a more personalized and longer intervention, and more comfortable fitting headset. Finally, the intervention presented with several advantages compared to other mindfulness experiences including reduced distractions and a sense of safety and privacy.

Conclusions: Self-guided VR mindfulness intervention is feasible and acceptable to patients and providers. VR mindfulness training provides an immersive experience that uplifts mood and reduces distractions. VR may provide a scaffolding tool to set the stage for deepening mindfulness skills. Results of the present study could inform further development and tailoring for future interventions.

Keywords

Virtual reality; Mindfulness; Substance use disorders; Inpatient

Mindfulness has been defined as "*awareness that arises through paying attention, on purpose, in the present moment, non-judgmentally*" (Kabat-Zinn, 2003). Mindfulness based interventions (MBIs) have been shown to be effective in the treatment of a variety of health and psychiatric conditions, including substance use disorders (SUDs) (Korecki et al., 2020). A number of evidence-based mindfulness-based treatment protocols for substance use have been developed, including Mindfulness-Based Relapse Prevention (Witkiewitz et al., 2005), Mindfulness-Oriented Recovery Enhancement (Garland et al., 2012), and mindfulness training for smoking cessation (Davis et al., 2014). In these protocols, mindfulness practices entail non-judgmental awareness of thoughts and sensations, including negative emotions, cravings, and withdrawal symptoms. Accordingly, mindfulness is thought to foster more flexible and adaptive responses that aid in breaking the habit of substance use, moving away from reflexive substance-related behaviors. Through mindfulness training, individuals can learn to identify triggers, accept them, and skillfully navigate them more adeptly without trying to avoid them through continued use. In addition, some mindfulness interventions targeting substance aim to increase positive affect via savoring (Garland et al., 2012). Moreover, a growing body of work suggests that mindfulness-based group therapy is effective in residential SUD treatment contexts, providing benefits in terms of reductions

in craving (Shorey et al., 2017), drug use days (Witkiewitz et al., 2014) reducing stress and improving treatment adherence (Félix-Junior et al., 2022).

Despite their promise for inpatient settings, significant barriers to implementation are evident in residential SUD treatment programs. Inpatient stays are usually of shorter duration, limiting the time available for delivering more comprehensive mindfulness training protocols. Providers often juggle multiple priorities and demands, making it difficult to effectively deliver mindfulness training within a limited time frame while also addressing other aspects of treatment. Moreover, patients in residential treatment settings are often practicing mindfulness for the first time and may benefit from additional scaffolding with the practice as they are getting started, particularly in a busy or noisy environment. In addition, staff might not be well-versed in mindfulness techniques or their applications, as providing adequate training to staff members to facilitate mindfulness sessions effectively requires time and resources. For example, in a study on uptake of MBIs among substance use treatment providers, the need for further training was cited as the greatest barrier to implementation (Edwards et al., 2016). In addition, while Roos et al. (2019) found that adapting Mindfulness-Based Relapse Prevention (MBRP) for inpatient settings using a rolling admission group format was effective and acceptable, attendance was low. Therefore, identifying approaches to effectively deliver mindfulness training to individuals in residential substance use treatment using self-guided digital health interventions could help increase uptake and has the potential of providing the benefits of mindfulness training while limiting additional provider burden.

Self-guided virtual reality mindfulness training (VRMT) offers a promising solution to overcome the challenges inherent in implementing mindfulness interventions within inpatient settings. Through interactive and immersive VR environments, individuals can engage at their own pace, effectively addressing the diverse clinical complexity of inpatient populations. The flexibility of self-guided sessions fits within the constraints of limited time and resources, allowing patients to participate at their convenience. The captivating nature of VR could enhance engagement and motivation to practice while providing a private space for practice. Moreover, by reducing the dependence on staffled sessions, self-guided VR training preserves clinical resources for other priorities.

A growing body of work suggests that self-guided VRMT interventions are effective in reducing anxiety and stress (Arpaia et al., 2021). In particular, practicing mindfulness in a virtual setting has shown promise in terms of promoting interoceptive awareness (Heeter et al., 2020), reducing distractions and transporting users from spaces of stress (Costa et al., 2019). While there has been a growing interest in the substance use field regarding the use of virtual reality for treatment more broadly (Trahan et al., 2019; Tsamitros et al., 2021), no studies to date have examined the efficacy of self-guided VRMT for individuals in residential substance use treatment. Establishing first whether such interventions are feasible and acceptable to both patients and providers, as well as examining potential benefits of VRMT for residential SUD treatment, is critical to lay the foundation for conducting larger efficacy studies using RCT designs.

As large healthcare systems strive to stay abreast of the latest developments in patient care, it is important to ensure that technologies available for patient use are scientifically vetted to ensure maximal benefit. For example, within the VA healthcare system, a recent initiative called VA Immersive has been developed by the Office of Healthcare Innovation and Learning. The aim of the initiative is to implement augmented and virtual reality healthcare applications across the VA system to give patients and providers the opportunity to test these new applications. However, many available applications have never undergone efficacy testing. Consequently, VR applications available commercially and within healthcare systems may purport to teach meditation, mindfulness, or relaxation exercises, and claim benefits to patients without sufficient data to back it up. In sum, there is a pressing need to conduct research studies and systematically document any efficacy of VR mindfulness applications, in addition to feasibility and acceptability within the healthcare settings within which they intend to be deployed, and with the target patient populations.

The aim of the present study was to explore the feasibility, acceptability, and potential benefits of using self-guided VRMT to enhance mindfulness training for veterans undergoing residential substance use treatment. We sought to answer the following research questions: 1) Is self-guided VRMT acceptable and feasible for both patients and providers?; 2) What are the potential benefits of the VRMT? We predicted that: 1) self-guided VRMT would be acceptable to both patients and providers and 2) practicing mindfulness in the virtual environment would increase positive emotions and decrease negative emotions from pre- to post-intervention.

1. Method

1.1. Participants

Participants were 20 Veteran patients enrolled in a four-week residential substance use recovery program. Patients ranged in age from 23 to 72 years ($M = 51.55$, $SD = 15.60$) and 15 % were women. Patient participants reported their race/ethnicity as follows: White (45 %, $n = 9$), Black (35 %, $n = 7$), Other (35 %, $n = 7$), and Hispanic/Latinx (20 %, $n = 4$). Patients' primary SUD diagnoses at intake (obtained from chart reviews) were as follows: Alcohol Use Disorder (75 %; $n = 15$), Stimulant Use Disorder (35 %; $n = 7$), and Opioid Use Disorder (10 %; $n = 2$). In addition, patients had the following comorbid mental health diagnoses: PTSD (45 %; $n = 9$), Major Depressive Disorder (35 %; $n = 7$), Generalized Anxiety Disorder (15 %; $n = 3$).

Participants also included 12 providers who provided feedback about the intervention. Providers ranged in age from 28 to 67 years ($M = 39.50$, $SD = 10.34$) and 16.67 % were women. 75 % reported their race as White ($n = 9$), 8.3 % reported as Black ($n = 1$), and 25 % reported as Asian ($n = 3$). Providers were 50 % psychiatrists (MD or MD/PhD; $n = 6$), 41.67 % clinical psychologists (PhD or PsyD; $n = 5$), and 8.33 % social workers ($n = 1$) (Table 1).

1.2. Study design

We conducted a pilot feasibility/acceptability study as a first step toward conducting a larger randomized controlled trial (RCT). Using a within-subjects design, patients provided

emotion ratings before and after a series of three guided mindfulness practices. Between each practice, the study asked three questions about the acceptability of each practice exercise. After the mindfulness practice portion, patients completed a semi-structured interview about their experiences in the VR mindfulness session. Finally, they completed a survey via Qualtrics to assess additional items about feasibility, acceptability, VR Presence, Mindfulness, and demographic information.

The study also recruited providers to solicit their feedback on the interventions. Providers underwent the same three mindfulness practices as the patients and were asked about the acceptability of each exercise. Afterwards, providers completed a survey via Qualtrics that included open-ended qualitative questions as well as quantitative questions regarding feasibility, acceptability, barriers and facilitators to implementation, satisfaction, and demographic information.

1.3. Study procedures

1.3.1. Recruitment of participants—The study recruited patients in person from April 2023–June 2023 via announcements at weekly community meetings at a 28-day residential SUD treatment program at a VA medical center. The announcement informed patients about the general aims of the study and asked them to complete an interest form if they wanted to volunteer for the study. The interest form contained a description of the study and the VA Immersive initiative, along with a brief questionnaire to assess risk for cyber-sickness using several items from the Cybersickness in Virtual Reality Questionnaire (CSQ-VR) (Kourtesis et al., 2023).The study invited veterans who filled out an interest form to participate in the study. All veterans were informed of potential risk of experiencing cybersickness prior to signing up for the study, and information from the CSQ-VR was used to alert the study team and participant to potential risk factors prior to conducting a session.

The study recruited providers from the treatment program staff via announcements at morning staff meetings during the same time period, and by reaching out directly to invite them to participate in the study. In addition, several providers were recruited from an adjacent inpatient psychiatry unit via personal invitation. Interested and available providers scheduled times to conduct a session within their own schedule. Providers were informed of the same potential risks as veterans.

1.3.2. Procedure—The local Institutional Review Board (IRB) determined the project to be a quality improvement project that is exempt from further IRB oversight. All project procedures were conducted according to the principles expressed in the Declaration of Helsinki. Veterans were informed during recruitment and during the session that the study was completely voluntary, that they could stop at any time, and that there was no pressure nor incentive to participate. The study remined veterans of the potential risks of cybersickness and instructed them to remove the headset if they started to experience symptoms, and provided the option to opt out of the study before beginning. No veterans experienced cybersickness in the present study, and no veterans opted out after being informed they met risk criteria.

Patients participated in the VR mindfulness intervention later the same day that they signed up. The first author and a research assistant supervised each session which lasted approximately one hour. At the start of the session, participants completed state emotion ratings and received a brief orientation to the VR headsets from the research team (10 mins). Then, they completed a self-guided tutorial within the headset on how to use and navigate the VR environment (10 mins). Patients were then instructed to locate the three target self-guided mindfulness exercises and to complete the three mindfulness exercises (10 mins). After each exercise, the study asked patients three questions about acceptability of the exercise, as described below. After all mindfulness exercises were completed, patients provided the second set of state emotion ratings. Finally, patients completed a semi-structured interview about their experience (20 mins), followed by a survey administered via Qualtrics (10 mins). Providers completed a shortened version of the same protocol (approx. 30 min) that excluded state ratings and the general study orientation. In addition, instead of an interview, providers completed a survey administered via Qualtrics (20 mins) that included both open-ended questions and quantitative measures (as described below).

1.3.3. Virtual reality headset—The present study used the REAL systems i-series virtual reality headset (Fig. 1). The headsets were obtained as part of the VA Immersive initiative, a pilot program for dissemination of augmented and virtual reality applications in healthcare. The i-series headset contains several apps geared toward enhancing well-being. In the present study, we used the three exercises from the Mindfulness app, including two exercises from the ‘guided mindfulness’ section and one exercise from the ‘skies and auroras’ section, as described below.

1.3.4. Intervention development—Treatment programming on inpatient units tends to be intensive; patients have multiple groups and appointments every day and clinician burden is high. To maximize its potential sustainability in these settings, we aimed to develop a brief, self-guided intervention that would introduce mindfulness skills as an adjunct to the comprehensive treatment plans that are already provided to those on inpatient units. Importantly, the present intervention was not meant to be a tool that could deliver a standalone MBRP protocol. Instead, in the present study, we aimed to develop a tool that, within a short period of time (i.e., <15 min) could help aid patients’ daily mindfulness practice and thereby help to foster mindfulness skills without (or with minimal) clinician involvement. Accordingly, the mindfulness exercises were selected based on their conceptual overlap with existing mindfulness-based interventions, length (i.e., ≤ 15 min each) and their ease of use (e.g., simple instructions to facilitate self-guided use by beginners). To select the exercises, a team of stakeholders (the first author, a staff clinician on the unit, a patient volunteer, and 4 research assistants) completed all the exercises within the Mindfulness app and provided their feedback based on the aforementioned criteria.

Prior to completing the mindfulness exercises, all research assistants underwent training from the first author in mindfulness interventions (e. g., discussion of background readings on the purpose of mindfulness, mindfulness interventions for substance use, adaptations of mindfulness for the inpatient context, and existing digital health interventions for

mindfulness). The first author and research assistants met weekly for one month to discuss these readings prior to evaluating and selecting the intervention components.

There are two main modules in the Mindfulness app: (i) *guided mindfulness exercises*; (ii) *virtual environments* that were created with the intention of providing peaceful environments within which to practice mindfulness exercises. We explored both of these options, though we focused primarily on the guided mindfulness exercises. The *guided mindfulness* module includes 10 exercises; four exercises were eliminated due to their length being >15 min, leaving six exercises left to be evaluated: 1) Foster forgiveness, 2) Gratitude practice, 3) Noticing the spaces between, 4) Restore your attention, 5) Breathing practice, 6) Body Scan Practice.

Following completion of the training and review of these six exercises through direct practice, the study conducted a 1-h focus group with the non-patient stakeholders. Stakeholders discussed exercises with respect to overlap with evidence-based mindfulness interventions, the extent to which stakeholders felt they were able to reach a state of mindfulness during each practice; and appropriateness for the context of an inpatient SUD program. The stakeholders reached consensus that fostering forgiveness and gratitude practice are more similar to other positive psychology interventions and therefore not consistent with evidence-based mindfulness practices within SUD interventions. The "noticing spaces in between" exercise did appear to have conceptual overlap with SUD-oriented mindfulness practice; however, the stakeholders concurred that the exercise did not engage them (e.g., voice of facilitator was very monotone and sleep-inducing). The stakeholders deemed the remaining exercises – Restore your attention (5 mins), Breathing practice (5 mins), and Body Scan Practice (3 mins) –to have the strongest overlap with theoretical conceptualizations of mindfulness for SUD interventions, including direct relationships with specific exercises within the MBRP protocol. In addition, the stakeholders experienced them as being conducive to mindfulness, appropriate for beginners, and easy to use/navigate. The stakeholders considered the other module that featured *virtual environments* in which to practice mindfulness (e.g., skies and auroras, beach retreats, lost in the desert) next. The focus group participants favorably viewed only one scene (aurora borealis) and considered it conducive to practicing mindfulness in that environment. Therefore, we opted to retain this as an experimental part of the intervention to gather further feedback and see whether we would like to develop it further.

After initial selection, an independent team of four clinician-researchers (one MD/PhD, three PhDs) completed a mock session of the selected exercises and provided their narrative verbal feedback via a brief, 15-min interview. The study selected these individuals to test the intervention based on their extensive experience working in inpatient care and research expertise in SUD and mindfulness. Through this process, there was consensus that the "Restore your attention" exercise was unsuitable due to a lack of pairing between the audio and visual elements of the exercise, which felt disruptive to the clinician-researchers. In addition, the clinician-researchers suggested adding instructions within the mindfulness practice environment of the aurora-borealis to ensure that participants were practicing mindfulness within it. The selected exercises are described in further detail below.

1.3.5. VR mindfulness intervention—

Each participant sat in a chair and wore a pair of REAL systems i-series goggles with head mounted in-built display. The headset features head and eye tracking that allowed participants to see 360 degree 3-D video footage of nature scenes while listening to audio instructions via in-built audio surround sound. Participants completed three mindfulness exercises as part of the single-session intervention: a guided breathing practice, a guided body scan practice, and a mindful observation of nature practice. The study presented the three mindfulness practices in a counterbalanced order by randomly assigning each veteran to receive one of six possible orders to minimize order effects.

The *guided breathing practice* featured a nature scene of a babbling brook, with background audio of nature sounds (e.g., bird calls, water sounds, rustling leaves) that were coordinated with the visuals. The breathing practice instructions came from Mindful.org and instructed participants to engage in diaphragmatic breathing, slowing the breath, and focusing on bodily sensations related to breathing. This practice lasted for 5 min.

The *body scan practice* immersed participants in a nature scene at the bank of a peaceful lake with mountain scenery in the background. Background audio of nature sounds was paired with video imagery of ripples on the lake, clouds moving through the sky, and wind rustling through the leaves of trees. The body scan practice instructions came from Mindful.org and are part of an empirically validated mindfulness app developed by UCLA's Mindful Awareness Research Center (Purdie et al., 2022). Instructions guided individuals to scan the body while paying attention to body sensations, along with suggestions to release tension. This practice continued for 3 min.

The *mindful observation of nature practice* featured a 3D timelapse video scene of the Aurora Borealis. Participants were immersed in the visuals of the scene from a seated angle such that they could look up and around at the aurora borealis. Before beginning the practice, the facilitator instructed veterans to, *"Mindfully attend to your surroundings and observe any thoughts and emotions that arise non-judgmentally."* Once the exercise began, there was relaxing music playing in the background but no further audio instructions. The duration was 2 min.

1.4. Measures

1.4.1. Acceptability and feasibility

1.4.1.1. Acceptability of each exercise.: After each mindfulness practice, veterans responded on a 4-point response format (1 = *strongly disagree* to 4 = *strongly agree*) to rate the following three questions: *"I felt engaged during this exercise"*, *"I would do the exercise again"*, and *"I would recommend the exercise to other veterans"*. We used a 4-point scale to reduce participant burden as the measure was administered verbally while participants were wearing the VR headset. Providers were asked the same three items, except the last item wording was adapted to ask about whether they would "recommend the exercise to veterans." Scores were averaged to create an overall composite for the acceptability of the mindfulness practices within the VR headset.

1.4.1.2. Usability and satisfaction.: Patients responded to four questions about the usability and satisfaction of the intervention, rated from 1 = *not at all* to 10 = *extremely*: *"Overall, how satisfied are you with the VR mindfulness intervention?"*, *"Overall, how confident do you feel about the VR mindfulness intervention?", "Overall, how helpful did you find the VR mindfulness intervention?", "How likely would you be to recommend the VR Mindfulness intervention to other veterans?"*. Providers responded to the same questions, except the last item was modified as follows: "*"How likely would you be to recommend the VR Mindfulness intervention to your patients?"*

1.4.1.3. Acceptability overall.: To assess overall acceptability of the VR mindfulness intervention, we constructed 14 items for patients and 8 items for providers, guided by the Theoretical Framework of Acceptability (Sekhon et al., 2017). Items were constructed to assess six relevant domains of acceptability: affective attitude toward the intervention, perceived burden, perceived effectiveness, intervention coherence, self-efficacy, and costs-benefits. Items were rated from 1 = *strongly disagree* to 7 = *strongly agree*. Example items for patients included, *"The intervention increased my confidence in my ability to practice mindfulness"* (self-efficacy), *"The intervention made me feel anxious"* (affective attitude–reverse-scored), *"The intervention was easy to understand"* (coherence), and *"The intervention enhanced my ability to practice mindfulness"* (perceived efficacy). Example items for providers included, *"I am excited about the prospect of using the VR intervention with my patients"* (affective attitude), *"It would be an effective mindfulness training tool"* (perceived efficacy), "*I feel confident that I could show my patients how to use the VR intervention"* (self-efficacy), *"It will be easy for providers to use"* (perceived burden), *"I believe the benefits of self-guided VR mindfulness interventions outweigh the costs"* (costs-benefits). The complete list of items can be found in Appendix A. Items formed a reliable index for both patients ($\alpha = 0.83$) and providers ($\alpha = 0.90$) and were averaged to create total scores.

1.4.1.4. State emotion ratings.: Patient participants rated the intensity of different emotions before and after the VR intervention using a visual analog scale (Gross & Levenson, 1995). The study used a briefer 6-item version of the original 16-item version to reduce participant burden. Patient participants rated their emotions on a 1–7 point Visual Analog Scale (1 = not feeling the emotion at all; 7 = feeling the emotion extremely) in terms of how they felt *at that moment* for the following emotions: happiness, sadness, surprise, anxiety, calm, excited. Providers did not complete the emotion ratings.

1.4.1.5. State mindfulness.: The study assessed the state of mindfulness using an adapted version of the Toronto Mindfulness Scale (Lau et al., 2006), a reliable and valid 13-item instrument assessing state mindfulness that comprises two factors: curiosity and decentering. We selected the two items from each subscale that had the highest factor loading in the original validation paper (Lau et al., 2006) resulting in four items (items 2, 3, 12, 13 from the original scale). Items were rated on a 7-point Likert scale (1 = *strongly disagree* to 7 = *strongly agree*). The study derived a state mindfulness score by averaging responses, where higher scores reflected a more mindful state ($\alpha = 0.69$). Providers did not complete state mindfulness ratings.

1.4.1.6. Sense of presence.: Sense of presence is a construct used in the computer science literature that refers to how immersive or "real" a virtual environment is. The sense of presence questionnaire consists of six items with a 7-point Likert scale ranging from 1 = *strongly disagree* to 7 = *strongly agree*. The six items were adapted from Slater et al. (1994) by changing the wording to reflect statements instead of questions and adapting the scale points from the original version to increase coherence and consistency of the measure. The six statements were as follows after the stem *"While in the virtual environment …":* 1) *"I had a sense of "being there";* 2) *"There were times during the experience when the virtual world became more real or present for me compared to the 'real world'"*; 3) *"The virtual world seemed to me to be more like a place that I visited in real life than a picture I saw"*; 4) *"I had a stronger sense of being in the virtual world than being elsewhere"*, 5) *"I thought of the virtual world as a place in a way similar to other places that I've been today*", 6) "*During the experience I often thought that I was really there in the scene"*. The study averaged items (α = 0.81). Providers did not complete sense of presence ratings.

1.5. Data analysis

1.5.1. Quantitative analysis—We conducted all analyses in *R* Version 4.1.0 and *RStudio* Version 1.4.1717 (R. Core Team, 2021). The *psych* package (Revelle, 2023) and *tidyverse* package (Wickham et al., 2019) provided descriptive statistics and reliability. Base R provided dependent samples *t*-tests. The study calculated effect sizes manually using the formula for dependent samples Cohen's D = M_{post}-M_{pre}/SD ($M_{difference}$). All data and code needed to reproduce the analyses are available via the Open Science Framework (OSF) (https://osf.io/hkc43/).

1.5.2. Qualitative analysis—Artificial intelligence via Microsoft Teams live transcription software transcribed audio recordings of the patient interviews verbatim. Research assistants later cleaned and refined transcripts along with review of patient interview notes to make any needed corrections. Three of the study authors analyzed the transcripts by using the framework method, a form of content analysis that allows for systematic reduction of textual data (Averill, 2002; Gale et al., 2013). To organize the textual data, this method uses matrices, in which rows correspond to cases, columns correspond to interview questions or codes, and cells contain summaries of the data. In applying this method, separate matrices were first created in Microsoft Excel for the patient and provider interview data, respectively. In each matrix, rows represented participants, and columns represented interview questions. A second individual double coded each transcript. Next, the data from each coder's transcript summary were combined to confirm completeness and accuracy of the summarized content.

The following research questions guided the qualitative analysis: 1) *What is helpful/unhelpful about the intervention?* 2) *How could the intervention be improved in future iterations?* 3) *Does the VR intervention facilitate a state of mindfulness/how does it aid in mindfulness practice?* Accordingly, for each question, thematic analysis identified themes in relation to each of these questions. All three analysts independently reviewed and coded all of the patient and provider qualitative responses into initial themes using the matrix method.

To resolve discrepancies across analysts, they met regularly until they reached consensus on the themes for each question.

2. Results

2.1. Acceptability and feasibility

As shown in Table 2, both patients and providers rated acceptability as high for each mindfulness exercise and overall, as indicated by high mean scores for engagement (M = 3.25–3.90, SD = 0.30–0.90), desire to use again (M = 3.27–4.00, SD = 0.00–0.90), and recommending the exercise to others (M = 3.40–3.90, SD = 0.12–0.75).

Table 3 displays the descriptive statistics for acceptability of the intervention overall, usability, and global satisfaction. Both patients and providers found the intervention to be acceptable overall (M = 5.67–6.06-, SD = 0.31–0.68). Moreover, patients and providers reported overall high satisfaction with the intervention, confidence in the intervention, generally found it helpful, and endorsed that they would recommend the intervention to other veterans (or their patients in the case of providers; M = 6.90–8.75; SD = 0.38–2.13).

2.2. Patient pre-post state emotion ratings, state mindfulness, and VR presence/immersion

Results are in Table 4. Results of dependent samples t-tests for patients showed large and significant reduction in overall negative affect (t (19) = −5.38, P < .001, d = −1.20) and increase in positive affect (t(19) = 6.18, P < .001, d = 1.38) from pre- to post-intervention. Specifically, patients experienced significant decreases in feeling sad and anxious (d = 0.71–1.35) from before to after the intervention, along with significant increases in feeling calm, happy, excited, and surprised (d = 0.48–0.98). Patients endorsed experiencing mindfulness while in the virtual environment (M = 5.33, SD = 1.73), as well as a strong sense of Presence/Immersion (M = 5.57, SD = 1.07).

2.3. Themes from qualitative analysis

Results of a targeted thematic analysis toward the below research questions identified the following themes synthesized across patient and provider transcripts. Under each umbrella question, the major themes are summarized. Sample quotes for each theme can be found in Table 5.

2.4. What is helpful about the intervention?

2.4.1. Calming and relaxing experience—A common theme in participants' impressions of the VR mindfulness intervention was its calming and relaxing impact. They described feeling at ease and peaceful during the exercises. They cited the serene nature scenes, clarity of guided meditation instructions, and soothing music as factors that contributed to the overall sense of tranquility and relaxation. Many participants found it helpful in relieving tension and reducing stress and anxiety. Participants reported that the immersive nature of the VR environment, with its vivid visuals and realistic nature scenes, contributed to the overall sense of peacefulness.

2.4.2. Escape and relief from negative thoughts and emotions—Participants reported that the VR mindfulness intervention provided a temporary escape from negative thoughts, worries, and anxieties. For example, participants described how the VR environment helped them to let go of worries and negative thoughts. Engaging with mindfulness in a VR environment felt transportive and helped them focus on the present moment and take their minds off their usual concerns. Participants expressed that the VR experience allowed them to find a sense of peace and positivity, providing a getaway from their usual stressors.

2.4.3. Focused attention and present-moment awareness—Participants reported an increased awareness of their thoughts, feelings, and bodily sensations during the VR mindfulness practice. For example, patients noted that by focusing on the guided meditation instructions and visuals, they were able to become more present in the moment, which facilitated mindfulness and self-awareness. Patients described a "zone" that the VR helped them achieve in which they were particularly able to attend to their own thoughts and environment. Providers similarly described VR as a tool for focusing one's attention.

2.5. How could the intervention be improved in future iterations?

2.5.1. Better integration of audiovisual elements—Some participants noted that the voice instructions and visuals did not always match up, leading to distractions and a less immersive experience. Some participants reported that the voice instructions could have been more relaxed and calming, while others preferred a female voice, which they believed would be more relaxing. Some participants, particularly providers, felt that visuals were sometimes distracting, such as when motion was integrated into a nature scene, which had the effect of pulling them out of a meditative state. Accordingly, better integrating meditation instructions with any visual elements containing motion could help ensure participants remain focused and do not become overstimulated.

2.5.2. Enhanced personalization and length—Participants suggested allowing veterans to customize the VR scenes based on their preferences, which could include choosing scenes, adding movement, or providing other options to personalize the intervention. Some participants recommended integrating the VR mindfulness intervention with a phone app to enhance accessibility and customization. Participants also recommended increasing the duration of the VR mindfulness intervention to allow for a more extended relaxing and immersive experience.

2.5.3. Improve headset comfort and fit—Participants mentioned discomfort due to the weight and tight fit of the VR headset, which detracted from the relaxation experience. Some participants with vision problems or glasses found it challenging to achieve a good focus while wearing the headset. A few individuals experienced issues with the recentering function or found the headset cumbersome.

2.6. How does the intervention aid in mindfulness practice (relative advantage/ disadvantage)?

2.6.1. Engaging and immersive experience—Participants reported that the VR environment provided an engaging and immersive experience. The captivating visuals, realistic nature scenes, and soothing sounds helped create a sense of presence and absorption in the virtual setting. This immersive nature of the VR experience allowed participants to become fully engrossed in the mindfulness practice, enhancing their focus and attention to the present moment, leading to a deeper connection with the meditation. For example, the immediacy of the visuals helped to refocus attention when distracted. The feeling of being transported to another place helped patients relax and let go of worries.

2.6.2. Reduction of internal and external distractions—Participants found the VR environment to be less distracting compared to traditional in-person mindfulness practices. The virtual setting blocked out external stimuli, such as noise and visual disturbances, allowing individuals to concentrate better on the meditation and mindfulness exercises. In addition, patients also noted how the VR environment helped refocus attention when their mind wandered off and how the gripping and immersive nature of the visuals would help to bring them back into a meditative state.

2.6.3. Sense of safety and privacy—Participants reported that the VR mindfulness intervention provided a sense of safety and privacy. They felt more comfortable and at ease in the virtual environment, compared to group mindfulness sessions. The privacy of the VR experience allowed them to relax and be more open to the practice in a space free of judgement. Several veterans spoke to a baseline sense of hypervigilance that normally makes mindfulness practice challenging, and how the VR environment helped reduce anxiety and facilitate relaxation.

3. Discussion

The present study investigated the feasibility and acceptability of a self-guided VRMT intervention for veterans undergoing residential substance use treatment, along with exploring the potential benefits of integrating VRMT in this population. Findings suggest that self-guided VRMT is feasible and acceptable to both patients and providers, and that the intervention holds promise for improving affective outcomes. Moreover, key themes from qualitative analyses suggested that self-guided VRMT provides an immersive experience that may have several advantages over other mindfulness training experiences, such as reduced distractions and a sense of safety. Overall, findings contribute to a deeper understanding of the experiences and perceptions of both patients and providers regarding the VR-based mindfulness intervention and underscore the potential of self-guided VRMT as a promising intervention for residential SUD programs.

Findings from the present study demonstrate that self-guided VRMT was well-received and considered acceptable by both patients and providers. For example, participants reported that each exercise was engaging, that they would recommend it to others, and had a desire to do it again, suggesting that participants are motivated to continue to engage with the intervention. Moreover, the high levels of satisfaction and confidence expressed by

participants highlight the potential for VR to effectively engage individuals in mindfulness practice, even within the complexities inherent in the context of a residential substance use treatment program. This acceptance is noteworthy, as it suggests that the immersive nature of VR environments can help address the challenges of environmental and personal distractions that often hinder traditional mindfulness training adoption (Anderson et al., 2019).

In terms of potential benefits of the intervention, results suggested that patients experienced reductions in negative affect and increases in positive affect from pre- to post-intervention. Moreover, effect sizes were large, with the greatest reduction in anxiety and greatest increases in feeling happy, surprised, and calm. Given one of the aims of mindfulness training is to achieve a state of calm (Baer, 2003), results are promising and suggest that VRMT may hold some of the same benefits of regular mindfulness training. However, it is important to note that achieving a state of calm is not the only goal of mindfulness. Specifically, mindfulness practices are intended to "bring one's complete attention to the present experience on a moment-to-moment basis" (Marlatt & Kristeller, 1999, p. 68). Consistent with this definition, both quantitative and qualitative results suggest that participants experienced enhanced present-moment awareness, as indicated by the qualitative theme *"Focused Attention and Present Moment Awareness"* and high scores on the TMS–an empirically validated measure of state mindfulness. Importantly, the TMS addresses a critical quality of mindful attention: *nonjudgmental* awareness (Kabat-Zinn, 2003). Given the high scores endorsed by participants on the TMS items, including *"I was more invested in just watching my experiences as they arose, than in figuring out what they could mean"* and *"I was more concerned with being open to my experiences than controlling or changing them"*, results suggest that participants were able to practice mindfulness as traditionally intended within the VR environment, in addition to experiencing a state of calm as an outcome of the practice.

The thematic analysis of participant feedback yielded valuable insights into the perceived benefits of the VR mindfulness intervention, suggested improvements, and relative advantages of this approach relative to other forms of mindfulness training. Participants reported experiencing a calming and relaxing effect, relief from negative thoughts and emotions, and enhanced focus on the present moment. Such outcomes align with the established benefits of traditional mindfulness practices. Additionally, participants' suggestions for improvements, such as enhancing audiovisual elements, personalization, and increasing the intervention length, highlight areas that could be refined to improve the intervention in future iterations. Finally, in terms of how the intervention compares to in-person mindfulness training outside the VR, it may reduce distractions, increase safety and provide an immersive space dedicated to the practice, which participants noted as advantages. Sense of safety is particularly notable given the higher rates of PTSD comorbidity (45 % of the patient sample) and may suggest that for individuals who have symptoms of PTSD, such as hypervigilance, hyperarousal, and intrusive imagery, the VR environment may provide additional advantages that enable relaxation that could otherwise interfere with mindfulness practices (Lustyk et al., 2009). The fact that the VR environment was also reported to decrease distractions is informative and may suggest that VRMT could

be helpful in other inpatient settings (e.g., psychiatric emergency) that tend to be more fast-paced, have high turnover rates, and more labile patients.

3.1. Strengths, limitations, and future directions

The present study had several notable strengths, including the inclusion of both patient and provider data, mixed methods (qualitative and quantitative measures), and examining the initial benefits of VRMT in a real-world treatment setting. Moreover, the present study adds to the literature on implementation of mindfulness training in residential substance use treatment programs. However, findings should be interpreted with caution given several important limitations of the present study.

First, as a small pilot feasibility and acceptability study, with a single-arm design and no control group, the present study cannot provide information about the efficacy of the intervention, but instead can only speak to patient and provider perceptions while giving some indication of potential benefits. Future work should employ random assignment using a larger sample of patients and test the effects of the intervention at multiple timepoints.

Second, while the use of a within-subjects experimental design was applied to pre-post changes in affect, mindfulness and presence were not measured before the intervention. Thus, we do not know how baseline levels of state mindfulness or sense of presence could impact the findings. Thus, future work should include pre-intervention measures of state mindfulness and sense of presence to examine effects of the intervention on these outcomes directly.

Third, limits on generalizability include the small sample size, specific population (veterans, mostly male), and setting (SUD residential treatment). Accordingly, testing the intervention not only in larger samples with random assignment, but also across other patient populations and treatment settings would be important to investigate in future work.

Fourth, it is important to note that the brief, 10-min self-guided intervention in the present study is not meant to replace a full MBRP or MORE protocol, and as such, does not address all the elements included in a full-length, multi-session protocol of a mindfulness-based intervention for SUD. Instead, the present intervention aimed to provide a way to practice mindfulness skills for individuals in residential SUD treatment that is feasible and acceptable to both patients and providers. As such, while the present intervention could potentially be used as an adjuvant treatment to foster skills that are taught within evidenced-based mindfulness protocols (e.g., breathing and body scan practices), we do not recommend that this stand-alone intervention should replace a more comprehensive protocol, but instead hope that this VRMT intervention could help patients in residential SUD programs to practice mindfulness during their stay.

Fifth, while the practices herein contain similarities to those in empirically validated mindfulness-based protocols for SUD, the practices are not drawn directly from MBRP or MORE protocols and contain some differences. For example, while the mindful breathing practice instructions aligns most closely with the MBRP protocol, the body scan practice instructions were similar to those used in MBRP, but included some additional

suggestions to release tension or soften the muscles, divergent from the MBRP body scan practice. In addition, the mindful observation of nature practice is not typically included in MBRP, though the principals in the instructions–namely to non-judgmentally observe one's surroundings, thoughts, and feelings–are conceptually similar to other mindfulness practices within MBRP. As such, the practices are not directly comparable to those used within the MBRP protocol, but instead represent adaptations for the inpatient context and await further efficacy testing.

Limitations notwithstanding, findings from this pilot study lay the groundwork for future VRMT intervention development efforts. The feasibility and acceptability demonstrated by both patients and providers suggest that VR mindfulness training holds promise as a complementary tool in residential substance use treatment programs. The immersion and engagement offered by VR technology can facilitate mindful attention and emotional regulation, potentially enhancing the overall treatment experience. However, the insights gained from this study, including participant suggestions for improvement, should guide the refinement of VR mindfulness interventions to ensure optimal efficacy and user experience. For example, recording a custom audio that is better paired with visual elements could help aid mindfulness practice. Furthermore, allowing more options for customization could help personalize the intervention to different patient preferences. An exciting area for future research is translating more elements of mindfulness protocols beyond skills practice within a self-guided VR intervention, such as providing further instructions within the VR on the intent of mindfulness and how it could be applied to addictive behaviors (e.g., how non-judgmental awareness of emotions and cravings could decrease use). In the present study, these instructions are provided in the context of ongoing mindfulness groups on the unit, but translating these to the VR environment could be a beneficial next step. Moreover, future work could benefit from assessing the impact of VRMT on craving outcomes, a critical treatment outcome for individuals with substance use problems (Witkiewitz et al., 2014). In addition to improving the intervention for future iterations, the present study may help guide future efficacy research. When testing interventions that are delivered through novel technology such as VR, it is particularly important to rule out placebo effects by using active controls. For example, given the novelty of the VR environment, any effects of positive emotions could be due to excitement about the experience overall. Thus, if the goal of VRMT is to teach mindfulness skills rather than simply engendering a state of positive mood and relaxation, using an active control group will be particularly important. Moreover, measuring key outcomes of interest at multiple timepoints would help investigate retention of mindfulness skills when learned in a VR environment. Gathering information on how long effects of VRMT are sustained compared to other forms of mindfulness training would also help inform whether VRMT is non-inferior to mindfulness training delivered via a therapist and/or in a group setting, for example, as well as enabling examination of dose-response effects. Finally, exploring moderators of treatment efficacy when using larger samples, such as prior mindfulness experiences and comorbidities, could help identify whether and what kinds of patients for whom VRMT is most appropriate. It is possible that VRMT may be best suited to mindfulness beginners to provide additional scaffolding, and once skills deepen, practicing outside the VR environment would be more appropriate.

4. Conclusion

In conclusion, the present study contributes valuable insights into the feasibility, acceptability, and potential benefits of VR mindfulness training for individuals in residential substance use treatment. Preliminary findings suggest that self-guided VRMT mindfulness training provides an immersive experience that uplifts mood and reduces distractions and may provide some of the traditional benefits of mindfulness training. Understanding patients and providers experiences of mindfulness training delivered via VR headsets can aid in future pilot projects testing the efficacy of VRMT compared to active controls. Using VR may provide an additional tool to set the stage for deepening mindfulness skills and could be a helpful adjuvant treatment for veterans in residential substance use treatment programs. Our hope is that the present work can set the stage for further investigations and developments that harness the power of immersive technologies to address the complex challenges of substance use disorders and enhance treatment outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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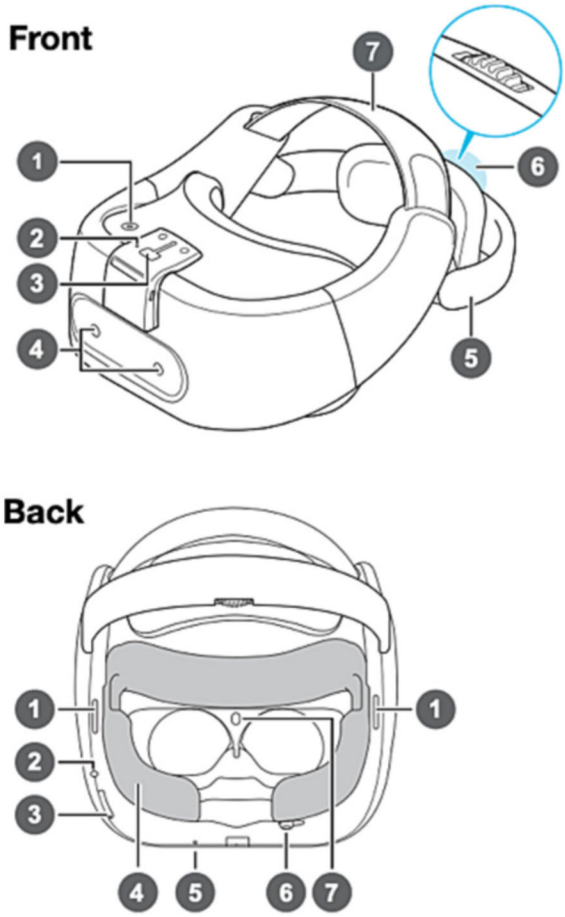

1	Power button
2	LED (Status light)
3	USB Type-C connector
4	Tracking sensors
5	Back head support
6	Adjustment dial
7	Adjustment head strap

1	Speaker
2	3.5 mm headset jack
3	Volume buttons
4	Face cushion
5	Microphone
6	IPD adjustment slider
7	Proximity sensor

Fig. 1.
Schematic of REAL systems i-series headset.

Table 1

Demographic information for patients and providers.

	Patients (N = 20)		Providers (*N* = 12)	
	N or Mean	***% or SD***	***N or Mean***	***% or SD***
Age	51.55	15.60	39.50	10.34
Gender				
Man	17	85 %	10	83.33 %
Woman	3	15 %	2	16.67 %
Race & Ethnicity				
White	9	45 %	9	75 %
Black	7	35 %	1	8.30 %
Asian	–	–	3	25 %
Latine	4	20 %	–	–
Other	7	35 %	–	–
Diagnoses				
Alcohol Use Disorder	15	75 %	–	–
Stimulant Use Disorder	7	35 %	–	–
Opioid Use Disorder	2	10 %	–	–
PTSD	9	45 %	–	–
Major Depressive Disorder	7	35 %	–	–
Generalized Anxiety Disorder	3	15 %	–	–

Table 2

Mean and standard deviation of acceptability for individual mindfulness exercises.

Exercise	Engaging				Would do again				Would recommend			
	Patient		*Provider*		*Patient*		*Provider*		*Patient*		*Provider*	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Observe	3.90	0.31	3.33	0.50	4.00	0.00	3.56	0.50	3.90	0.31	3.78	0.44
Body	3.40	0.80	3.27	0.79	3.30	0.90	3.27	0.90	3.40	0.75	3.55	0.69
Breath	3.25	0.91	3.42	0.51	3.50	0.76	3.58	0.50	3.60	0.60	3.67	0.69
Overall	3.52	0.43	3.33	0.51	3.60	0.41	3.44	0.58	3.63	0.42	3.64	0.50

Note. Acceptability ratings for each exercise were rated from 1 = *strongly disagree* to 4 = *strongly agree*. Observe = mindful observation of nature practice. Body = body scan practice. Breath = mindful breathing practice.

Table 3

Descriptive statistics for acceptability overall, usability, global satisfaction.

Survey measure	*Patients (n = 20)*		*Providers (n = 12)*	
	M	***SD***	***M***	***SD***
Acceptability (1–7)	6.06	0.68	5.67	0.31
Satisfaction (1–10)	8.55	1.47	6.92	1.98
Confident (1–10)	8.50	1.40	7.00	2.13
Helpful (1–10)	8.55	1.47	6.42	1.88
Recommend (1–10)	8.75	1.59	7.00	2.13

Note. Acceptability items were rated from 1 = *strongly disagree* to 7 = *strongly agree*. Satisfaction, confidence, helpfulness, and recommend were rated from 1 = *not at all* to 10 = *extremely.*

Table 4

Dependent samples *t*-tests for pre-post patient emotion ratings.

Emotion	Pre-Intervention		Post-Intervention		*t(19)*	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Sad	2.60	1.54	1.60	1.05	−3.16**	0.005	−0.71
Anxious	3.80	1.74	1.80	1.28	−6.02***	<0.001	−1.35
Happy	4.20	1.36	5.60	1.05	4.38***	<0.001	0.98
Surprised	1.95	1.32	3.75	2.15	3.72***	<0.001	0.83
Calm	3.90	1.65	5.70	1.56	3.42***	0.003	0.76
Excited	3.90	1.68	4.80	1.61	2.16*	0.044	0.48
Positive	3.49	1.74	4.96	1.79	6.18***	<0.001	1.38
Negative	3.20	1.73	1.70	1.16	−5.38***	<0.001	−1.20

Note.

* p<.05;

** p<.01;

*** p<.001.

Emotions were rated on a visual analog scale from 1 = not at all to 7 = extremely.

Table 5

Themes from qualitative analysis and sample quotes.

Guiding Questions and Themes	N	Sample quotations
What is helpful about the intervention?		
Calming and relaxing experience	27	"I felt very peaceful and at ease." (P3859) "It brought me down to an even keel and [a sense of] tranquility. It was perfect … my mind was at peace." (P3855) "Relaxing as hell. It had me breathing right, I felt totally relaxed." (P3864) "I felt tension just disappearing." (P3857)
Escape and relief from negative thoughts and emotions	19	"It got my mind off my worries for the minute I was on it … It was like a getaway without the stressors and anxiety of driving 2 or 3 h". (P3866) "None of my anxiety came up. I didn't think about my health. I didn't think about anything except relaxing." (P3864) "It takes my mind off all my worries to be honest … for a moment, I was not worrying about anything. It's a great way to take your mind off your anxiety." (P3870)
Focused attention and present-moment awareness	15	"[The VR] really captured my attention… It redirects your attention and focus. Rather than on drugs, you're focusing on finding that source of peace, in a meditative state." (P3853) "It really helped me to zone in." (P3852) "The guided meditation and immersion visually helped focus my attention, particularly on a busy day." (Pr5) "Puts me in the here and now." (P3857) "My whole mind was focused." (P3861)
How could the intervention be improved in future iterations?		
Better integration of audiovisual elements	13	"The speaking didn't match up with what [the VR] was doing." (P3854) "Add music with the nature sounds." (P3853) "Better integration of audio with visual, relating the audio to what is visualized." (Pr9)
Enhanced personalization and length	14	"I think the ability to customize [the VR] would be helpful. Because some people find water relaxing, other people might be scared of water." (P3867) "Let the veterans choose their own scene." (P3852) "I'm pretty much in love … something like this doesn't happen too often, so I'd want it to last a little bit longer." (P3864) "I could be on that thing for an hour. It wasn't long enough." (P3866). "I'd make it longer." (P3855).
Improve headset comfort and fit	16	"Just the weight of it. I would have it personalized to fit my face better." (P3868) "The headset was not that comfortable. It was tight around my forehead." (P3871) "Weight of the headset might be a barrier for those with neck or back issues." (Pr11)
How does the intervention aid in mindfulness practice?		
Engaging and immersive experience	29	"It's very serene and realistic; made it seem like you were really there." (P3859) "Quite effective in transporting my mind to a different place." (Pr4) "[The intervention] took me out of my environment and put me in another place … my happy place. It was super calming. It really touched all my senses. Everyone should do this." (P3857) "I'm not searching for a peaceful place. It's right in front of me. There's no pressure to create what is being narrated. Feels easier." (P3858)
Reduction of internal and external distractions	13	"When practicing mindfulness in other settings, I think about things that are worrying me, or my mind wanders off. I may think of a random word. I have automatic thoughts and keep trying to ground myself, but my mind keeps wandering off. When practicing in the VR setting, I wouldn't wander off [as much] because I was looking at things that brought my mind back to the meditation." (P3861) "I have a hard time [in conventional mindfulness training] when we're sitting there or closing our eyes and focusing on breathing. I just can't do that. I have other thoughts in my mind that distract… I'm not even paying attention. This helped me." (P3866) "I can imagine this being very helpful in hectic environments where it's hard to focus on breathing or mindfulness due to distractions." (Pr8)
Sense of safety and privacy	6	"This felt more private; you're in your zone. You're not worried about who's looking at you or 'one-eying it' … It's easier to relax and I feel safer." (P3858) "I have PTSD and I react when people are behind me. In [the VR] I have no fear, I have no anxiety, I have nothing to be worried about… It just puts me in my own little comfort zone. My little bubble. I felt safe, at ease, relaxed. It takes away judgement." (P3857) "I like it better cause it's just me myself, rather than a whole group of people … No distractions." (P3862) "I found a place to be myself [in the VR]; this gave me a perspective that everything is going to be OK. It helped me look at the bright side of all I have in my life instead of just focusing on all the negative." (P3868)