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Evaluation of a novel interactive virtual reality environment for mindfulness skills training

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Abstract

Objectives Although virtual reality (VR) has been shown to be an acceptable and feasible format for mindfulness training, most evidence to date is based on use of passive 3D-video environments and typically single-use evaluation. This study aimed to evaluate the impact of sustained mindfulness practice in a fully interactive bespoke 3D VR environment.

Methods This mixed-methods study compared mindfulness data from pre-registration healthcare students using a VR-based mindfulness intervention programme with an audio mindfulness control. Participants completed the State Mindfulness Scale after each week's experience and were invited to an interview to gather qualitative data for triangulation.

Results A total of 32 participants consented to participate and 21 completed both arms of the study to provide their paired state mindfulness scale scores. There was a significant ($p=0.0002$) improvement of just under 5% in mindfulness score for the VR cohort compared to the control cohort. 15 participants undertook interviews; themes from these related to the "Impact" of the VR environment, "Engagement" with mindfulness and "Immersion" in the environment.

Conclusions An interactive VR-based mindfulness intervention is effective at increasing mindfulness in health sciences students. VR enabled users to escape from reality and immerse themselves in a relaxing environment; in turn this increased adherence and motivation with the practice. Users appreciated the value of being able to interact with the environment, find their own space within it and focus their practice on VR-based objects and sounds.

Keywords Mindfulness, Undergraduates, Health sciences, Virtual reality

Introduction

Mindfulness meditation

In recent decades, mindfulness meditation has gained significant attention in both scientific research and popular culture as a potential tool for enhancing overall wellbeing. Rooted in ancient contemplative traditions, mindfulness meditation involves paying deliberate and non-judgmental attention to the present moment [14]. This practice has been the subject of extensive investigation in psychology and neuroscience, leading to a growing

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body of empirical evidence supporting its positive impact on various aspects of wellbeing. Mindfulness meditation has been associated with numerous benefits for psychological wellbeing. Research has shown that regular mindfulness practice can reduce symptoms of anxiety and depression [13] and improve overall emotional regulation [12]. Strong evidence [10, 17] has consistently linked mindfulness meditation to a range of positive effects in University students including self-awareness, reduced stress and life satisfaction [6], contributing to enhanced psychological flourishing. While "internal" mindfulness meditation involves closing the eyes and focussing attention internally, many practitioners also favour externally focussed practice using objects as the focus for practice [1],this is thought to help transference of mindfulness to practical every day usage.

Virtual reality and meditation

The integration of virtual reality (VR) technology into "external" meditation practices has garnered significant attention from researchers and practitioners alike with clinical experts at a 2016 mindfulness meeting agreeing that VR was a feasible and acceptable format for mindfulness [21]. VR meditation offers users the opportunity to immerse themselves in visually and audibly captivating environments, enhancing the meditation experience. A review by Riva et al. [24] suggested that immersion in VR environments can facilitate relaxation and increase sense of presence, leading to "personal and clinical changes". The immersive nature of VR may contribute to these stress-reduction effects by removing users from their real-world concerns [21]. However, there is a tension here as mindfulness is rooted in developing awareness and skills that promote the wellbeing of individuals in everyday life in the face of difficulty as well as 'good' times. There is a potential role of VR, however, in providing an external focus to meditation, as opposed to internally focussed meditation but this relies on the environment being immersive and realistic [22]. VR can also reduce the impact of any external distractions and encourage users to stay present in the virtual environment. A recent review [18] exploring the impact of VR-based applications on mindfulness reported data from 7 studies and concluded that VR-based meditation improved both state and trait mindfulness. More immersive experiences tended to be more effective than less immersive or conventional meditation. A good example was the study by Navarro-Haro et al. [22] who found that mindfulness training utilising VR to float participants down a river made a significant impact on both anxiety and adherence to therapy when compared to group-based mindfulness. Although this study lacked qualitative data exploring factors impacting on this, these findings provided sound rationale for additional research into the value and role of VR-based mindfulness meditation. None of the reported studies in Ma's review utilised an interactive VR environment and most relied on 360-degree videos,our study aimed to increase immersion by enabling navigation and interaction within the environment.

Mindfulness meditation has been shown to contribute to the development of a set of skills central to the learning process for students in higher education and in emerging adults, including concentration, attention, awareness, open-mindedness and information processing [7, 9, 25]. In addition, mindfulness meditation has been linked with the development of emotion regulation strategies [2]. These skills are particularly relevant to healthcare professionals working in challenging clinical situations, and mindfulness training is increasingly common within allied health and nursing professions [29].

The intervention in this study was designed to combine the immersion of a fully interactive VR environment with the embodied experience and training of practising mindfulness meditation using an external focus. Additional options provided by the VR format include the previously unreported ability to personalise the experience by choosing a favourite place in the environment in which to meditate; this was hypothesised to help improve engagement with practice.

The aim of this pilot study was to evaluate the impact of an interactive VR environment-based mindfulness meditation on mindfulness skills development among undergraduate health science students.

Methods

Study design

This quasi-experimental design study adopted a mixed methods approach to gather both quantitative longitudinal survey-based data and qualitative feedback from users. Approval for the project was granted by the Central University Research Ethics Committee and all participants provided informed consent to participate after receiving written information. Participation was voluntary and all quantitative data was provided anonymously. Qualitative data was anonymised at transcription. Participants were recruited via email from undergraduate health science cohorts and allocated to experience either VR or control support for their first placement; these were then swapped for the subsequent placement. Allocation utilised a non-randomised cluster method [26], depending entirely on participant clinical placement schedules and headset availability. All participants were

asked to complete a short survey prior to their first placement and then a mindfulness survey at the end of each placement following engagement with their mindfulness resource. They were all invited to an interview after experiencing both formats of mindfulness support.

Participants

All students studying one of 6 undergraduate pre-registration degrees at a single large Higher Education Institution were invited to participate. Included degree subjects were Diagnostic Radiography, Nursing, Occupational Therapy, Orthoptics, Physiotherapy and Therapeutic Radiography. Students were asked to read the participant information and submit a consent form to the principal investigator if they wished to participate.

Intervention

Participants undertaking the VR experience were provided with an Oculus Quest 2 headset for use during an extended clinical placement block; these ranged from 4 to 8 weeks in length. They were also provided with access to a specifically designed VR environment which comprised a calming and fully interactive 3D tropical beach filled with a range of flora, fauna and other features as seen in Fig. 1.

Users were able to explore the beach and access a series of bespoke mindfulness meditation tracks; it was hypothesised that this would be the main contribution to mindfulness. The Mindfulness recordings were created specifically for this application and were influenced by the work of both Jon Kabat-Zinn [15] and Zindel Segal et al. [27]. It was essential to the design of the mindfulness sessions to situate the participants within the VR island environment and therefore refer to the island and some of its characteristics. Supplementary File 1 provides an overview of the sessions and, along with Supplementary File 2 demonstrates how mindfulness practices were situated in and drew from the VR environment. In this way the mindfulness practices were intended to support and encourage immersion in this novel environment distinct from the students' day to day experience. In this relaxed and original environment, students had the opportunity to learn mindfulness principles and skills which could be transferred to their day to day study and clinical practice settings. In this way the VR environment could be seen as a way of offering a stepping stone, or graded environment, to learn skills that may be useful to students in more challenging environments and situations.

Fig. 1 The 3D environment including meditation space

Although there are now several mindfulness apps available, such as The Mindfulness App (https://www.themindfulnessapp.com/) mindfulness is often learnt and experienced in workshop settings with opportunities to ask questions, share experiences and learn from a facilitator and peers. Therefore the 6 recorded guided mindfulness practices included principles of mindfulness. Examples from mindfulness mindful practices 1, 2 and 4 in Supplementary File 2 illustrate the following principles: The Beginner's Mind; the importance of Focussing on the Breath; Paying Attention and Acceptance of the Mind Wandering. In this way students learned about mindfulness whilst experiencing the practices which it was hoped would be more engaging than a more formal approach to teaching these principles.

One of the paper authors and the mindfulness facilitator (Hanna) had experience of delivering a shortened mindfulness-based programme to veterinary students, in a pilot research study [23]. Health care and veterinary students are likely to experience time constraints and therefore shortened mindfulness programmes should be considered if they still maintain efficacy [4, 8, 16, 20]. All mindfulness sessions in this current study were therefore around 20 min in length, including arriving and departing from the VR environment. Students were guided to access the meditation modules at their own pace and were self-guided. They were permitted to skip modules and return to previous modules but were advised to access them all, to engage at least once a week and to work through the modules in the suggested order at first. In addition, the facilitator guided the students' attention initially to either the VR environment, or, for the control group, to the space participants were in. Often in mindfulness practices attention is first brought to the breath

or the body as an "internal" meditation, but within our study, students' attention was drawn to the novelty of the VR environment or to the real space in which they were practising in order to capture their interest and curiosity as an external meditation.

Control

Participants in the control group were provided with a series of audio tracks that provided similar mindfulness resources. These followed a similar pattern and format to the 6 VR sessions except that the practices were not situated in the VR island environment. Users in the control group were guided to utilise specific objects as focal points for external meditation. All participants were asked to engage with both the VR sessions and the control sessions; this allowed paired data to be gathered for evaluation.

Outcome measures

The primary outcome for the study was state mindfulness and quantitative data relating to this utilised the State Mindfulness Scale [28]. This is a psychological assessment tool comprising 21 questions and used to measure an individual's level of mindfulness in a specific moment or state. It is designed to assess how fully a person is engaged with their current experience, thoughts, and sensations, without judgment or distraction. Permission to use this scale is granted for research purposes. Users are asked to respond to statements by indicating the degree to which they are experiencing different aspects of mindfulness at a given moment. The Scale has been used to investigate the effects of mindfulness-based interventions, mindfulness training programs, or the impact of mindfulness on various aspects of well-being.

Motivation is an important factor impacting on success of mindfulness and this was assessed prior to provision of resources using the Readiness for Therapy Questionnaire [11]. This comprises 6 questions, helping to increase compliance while retaining reliability and good correlation with recovery. It should be noted that 3 questions in this tool were reverse marked,in these cases a high score indicates a lack of agreement with the statements. A short survey was chosen in order to increase compliance and not increase existing workload for participants. Permission to use the questionnaire was granted. Additional survey questions were utilised to gather demographic data (Supplementary File 3).

Qualitative data was gathered for triangulation through voluntary interviews which continued until data saturation had been achieved. Interview methods are invaluable in mental wellbeing research due to their ability to capture rich, qualitative data [19]. They enable researchers to explore the complexities of individuals' experiences, emotions, and perceptions related to mental health. In this case the mindfulness question formed part of a more extensive interview related to other aspects of the intervention which are to be reported elsewhere.

Interview questions were developed in collaboration with a multi-stakeholder steering group including mental wellbeing professionals, academic staff and students (Supplementary File 4). Participants were asked to describe what they found most useful, most enjoyable as well as what they thought should be changed. They were also asked about which format they preferred and how the VR environment impacted on their mindfulness experience and engagement. Four members of the academic research team with at least 3 years of experience with interview methods performed all the interviews with each participant being assigned to a researcher who was unknown to them to avoid any power relationships. Interviews were conducted online via Zoom at a date and time chosen by participants. Interviews were planned to last less than one hour but continued until all data had been collected to the interviewee's satisfaction. Interviews were audio recorded and transcribed anonymously by an external transcription company. Checking of transcription against recording was performed by the research team.

Data analysis

Demographic data was collated using descriptive statistics to provide an overview of participants. The State Mindfulness Scores for each participant's VR and control experience were compared using a Mann–Whitney (paired data) test following normality testing with Shapiro-Wilkes.

Qualitative data analysis adopted a phenomenological approach to explore the lived experience of using VR on practice placement. This required the researchers to bracket their own assumptions and focus on describing the phenomenon from the user's perspective. A thematic analysis approach [5] was utilised. Two researchers independently read through transcripts to familiarise themselves with the content and the responses were coded manually using Excel. The resulting codes were collaged and discussed to develop the subthemes and themes. A third researcher was engaged to resolve any arising conflicts,there were none.

Results

A total of 32 participants consented to participate; these comprised representatives from all courses, years and genders as well as including a range of ages. Table 1 illustrates the relevant demographics for the participants; it

Table 1 Demographics ($n=32$)

Demographic	Value	Count (%)
Age	Mean	23.9
	Median	20
	Minimum	18
	Maximum	51
Gender	Female	25 (78%)
	Male	7 (22%)
	Prefer not to say	0
Status	Home	29 (91%)
	International	3 (9%)
	Prefer not to say	0
Course	Diagnostic radiography	7 (22%)
	Nursing	4 (13%)
	Occupational Therapy	3 (9%)
	Orthoptics	3 (9%)
	Physiotherapy	6 (19%)
	Therapeutic Radiography	9 (28%)
Year	1	10 (31%)
	2	16 (50%)
	3	6 (19%)

can be seen that there was a gender imbalance but this correlated well to the existing gender imbalance within the cohorts. Results from the Readiness for Therapy Questionnaire (as seen in Table 2) indicated that participants were generally not well motivated to engage with therapy, with only 1 participant scoring high (19). It should be noted that Questions 2, 3 and 6 are reverse marked; in these cases a high score indicates a lack of agreement with the statements.

Of the 32 participants, only 21 completed both arms of the study to provide their paired state mindfulness scale scores. All the remaining participants chose not to engage with the control arm of the study. It should also be noted that of these, 20 out of 21 completed the VR arm first; most users chose to continue using the VR application instead of the control for their subsequent placement. Each participant completed a weekly mindfulness scale upon conclusion of their mindfulness practice. Following normality testing, a Mann–Whitney paired test ($n=21$) demonstrated a significant ($p=0.0002$) improvement of just under 5% in mean mindfulness score for the VR cohort (37.48) compared to the control cohort (32.57).

Out of the 32 participants, 15 self-selected to engage with the interviews and qualitative themes arising from these are presented in Table 3. These form the basis for the following discussion.

Discussion

Overall impact on mindfulness

It was clear that the VR environment had enhanced enjoyment of the mindfulness practice and led to improvements in state mindfulness scores compared to conventional practice. Our reduced numbers of paired data (compared to the full numbers of users) mostly represented students who had experienced the VR provision first and then stopped using the audio-only resources. This has caused a possible order effect but echoed the findings of Navarro-Haro et al. [22] who reported that their VR cohort were significantly more adherent to therapy. Use of aspects of the VR environment as a focus for mindfulness appeared to be valuable to students who appreciated the detailed flora, fauna and especially the background sounds as valuable focal points.

Evidence thus far suggests that VR-based mindfulness practice is as good as but no better than conventional practice [9]. This study noted a significant improvement in mean mindfulness state score after each meditation; this could be attributed to the longitudinal nature of the mindfulness practice with our users undertaking practice over a number of weeks as opposed to a single session as reported in previous works. Sustained practice is more likely to yield benefits [1]. The use of repeated state mindfulness measures throughout the mindfulness programmes enabled capture of the sustained nature of the impact,future work is planned to evaluate the long-term impact of this.

Table 2 Readiness for therapy questionnaire data ($n=32$)

Readiness	Mean score	Range
Q1) It's essential that I work on my problems as soon as possible because they are affecting the quality of my life	2.8 (out of 4)	1–4
Q2) I like to do things the way I've always done them, and I don't want to change	1.9 (out of 4)	1–4
Q3) If I'm sceptical about something, I'm not willing to try it	2.4 (out of 4)	1–3
Q4) Even if therapy becomes difficult, I will stick with it to the end	2.8 (out of 4)	1–4
Q5) In between the sessions, I will dedicate time to regularly practise the things I learn in therapy	2.8 (out of 4)	1–4
Q6) I won't attend therapy if I have something more pressing or interesting planned	2.3 (out of 4)	1–4
Total score	15.1 (out of 24)	9–22

Table 3 Themes related to mindfulness (interviews $n = 15$)

Theme	Subtheme	Indicative comments
Impact	Useful	"I'm…in an A&E department. So, coming home from that to, you know, just sit on the couch, on a nice little island, just hear this voice in your ear and, kind of, follow along with the breathing instructions, it did calm me down, it was quite nice. Then, I'd come out of the experience feeling a little bit more chilled than I otherwise might have"
		"anything like that where you can just switch off from the world, that was useful, especially for me, because, like I say, I had a bad year last year. It was kind of good just to go, "Right." Put the thing on and then kind of like just go, "Right, I'm just doing this for a bit." and just putting that time aside…"
Engagement	Enjoyment	"logging on to try to do the exercises just online just felt like another task in my day, but the VR environment was quite nice. It was a novelty, it was a change of scenery, a breath of fresh air, kind of thing. It didn't seem like a chore, it just seemed like something fun to relax myself"
		"usually when I've done mindfulness stuff in the past, it's always just a recording and you just listen to it. With the addition of the whole island and stuff, that was pretty cool"
Engagement	Choice	"You know, there was that choice, there were good options there to spend a long time there or a short… So, yes, I just liked that. Then having that, "I'm here now for X amount of time to just get into the mindfulness." So, yes, I found that really good"
		"You know, you can't just pop away of an evening to go and see a beach somewhere all the time, so it's quite nice to just sit on the couch when you have half an hour and suddenly be on a tropical island. It's not the real thing, of course, but it's a nice simulation of one and it genuinely did help a little bit"
Presence	Escape	"I liked the way it created a little bit of space between yourself and the immediacy of problems that you might be having at the time. It, sort of, just gave you a little bit of a breather. Your problems are still there, as soon as you come off the island your problems are still there, but it's nice to get away from them for a little bit. That guided meditation did that for me"
		"Well really good, like I say, it just kind of took you out of the moment, literally, because you were in this virtual world but then you were doing the mindfulness as well. So it was really quite good in that way"
Presence	Focus	"I liked being immersed in it. Yes, I don't think that I would listen to mindfulness things just while, you know, not… Like just sat in my flat, looking around, or something, yes"
		"I think I was more engaged with the VR than without. With the conventional it's the same audios, but I find myself lying in bed and listening to them instead of exploring something. It's harder for me to stay focused on it when it's just the audio"

Another aspect where our mindfulness practice differs from other reported papers such as Navarro-Haro et al. [22] is in the interactive nature and the provision of choice, as opposed to 3D video based environments as used by Chandrasiri [9] and Navarro-Haro et al. [21]. Several students reported finding their own favourite spot on the island to practice their mindfulness. This personalisation of the experience is a novel aspect of the VR application and is likely to be another factor increasing engagement and adherence to the VR-based mindfulness meditation programme.

Engagement and motivation

Motivation is a challenge for people suffering from depression and anxiety [21], for our cohorts who did not score particularly highly on the Readiness for Therapy scale this was clearly an issue. A recent systematic review [30] highlighted the potential of VR to enhance the adherence and motivation of mindfulness novices. Their finding was reinforced by this study with comments from the cohort reporting how they looked forward to practice within the VR environment. Some participants referred to the VR environment as "my slice of relaxation" or "my reward", suggesting high levels of motivation. This may be linked to the novelty of the VR itself but this was sustained for several weeks and, in most cases, users requested to keep using the headset after the project completion to provide continued support. These encouraging findings suggest that VR-mediated mindfulness support could be valuable for supporting students on remote and off-campus placements in the future.

Presence

The comments from students that directly compared their VR and audio-only experiences highlighted how the lack of distraction within the VR environment aided their cognitive engagement with the mindfulness practice. Several comments specifically identified how the VR environment supported their mindfulness practice by focussing them more effectively than if they had just been in their normal environment. This is an important finding as novice practitioners reportedly struggle to maintain focus [21], although this does improve with repeated engagement with mindfulness practice. Again it is likely that the interactive nature of our VR environment increases feelings of immersion and sense of presence for users compared to more passive 3D video resources. "Spatial exploration" within a VR environment is strongly

linked to greater presence [3] and future development of this resource is planned to embed additional opportunities for exploration and discovery to increase a sense of presence and expand the number of potential mindfulness points of focus.

Limitations

One of the key limitations with this work was the small sample size and use of a single site. Despite incentivising participation with shopping vouchers, there was a remarkably low uptake within the 900 students within the target cohorts. Reasons for non-engagement are hard to identify but it is possible that fear of VR or high existing workloads contributed to this. Although most students are accustomed to screens and technologically adept, neurodiverse or anxious people or those who suffer from motion sickness can be averse to using VR. There may also have been issues due to potential participants' perceptions of the intervention and use of wording such as 'therapy' may have led some students to de-select. This pilot study was open to all students, but it should be acknowledged that selection bias may have skewed the findings with results representing students with existing mental wellbeing issues who are keen to try VR. Another potential limitation is that mindfulness was initially developed to help people with diagnosed illnesses such as chronic pain, anxiety or depression, although it is now recognised to also be of value for those without a clinical diagnosis. The novelty value of VR and the environment itself should also be acknowledged as a potential factor influencing its success and further study will be needed to identify the extent to which this reduces over time. Finally, this pilot data does indicate that the intervention increases mindfulness but did not test how well this transfers to mindfulness practice within a healthcare clinical setting.

Future research

The use of VR for mindfulness meditation raises ethical questions, such as the potential for addiction or detachment from reality. Researchers and developers must address these concerns and implement safeguards to ensure responsible usage. Access to VR technology may be limited due to its cost and the need for specialized equipment. This poses a barrier to widespread adoption, particularly in underserved populations. People have varying preferences and sensitivities to VR environments. Some may find certain virtual settings more relaxing, while others may experience discomfort or motion sickness. Tailoring VR meditation experiences to individual needs is essential and use of live guided sessions within VR may help with this in the initial stages of practice. Conducting a live orientation session in the VR environment can ensure that users are familiar with the theoretical basis and troubleshoot any discomfort or sensitivities that may arise. Future research into this is planned. With the aim of mindfulness training being to prepare users to practice anywhere, it is important that future work establishes the level of skills transfer from the VR environment to real life and to challenging situations. A transition module incorporating non-VR practice elements would be a useful inclusion and work is under way to develop this.

Conclusions

This pilot study has shown that an interactive VR-based mindfulness intervention is effective at increasing state mindfulness in health sciences students. Use of the VR format enabled users to escape from reality and immerse themselves in a relaxing environment; in turn this increased adherence and motivation with the practice. Users appreciated the value of being able to interact with the environment, find their own space within it and focus their practice on VR-based objects and sounds. A VR-based solution can be an effective support resource for healthcare students undertaking remote clinical placements and could potentially have wider usage among mindfulness students and practitioners. Future research should evaluate the long-term impact of VR-based training on mindfulness practice as well as establish the feasibility and potential value of using the environment for live guided mindfulness practice within VR.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s44247-024-00141-5.

Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

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NA.

Authors' contributions

PB, JH, HW, PK, JM and NW wrote the main manuscript text and all authors reviewed the manuscript. PB, JH, HW, PK and JM planned and executed the data collection and analysis. NW, PK, JM and PB performed data analysis.

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Data availability

Summary anonymous data is provided within the manuscript as per the terms of ethical committee approval.

Declarations

Ethics approval and consent to participate

Approval for this project was provided by The University of Liverpool Central University Research Ethics Committee (Reference 10882) in accordance with the Declaration of Helsinki. All participants provided informed consent.

Consent for publication

NA.

Competing interests

The authors declare no competing interests.

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