Cawley, A and Tejeiro, R

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ORIGINAL PAPER

Brief Virtual Reality Mindfulness is More Effective than Audio Mindfulness and Colouring in Reducing Stress in University Students

Amy Cawley[1] · Ricardo Tejeiro[2]

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Abstract

Objectives Although various multi-week mindfulness programs have been introduced for stress reduction over the past decades, there is still little evidence on the effectiveness of short, self-applied interventions. This study aims to compare the effectiveness of virtual reality mindfulness and audio mindfulness, as well as a simple colouring session.

Method Sixty-seven participants were initially enrolled, with 64 remaining after exclusions. They were randomly allocated to one of three face-to-face stress management interventions: virtual reality (VR) mindfulness, audio mindfulness or colouring. Before and after the 10-min intervention, questionnaires were administered to assess differences in perceived stress, psychological well-being, and engagement. Heart rate was also measured to indicate physiological stress.

Results VR mindfulness was the only intervention to significantly increase wellbeing. Both VR and colouring significantly reduced stress, with VR producing the largest reduction in heart rate, though this was not statistically significant when compared to baseline. The three conditions were perceived as highly engaging, with the highest scores corresponding to VR mindfulness and the lowest to audio mindfulness.

Conclusions This study shows that a single brief session of VR mindfulness can produce short-term beneficial effects in people at high risk of stress, greater than those achieved through colouring and audio mindfulness. This suggests promising direct implications for university mental health services, although future research is needed to explore long-term benefits as well as the relative efficacy of longer interventions.

Preregistration This study is not preregistered.

Keywords Mindfulness · Virtual Reality · Stress · Psychological Well-being · Mental Health

Mindfulness involves paying conscious attention to what is occurring in the present moment with a non-judgemental attitude, noticing any changes in thoughts, feelings, and sensations (Bishop et al., 2004). Unlike relaxation practises, mindfulness focuses on accepting the present moment of internal events rather than changing them (Luberto et al., 2020), with an emphasis on attention, awareness, and acceptance (Greeson, 2009).

Extensive scholarly literature substantiates the notion that interventions rooted in mindfulness possess the capacity to enhance mental well-being and alleviate stress (Hathaisaard et al., 2022). Four decades ago, Kabat-Zinn (1982) proposed one of the most successful intervention programmes, the Mindfulness-Based Stress Reduction (MBSR); consisting of 10 sessions (later reduced to 8), it includes weekly 2-2.5 hr group-based classes, daily home practice, and a day-long retreat. Other programmes have followed the MBSR concept, length, and structure, often adapting them to specific populations, like the Mindfulness-Based Cognitive Therapy (MBCT; Teasdale et al., 2000), the Mindfulness-Based Relapse Prevention (MBRP; Bowen et al., 2014), the Mindfulness-Based Relationship Enhancement (MBRE; Carson et al., 2004); whilst others suggest residential retreat programmes of varying duration (Montero-Marin et al., 2016; Rosenberg et al., 2015).

However, these programs may not be accessible to everyone because of their length, even when shorter 1-week to 3-week interventions (e.g. Adhikari et al., 2018; Taren et al., 2017) are suggested. On the other hand, there are few

✉ Ricardo Tejeiro
psyrteje@ljmu.ac.uk

[1] University of Liverpool, Liverpool, UK

[2] School of Psychology, Liverpool John Moores University, Liverpool L3 3AF, UK

studies comparing the effectiveness of different durations. It has been reported that 6-week and 3-week mindfulness training were equally associated to a reduction in test anxiety (Priebe & Kurtz-Costes, 2022), but also that people in a 6-week mindfulness program – but not those in a single-day mindfulness workshop – reported a significant reduction in perceived stress (Chin et al., 2018).

The literature includes several brief 10–30 min mindfulness exercises, though in most cases these are utilised as experimental interventions to analyse their impact on cognitive functioning (e.g., Aly et al., 2023; Jankowski & Holas, 2020). Their potential application to improving wellbeing is therefore still underexplored or circumscribed to specific populations. For instance, Hanley et al. (2023) found that 3-min nurse-led mindfulness-based interventions resulted in less pain intensity and unpleasantness in a sample of arthroplasty patients, and Fincham et al. (2023) reported that brief 10- or 30-min sessions of mindfulness practice yielded similar positive results on mental wellbeing – but their participants were instructed to practice daily for 2 weeks.

As in many other areas, the technological advances of the last decades are providing new solutions to mindfulness intervention that, as Creswell (2017) points out, "have a tremendous advantage in that they are inexpensive, portable and can be more easily implemented in harder-to-reach populations that can access the Internet" (p.495). In this regard, one of the most easily accessible resources are smartphone applications, some of which, such as Headspace or Calm, have been downloaded by millions of people (Curry, 2023). Mindfulness audio tracks use a calming voice and soothing sounds to direct the individual through a series of mindful practices, allowing the individual to focus on their breathing and bringing awareness to their body sensations (Segal et al., 2018). These digital interventions can increase accessibility, as the tracks can be played at any time, and allow the standardisation of the intervention with a highly skilled individual directing participants through the mindful practises (Mrazek et al., 2019). Several studies have confirmed the effectiveness of audio mindfulness in the improvement of subjective wellbeing (e.g., Bear et al., 2022; Keng et al., 2022); however, significant within-group differences in perceived stress and difficulties in sustaining engagement are often reported (Huberty et al., 2019).

By using a headset with a built-in 360-degree audio-visual system, virtual reality (VR) mindfulness has the potential to improve the experience provided by audio apps by using immersive technology to create a sense of presence, the feeling of "being there" in the virtual environment (Steuer, 1993). By visualising relaxing virtual environments (VE) and following audio clues, individuals can focus on the present moment, "shifting their attention from the real-world environment" (Seabrook et al., 2020, p.2) and improving their breathing techniques. The VR software used in the present study (Spirit VR) offers the participants a range of VEs to choose from, which has the potential to enhance feelings of autonomy and increase motivation and engagement (Martela & Riekki, 2018; Peters et al., 2018). The themes in these VEs correspond to natural outdoors settings, which have been reported to promote stress recovery and trigger positive physiological responses and feelings of happiness (Li et al., 2023). In terms of Kaplan's (1995) Attention Restoration Theory (ART), natural environments can be restorative as they allow an individual to benefit from the sense of being away, effortlessly attending to fascinating patterns whilst having "ample opportunity for thinking about other things" (Kaplan, 1995, p.174).

The potential benefits from VR-based mindfulness have been evidenced in studies associating this intervention with lower levels of sadness, anger, anxiety (Kaplan-Rakowski et al., 2021; Navarro-Haro et al., 2017) and perceived stress (Pallavicini et al., 2016), as well as increased relaxation (Scates et al., 2020; Waller et al., 2021), calmness (Tarrant et al., 2022), and positive emotions (Seabrook et al., 2020). However, as emphasised by Failla et al. (2022) in their comprehensive review, "the vast majority of immersive VR-enhanced mindfulness applications have focused on clinical settings, with little evidence on healthy subjects", and "most studies have several limitations" (p.1).

At a simpler level, stress is often managed through distraction coping strategies, or undertaking an alternative task to act as a distraction from the stressful thoughts or events (Stanisławski, 2019). An increasingly popular example of this coping strategy is colouring. Colouring has been shown to reduce stress, anxiety and negative thoughts whilst also improving mood and relaxation (Curry & Kasser, 2005; Eaton & Tieber, 2017), even in interventions as short as 20 min (Ashdown et al., 2018). Mandalas have been found to be particularly more successful at this than other formats, such as unstructured colouring (Vennet & Serice, 2012), and even different shapes of mandalas have been compared – with circle mandalas having a significantly greater mood improvement than square mandalas (Babouchkina & Robbins, 2015). However, a recent study found that colouring mandalas or blank papers were equally effective techniques for reducing anxiety in university students (Duong et al., 2018).

Our research also focuses on university students, who have been identified as being a specifically vulnerable population for stress (Stallman, 2010). The reasons for high-stress levels in students are well-known and beyond the themes of the present paper, but highly stressed university students have been systematically associated with low quality of life, poor sleep quality, and high levels of depression (Dinis & Bragança, 2018). Supporting students

to cope with stress is amongst the objectives of most universities' counselling services – and the literature review supports the usefulness in this regard of research-led, long-duration interventions. However, even before COVID-19, university funding for counselling and support services was insufficient and needed to, at least, be tripled to meet the required counsellor-to-student ratio (Brown, 2016). It is therefore necessary to identify interventions that require a minimum deployment of resources and that can be applied by the university students themselves with minimum support and maximum flexibility. Mindfulness appears as an approach that can meet this need – several studies have shown that mindfulness is not only an effective strategy to manage stress in university students (Firth et al., 2019; Martín-Asuero & García-Banda, 2010), but likely one of the most successful (Hathaisaard et al., 2022).

Considering the literature, our aim was to measure and compare heart rate, psychological well-being, and perceived stress, before and after one brief session (10 min) of these interventions in three comparable groups; self-reported differences in engagement were also analysed. We hypothesised that the three 10-min interventions would be effective in (H1) reducing participants' heart rate, (H2) improving their subjective psychological well-being, and (H3) reducing perceived stress, with the VR condition resulting in greater effects than the other two. Additionally, we hypothesised that (H4) the three interventions would be perceived as highly engaging, again with the VR condition yielding more significant effects than the other two.

Method

Participants

Sixty-seven students from the university where this research was conducted volunteered to participate. The estimated sample size for a medium effect size of 0.40, with a power of 0.80 and three comparison groups, was 66 using the G*Power 3.1. software (Faul et al., 2009). Two participants whose HR was higher than the 60–100 bpm range considered normal by the British Heart Foundation, and one participant whose score in the World Health Organisation Well-being Index (WHO-5; World Health Organization, 1998; see below) was identified as an outlier (more than two standard deviations from the mean) were excluded; this left a final sample of 64 (67.2% females; ages 18–24). Exclusion criteria included participants with a visual impairment (due to the risk that glasses may damage the lens when using the VR headset), participants with a history of motion sickness (due to the risk of VR triggering motion sickness; Kim et al., 2018a), and participants with a hearing impairment (as the study used audio in two conditions).

Procedure

Ethical Approval was obtained from the university where this study was carried out. Once a participant signed up to the study, they were sent the participant information sheet and details regarding the location via email. Participants were randomly allocated to one of the three interventions: VR mindfulness, audio mindfulness or colouring. It should be noted that each of the three excluded outliers corresponded to a different condition. The study took place face-to-face individually within a small room at the university; after the participant arrived at their allocated timeslot, they were reminded of their rights and asked to sign the consent form. An Apple Watch was then placed on their wrist, and the participant answered the first part of the questionnaire using their own mobile phones. Upon completion, the participant was told the condition they were allocated to and informed that, five minutes into the intervention session, their heart rate would be recorded again. Those randomly allocated to the VR condition were also instructed how to use the VR controllers and how to appropriately fit and adjust the headset. After the session was complete, the participant then filled out the post-intervention questionnaire and was fully debriefed.

The VR mindfulness session included two elements: a mental body scan and interactive breathing exercises. In the 6-min body scan, participants were guided by the VR to sequentially and non-judgmentally focus their attention on parts of their body (Sauer-Zavala et al., 2012), whilst immersed in a natural VE. The remaining 4 min were spent practicing breathing techniques. The participant was allowed to customise their VR experience by choosing the location of their virtual world (a courtyard in Japan, a woodland campfire, a beach on a desert island, or beside a lake). Figure 1 shows the breathing exercise taking place beside the lake. In the audio condition, the participant listened to the 10-minute audio track, and were guided step by step, focusing on different parts of the body in order to relieve tension. They were encouraged by the audio clip to close their eyes and sit comfortably in their chair whilst they listened to the track. For the colouring condition, participants had 10 min to colour in a colouring picture of their choice from the book provided by the researcher. In all conditions, one researcher was present during the intervention session, using their laptop to avoid making eye contact with the participant whilst they engaged in the mindful practices.

Fig. 1 Screenshot of the 360° experience showing the box breathing exercise at the lakeside (source: https://spiritvr.co.uk/; reproduced with permission)

Measures

A survey was built on the online platform Qualtrics with four different elements: (1) Demographics included gender (Male, Female, Other), and prior experience with mindfulness (Likert scale from 1 = *I haven't heard of it*, to 5 = *I practise mindfulness regularly*); (2) World Health Organisation Well-being Index (WHO-5; World Health Organization, 1998): self-report measure of subjective psychological well-being (Topp et al., 2015). The WHO-5 contains five statements (e.g., "I have woken up feeling fresh and rested") rated based on how often the participant has experienced those feelings in the last 2 weeks (from 1 = *All the time*, to 6 = *At no time*). Items' scores are recoded (*All the time* = 5, *At no time* = 0) and summed to obtain a raw score ranging from 0 to 25; this is then multiplied by 4 to obtain a percentage, with 0% being the worst imaginable well-being to 100% representing the best imaginable well-being (Topp et al., 2015). McDonald's omega in our study was ω = 0.87; (3) Perceived Stress Scale (PSS-10; Cohen et al., 1983): it measures the degree to which an individual has found their life to be overloaded, unpredictable and uncontrollable over the last month. The PSS-10 includes 10 items rated on a 5-point Likert scale from *never* to *very often*. After data collection, four positive questions were reversed, and a total PSS score was obtained from the sum of the scores to each question. Higher PSS scores reflect higher levels of perceived stress (Liu et al., 2020). Previous literature has indicated that the PSS-10 has good internal consistency (α = 0.82), acceptable test-retest reliability (r = 0.77) (Lee, 2012; Remor, 2006), and good concurrent validity with various measures of anxiety and depression in university students (Lee, 2012); McDonald's omega in our study was ω = 0.85; (4) Engagement was measured with one item where participants rated their perception of the procedure from *not at all* to *extremely* engaging.

An Apple Watch (Series 8), which has been found to have lower error rates compared to other wearable devices (Thomson et al., 2019), was used to measure heart rate (HR) before, during (5 min) and after the intervention session. The VR software utilised was Spirit VR, developed by Scenegraph Studios, and was delivered on an Oculus Quest 2 Headset, alongside two handheld controllers (Fig. 2). The audio mindfulness track was Guided breathing to release tension, narrated by Dr. Julie Smith, from the Overcome Stress and Anxiety section of the app Calm; this track was chosen because it was 10 min long and focused on stress. In the colouring condition, participants choose one picture from a colouring book commercially available (Elsharouni, C. (2017). *Adult Coloring Book: Stress Relieving Designs*

Fig. 2 Hand-held controllers and Oculus Quest 2 Headset. (source: https://spiritvr.co.uk/; reproduced with permission)

Animals, Mandalas, Flowers, Paisley Patterns And So Much More. Selah Works.) that the researcher provided with pens and pencils.

Data Analyses

Analyses were conducted using SPSS version 28. The outcome of checking normality using Shapiro-Wilk's test given the moderate sample size (Ghasemi & Zhahediasl, 2012), and homoscedasticity with Levene's test (Dancey & Reidy, 2014) determined whether parametric or non-parametric analyses were selected. Within-group pre-post intervention comparisons were done with paired Student's *t* tests with Cohen's *d* for effect size (Dancey & Reidy, 2014) or Wilcoxon's signed rank test with *r* as a measure of effect size (Tomczak & Tomczak, 2014). Between-groups comparisons were done with Kruskal-Wallis *H* tests because of the non-normal distribution of pre-post (change) variables; post hoc tests were carried out with Bonferroni-corrected Mann-Whitney's *U* tests (Lee & Lee, 2018) and *r* as a measure of effect size. Finally, chi-square with Cramer's *V* for effect size was used to compare the groups in gender and experience with mindfulness (Tomczak & Tomczak, 2014).

Results

Descriptive Statistics and Baseline Comparison

Baseline and post-intervention values for HR, WHO-5, PSS-10, and engagement are shown on Table 1. There was no statistically significant difference between groups in baseline HR ($F(2,61) = 0.43$, $p = 0.654$, $\eta^2 = 0.01$), pre-WHO-5 scores ($H = 1.59$, $p = 0.453$) or in pre-PSS-10 scores ($H = 0.89$, $p = 0.641$). Furthermore, the three groups did not differ in their percentages of males and females ($\chi^2(2,64) = 1.79$, $p = 0.408$, Cramer's $V = 0.17$) nor in their previous experience with mindfulness ($\chi^2(2,63) = 4.89$, $p = 0.770$, Cramer's $V = 0.20$).

Inferential Statistics

A significant pre-post increase in HR occurred in the colouring group ($t(19) = 2.50$, $p = 0.022$, $d = 0.57$) but not in the VR group ($t(25) = -1.24$, $p = 0.226$, $d = 0.24$) or in the audio group ($Z = -0.26$, $p = 0.793$, $r = 0.06$). Significant between-group differences in pre-post HR change were found ($H = 7.42$, $p = 0.024$); differences were significant between VR and colouring ($U = 145.50$, $p = 0.006$, $r = 0.35$), and between audio and colouring ($U = 107.50$, $p = 0.011$, $r = 0.35$), but not between VR and audio ($U = 193.00$, $p = 0.071$, $r = 0.19$).

Pre-post differences in WHO-5 scores in the VR group reached statistical significance ($t(25) = 3.49$, $p = 0.002$, $d = 0.69$), but not in the audio group ($Z = -0.64$, $p = 0.521$, $r = 0.15$) or in the colouring group ($Z = -1.91$, $p = 0.056$, $r = 0.44$). Significant between-group differences in pre-post WHO-5 change were found ($H = 7.033$, $p = 0.030$); differences were significantly higher in the VR condition than in the audio condition ($U = 136.50$, $p = 0.003$, $r = 0.39$) as well as between audio and colouring ($U = 126.00$, $p = 0.034$, $r = 0.27$), with no differences between VR and colouring ($U = 207.50$, $p = 0.116$, $r = 0.14$).

No significant between-group differences in pre-post PSS-10 change were found with a Kruskal-Wallis test ($H = 2.126$, $p = 0.345$). A significant pre-post change in PSS-10 scores was found in the VR group ($t(25) = -2.78$, $p = 0.010$, $d = 0.54$) and in the colouring group ($t(18) = -2.59$, $p = 0.018$, $d = 0.59$) but not in the audio group ($Z = -1.173$, $p = 0.241$, $r = 0.27$).

Finally, a Kruskal-Wallis test indicated statistically significant differences between the groups in engagement ($H = 10.494$, $p = 0.005$); post hoc analyses with Bonferroni corrections revealed significant differences between the VR and the audio groups ($U = 125.50$, $p < 0.001$, $r = 0.45$) and between the audio and the colouring groups ($U = 111.00$, $p = 0.007$, $r = 0.38$), but not between the VR and the colouring groups ($U = 208.00$, $p = 0.105$, $r = 0.15$).

Table 1 Descriptive statistics; Mean(SD)

Variable		Condition			
		VR	Audio	Colouring	Total
Heart rate	Baseline	82.00(10.69)	82.00(11.01)	79.42(8.47)	81.23(10.09)
	Post	79.69(11.91)	81.00(11.08)	83.89(10.36)	81.33(11.18)
WHO-5	Baseline	62.92(14.38)	57.89(17.09)	59.16(16.20)	60.31(15.67)
	Post	67.23(14.26)	56.42(19.64)	64.00(15.43)	63.06(16.95)
PSS-10	Baseline	16.46(4.51)	17.16(5.10)	17.79(4.60)	17.06(4.68)
	Post	14.77(5.42)	16.53(5.40)	16.05(4.73)	15.67(5.20)
Engagement	Post	4.42(0.64)	3.63(0.96)	4.26(0.56)	4.14(0.79)

Discussion

The current study aimed to compare VR mindfulness, audio mindfulness and colouring at reducing stress, improving well-being, and increasing engagement. For this purpose, three brief 10-min face-to-face interventions were designed from commercially available materials and completed with a sample of university students.

Contrary to our first hypothesis, none of the interventions significantly reduced HR as compared to the baseline – in fact, colouring had an opposite effect – which is inconsistent with previous research (Kwon et al., 2020; Rockstroh et al., 2019; Weibel et al., 2023) though consistent with studies where colouring failed to significantly reduce HR (Piri, 2018; Schrade et al., 2011). The increase in HR in the colouring condition in our study can be explained by the higher level of physical activity as compared to the mindfulness conditions; this is consistent with Loudon and Deininger's (2017) finding that 2 min of colouring were associated to higher mean heart rate than 2 min of a relaxation activity.

The second hypothesis is only partially supported. On the one hand, our finding that VR mindfulness was the only intervention that significantly improved subjective psychological well-being as compared to the baseline challenges previous findings that audio mindfulness could have small- to moderate effects on well-being (Bostock et al., 2019), and that colouring could enhance well-being (Babouchkina & Robbins, 2015; Dresler & Perera, 2019; Piri, 2018), decrease anxiety (Campenni & Hartman, 2019; Carsley & Heath, 2018; Khademi et al., 2021) and distress (Yakar et al., 2021). As expected, the magnitude of the change in subjective psychological well-being promoted by VR was significantly higher than in the audio condition (though no significant difference was found with the colouring condition, or between colouring and audio). This result can be seen as in line with the suggestions that the nature based VEs provide additional restorative benefits (Liszio et al., 2018) and trigger positive physiological responses (Gu et al., 2022). Additionally, the personalised VEs in the VR intervention would have satisfied the basic psychological need for autonomy, which has been linked to improved well-being (Martela & Riekki, 2018; Peters et al., 2018). To further this impact, further VR design features could be included that enhance a sense of competence by providing positive feedback or unlocking new VE designs in relation to the frequency of practice of mindful exercises (Peters et al., 2018), which would also facilitate a sense of mastery and efficacy (Arpaia et al., 2022; Martela & Riekki, 2018).

Similarly, only partial support was found for H3, as VR and colouring were equally effective in reducing perceived stress, with audio mindfulness failing to bring a difference. Prior research has suggested that a single session may fail to have meaningful effects on stress, with longer periods (6 or 8 weeks) of mindfulness having a significant effect on perceived stress (Chin et al., 2018) and well-being (Bostock et al., 2019). The fact that VR and colouring were equally effective plays against the argument from the ART that exposure to natural settings can promote stress recovery (Kaplan, 1995). However, research on rituals has evidenced that repetitive behaviours like the movements of hands whilst drawing induce calm and help manage stress and cope with unpredictability and uncontrollability (Eilam et al., 2011).

Our fourth hypothesis receives support as the three conditions were perceived as highly engaging, with the highest scores corresponding to VR mindfulness and the lowest to audio mindfulness. Other authors have also reported that long-term mindfulness interventions present higher retention rates and session attendance when VR is used (Modrego-Alarcón et al., 2021). The sense of presence in the VE facilitated by its visual and auditory elements has been found to help participants to be engaged in the mindful exercises (Seabrook et al., 2020). However, the resolution of the VR headset can affect the sense of presence, hence the need to balance costs and affordability (Lorenz et al., 2018). We did not directly measure the sense of presence using, for instance, the IGroup Presence Questionnaire (IPQ; Schwind et al., 2019), which could be a task for future studies. The similar engagement found for the VR and colouring conditions in our study may be partly explained by the satisfaction of autonomy when the participant selects the VE or the image to colour in (Martela & Riekki, 2018; Peters et al., 2018).

This study empirically shows that a single brief VR mindfulness session can produce a significant short-term increase in subjective psychological well-being and a reduction in perceived stress; furthermore, although not statistically significantly, it can reduce the HR in the short term. Another very popular form of mindfulness delivery, the audio format, shows low to no results, while colouring activity is associated with irregular impact (including a short-term HR increase).

The fact that our study was carried out with university students advises prudence not only in the interpretation of the results, but also in the proposal of implications. In this sense, psychological support services at universities could consider hosting VR mindfulness sessions or providing a VR headset loan scheme enabling students to engage in regular mindfulness practise, especially during stressful periods such as exam time. While VR mindfulness is not a substitute for professional mental health services, our findings suggest that it could be a useful first defence, potentially reducing demand on mental health services and allowing better support to be provided to those who need it most. These results may also encourage popular smartphone mindfulness apps

to embrace VR technology to enhance the engagement and effectiveness of their mindfulness programs.

Limitations and Future Research

For practical reasons we could not establish an adaptation period for the VR condition, which is common to many studies in this area (Snyder & Cinelli, 2021). This could have influenced the findings, as 43% of participants had no prior VR experience, though our analyses evidenced that the three groups were fully equivalent in HR, subjective psychological well-being, and perceived stress before the intervention. Another limitation of the study that future works might consider was that also due to practical reasons no follow-up monitoring was scheduled, and therefore any long-term effect of the interventions remains unknown. This is particularly relevant, as one previous study based on eight weeks of audio mindfulness found that the improvement in well-being lasted for 2 months after the intervention endpoint (Bostock et al., 2019).

Other studies have analysed the physiological correlates of stress using heart rate variability (HRV), the fluctuation in time between each heartbeat, as it has been found that it is better than HR to capture resting parasympathetic activity, and thus physiological stress (Altini & Plews, 2021). In a somewhat simplified manner, it can be said that high HRV at rest is associated with higher resilience to stress (Kim et al., 2018b). Although these studies have reported mixed results – with some showing that audio mindfulness could increase HRV more than VR mindfulness (Ahmaniemi et al., 2017; Azam et al., 2015), while others found the opposite (Pascual et al., 2023) – future research should consider including HRV as an additional indicator of psychological stress. The impact of the different location choices was not investigated and thus has the potential to be a confounding variable, which should be examined in future studies. Finally, the VEs in our simulation were animated, which could have limited their potential for stress recovery (Annerstedt et al., 2013), and the impact of simulations is likely to be smaller than that of natural settings (although with the continual improvement of graphic engines this gap may be reduced in the future).

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Author Contribution Amy Cawley: Conceptualization, Methodology, Investigation, Formal analysis, Writing Draft. Ricardo Tejeiro: Conceptualisation, Methodology, Review and Editing.

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Data Availability The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declarations

Artificial Intelligence AI was not used during any stage of the study.

Ethics Approval The study received approval from the University of Liverpool's Institute of Population Health Research Ethics Committee on 20th December 2022 (Ref. 11888).

Informed Consent Participants were asked to read an information sheet containing details of the study, before being presented with a consent form. Participants could only proceed with the study after providing informed consent. All research participants provided consent in accordance with the Declaration of Helsinki (2013) Ethical Principles (Seventh revision, 64th Meeting, Fortaleza).

Conflict of Interest The authors declare no competing interests.

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