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Can simulated nature be as effective as actual nature in promoting health and well-being in healthcare settings?

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Abstract: Simulated nature has been widely implemented in healthcare settings to create spaces that promote positive emotional responses and support overall health and well-being. The notion of indirect experience refers to the integration of natural elements into the design of built environments to allow occupants to experience nature indirectly. Nevertheless, the question of whether simulated nature is a satisfactory substitute for actual nature remains largely unexplored. In this study, we examined whether a therapeutic intervention is more effective when implemented within a simulated natural environment versus a real one. We found that both nature settings boosted the outcomes of the mindfulness program. However, the actual nature resulted in greater reduced stress and increases in nature connectedness compared to the simulated one. These findings demonstrate the potential value of both simulated and actual nature as settings for enhancing healthcare delivery.

Keywords: Virtual nature; nature connection; mental health; therapeutic intervention

1. Introduction

A UK survey revealed that people tend to spend approximately 95.6% of their time indoors, with more vulnerable groups such as the elderly or disabled often spending all their time inside. Such sedentary lifestyle results in lower levels of physical activity, an upsurge in obesity and diabetes rates, and subsequently, a higher prevalence of mental health problems (Vardoulakis et al., 2015). Furthermore, spending so much time inside has declined human connection with nature. According to Wilson's Biophilia Hypothesis (1986), this disconnection may lead to deteriorating mental health and well-being, given humans' innate affinity with nature. Thus, fostering a strong connection with nature is crucial for mental well-being and personal development. A study by Dzhambov et al. (2018) found neighbourhood green spaces are beneficial to physical activity and social cohesion and lead to reduction in mental disorders. Van den Berg et al. (2016) also found that spending more time in green spaces led

to improved mental health and vitality. However, access to outdoor natural environments is often restricted in settings such as hospitals, underground workplaces, or residential care homes. In such environments, alternatives such as incorporating nature-related images or patterns into these spaces are frequently utilised.

Simulated environments have been widely used in studies on the restorative potential of environmental exposures. Choe et al. (2020) used images to simulate the experience of being in natural or built urban landscapes. The participants showed better stress recovery and positive emotions in natural settings compared to urban ones. In addition, Chiang et al. (2017) employed a three-dimensional depiction of nature scenes to explore individuals' physiological and psychological responses to different vegetation types. Virtual reality (VR) with auditory simulation has been also employed to provide a more engaging experience in nature. For example, Song et al. (2021) found the physiological and psychological relaxation effects of the combined forest-derived visual and auditory stimuli. Further, Tanja-Dijkstra et al. (2018) showed an alleviating effect on pain experience in dental patients who were exposed to virtual coastal views by reducing anxiety and intensiveness of memories. These studies indicate that simulated and virtual natural environments have the potential to make significant contribution for better mental health and well-being by providing restorative benefits.

However, the question of whether simulated or virtual nature can serve as an adequate substitute for actual nature is hardly addressed. Some elements make simulated nature different from "real nature," such as limited sensual aspects, the inability to interact with the environment, and image resolution. These limitations make the simulated environment feel less "authentic" and deviate from the real environmental experience (Choe *et al*. 2021). Kahn et al. (2008) compared the physiological responses of individuals when exposed to a real-time nature view displayed using a plasma display window versus an actual glass window with a view of a nature scene. Interestingly, the study found that the glass window had a more pronounced restorative effect compared to the plasma window. In fact, the plasma window did not demonstrate any more restorative impact than a blank wall. These findings suggest that the "plasma window" was unable to replicate the same positive effects as an actual window. Gatersleben and Andrews's (2013) study also showed that engaging in a walk in a natural outdoor environment yielded greater recovery from attention fatigue and reduced feelings of sadness when compared to a simulated walk. Likewise, Browning et al. (2020) found that both types of nature exposure resulted in heightened physiological arousal, but the outdoor exposure elicited a higher increase in levels of positive mood compared to the virtual experience. While the evidence suggests that actual nature may have more restorative benefits than simulated nature, the differences in experience between actual and simulated/virtual natural environments are not fully understood.

This study aims to examine whether the outcomes of a therapeutic intervention are enhanced when carried out in an actual natural environment as opposed to a simulated natural environment. To address this inquiry, we explored the effects of simulated and actual nature experiences using quantitative and qualitative methods.

2. Methods

2.1 Participants and data selection

The study comprised two experiments involving university students and staff aged 18 or older. In the first experiment, 140 participants were randomly selected using stratified random sampling. After excluding 15 participants who did not complete the preliminary questionnaire, 125 participants were evenly divided into two groups experiencing different simulated environments and attended either mindfulness or relaxation activities for three weeks. For the second experiment, 99 participants were also randomly chosen using stratified random sampling. They took part in weekly hour-long mindfulness courses in one of three different settings (i.e. natural, built outdoor or indoor settings). Baseline data were collected at the beginning of both experiments with the same set of evaluative measures implemented after the third session.

Figure 1 illustrates overall study design. The quantitative analysis involved 96 participants (39 males, 57 females; mean age of 31.76). Of these participants, 34 (35.4%) were selected from a sample who completed three mindfulness sessions within a simulated setting (experiment 1), and 30 responses (31.3%) came from a sample who completed three mindfulness sessions within a similar actual setting (experiment 2). To assess the impact of natural environments as compared to different physical surroundings, 32 responses (33.3%) from indoor setting from experiment 2 were also included the analysis. As part of this study, qualitative data from focus groups were analysed to gather detailed information about the participants' experiences in their respective environments.

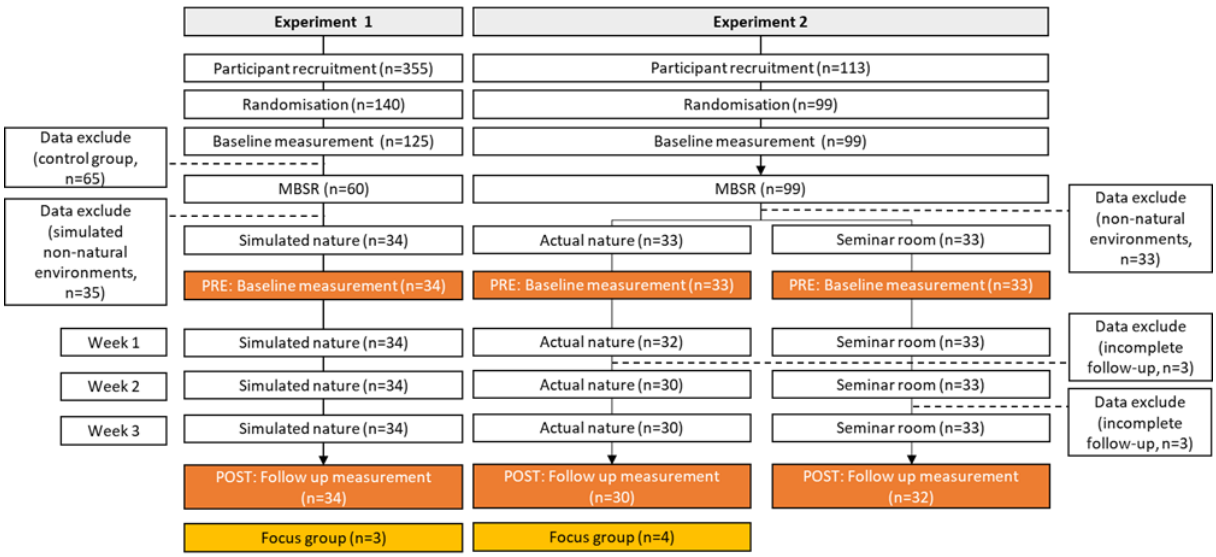

Figure 1 Overall study design flowchart

2.2 Measurements

Quantitative measurements: self-reported questionnaire

The quantitative data was collected using three validated scales: Five Facet Mindfulness Questionnaire (FFMQ) and Depression Anxiety Stress Scales (DASS-21) and Nature Relatedness Scale (NR-6) at baseline and after the third mindfulness session.

Five Facet Mindfulness Questionnaire

The Five Facet Mindfulness Questionnaire (FFMQ: Baer *et al.*, 2006) is a commonly used to measure level of mindfulness. The questionnaire comprises 39 items, which gauge mindfulness across five distinct facets: observing, describing, acting with awareness, non-judging and non-reactivity to inner experience on a five-point scale (1= never or rarely true, 5= very often or always true).

Depression Anxiety Stress Scales

Depression Anxiety Stress Scales (DASS-21: Antony *et al.*, 1998) are utilized to measure the severity of symptoms related to depression, anxiety, and stress. Participants rate the frequency of experiencing symptoms, such as difficulty relaxing, feeling easily upset, irritability, and over-reacting over the past week, using a four-point scale (0=never, 3=almost always).

Nature Relatedness Scale

Nature Relatedness Scale (NR-6: Nisbet et al., 2009) serves as a means of measuring an individual's level of connection or affinity with nature. The NR-6 consists of six items that capture the feeling of connectedness to nature and predict psychological health and well-being, measured on five-point scales (1= disagree strongly, 5= agree strongly).

Qualitative measurements: focus group discussions

Participants who had completed three sessions of mindfulness programme in the simulated natural environment (Experiment 1) and the actual natural environment (Experiment 2) were invited to participate in the focus groups after completion of the mindfulness programme. The focus groups, facilitated by the lead author as moderator, together with a mindfulness teacher, took place in a quiet room and refreshments were provided for participants. Each focus group lasted for 1.5 hours. To begin, a 10-minute mindfulness session was conducted to assist participants in relaxing and revisiting their earlier mindfulness sessions, facilitating the recall and discussion of their experiences. This was followed by an approximately one-hour discussion, and the session concluded with a follow-up mindfulness activity to aid in relaxation and express gratitude for their participation. The moderator followed a semi-structured focus group guide (Figure 2) designed to structure the discussion to effectively guide the discussion and delve into the participants' experiences and attitudes towards the mindfulness sessions in various environments. The guide focused on two key concepts: 1) assessing the effectiveness of mindfulness practice, and 2) exploring the partici-

pants' experiences in their respective environments, both simulated and actual natural settings. Open-ended questions were designed to elicit comprehensive responses on the participants' perspectives and perceptions of the mindfulness program. (e.g. "*In what way did this mindfulness practice affect you?*"), as well as the changes that the participants felt during and after the experiment (e.g. "*Can you provide examples of any changes you have noticed in your routines, habits, or thoughts?*"). Next, participants described their experiences in the environments (e.g. "*How did you find your experiences in the environment to which you were assigned?*"). The participants were also asked about the barriers and motivators to focus on the mindfulness practice in the specified setting (e.g. "*During the mindfulness practice, were there any environmental factors that either hindered or helped you in maintaining your focus?*").

Focus group: moderator's guide

1. The effectiveness of mindfulness practice

Key question A. General benefits of mindfulness practice
- Is anyone still using mindfulness practices and if so, which mindfulness practices are you continuing? and why is this?
- In what way did this mindfulness programme affect you, if at all?

Key question B. Habit formation
- Let's think now about any changes during or after the mindfulness programme.
- Have you experienced changes in your routines or habits?
- What has helped in your changes? What made them difficult?

2. Participants' experience in their environments

Key question A. Participants' experience in their settings
- Please tell us which environment you were in.
- How did you find your experiences in the environments which you were assigned?
- In what ways do you think this context had a particular bearing on your practice/health and wellbeing? Have you noticed any changes in your mental health and wellbeing?

Key question B. Environmental challenges
- How did you find attending the sessions and taking the time out to do so?
- We are really interested in there was anything that made it difficult / easy to keep attending.
- Did you find any difficulties during the time you were attending the sessions?
- Was there anything about the context that distracted/helped you to focus on the sessions?

Figure 2 Moderator guide for focus group discussions

2.3 Experimental settings

Simulated natural setting

In the laboratory environment, a simulated experience of the natural environment was created by displaying an image on a 5.8 m x 2.2 m screen. The image represented a parkland scene with trees and shrubs, situated alongside an open expanse of mown grass (Figure 3).

Nature-imitating sounds were also introduced, incorporating audio clips featuring birds' chirping and leaves rustling in the wind.

Actual natural setting

Weston Park, conveniently located near the university, was selected to embody an actual natural setting. The park, like its simulated counterpart, consists of green landscapes rich in trees, shrubs, and grassy areas. During the experiment, the participants' experience was enhanced by the background sounds of birds chirping and distant conversations.

Indoor setting

To accurately assess the genuine benefits of natural environments, we replicated the intervention in a controlled indoor environment that lacked any natural elements. This setting comprised a windowless room in the university's basement, painted white, with no vegetation, and equipped with neutral-coloured pictures and artificial lighting.

Figure 3 Experimental settings for mindfulness intervention

2.4 Analysis strategy

Quantitative measures: Self-reported questionnaire

Prior to conducting the ANCOVAs, preliminary checks were conducted to ensure the validity of the data. To begin, chi-square and ANOVA tests were conducted to examine any baseline differences (pre-intervention). Following this, a one-way ANCOVA was carried out to compare the effects of the two environments on mindfulness outcomes. Then, paired samples t-tests were used to assess the impact of mindfulness practice within each group. All statistical analyses were performed using SPSS for Windows, version 24.0, with a significance level (alpha) set at .05.

Qualitative measures: Focus groups

The transcripts obtained from the focus groups underwent deductive analysis. The deductive approach involves assessing whether the data align with the prior assumptions, theories, and hypotheses outlined by the researcher (Thomas, 2006). Initially, a professional transcriber transcribed the data obtained from the focus groups. The researcher then thoroughly read the transcripts several times to grasp the overall context and familiarize themselves with the content. Content that provided responses to the research questions was identified:

"*Do participants describe differences in mental well-being outcomes in a simulated compared to an actual natural setting?*" and "*How do participants practising mindfulness in an actual nature describe nature connectedness compared to those experiencing a simulated nature?*" Following an assessment of all the data's relevance to the research questions, specific statements were organized into codes that represented the properties of specific categories. Consequently, the analysis involved reviewing the transcripts, identifying relevant text sections related to the research questions, and labelling them with appropriate codes and sub-codes.

3. Results

3.1 Quantitative results: self-reported questionnaire

Preliminary analysis

There were no significant differences in age (χ^2 = 35.56, p = .10) and gender (χ^2 = 1.76, p = .42) between the three settings at baseline. The values of mean and standard deviation for all outcome measures before and after a three-week mindfulness practice, as well as the results of the Paired T-test and ANCOVA, are presented in Table 1.

Table 1 Preliminary analysis on outcome measures

Outcome measures	Group	Mean (SD)		T-test		ANCOVA	
		Pre-intervention	Post-intervention	Mean difference (95% CI)	t	F	p
FFMQ - Mindfulness	Simulated nature	15.52 (2.47)	16.15 (1.77)	0.63 (-0.40, 1.66)	1.25*	0.08	0 .78
	Actual nature	15.43 (2.14)	16.01 (1.81)	0.58 (0.02, 1.13)	2.10*		
	Indoor (reference)	15.33 (2.59)	15.18 (2.20)	-0.15 (-1.09, 0.79)	-0.32		
DASS-21 - Stress	Simulated nature	15.12 (8.30)	13.88 (6.91)	-1.24 (-3.79, 1.32)	-0.98	8.47	0.01 *
	Actual nature	16.20 (7.71)	10.47(4.19)	-5.73(-8.52,-2.95)	-4.21**		
	Indoor (reference)	14.66 (9.81)	13.44 (7.98)	-1.22 (-2.59, 0.15)	-1.82		
NR-6 - Nature connectedness	Simulated nature	3.65 (0.69)	3.78 (0.62)	0.13 (-0.03, 0.28)	1.67	5.70	0.02 *
	Actual nature	3.35 (0.91)	3.85 (0.76)	0.50 (0.28, 0.72)	4.65**		
	Indoor (reference)	3.36 (0.76)	3.39(0.75)	0.03 (-0.11, 0.16)	0.40		

Level of mindfulness

There was no significant difference observed in the post-intervention scores for mindfulness between the simulated and actual natural settings. However, the paired t-tests revealed that both natural environments showed a significant improvement in mindfulness, while the indoor environment did not demonstrate the same benefits (Figure 4).

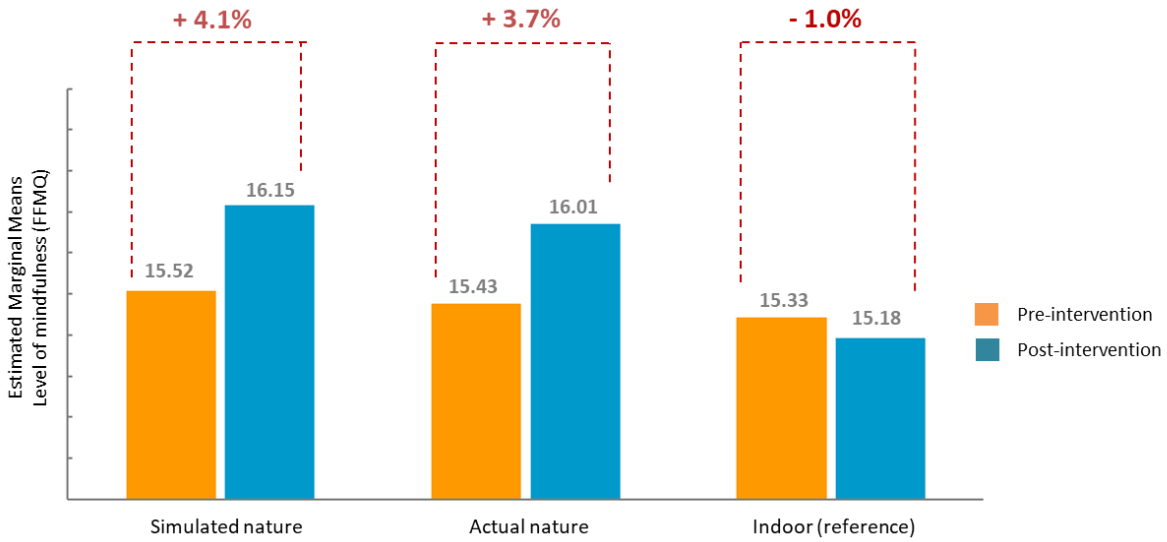

Figure 4 Change in mindfulness by environmental settings

Stress

A significant difference was found in the post-intervention score for stress between the settings. The group exposed to the actual nature exhibited a statistically significant reduction in stress from pre- to post-intervention (35.4%), while the simulated setting (8.2%) and indoor setting (8.3%) did not. Figure 5 illustrates that the actual nature had a greater impact in reducing stress compared to both the simulated and indoor settings.

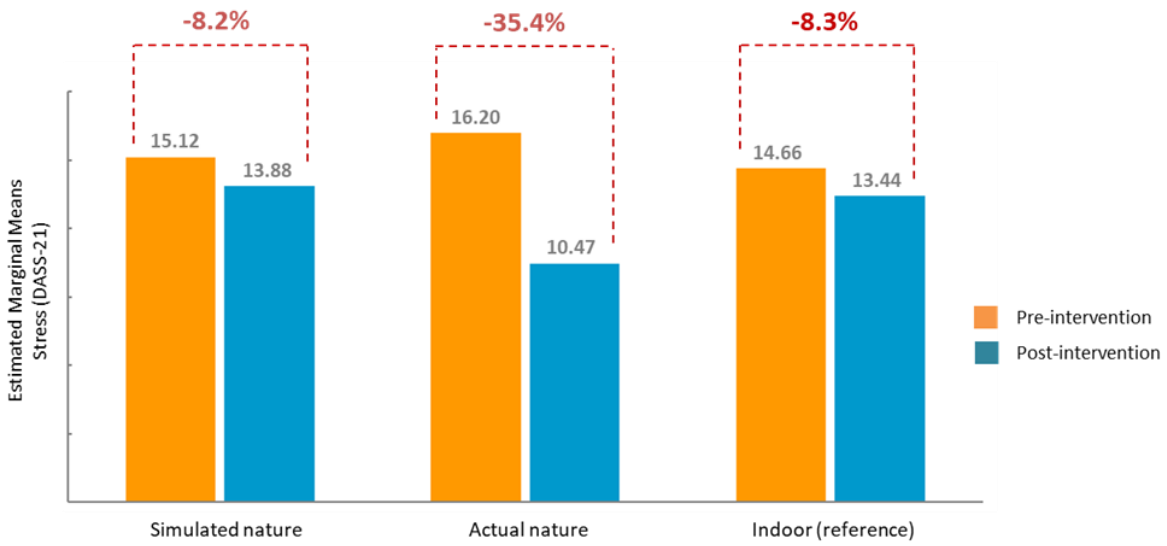

Figure 5 Change in stress by environmental settings

Nature connection

A significant difference was found in the post-intervention score for natural connection between the settings. The group that experienced the actual nature demonstrated a significant increase (14.9%) in their level of nature connectedness from before to after the intervention. In contrast, the simulated nature (3.6%) and indoor setting (0.9%) did not exhibit significant differences. These results indicate that the actual nature was more effective in promoting an increase in natural connectedness compared to both the simulated and indoor environments (Figure 6).

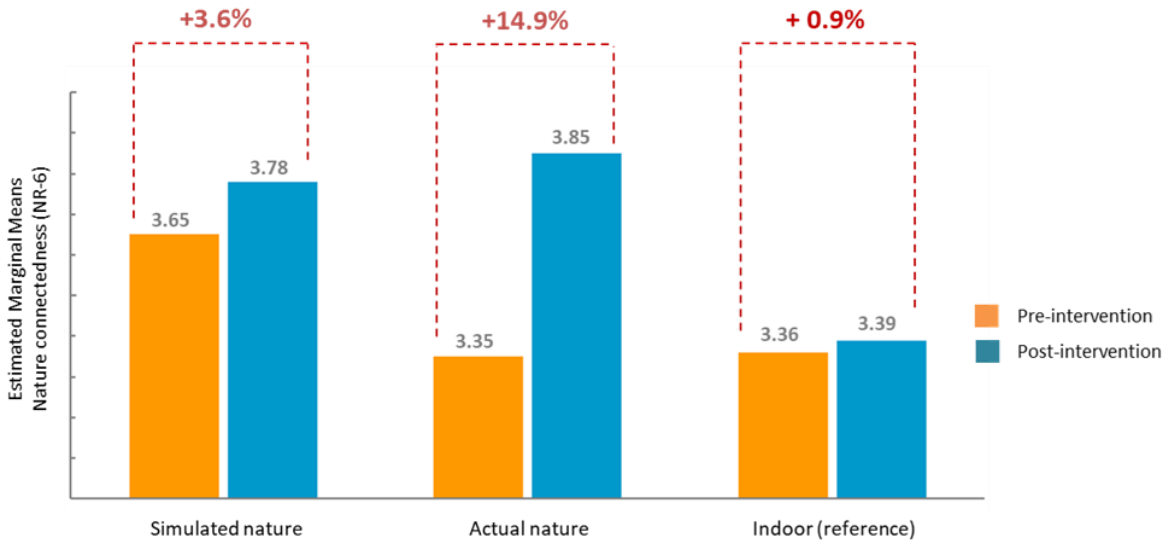

Figure 6 Change in nature connection by environmental settings

3.2 Qualitative results: focus groups

A total of seven participants (3 males, 4 females) who had attended the initial three mindfulness sessions in either the simulated or actual natural settings were involved in the focus groups.

Table 2 Demographic characteristics of focus group discussion

	Focus group	Gender	Age	Experienced setting
Participant 1 (P1)	FG 1	Female	50	Actual nature
Participant 2 (P2)	FG 1	Male	35	Simulated nature
Participant 3 (P3)	FG 1	Female	26	Actual nature
Participant 4 (P4)	FG 1	Female	27	Simulated nature
Participant 5 (P5)	FG 2	Female	31	Simulated nature
Participant 6 (P6)	FG 2	Male	28	Actual nature
Participant 7 (P7)	FG 2	Male	32	Simulated nature

During the deductive analysis, the outcomes were categorized into two main codes. The first code pertained to the "Mental health and well-being benefits of mindfulness practice in natural environments," which further included three sub-codes: "Enhanced cognitive function," "Positive emotions," and "Reduced stress and anxiety." The second code focused on the "Experience of nature connection" and comprised two sub-codes: "Multisensory experiences" and "Noticing (visual) surroundings and sounds". The following section presents the results, with relevant direct quotes from the focus group discussions included. The quotes are identified by individual code numbers, along with the associated environments.

Mental well-being benefits of mindfulness practice in natural environments: Do participants describe differences in mental well-being outcomes in a simulated compared to an actual natural setting?

Enhanced cognitive function

Mindfulness practice has been linked to enhanced cognitive performance, including attention and awareness. In this study, two participants from each environment reported that the mindfulness approach helped them prioritize their work, resulting in increased focus and improved efficiency and productivity.

> "I'm more productive in my work hours. I can think straight and just focus on that exact moment, while not being worried about all process. There was a gain in productivity, quality as well." (P4 from simulated environment)

> "I'm not rushing as much as I was before … I feel myself, more able to cope with things or even just accept things" (P1 from actual environment)

Positive emotions

Among the participants who experienced the actual nature, two individuals shared their newfound happiness and enjoyment in their daily routines following the three-week mindfulness intervention. This indicates that the practice of mindfulness enhanced their level of mindful awareness, leading to a greater appreciation and enjoyment of their present moments.

> "There are things that we notice more when we're going about our day to day life that actually makes us happy and we didn't realise that they were making us happy before." (P1 from actual environment)

> "I normally have a to do list spinning like a tumble dryer in my head constantly, but … now in a morning I really enjoy being outside." (P3 from actual environment)

Reduced stress and anxiety

Participants in both the simulated and actual nature reported utilising acceptance and awareness of negative thoughts as coping strategies to deal with their stressful situations. They described experiencing changes in the way they approached and dealt with these challenges.

> "…every day you can be in front of situations that can be very stressful and you will be able to live with the stress and, for example in lectures and when you are going to present something to a group. It (mindfulness practice) is a very good exercise for yourself to be calm and relaxed and then to prepare for your presentation." (P2 from simulated environment)

> "…like somewhat stressful environment, I was more aware than I was before the course… I've been like a bit panicky. (But after the course) I think it's just completely slipped from my mind basically." (P6 from actual environment)

Furthermore, it was highlighted by two participants from the simulated nature that the environment itself contributed to their relaxation during the mindfulness program. This observation indicates that even a simulated nature can have a positive impact on the outcomes of mindfulness practice.

> "When we were working in that environment, it was very, very relaxing" (P7 from simulated environment)

> "There were nice sounds of birds and sounds of leaves. It actually helped me a lot to relax and destress" (P5 from simulated environment)

Connecting to nature: How do participants practising mindfulness in an actual nature describe nature connectedness compared to those experiencing a simulated nature?

Multisensory experience

Participants from the actual nature described visual scenery, sounds, and engaging multisensory experience such as "standing on grass in your socks," "breathing in air," and "feeling the fresh air and movement." These multisensory encounters seemed to enhance awareness of the natural environment and foster a more comprehensive connection with it. They also appeared to play a role in establishing a personal and meaningful relationship with the natural world.

> "…It's just things like standing on grass in your socks. I don't think I've done that since I was a child...There were trees, leaves, insects (in the park). I just love that kind of sense of space all around us and, I think it was really good for me and just feeling like you're breathing in like air rather than recycled air in a room." (P1 from actual environment)

> "…what I liked that it was outside, so you did feel fresh air and movement." (P6 from actual environment)

Noticing (visual) surroundings and sounds

Conversely, participants who were exposed to the simulated natural environment appeared to primarily pay attention to the projected image and the accompanying background sounds, such as the chirping of birds and the rustling of leaves in the wind.

> "It helped me to relax by seeing this setting (natural simulated setting) and also there were nice sounds of birds and sounds of leaves." (P5 from simulated environment)

> "I like nature and I really enjoy the sound of the birds, the sound of nature." (P7 from simulated environment)

In summary, the qualitative analysis conducted in this study may not provide sufficient evidence to determine the differences in the effectiveness of mindfulness practice between a simulated and an actual natural environment. Nevertheless, the analysis did reveal some variations in participants' experiences of the environment, particularly regarding multisensory experiences.

4. Discussion and conclusions

This study aims to investigate whether the effectiveness of a therapeutic intervention is enhanced when conducted in an actual natural setting rather than in a simulated one. Specifically, we analysed the changes in level of mindfulness, stress and nature connectedness after the completion of the intervention in either a simulated or actual natural setting. Additionally, insights from two focus groups were gathered to gain a deeper understanding of participants' experiences with mindfulness practices in these natural environments.

The results of this study suggest that both simulated and actual natural settings had positive outcomes for mindfulness-based interventions. Significant improvements were observed in

mindfulness and stress reduction, regardless of the setting. These findings support previous studies that conducting a mindfulness practice in nature leads to enhancements in psychological well-being and overall mental health. For instance, Lymeus *et al*. (2018) indicated that a five-week mindfulness practice conducted in a botanical garden improved participants' attentional resources. Choe et al. (2020) previously conducted a laboratory experiment utilising simulated woodland and parkland environments and found that a three-week mindfulness program in these settings was more effective in reducing stress compared to a simulated non-natural setting.

Although both simulated and actual natural settings yielded similar benefits for mindfulness, the actual nature had greater reductions in stress and increased feelings of connectedness to nature. Previous studies by Kjellgren and Buhrkall (2010) and Gatersleben and Andrews (2013) have also showed that activities, such as walking or relaxation, in actual nature offered greater restoration effects compared to performing the same activities in simulated nature. They argued that this difference may be attributed to the fact that simulated settings lack the genuine natural scenery, which fails to capture the captivating and restorative characteristics associated with environments, as proposed in Kaplan's Attention Restoration Theory. Consequently, individuals may need to exert more effort to maintain focus in a simulated setting compared to an actual natural setting.

Further, the qualitative description of the participants' subjective experiences in the actual nature, compared to the simulated natural setting, reinforce some of the quantitative findings. The participants' descriptions of their sensory experiences in the actual natural setting indicate that these sensations enhance their awareness of their surroundings, resulting in a stronger connection to nature. On the other hand, those in the simulated natural environment only mentioned visual and auditory experiences. A participant in the simulated setting pointed out that the seating arrangement during mindfulness practice obstructed their view of the projected image on one side of the wall when sitting in a circle. In contrast, the actual nature offered unobstructed access to nature from all directions. This finding suggests that while audio-visual simulation can induce a sense of calm and relaxation, it may not provide the same immersive and multisensory experience as the actual environment. The simulation only seems to promote general relaxation, rather than a more intense natural experience that fosters a stronger connection to nature. This finding highlights the need for further research to determine the elements in the real natural environment that lead to psychological benefits, such as sounds, scents, air movement, humidity, and light.

It is worth noting that simulated and virtual environments are mainly utilised in environmental science and technology and are not extensively used in health and social care settings. In experimental studies by Depledge et al. (2011) and Small et al. (2015), nature images were employed to reduce anxiety, fear and distress through Virtual Restorative Environment Therapy (VRET). Similarly, Seabrook et al. (2019) investigated the effectiveness of a VR mindfulness app that featured a 360-degree video of a serene forest environment accompanied by guided mindfulness practice. Continued efforts are needed to make virtual nature more accessible to everyday living.

However, it is important to acknowledge that this study has some limitations. First, this study used two different experimental studies conducted by the author, which had slightly different objectives originally. These differences in research goals, participant recruitment, and experimental designs could potentially influence the outcomes. Future studies should validate these findings and provide more conclusive evidence on the potential of virtual or simulated natural environments. Second, the study primarily relied on self-report measures to assess the effectiveness of the interventions. While self-report measures provide valuable insights into participants' subjective experiences, they are also susceptible to biases and may not accurately reflect objective outcomes. Future research should consider including objective measures, such as physiological measurements or behavioural observations, to provide a more comprehensive evaluation of the interventions' effectiveness.

Despite these limitations, the findings of this study suggest that both simulated and actual natural environments have potential in healthcare and therapeutic settings. While actual nature is preferable, simulated and virtual nature can serve as alternatives in cases where direct contact with nature is not possible. This provides a foundation for further research exploring the use of simulated natural settings as interventions for vulnerable populations, including those in hospitals, rehabilitation centres, and long-term care facilities. By improving our understanding of the benefits and limitations of these interventions, we can optimize their implementation and enhance the well-being of individuals in need of therapeutic support.

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