Nature Inspired Scenes for Guided Mindfulness Training: Presence, Perceived Restorativeness and Meditation Depth

Mark R. Costa[1](✉), Dessa Bergen-Cico[1], Trevor Grant[1], Rocio Herrero[2], Jessica Navarro[3], Rachel Razza[1], and Qiu Wang[1]

[1] Syracuse University, Syracuse, New York, USA
mrcosta@syr.edu
[2] Universidad Jamie I, Castellón de la Plana, Spain
[3] Universidad de Valencia, Valencia, Spain

Abstract. Practicing mindfulness-based stress reeducation and other contemplative practices generates a number of health and human performance benefits. However, limited access to qualified training and practice support, as well as poor practice environments, makes it difficult to sustain the habits necessary to develop the attentional regulation skills needed to benefit from mindfulness. In this paper, we report on our research, which focuses on developing immersive environments to support mindfulness-based stress reduction practices. We specifically look at how the design of a virtual environment can foster a restorative experience, if that restorative experience is associated with the depth of the meditation session, and if there are associations between presence and the depth of the meditation session and the restorative properties of the virtual experience. Results show there are significant relationships between the three core concepts, suggesting future work is needed to determine if there are causal relationships exist between the presence, meditation depth, and perceived restorativeness. Understanding how the design of virtual environments may facilitate mindfulness and other contemplative practices has implications for promoting the use of the practices in a variety of contexts.

Keywords: Mindfulness · Virtual reality · Mental health · Presence · Meditation

1 Introduction

There is growing empirical evidence demonstrating the efficacy of contemplative practices and mindfulness-based interventions for treating and managing physical and mental health problems; as well as improving attentional regulation [33]. One of the most widely studied programs is mindfulness-based stress reduction (MBSR) which helps veterans with post-traumatic stress disorder [7]; patients with chronic pain [30]; as well as job stress and interpersonal relationships [3, 29].

Although we know that training in contemplative practices can benefit individuals in various professions, we find that accessibility to qualified trainers, time commitments associated with attending guided practices, environmental distractors, and lack of social support can make sustained engagement with training and practice difficult. The

D. D. Schmorrow and C. M. Fidopiastis (Eds.): HCII 2019, LNAI 11580, pp. 517–532, 2019.
https://doi.org/10.1007/978-3-030-22419-6_37

effectiveness of mindfulness and other contemplative practices are dependent on quality of instruction and group instruction is the prevailing format of delivery. However, access to qualified instructors is limited and many people often find that access to groups is limited due to time and travel constraints, coupled with limited class offerings. Veterans and active duty military who are juggling multiple priorities face extra time constraints and are often in isolated environments where it is difficult to find other individuals to practice with.

Our ongoing research focuses on the question of whether immersive technologies can increase access to mindfulness and other contemplative practices. We identified three areas to focus where immersive technologies can help. First, we are exploring whether immersive environments like virtual and mixed reality (VR, MR) can be designed to provide a comfortable and engaging space to practice mindfulness. Second, whether technology-based solutions can adapt the to the learner to optimize the skill acquisition process. For novice meditators that may be a secluded and quiet virtual forest with basic guided meditations, while more advanced practitioners may want specific feedback on aspects of their practice or to be exposed to more challenging scenarios where attention is harder to maintain. Second, whether virtual environments can support the social component of practice, including group meditation, to mitigate geographical challenges and practice such that geographically distributed users can experience the social interactions necessary to learn contemplative skills like MBSR.

This paper reports on the first question related to whether virtual environments can serve as a comfortable and engaging space to practice mindfulness. Our current research focuses on providing basic instruction in awareness of breath (AOB) and sitting meditation in virtual nature environments. We are specifically working on fine-tuning virtual environments to assist people who may have difficult with meditation practice due to personal barriers and environmental distractions that tax limited attentional resources. This report presents our research process related to creating an optimized environment for people to learn mindfulness-based meditation. The specific research questions guiding this paper are – Can virtual nature immersive environments have restorative properties? and Do the virtual nature immersive environments improve the quality of a meditation session?

2 Theoretical Framework and Research Questions

Our teams' research focuses on developing interventions to help high stress populations manage their stress effectively through the use of complementary health practices. In particular, we focus on questions related to the efficacy of mindfulness-based practices for self-regulation of emotions and behaviors, based on the mindfulness-based stress reduction MBSR curriculum [22].

Mindfulness and other contemplative approaches require regular practice for sustained change. However, many people find engaging in regular practice difficult, as noted by Grow and colleagues who found daily practice drops off significantly [17]. For those of us who are interested in developing tools to make mindfulness more widely available, one of the core challenges we face is making is easier for people to maintain a consistent practice schedule because consistent and frequent practice accelerates the skill acquisition process [13].

One of the fundamental skills associated with contemplative practices is attentional regulation. The ability to engage in advanced techniques is predicated upon the ability to monitor and direct one's attention. Some of the early training novices receive in mindfulness-based intervention is on breath awareness and focus, which helps the participant learn to monitor their attention and redirect it as necessary. Part of the mindfulness practice is to set aside time each day to work on managing attention. In some sense, there is a feedback loop between attentional regulation and quality of mindfulness practice. Attentional regulation makes it easier to practice mindfulness, but practicing mindfulness improves attentional regulation. As other researchers have noted, many people who need or want to train their attentional regulation skills have difficulty focusing, which makes mindfulness practice more difficult [2, 12, 26].

There are several factors that make it difficult to direct one's attention. There are external factors, such as noise and light pollution, and internal factors, such as stress, that make it difficult to focus on mindfulness practices; this is especially true for novices [26]. When we say something acts as a drain on attentional resources, we are adopting the position that attention is a limited resource, and chronic stress and/or intense focus will deplete that resource [25]. Therefore, if someone is chronically stressed or they are distressed, they have difficulty focusing. Mindfulness can help mitigate the negative consequences of stress, but one needs to be able to focus in order to practice mindfulness. If stress has depleted a person's attentional resources, they cannot tune out distractors to focus on the practice. In situations where there is a confluence of factors, such as chronic stress and distracting environments, serving to impede practice, we can leverage aspects of technology to mitigate those impediments. Thus, we specifically look at whether virtual reality environments can help mitigate the effects of chronic stress on attention fatigue through simulation of natural environments, and whether a controlled virtual environment increases the quality of meditation sessions because of its ability to mitigate the effects external stimuli.

With respect to directed attention fatigue, attention restoration theory [18, 23] posits that attention is a limited resource that is frequently depleted through stress and over taxation due to excessive stimulation and cognitively demanding environments. Research has shown that natural environments have inherently restorative properties, if they cultivate a sense of being away, extent, compatibility, and soft fascination [23]. In fact, there is a larger movement of research on biophilic design principles, which focuses on the ways in which the integration of nature into our built environments affects us physiologically and psychologically [31]. These design features include:

Extent is the quality of environments that leaves you totally immersed. An environment that satisfies the extent quality has both coherence and scope such that it constitutes a "whole other world" [23].

Compatibility broadly refers to the match between the person and the environment. Kaplan argues there are two types of compatibility. The first is information compatibility, where a person understands exactly what he or she can do in that environment with little effortful direction of attention towards decision making [24]. The second type of compatibility is motivational compatibility, where there is a match between what the environment affords and what the person wants to do.

Fascination can either be hard fascination, where your attention is held easily by a fascinating activity (like a game), or soft fascination, where your attention is held by a less stimulating activity. Our work focuses more on soft fascination, where we create virtual environments to gently relax one's attention to ease them into the practice of meditation [23].

Being away refers to the sense of being separated from usual concerns and the environment those concerns arise from [23].

If an environment meets several of these criteria, it can increase the perceived restorativeness of the environment [18]. A restorative environment promotes the recovery of mental resources and well-being [9, 18]. Lymeus et al. [27] argue that a restorative environment refreshes the mental capacity of individuals and can thus make a meditation session more productive, particularly for novice practitioners. **Our first research question is** – what is the relationship between perceived restorativeness of an environment and the quality of the meditation session? Two questions that would help us answer that question are – (1) Do any of the factors associated with **perceived restorativeness** have a stronger relationship with the **quality of the meditation** session than the others?, and (2), Is it possible that certain factors are necessary, but not sufficient for quality meditation sessions?

Any time we design a virtual environment to have restorative properties, we need to identify ways in which we can maximize the user's sense of extent, compatibility, fascination, and being away with the virtual environment. Before we can meet any of those criteria, the user needs to feel present in the virtual environment. The concept of physical presence, or the sense of "being there", best captures what we need to optimize [32]. However, the exact relationship between presence and perceived restorativeness of the environment has yet to be determined; therefore, we are not proposing a causal model in this paper.

In the past, we could argue that a sense of presence is required before the media produced the desired psychological effects. However, recent research has shown that certain elements of a virtual environment might induce higher levels of presence if the element or stimuli has a significant relationship to emotions outside of the virtual environment. For example, the presence of phobia inducing stimuli in a VE increased the subjects' sense of presence [14]. It may be possible that there is a positive, causal relationship between compatibility and presence or that several variables related to the design of the VE mediate the relationship between presence and the factors of perceived restorativeness. Based on the uncertain relationships between the constructs of presence and perceived restorativeness, we identified our **second research question** - What is the relationship between **physical presence** and the **perceived restorativeness** of an environment? Sub-questions related to that question are - Do any of the factors associated with perceived restorativeness have a stronger relationship with the presence than the others?

3 Methods and Measures

3.1 Testbed and Environment

For this study, we built a custom virtual reality-based meditation app to test the relationships between concepts outlined in the theoretical framework section above. The meditation area was designed with specific features that other researchers have found to be critical to creating the sense of nature that is required for restorativeness. More specifically, the meditation area was an open forest scene next to a waterfall and stream with running water. We have trees and grass swaying gently in the background. Additionally, we incorporated bird song and scenic views into the virtual environment. We also set the environmental conditions to a bright, sunny day with clouds periodically passing overhead (Fig. 1). Part of the experiment included a 10-min guided meditation, which was recorded by a member of the research team who is a certified Mindfulness-Based Stress Reduction coach; the track was edited by local sound engineers to improve the sound quality of the track.

Fig. 1. A nature-inspired theme with running water and birdsong

The MIND Lab has a suite of sensors and data collection computers supporting the virtual environment. We displayed the virtual environment on an HTC Vive while the subjects were seated in an office chair. The virtual environment was configured to send signals to a suite of sensors when certain interactions or events happened in the virtual environment (see below). The suite of sensors includes a BOPAC system with galvanic skin response (tech specs), and ECG (tech specs), and a 52-channel Hitachi functional near infrared spectroscopy system (fNIRS) (tech specs) to capture participants' neural hemodynamics. Signals from the virtual environment to the sensors were time locked via a custom Arduino setup, which allows us to compare data from different sensors that sample at different frequencies.

3.2 Protocol

Adult subjects were recruited from Syracuse University and the surrounding Syracuse, New York community. Exclusion criteria included epilepsy and advanced neurodegenerative diseases (e.g. Parkinson's Disease). Subjects were invited into the lab, where they were greeted and given a brief explanation of the experiment. After listening to the lab manager's explanation, the individuals were placed in front of a standard computer and given access to a digital version of the informed consent document. If the participants agreed to the informed consent, the digital survey would proceed on to the pre-test measures; if the subjects declined to give consent, they would be thanked for their time and be allowed to leave. No subjects declined to participate. At the end of the pre-test surveys, the survey system displayed a thank you message along with information on the next steps. The lab manager explained how the virtual reality headset worked and what was going to happen over the next ten minutes. The manager used the following text:

In a moment we will place the headphones on your head and outfit the sensor [fNIRS] over the headset. Once that is set up, we will begin the meditation track. Please follow the instructions of the audio track as best as possible. If you feel your mind wander, pull the trigger on the control [technician demonstrates which trigger to pull]. Once you are done, let the technician know and they will help you remove the headset.

After the participants acknowledged that they understood the next steps, they were connected to the physiological sensors and the headset and headphones were placed on their heads and adjusted for comfort. We asked the subjects to indicate when they noticed their mind wandering so we incorporate feedback in the future to bring attention to the wandering mind; that feedback system will be built on a classified that identifies, from the physiological data, when a person's mind is wandering.

The mindfulness track incorporated elements of awareness of breath The narrator also leveraged stimuli in the virtual environment as objects of focus for the track, including the swaying grass, falling water, water running down the stream, and passing clouds. The audio track began one minute and thirty seconds after the participants entered the virtual environment. We delayed the onset of the track because we noticed, even among members of the research staff, that people who entered the virtual environment needed a few moments to get settled in the space and to look around.

When the track was complete, the technician removed the fNIRS cap, headphones, and virtual reality headset from the subjects. The technician then removed the remaining sensors and asked the subjects to complete the post-test measures via an online survey. After the subjects completed the survey, they were thanked for their time and informed them that the experiment was complete.

3.3 Measures

Pre-test measures included a basic demographic survey, which included self-reported measures of meditation experience (style of meditation and estimated hours practiced), whether the subject had ever attended a meditation retreat, and veteran status. We asked subjects to provide self-reported measures of total practice and experience with retreats per [15] because both total practice time and time spent at retreats has been found to affect a person's overall mindfulness and the level of physiological changes associated with long-term meditation. Participants also completed the following self-reported measures:

Five Facets of Mindfulness Questionnaire (FFMQ; [4]) [Pre-test]. FFMQ is a 39-item, five factor instrument designed to capture one's mindful disposition towards daily life. The five factors are: observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience.

Positive and Negative Affect Scale – Short Form (PANAS-SF [34]). [Pre- and Post- test] We used a modified version of the PANAS-SF, worded to capture the strength of their current positive and negative moods. Subjects completed both a pre- and post- test PANAS to capture changes in mood due to the mindfulness session.

Perceived Stress Scale (PSS [11], 1983) [Pre-test]. PSS consists of ten items grouped into two dimensions – positively and negatively worded questions related to how one appraises the stressfulness of situations in their life.

Perceived Restorativeness Scale (PRS [18]) [Post-test] PRS is a four-factor, 26-item scale intended to capture properties of natural environments that are expected to facilitate emotional and attentional rejuvenation.

SUS Presence Questionnaire (SUSPQ, [18]) [Post-test] SUSPQ has six questions, focused on three presence indicators: sense of being there, extent to which the virtual environment becomes more "real" than reality, and the extent to which the virtual environment is thought of as a place visited [6].

Meditation Depth Questionnaire (MDQ [28]) [Post-test]. MDQ was Developed to measure the depth or intensity of a meditation experience while simultaneously being agnostic to the school of meditation. The thirty-item scale has five factors – hinderances, relaxation, personal self, transpersonal qualities, and transpersonal self.

The following physiological instruments were used to capture data during the experiment:

Electrodermal Activity (EDA) for arousal [5]. BIOPAC MP-150 system, data transmitted wirelessly with BIONOMADIX, data collected with BIOPAC's Acknowledge Software. The sampling rate was set at 2000 Hz. Raw data from the module pair is bandlimited from DC to 10 Hz for both channels. Two sensors were placed on the participant's non-dominant hand.

Electrocardiogram (ECG) for heart rate variability for arousal [5]. The module pair has a fixed gain rate of 2,0000Db, with bandlimits from 1 Hz to 35 Hz. Two sensors were placed on the participant's collar bone and a ground electrode on the right hip using the BIOPAC MP 150.

Respiration Sensor (RSP) for breath rate. Raw RSP data from the module pair is bandlimited from DC to 10 Hz, to provide for the measurement of relatively static respiratory conditions, such as cessation of breathing, up to the extremely rapid respiratory effort variations (up to 600 breaths per minute) associated with coughing or sneezing. An elastic band with a pressure sensor was wrapped around participant's chest so that the pressure sensor was located at the inferior section of the participant's sternum using the BIOPAC MP 150.

Function Near Infrared Spectroscopy (fNIRS) for hemodynamic patterns of the brain for assessing cognitive states [19, 21]. Captured with a Hitachi ETG-4000, sampling oxygenated and deoxygenated hemoglobin at 10 Hz. Probes were placed in 2, 3 × 5 arrangements above both the right and left frontal cortex, which resulted in 24 channels of data.

4 Analysis

This paper focuses on the associations between mindfulness disposition via the Five Facets of Mindfulness Questionnaire, sense of presence experienced by participants in the virtual environment via the SUS Presence Questionnaire, perceived restorativeness of the virtual environment via the Perceived Restorativeness Scale, and quality of the mindfulness session via the Meditation Depth Questionnaire. We will report on the associational relationship among the other measures in subsequent publications.

4.1 Descriptive Statistics and Measure Assessment

Twelve subjects participated in the study (Female = 5), ranging in age from 20–54 (M = 32.92, SD = 11.22). Five of the subjects had a master's degree or greater, five either had no degree or some college but no degree, and the remaining had college degrees.

Six of the subjects practiced meditation in the past, covering a variety of styles, including focused attention meditation, yoga meditation, body scan meditation, and transcendental meditation. Of the six subjects who have practiced meditation in the past, three participated in retreats. The least experienced practitioner had about one hour of meditation experience, the most around 10,000 h (M = 110 h, SD = 3996).

Table 1 summarizes the descriptive statistics for the four main variables. Results for tests of normality in the last column ($p > .05$) indicate the data adhere to a normal distribution (Fig. 2). The Presence Scale is calculated differently in that the final score is a count of all instances where a participant rated an item a 6- or a 7- on the Likert Scale [6].

Table 1. Descriptive statistics and normality tests for main variables

Measure	Mean	CI (95%) Lower/upper	S.D.	Shapiro-Wilk	*p*
Five facets mindfulness	3.370	3.165/3.574	.323	.974	.947
Perceived restorativeness	3.435	2.966/3.905	.739	.966	.865
Meditation depth	2.694	2.253/3.135	.694	.951	.649
Presence	1.167	.632/1.70	.835		

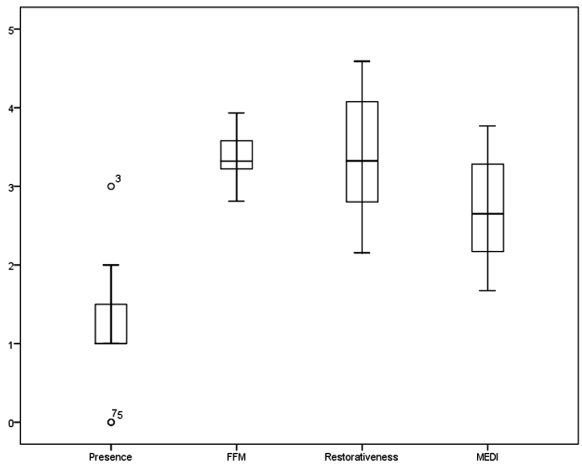

Fig. 2. Boxplots for main variables

We attempted to conduct confirmatory factor analysis on the variables with multiple scales (Five Facets of Mindfulness, Perceived Restorativeness, and Meditation Depth Questionnaire), but the sample size was too small to produce results. The (sub) scales were also tested for internal consistency; all but two scored in the acceptable to good range ($0.7 < \alpha < 0.9$), except for Presence scale and the *Describe* subscale from the Five Facets of Mindfulness questionnaire (see Table 2).

Table 2. Reliability analysis

Scale	Subscale	No. items	Cronbach's α
Five facets of mindfulness	Observe	7	.806
	Describe	8	**.698**
	Act	8	.891
	Non-judgmental	8	.883
	Non-reactive	7	.812
Perceived restorativeness	Away	5	.883
	Fascination	8	.871
	Coherence	4	.707
	Compatibility	9	.838
Meditation depth questionnaire	Hinderances	6	.756
	Relaxation	3	.893
	Transpersonal qualities	8	.799
	Transpersonal self	6	.810
	Personal self	7	.857

Another area where we expected to see divergent patterns is in the meditation depth results. Some of the factors and their associated items were written to ostensibly written to apply to all types of meditation [28], but do not necessarily apply to mindfulness-based stress reduction. For example, *There was no meaning of any meditation techniques any more*, *I felt myself at one with everything*, because of its secular bent. In the future, we expect to collect additional data to support more detailed analysis of the relationship between meditation experience and reported meditation depth.

4.2 Correlations

Two-tailed Pearson's correlation analyses were run among presence, perceived restorativeness, and meditation depth. We also tested for correlations between meditation depth and general mindfulness to determine if a predisposition towards mindfulness impacted the quality of the meditation experience.

The relationship between meditation depth and perceived restorativeness of the experience was more pronounced (see the five significant correlations in the last column of Table 3). The sense of being away was positively and significantly correlated with hinderances (r = .842, p = .001). As a sense of Away increased, Hinderances, such as *I found it difficult to relax*, and *There was a constantly change of thoughts in my mind*, decreased. Positive correlations are shown in Table 3 because the values were reverse coded for Hinderances. The sense of being Away was also positively correlated with Relaxation (r = .847, p = .001), Transpersonal Qualities (r = .690, p = .013), and General Meditation Depth (r = .767, p = .004). Relaxation also had significant correlations with Fascination (r = .580, p = .048) and Compatibility (r = .672, p = .017). Compatibility was significantly correlated with Transpersonal Qualities (r = .700, p = .011) and General Meditation Depth (r = .680, p = .020). Overall Perceived Restorativeness had positive correlations with all factors of Meditation Depth except Transpersonal Self.

Table 3. Relationships between meditation depth and perceived restorativeness of the virtual environment, along with factors

			Perceived restorativeness				
			Away	Fascination	Coherence	Compatibility	Perceived restorativeness
Meditation depth	Hinderances	*r*	**.842**	.308	.370	.573	**.610**
		p	**.001**	.330	.236	.052	**.035**
	Relaxation	*r*	**.847**	**.580**	.569	**.672**	**.768**
		p	**.001**	**.048**	.053	**.017**	**.004**
	Personal self	*r*	.533	.484	.505	.496	**.576**
		p	.075	.111	.094	.101	**.050**
	Transpersonal qualities	*r*	**.690**	.361	.450	**.700**	**.629**
		p	**.013**	.249	.142	**.011**	**.028**
	Transpersonal self	*r*	.351	.219	.402	.384	.385
		p	.263	.494	.196	.218	.216
	General meditation depth	*r*	**.767**	.475	.544	**.658**	**.702**
		p	**.004**	.119	.068	**.020**	**.011**

In Table 3, several $p < 0.10$, indicating the marginal significance due to the impact of small sample size. Looking at Tables 4 and 5, there are several significant or marginally significant correlations between Presence and factors of Perceived Restorativeness or Meditation Depth. Presence was significantly associated with Compatibility ($r = .596$, $p = .041$), Transpersonal Self ($r = .765$, $p = .004$), Personal Self ($r = .679$, $p = .015$), and General Meditation Depth ($r = .673$, $p = .017$).

Table 4. Correlations between presence and perceived restorativeness and its factors

		Perceived restorativeness				
		Away	Fascination	Coherence	Compatibility	Perceived restorativeness
Presence	*r*	.404	.467	.506	**.596**	.554
	p	.193	.126	.093	**.041**	.061

Table 5. Correlations between presence and meditation depth and its factors

		Meditation depth					
		Transpersonal self	Hinderances	Relaxation	Personal self	Transpersonal qualities	General meditation depth
Presence	*r*	**.765**	.493	.433	**.679**	.493	**.673**
	p	**.004**	.103	.160	**.015**	.103	**.017**

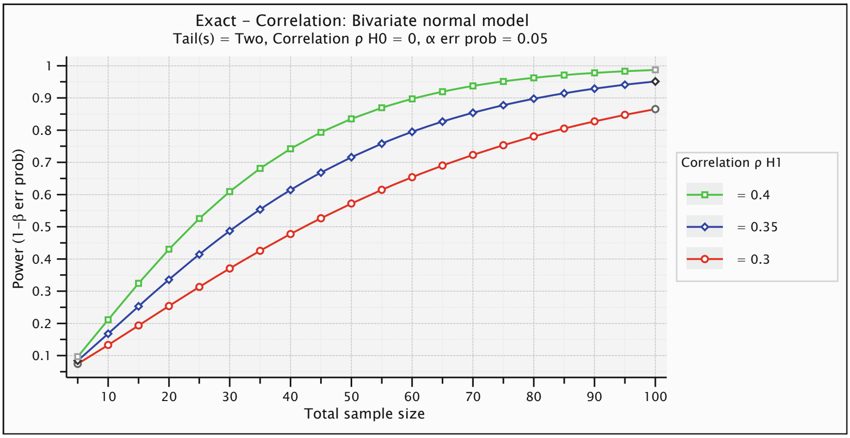

Fig. 3. Post-hoc empirical power analysis for sample sizes across three correlations

One area where we expected to see stronger correlations was between general mindfulness, as measured by the Five Facets of Mindfulness, and meditation depth, as measured by the Meditation Depth Questionnaire (Table 6). Only Acting with Awareness showed significant correlation relationships with Personal Self ($r = .619$, $p = .032$) and Transpersonal Self ($r = .623$, $p = .030$). The small correlation (i.e., $r < .30$) [10] between meditation depth and mindfulness disposition could be because so few skilled meditators were in the group. The empirical power analysis (Fig. 3) shows that a larger sample size (e.g., N $\geq$ 85) is needed to reach a significant relationship. Alternatively, the non-meditators may have rated their mindfulness disposition inconsistently because they do not fully understand the experience they are trying to rate. Having novices use the Meditation Depth Questionnaire may be problematic because the questionnaire was designed for, and validated on, expert meditators to assess the depth of their meditation sessions [28].

Table 6. Relationships between mindfulness and meditation depth, include factors

			Five facets of mindfulness (FFM)					
			Observe	Describe	Acting with awareness	Non-judging	Non-reactivity	FFM
Meditation depth	Hindrances	*r*	−.278	.167	−.007	−.230	.033	−.168
		p	.381	.604	.984	.471	.920	.601
	Relaxation	*r*	−.301	−.045	.145	−.202	−.200	−.258
		p	.341	.890	.653	.530	.534	.419
	Personal self	*r*	−.213	−.002	**.619***	.071	−.003	.200
		p	.506	.995	**.032**	.826	.992	.533
	Transpersonal qualities	*r*	.005	.221	.267	−.265	.160	.121
		p	.988	.491	.401	.405	.620	.709
	Transpersonal self	*r*	−.298	.141	**.623***	−.041	.315	.284
		p	.348	.662	**.030**	.900	.319	.371
	General meditation depth	*r*	−.263	.091	.376	−.150	.040	.018
		p	.409	.779	.228	.643	.902	.956

5 Discussion and Conclusions

Our first research question focused on the relationship between perceived restorativeness of an environment and the quality of the meditation session. We specifically wanted to know if any of the factors associated with perceived restorativeness have a stronger association with the quality of the meditation session than the others?

All factors in the Meditation Depth Questionnaire and the Perceived Restorativeness Scale passed tests for internal reliability (see Table 2), with all α falling in the good range ($0.7 < \alpha < 0.9$), which is a positive result given the small sample size. Of the factors in Perceived Restorativeness, *Away*, or the sense of being separate from problems and spaces they arise in, had the strongest correlation with aspects of meditation depth. Despite participants rating the environment as being a place separate from the participants' usual concerns, there was no correlation between the sense of presence in the environment and the sense of being away. There is no clear reason for this disconnect. These findings may be reflective of the limitations of the instruments used and/or the need for a larger sample size in future research.

In addition to the factor *Away*, *Compatibility* had a significant correlation with meditation depth, which has face validity. If the participants were not comfortable with the virtual environment, it would not be a relaxing experience and the lack of comfort might interfere with the quality of the meditation session.

The fact that Restorativeness had significant correlations with all factors of *Meditation Depth*, except *Transpersonal Self*, suggests that the act of meditation may be restorative. Experienced meditators may be able to conjure up the feeling of being away, without the need to travel (virtually or physically). For those participants who were not as skilled in meditation, the sense of being away (*Away*), in an environment that supported gentle fascination (*Fascination*), and was compatible with their schemas of what constitutes a relaxing environment (*Compatibility*), was relaxing and restorative.

The finding in this paper related to meditation depth mirror the findings in [26], which reported greater depth of meditation along all factors in the virtual environment with neurofeedback than the virtual environment alone, which in turn had greater levels of depth than a standard computer screen. The extreme variance in time spent meditating makes it difficult to use the self-report data to explore in greater detail the relationship between meditation experience, meditation depth, and perceived restorativeness of the environment. Our current work focused on classifying mindful experiences [20] may provide more objective ways to tease out the complex relationship between meditation experience, the role of practice environment, the quality of a meditation session, and the restorative property of the environment.

Our second research question focused on the relationship between physical presence and the perceived restorativeness of an environment. We were specifically interested in whether any of the factors associated with perceived restorativeness have a stronger association with the presence than the others. Only *Compatibility* and *Coherence* showed significant correlations to presence. This is expected because incoherence, or a mismatch between what is expected of an environment and what is perceived, can break the perceptual illusion that presence is founded on. We suggest that compatibility is important for presence because incompatibility creates a barrier to accepting the environment and being in the present moment of the experience; although the exact conceptual linkage would need to be further explored. Presence was also marginally correlated with General Perceived Restorativeness, which would indicate that being in the virtual environment had some effects associated with restorative environments on the participants. We would need to further tease out whether the restorativeness of the environment helped improve the meditation depth of the session.

We do see significant correlations between transpersonal self, personal self, and general meditation depth, and presence. We attribute these results to participants' abilities to reach transpersonal and personal self-states. Their ability to do so may enable them to feel more present, regardless of the context, which may support greater meditation depth. It is noteworthy that, a sense of being in the space was correlated with overall meditation depth, which is encouraging because it would indicate the environment facilitated meditation.

Finally, we explored whether general mindfulness had any correlation with meditation depth. Results show little support for the effects of disposition towards mindfulness, as measured by the FFMQ, and the quality of the meditation session. Only acting with awareness showed any correlation with personal self and transpersonal self.

Brown and Ryan [8] argue that present-centered attention, or acting with awareness, is foundational to mindfulness; therefore, we would expect participants who report greater awareness of self and of transpersonal experiences to have higher levels of the basic skill of acting with awareness.

Similar to previous studies [1, 2, 12, 16], the results from this study indicate that a nature inspired virtual environment may has some restorative or relaxing properties and that the restorative effects may translate to higher quality or deeper mindfulness sessions. Researchers and practitioners who are promoting mindfulness as a possible intervention may want to consider paying attention to the physical space they are teaching in, as it will have an impact on the perceived depth of the session.

Major limitations to this study include a small sample size, lack of longitudinal analysis assessing whether the virtual practice environment supports sustained practice, and reliance on self-report measures to assess depth of the meditation experience. Our future work will integrate the use of sensors to assess the quality of the meditation session as well as deploy the virtual reality app to test whether the environment promotes sustained engagement in the practice.

References

1. Andersen, T., et al.: A preliminary study of users' experiences of meditation in virtual reality. In: 2017 IEEE Virtual Reality (VR), pp. 343–344 (2017). https://doi.org/10.1109/VR.2017.7892317
2. Allison, P., et al.: Relaxation with immersive natural scenes presented using virtual reality. Aerosp. Med. Hum. Perform. **88**(6), 520–526 (2017). https://doi.org/10.3357/AMHP.4747.2017
3. Anderson, V.L., Levinson, E.M., Barker, W., Kiewra, K.R.: The effects of meditation on teacher perceived occupational stress, state and trait anxiety, and burnout. School Psychol. Q. **14**(1), 3–25 (1999). https://doi.org/10.1037/h0088995
4. Baer, R.A., Smith, G.T., Hopkins, J., Krietemeyer, J., Toney, L.: Using self-report assessment methods to explore facets of mindfulness, using self-report assessment methods to explore facets of mindfulness. Assessment **13**(1), 27–45 (2006). https://doi.org/10.1177/1073191105283504
5. Bandara, D., Song, S., Hirshfield, L., Velipasalar, S.: A more complete picture of emotion using electrocardiogram and electrodermal activity to complement cognitive data. In: Schmorrow, Dylan D.D., Fidopiastis, Cali M.M. (eds.) AC 2016. LNCS (LNAI), vol. 9743, pp. 287–298. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-39955-3_27
6. Van Baren, J., W.A IJsselsteijn, J., Deliverable 5. measuring presence: a guide to current measurement approaches (2004)
7. Bergen-Cico, D., Possemato, K., Pigeon, W.: Reductions in cortisol associated with primary care brief mindfulness program for veterans with PTSD. Med. Care **52**, S25 (2014). https://doi.org/10.1097/MLR.0000000000000224
8. Brown, K.W., Ryan, R.M.: The benefits of being present: mindfulness and its role in psychological well-being. J. Pers. Soc. Psychol. **84**(4), 822 (2003)
9. Carrus, G., et al.: a different way to stay in touch with 'urban nature': the perceived restorative qualities of botanical gardens. Front. Psychol. **8** (2017). https://doi.org/10.3389/fpsyg.2017.00914
10. Cohen, J.: Statistical Power Analysis for the Behavioral Sciences, 2nd edn. Routledge, New York (1988)

11. Cohen, S., Kamarck, T., Mermelstein, R.: A global measure of perceived stress. J. Health Soc. Behav. **24**(4), 385–396 (1983). https://doi.org/10.2307/2136404
12. De Kort, Y., Meijnders, A.L., Sponselee, A.A.G., IJsselsteijn, W.A.: What's wrong with virtual trees Restoring from stress in a mediated environment. J. Environ. Psychol. **26**(4), 309–320 (2006)
13. Ericsson, K.A., Charness, N.: Expert performance: its structure and acquisition. Am. Psychol. **49**(8), 725 (1994)
14. Felnhofer, A., Hlavacs, H., Beutl, L., Kryspin-Exner, I., Kothgassner, O.D.: Physical presence, social presence, and anxiety in participants with social anxiety disorder during virtual cue exposure. Cyberpsychol. Behav. Soc. Netw. **22**(1), 46–50 (2018). https://doi.org/10.1089/cyber.2018.0221
15. Golem, D., Davidson, R.J.: Altered Traits: Science Reveals How Meditation Changes Your Mind, Brain, and Bod. Avery, New York (2017)
16. Gromala, D., Tong, X., Choo, A., Karamnejad, M., Shaw, C.D.: The virtual meditative walk: virtual reality therapy for chronic pain management. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI 2015), pp. 521–524. https://doi.org/10.1145/2702123.2702344
17. Grow, J.C., Collins, S.E., Harrop, E.N., Marlatt, G.A.: Enactment of home practice following mindfulness-based relapse prevention and its association with substance-use outcomes. Addict. Behav. **40**, 16–20 (2015)
18. Hartig, T., Korpela, K., Evans, G.W., Gärling, T.: A measure of restorative quality in environments. Scand. Hous. Planning Res. **14**(4), 175–194 (1997). https://doi.org/10.1080/02815739708730435
19. Hincks, S.W., et al.: Entropic brain-computer interfaces-using fNIRS and EEG to measure attentional states in a bayesian framework. In: PhyCS, pp. 23–34 (2017)
20. Hirshfield, L., Bergen-Cico, D., Costa, M.R., Jacob, R.J.K., Hincks, S., Russell, M.: Measuring the neural correlates of mindfulness with functional near infrared spectroscopy. In: Empirical Studies of Contemplative Practices. Nova (2019)
21. Hirshfield, L., Williams, T., Sommer, N., Grant, T., Gursoy, S.V.: Workload-driven modulation of mixed-reality robot-human communication. In: Proceedings of the Workshop on Modeling Cognitive Processes from Multimodal Data, p. 3 (2018)
22. Kabat-Zinn, J., Hanh, T.N.: Full catastrophe living: using the wisdom of your body and mind to face stress, pain, and illness. Delta (2009)
23. Kaplan, S.: The restorative benefits of nature: toward an integrative framework. J. Environ. Psychol. **15**(3), 169–182 (1995). https://doi.org/10.1016/0272-4944(95)90001-2
24. Kaplan, S.: Meditation, restoration, and the management of mental fatigue. Environ. Behav. **33**(4), 480–506 (2001). https://doi.org/10.1177/00139160121973106
25. Kaplan, S., Berman, M.G.: Directed attention as a common resource for executive functioning and self-regulation. Perspect. Psychol. Sci. **5**(1), 43–57 (2010). https://doi.org/10.1177/1745691609356784
26. Kosunen, I., Salminen, M., Järvelä, S., Ruonala, A., Ravaja, N., Jacucci, G.: RelaWorld: neuroadaptive and immersive virtual reality meditation system. In: Proceedings of the 21st International Conference on Intelligent User Interfaces (IUI 2016), pp. 208–217. https://doi.org/10.1145/2856767.2856796
27. Lymeus, F., Lundgren, T., Hartig, T.: Attentional effort of beginning mindfulness training is offset with practice directed toward images of natural scenery. Environ. Behav. **49**(5), 536–559 (2017). https://doi.org/10.1177/0013916516657390
28. Piron, H.: The meditation depth index (MEDI) and the meditation depth questionnaire (MEDEQ). J. cand Meditation Res. **1**(1), 69–92 (2001)

29. Roeser, R.W., et al.: Mindfulness training and reductions in teacher stress and burnout: Results from two randomized, waitlist-control field trials. J. Educ. Psychol. **105**(3), 787 (2013)
30. Rosenzweig, S., Greeson, J.M., Reibel, D.K., Green, J.S., Jasser, S.A., Beasley, D.: Mindfulness-based stress reduction for chronic pain conditions: variation in treatment outcomes and role of home meditation practice. J. Psychosom. Res. **68**(1), 29–36 (2010). https://doi.org/10.1016/j.jpsychores.2009.03.010
31. Ryan, C.O., Browning, W.D., Clancy, J.O., Andrews, S.L., Kallianpurkar, N.B.: Biophilic design patterns: emerging nature-based parameters for health and well-being in the built environment. Int. J. Architect. Res.: ArchNet-IJAR **8**(2), 62–76 (2014). https://doi.org/10.26687/archnet-ijar.v8i2.436
32. Slater, M., Usoh, M., Steed, A.: Depth of presence in virtual environments. Presence: Teleoperators Virtual Environ. **3**(2), 130–144 (1994). https://doi.org/10.1162/pres.1994.3.2.130
33. Tang, Y.-Y., et al.: Short-term meditation training improves attention and self-regulation. Proc. Nat. Acad. Sci. **104**(43), 17152–17156 (2007)
34. Thompson, E.R.: Development and validation of an internationally reliable short-form of the positive and negative affect schedule (PANAS). J. Cross-Cultural Psychol. **38**, 2 (2007)