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Fostering Interactive Mindfulness Experiences in VR

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Abstract. In Positive Computing, Virtual and Mixed Reality have become established technological tools to foster positive subjective experiences and individual traits. A particular focus is on the development of applications for mindfulness practices. However, such applications only offer people an alternative way of presenting the guided imagery flow on which the mindfulness experience is grounded. Indeed, people can experience a concrete rendering of the environment. This study investigates whether allowing people to actively explore and manipulate the guided imagery flow through their actions affects their mindfulness experience. To this aim, we present an interactive VR application for mindfulness practice, facilitating the user's interactive behavior. Twenty-four persons participated in a pilot experiment practicing mindfulness in a between-subjects design with interactive VR vs. audio-only conditions. In both, participants self-reported their perceived effectiveness of mindfulness and their moods. Results show that the immersive interactive VR practice resulted in improving a more comprehensive range of moods than the audio-only condition, while both conditions proved to be on par when assessing self-reported mindfulness.

Keywords: Virtual Reality · mindfulness · wellbeing · multimodal interaction

1 Introduction

The emerging research field of Positive Computing [5] focuses on technological solutions that may support the aims of Positive Psychology, i.e., promoting "positive subjective experience, positive individual traits, and positive institutions [...] it aims to improve quality of life" [26]. More specifically, flow and happiness, i.e., being in the present, is one of the three pillars of Positive Psychology.

Mindfulness [25], i.e., meta-cognitive skills improving awareness of being in the present, is a critical component of Positive Psychology, as it helps individuals cultivate a positive mindset, build strengths, and increase positive emotions.

The well-known mindfulness practices include the body scan and focusing on one's breath. Other practices, such as mindful walking or multi-sensorial exploration, require more active behaviors from practitioners. Several technological solutions were developed to enhance the benefits of mindfulness practices by using Extended Reality [6], [21], [23], interactive mobile devices [28], [24], and physiological sensors [8].

We propose an application for mindfulness practices that uses immersive Virtual Reality (VR) and allows interaction with virtual objects by grasping and dropping them. Interaction is, indeed, one of the five leading research lines in Human-Computer Interaction (HCI) for mindfulness [29], but existing VR-based solutions are usually "passive" as the specific visual content (e.g., beautiful nature) is displayed to accompany the audio guide (e.g., [6], [21]). People practicing mindfulness are thus "instructed to observe the video passively" [6]. Interaction in such applications is minimal (e.g., the content is adjusted according to head movements) or even absent. Such VR-based solutions are often evaluated against their counterparts using only audio guiding (e.g., [6], [31]). Results of such a comparison show a positive impact of VR on self-reported levels of mindfulness (see also the recent survey [18]). However, very few works use interaction with virtual objects as a part of mindfulness practice (see [10] for a review). It remains an open question whether/how the interactions with virtual objects may positively contribute to the long-term outcomes of mindfulness practices [10]. The existing literature, indeed, shows controversial results. While the work of [29] highlights the positive role of *interactive* VR in mindfulness practice, [16] points out that too much interaction may result in "moving the user's attention away from observing their experience".

The research questions addressed in this paper are as follows:

1. (research question 1) investigating whether interactive VR is more effective than audio-only solutions;
2. (research question 2) investigating whether interactive VR affects self-reported moods.

Twenty-four people participated in the pilot experiment. They practiced mindfulness in a between-subjects design, with interactive VR vs. audio-only conditions. Each condition lasted about 10 minutes. We collected the self-reported mood and self-reported mindfulness through well-established questionnaires.

2 Related Work

Mindfulness techniques recently demonstrated high effectiveness in promoting physical and mental health. The most widely used mindfulness protocols, such as the Mindfulness-Based Intervention (MBI) and the Mindfulness-Based Stress Reduction (MBSR), appear simple enough to be administered and relatively effective for dealing with several physical and mental conditions. One of the main issues reported by people who experience mindfulness practices is the difficulty in staying focused on the present moment without being distracted by thoughts related to the past or future [11].

Evidence was found regarding the effectiveness of VR-mediated protocols to promote attentional processes [17], social skills [27], phobias treatment [12][13], and emotion elicitation [7][3]. Several VR mindfulness applications use computer-generated [20][21], or real (photos, videos) [6][25] visual content. Fostering immersion and engagement by providing participants with a virtual world to explore can mitigate, e.g., attentional issues by diverting attention from the real world. As a result, decreased anxiety is the most frequently reported outcome of such practices, possibly benefiting depression, insomnia, anger, and tension. The rationale behind using VR is that it moves away the attention from the real world; thus, it may help to focus on the mindfulness practice [20]. In other words, VR is used as an attentional anchor. The growing interest in VR mindfulness practice is witnessed by many survey papers on this topic recently published [10][18][30][1].

Existing applications bring people into VR natural landscapes, such as oceans, beaches, fields, meadows, forests, flowers, and fire camps [30]. For instance, the audio-guided mindfulness experience is accompanied by a 360-degree landscape video of South Australia's coastal suburb in [6] or a rendered 3D beach with environmental audio in [31]. Such VR applications are evaluated against the audio-only guided experiences in a between-subjects design. In [6], no significant difference was observed in self-reported mindfulness measured with the Toronto Mindfulness Scale. Still, the VR experience was characterized by a more significant increase in de-centering. In [31], a greater state of mindfulness, measured with the State Mindfulness Scale, was reported in the VR condition.

[25] and [16] propose a 15-minute guided mindfulness practice in VR composed of 360-degree video footage of a forest, ambient sounds originating from the forest, and voice guidance. On a similar note, the Virtual Meditative Walk [14] is a VR-based environment that allows the user to be immersed in a virtual forest, with the camera "slowly moving along a worn dirt pathway". These applications reduce interaction to navigation within the environment (e.g., visual exploration by moving ahead).

Fewer VR applications facilitate interactive behaviors [10]. [23] propose a mindfulness interactive experience with Inner Garden, an augmented sandbox: the user shapes a model of the world in the sand, augmented by a video projection that varies according to the user's breath and heart rate. [9] proposes three exercises with varying degrees of interaction: "no interaction" (an animation of a blooming flower), "minimal interaction" (exploring the virtual forest),

and "full interaction" (a puzzle game). Last, the user's physiological signals can affect the virtual content. E.g., user's breath can control a virtual tree expansion/contraction [22].

Our VR application for mindfulness diverges from previous work in that it enables users to engage with objects within the virtual environment in a more interactive (i.e., direct manipulation of objects) manner. In contrast, existing approaches limit user interaction to non-interactive scenarios or viewpoint manipulation only.

3 VR interactive settings

We develop a Unity[5] VR application whose architecture is depicted in Figure 1. The 3D coordinates data (position, rotation) of the VR headset and controllers are the input of the XR Plug-in Framework[6]. Besides performing the audio and video rendering of the 3D scene, Unity saves the headset, controller, and sensor data in a log file for further offline analysis of the interactive behavior. The application consists of a VR scenario of an island, which the user can freely explore. The user is asked to walk along the dock and stand in front of the sea (see Figure 2) to perform the mindfulness experience (see next Section for more details).

4 Materials and Methods

The experiment has 2 conditions: interactive VR, in which participants experience mindfulness in the VR application, and audio-only, in which participants experience mindfulness through audio only. The mindfulness experience in both conditions is guided by a pre-recorded audio excerpt based on the "leaves on a stream" exercise in [15]. In our version of the exercise, the user can manipulate (e.g., grab and throw away using controllers) the glowing spheres containing the user's thoughts.

Before and after each condition, participants were asked to fill out questionnaires evaluating mood states. Additionally, after each condition, they also filled out the mindfulness questionnaire. The Visual Analogue Scale (VAS), a well-established questionnaire, measured participants' moods. It consists of several 7-cm horizontal lines, where each line's extreme is associated with a verbal cue representing the intensity of mood. Subjects mark a point on the line representing the perceived intensity level. The assessed moods are: Sad-Happy, Bored-Enjoyed, Relaxed-Tensed, Tired-Full of Energy, Quiet-Vivid, Slow-Active, Nervous-Calm, Irritated-Serene, Angry-Peaceful, Lazy-Motivated, Worn out-Energetic, Exhausted-Vigorous, Confused-Clear, Irritable-Patient, Sluggish-Restless, Demoralized-Enthusiast. Some of them are described in [4] and [2] (e.g., Tensed-Relaxed). Mindfulness is measured through the TMS scale [19].

[5] https://unity.com
[6] https://docs.unity3d.com/Manual/XRPluginArchitecture.html

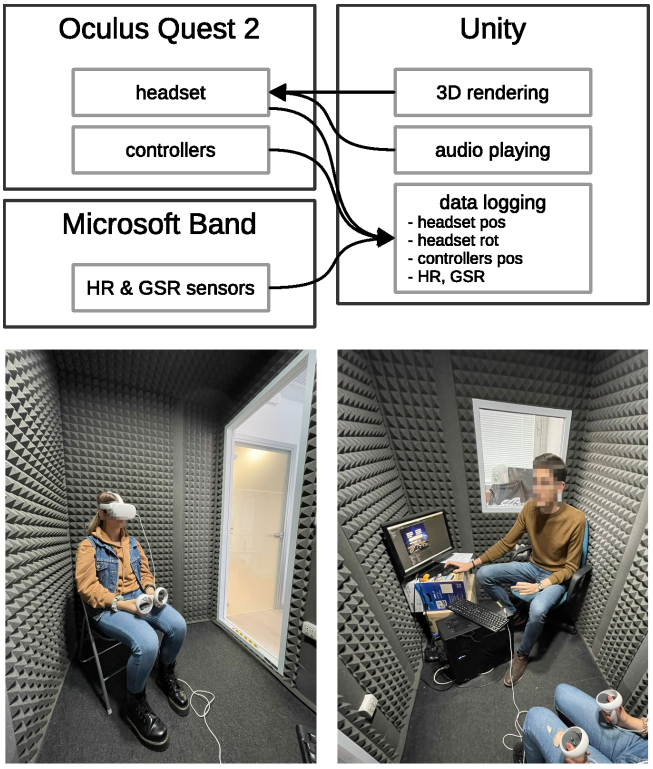

Fig. 1. The application architecture and the experimental setup. The participant (left) and the experimenter (right) are sitting in an acoustically isolated room (the experimenter leaves the room after starting the VR experience). The Unity application deals with rendering the 3D scene and the audio.

Twenty-four participants took part in the present experiment, randomly allocated into two groups: the first group (N=12) experienced the VR condition first, followed by the audio-only. In contrast, the second group (N=12) experienced audio-only, followed by VR.

In the VR condition, they were invited into a lab. They were administered the VAS scale (VAS pre-condition) upon their arrival. After that, they entered an acoustically isolated room where the VR equipment was set up (see Figure 1). After wearing the VR headset, the experimenter started the application and left the room. A pre-recorded voice tutorial was played back to the participants, instructing them how to use the controllers to walk, turn around, and manipulate objects. After that, another pre-recorded voice asked them to reach the end of the dock (see Figure 2) to start the mindfulness exercise, lasting about 7 minutes. After finishing the mindfulness exercise, participants were allowed to explore the VR environment for 3 minutes max, and after that, they could end

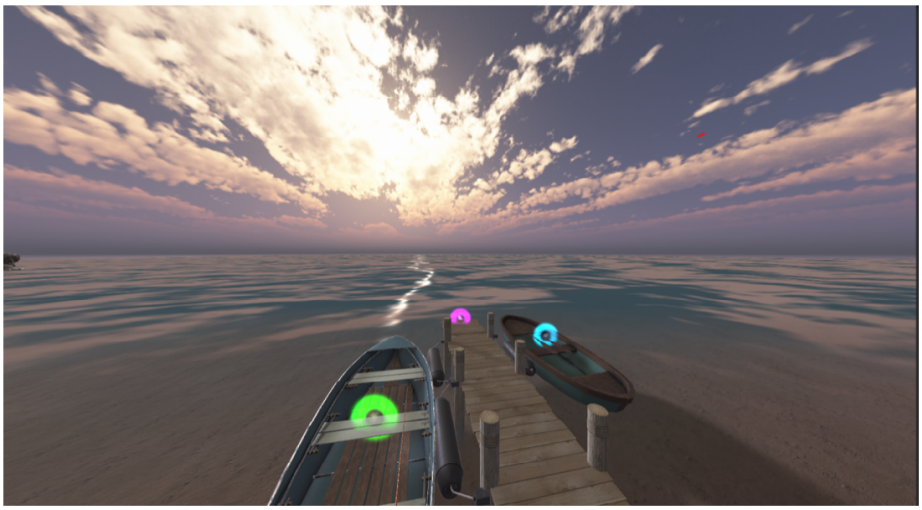

Fig. 2. The dock on which participants practice mindfulness. Three colored glowing spheres appear on the dock and on two boats on the dock's sides. The participants can grasp them up, release them, or let them go on the seawater. The glowing spheres float away toward the horizon when they touch the water. After that, new spheres appear on the dock and the boats.

the experience. Before leaving the lab, each participant filled out the VAS scale again (VAS post-condition), plus the TMS questionnaire.

Participants took the audio-only condition at home. They were instructed to complete the VAS scale and perform the audio-only version of the mindfulness practice. Finally, they completed the VAS scale and the TMS questionnaire again.

The two conditions, no matter the order they were taken by the two groups, were separated by one week to allow for proper brainwashing.

5 Analysis and Results

Descriptive analyses were performed for all the study variables to check for distribution normality. All the variables showed normal distribution (Skewness and Kurtosis between -1 and 1). Cronbach's alpha was used to evaluate the internal validity of the TMS global score (alpha = .876). A repeated measures analysis of variance (ANOVA) with a two-level within-subjects factor, namely "time" (pre vs. post), and a two-level within-subjects factor, that is "condition" (VR vs. audio), was performed using the Jamovi software[7], considering as dependent variables the mood states evaluated with VAS scale. Furthermore, we evaluated the effect of mindfulness practice by performing a repeated measures analysis of

[7] https://www.jamovi.org

Table 1. Estimated marginal means for significant interaction effects

	Device	**Time**	**Mean**	**SE**
Exhausted-Vigorous	VR	Pre	3.36	0.282
		Post	4.20	0.191
	Audio	Pre	3.92	0.182
		Post	3.72	0.178
Worned out-Energetic	**Device**	**Time**	**Media**	**SE**
	VR	Pre	3.20	0.294
		Post	4.16	0.281
	Audio	Pre	3.76	0.240
		Post	3.72	0.187
Lazy-Motivated	**Device**	**Time**	**Media**	**SE**
	VR	Pre	3.96	0.268
		Post	4.60	0.224
	Audio	Pre	4.00	0.238
		Post	3.80	0.216
Bored-Enjoyed	**Device**	**Time**	**Media**	**SE**
	VR	Pre	3.52	0.265
		Post	4.48	0.193
	Audio	Pre	3.60	0.216
		Post	4.00	0.153

variance, considering the TMS global score as the dependent variable, evaluated post the different conditions. Furthermore, learning effects were controlled by comparing the two groups who had experienced VR before audio-only versus the other group on the key variables of the study.

5.1 Mood

A 2 × 2 ANOVA was performed considering each level of the affective states as dependent variables, as measured by the VAS scale. Results showed significant interaction effects (time * condition) for the following variables: Worn out-Energetic ($p < 0.01$, $\eta^2 p = .287$), Bored-Enjoyed ($p < 0.05$, $\eta^2 p = .141$), Lazy-Motivated ($p < 0.01$, $\eta^2 p = .208$), Exhausted-Vigorous ($p < 0.01$, $\eta^2 p = .294$). As shown in Figure 3, VR improved mood states related to the activation of participants. In contrast, the audio-only condition did not show any effects (see Table 1 for estimated marginal means). The main effects of time were significant for all the 16 moods ($p < .001$). Overall, these effects significantly improved mood states for the participants in both conditions.

5.2 Mindfulness

Results of a repeated measures ANOVA for TMS showed no significant differences between audio and VR mindfulness practice. Overall, data showed an average mindfulness state in both conditions, with the audio-only condition (Mean = 3.1; SE = 0.123) descriptively higher than the VR (Mean = 2.91; SE = 0.103).

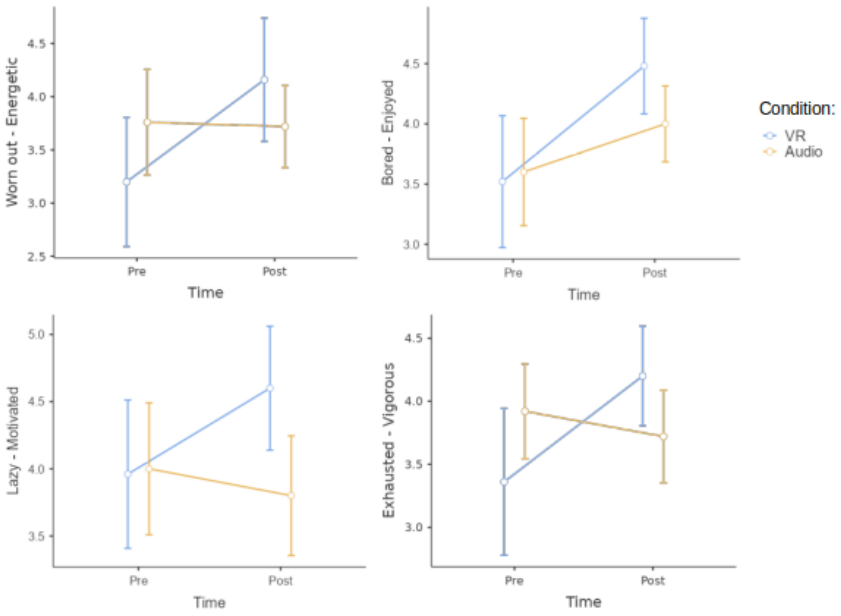

Fig. 3. Results showing significant interaction effects (time * condition) for the moods: Worn out-Energetic, Bored-Enjoyed, Lazy-Motivated, Exhausted-Vigorous.

The learning effect (group effect) was controlled with linear model comparison and was absent ($p = .512$).

6 Discussion

As reported above, the number of mood variables exhibiting statistically significant increment is higher in the VR condition than in the audio-only condition. More specifically, experiencing the interactive VR mindfulness practice positively influenced participants' self-reported enjoyment, motivation, energy, and vigor (see Figure 3). This result aligns with our expectations (research question 2), as the interactive VR condition seems more beneficial (at least in the short term) than the audio-only practice. Our results also align with recent literature dealing with mindfulness technology-based apps [10].

The two conditions did not show significant differences regarding self-reported mindfulness (research question 1). That aligns with results by Chandrasiri and colleagues [6] who used the same questionnaire to assess mindfulness. We have noticed, however, that there is a trend in the data of our experiment, suggesting that the audio-only condition may accomplish a higher mindfulness compared to the VR one.

It is possible that the audio-only condition cognitively stimulates a more relaxed mood, which also tends to be improved by the lack of interactivity of that condition, while in recent literature, studies have shown the ability of XR mindfulness application to empower the participants' relaxation self-efficacy[1]. However, we did not evaluate this latter variable in the present study. Overall, the results of the present study should be confirmed in future studies. The results of the present study should be interpreted with caution because of its limitations, mainly due to the small sample size and the use of low-structured tests such as VASs.

7 Conclusion

This paper presented an interactive VR application for practicing mindfulness. Unlike most previous work, we focused on interactive behaviors. According to the results of a pilot experiment involving 24 participants: 1) the interactive VR condition influences more mood variables compared to the audio-only condition; 2) the interactive VR and audio-only conditions do not differ regarding self-reported mindfulness.

Our results may contribute to the development of more effective VR-based technology for mindfulness. In the future, we plan to extend the analysis by evaluating how people interact with the virtual objects in the scene during the mindfulness experience. For example, we intend to measure the quantity of interaction with the virtual objects to see its relation to self-reported mindfulness. Moreover, we envisage conducting studies involving vulnerable persons, such as people affected by severe diseases, who may benefit from mindfulness training. Lastly, a longitudinal study could address the long-term effects of VR-based mindfulness practices.

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