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Influence of Mindfulness Practices on Feelings of Place Illusion in Virtual Reality

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Abstract

This study investigates how mindfulness influences feelings of place illusion in Virtual Reality (VR) experiences, i.e. the feeling of being inside the mediated world that is displayed through the VR technology. To research the effects, a design called Mindsition was proposed that consists of two Virtual Environments (VEs). The VEs transfer the user from the physical world to a task environment in VR, and alters the user's state of mind. In the first VE, a guided meditation exercise was introduced to bring the user to a more mindful state, changing how the mediated world was perceived. The user was then brought to the task environment to complete a task. The design was evaluated using a between-subjects experimental design in which half of the participants were exposed to the entire experience, while the other half only experienced the task environment. Results are inconclusive, but revealed tentative evidence that Mindsition does increase feelings of place illusion, as participants felt more captivated by the environment and had a stronger overall feeling of 'being inside' the VE. However, the results also show that Mindsition compromises reality judgement, i.e. how veritable the environment felt, as participants were more aware that the virtual world co-existed with the physical world. Overall, the study suggests that mindfulness has the potential to make users more observant about various aspects of the VE, and place less attention on the fact that the environment is perceived through a screen, making memories about the VR experience more vivid. Implications of these findings are discussed in relation to place illusion as well as mindfulness, and directions are given for future research.

Sammanfattning

Denna studie undersöker hur mindfulness påverkar känslor av "Place Illusion" i Virtual Reality-upplevelser, d.v.s. känslan av att vara inuti den förmedlade världen som visas genom VR-tekniken. För att undersöka effekterna föreslogs en design som kallades Mindsition som består av två virtuella miljöer. De virtuella miljöerna för över användaren från den fysiska världen till en arbetsmiljö i VR och ändrar användarens sinnesförfattning. I den första arbetsmiljön introducerades en guidad meditationsövning för att försätta användaren i ett mer medvetet tillstånd och därmed ändra hur den förmedlade världen uppfattades. Användaren placerades sedan i den andra arbetsmiljön för att slutföra en uppgift. Designen utvärderades med hjälp av utvärderingsmetoden "between-subjects" i vilken hälften av deltagarna upplevde hela upplevelsen, medan den andra hälften endast upplevde arbetsmiljön. Resultaten är ofullständiga, men avslöjade preliminära bevis för att Mindsition ökar känslorna av Place Illusion, eftersom deltagarna kände sig mer fängslade av miljön och hade en starkare övergripande känsla av att 'vara inne' i arbetsmiljön. Dock visar resultaten också att Mindsition äventyrar bedömningen av verklighet, d.v.s. hur äkta miljön kändes, eftersom deltagarna var mer medvetna om att den virtuella världen samexisterade med den fysiska världen. På det hela taget föreslår studien att mindfulness har potential att göra användarna mer uppmärksamma på olika aspekter av VE och lägga mindre uppmärksamhet på faktumet att miljön uppfattas genom en skärm, som gör minnena av VR-upplevelsen mer levande. Innebörden av dessa fynd diskuteras i relation till "Place Illusion" och mindfulness och anvisningar ges för framtida forskning.

Influence of Mindfulness Practices on Feelings of Place Illusion in Virtual Reality

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ABSTRACT

This study investigates how mindfulness influences feelings of place illusion in Virtual Reality (VR) experiences, i.e. the feeling of being inside the mediated world that is displayed through the VR technology. To research the effects, a design called Mindsition was proposed that consist of two Virtual Environments (VEs) that transfers the user from the physical world to a task environment in VR and altering the user's state of mind. In the first VE, a guided meditation exercise was introduced to bring the user to a more mindful state, changing how the mediated world was perceived. The user was then brought to the task environment to complete a task. The design was evaluated using a between-subjects experimental design in which half of the participants were exposed to the entire experience, while the other half only experienced the task environment. Results are inconclusive, but revealed tentative evidence that the Mindsition does increase feelings of place illusion, as participants felt more captivated by the environment and had a stronger overall feeling of 'being inside' the VE. However, the results also show that Mindsition compromises reality judgement, i.e. how veritable the environment felt, as participants were more aware that the virtual world co-existed with the physical world. Overall, the study suggests that Mindfulness has the potential to make users more observant about various aspect of the VE and place less attention on the fact that the environment is perceived through a screen, making memories about the VR experience more vivid. Implications of these findings are discussed in relation to place illusion as well as mindfulness, and directions are given for future research.

Author Keywords

Place Illusion; Mindfulness; Virtual Reality (VR); Virtual Environments (VE); Transitional VE

INTRODUCTION

Recent years, Virtual Reality (VR) has become of interest as an effective tool to simulate specific situations without the need of a physical environment. Previous studies show that, due to the immersive capabilities, VR can be effectively used in therapy treatment of specific phobias and anxiety [4, 8, 17], as well as simulating Human-Robot Interactions (HRI) without the need of an actual robot [16, 26].

The key factor in these VR experiences is that the user feels as if the Virtual Environment (VE) is real, as a user will then, most likely, behave similarly as in a physical world [23] and would increase the overall effectiveness of the VE [23]. This feeling of *being there* in a VE is therefore considered an important concept in VR experiences and VE designs as it measures, to some extent, the quality of user's experience [22, 23]. In literature this experience has been termed by a variety of names, largely under the construct of 'presence' [22, 7, 21]. However, in this paper, this experience is referred to as Place Illusion (PI) as proposed by Skarbez, Brook and Whitton [22] and introduced by Slater [23] as it better emphasizes the concept of being in another place. Instead, 'presence' itself refers to the acknowledgment that something, either virtual or physical, exists in the surrounding space.

Through technical means, it is well known how to manipulate PI, as for example, frame rate, field of view and multi-modality are positively related to this concept [7, 21]. These adaptations improve the system such that the experience has less interference with the used technology, making the illusion more real. Cognitively, it is also possible to make a VE more immersive by making users focus their attentional resources towards the VE, however, this is a more difficult process. Either the VE must capture once attention involuntary through sensory stimulus (e.g. novelty or surprise) or voluntarily by interest and motive (e.g. enjoyment or relevance) [30]. For example, research on PI shows that emotional arousal is related to PI [7]. If participants are more emotionally affected by the VR experience, this will result significantly in higher PI ratings. Similarly, it is shown that contextual information about the VE can increase feelings of PI [9]. Nonetheless, these manners of increasing PI are only suitable for specific VEs that contain emotion or context, but not neutral scenarios or scenarios with little context (e.g. an HRI experiment).

To investigate other ways of increasing PI, this research examines the use of mindfulness practices in VR experiences. Mindfulness is a type of meditation in which one is cultivating once attention with the present moment without judgment [3, 2]. In other words, in mindfulness, one is guided in clearing the mind by focusing attention on internal or external sensations. Research in mindfulness shows that it increases both focused and selective attention, increasing awareness of the environment and person's inner self [3, 2]. This in combination with a VR experience, could potentially be used to emphasize the user sensation towards the VE and allow the user to construct a better mental model of the mediated environment, increasing ones feeling of PI. To be specific, the research question that will be examined is *"What effect does Mindfulness have on ones feeling of Place Illusion in Virtual*

Reality experiences?". To answer this, it is also explored what the best way is to introduce mindfulness in a VR experience.

To explore this research question, this study proposes and evaluates Mindsition, a design that transfers someone from the physical world to a virtual task environment by altering their state of mind. The goal of Mindsition is to focus one's attention towards the VR exposure and make one acquainted with its interaction modalities, before entering the actual VE in which a task has to be performed. In the following section, more information about mindfulness will be provided and examples of its current implementations in VR. Afterwards, the design rationale of Mindsition will be presented, based on different frameworks related to PI and mindfulness. In the sections thereafter, this designed experiences will be evaluated through physiological and self-report measurements. Finally, the study will be discussed and future implications will be suggested.

BACKGROUND & RELATED WORK

Mindfulness has been described as a state in which one has an increased attention towards the present moment, without judging it with thoughts or emotional responses [3, 2]. Studies report many health benefits as result of Mindfulness, including an enhanced attention span [13], reduction of stress [2] and improve cognitive abilities [6] of individuals. For this reason, research in this field has grown tremendously in the past decades as a treatment for chronic pain and disorders [2]. To reach this state of Mindfulness, several meditation practices are developed that train self-regulation in attention and awareness promoting greater control of mental processes [29, 19].

There have been numerous applications that successfully evoke mindfulness through technological means. For example, through physical installations that include light and sound, mindfulness was effectively introduced to both experienced mindfulness meditators as well as novice users [12, 28]. In these kinds of applications, biofeedback is often used as interaction modality to help users self-regulate their mindful state as light, for example, reacts on one's breathing, while sound acts as a feedback channel that reflects the interaction of the user [28].

In the domain of VR, researchers use visual sensations in combination with biofeedback as well to capture and guide the users' attention, although the visual sensations are of higher quality and are, most often, related to nature. Virtual Meditative Walk (VMW), for example, brings chronic pain patients to a virtual forest with the intention to teach pain management through mindfulness [10]. While being in the forest, the user's Electrodermal Activity (EDA) is measured to alter the weather positively or negatively, depending on whether the EDA levels favor a mindful state.

Life Tree uses a breathing headset to synchronize visual feedback with the users breathing [18]. By practicing pursed-lip breathing, users control the growth of a virtual tree. In addition to this, the tree also visualizes the users' inhalations and exhalations by expanding and contracting its shape of inhalation and exhalation and colors of the leaves change if the users breathing is rhythmic. The VR game DEEP takes it even a step further and uses a repository monitor as the main interaction modality of the game [27]. In the game, users explore a virtual underwater world, going deeper as progress in the game is made. Users can control the direction and speed of their movements by their inhaling and exhaling. These game mechanics promote slow and deep breathing that are comparable to the techniques used by meditation practitioners.

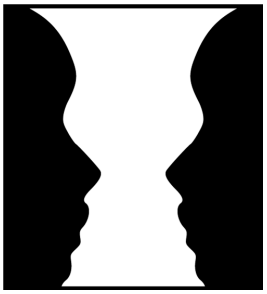


Figure 1. The "Rubin's Vase" Illusion. Depending on what color you see as the background, you can either see two human faces or a vase.

Lastly, RelaWorld uses neurofeedback to provide users with biofeedback in their VR experience [15]. With the system, the user can perform several meditation exercises that will make them levitate. The system measures the users' brain activity in real time to measure concentration and relaxation levels that will determine the state of the users' meditation. The system was evaluated through the meditation depth questionnaire, showing that the system is capable of adding value to a meditative experience on all measured levels.

In the implementation of RelaWorld, PI was also measured through a subset of ITC-Sense of Presence Inventory (ITC-SOPI). Their results show that users give higher PI ratings when biofeedback is included in the VR experiences, compared to a VR experience that is only based on visual stimuli. Their analysis is however brief and does not include statistical information. The idea of Mindfulness approaches making mediated environments more immersive is however not new. Vidyarthi, Riecke and Gromala [28] proposed the *Psychological Framework of Immersion*, theorizing how mind and consciousness can influence PI in a variety of media. It is articulated that immersive experiences result from a combination of 'bottom-up' and 'top-down' processes of sensory stimulation and cognition. The optical illusions in figure 1 illustrate this well - the visual sense observes the arrangement as is (bottom-up), but our mind can influence how it is perceived (top-down; we can either see two faces or only one vase). Mindfulness could be used as a manner to exploit this principle, by making users focus on the sensory stimulus that is important to create the mediated world, making the experience of this new world more real. Similarly, in context of this study, VEs can be perceived more immersive by directing one's senses and attention on, for example, controller interaction with the VE and freedom of movement, creating a more holistic experience in the mediated world.

Overall, the literature shows that it is quite well possible to use VR as a media to teach people meditative practices and evoke mindfulness. Nonetheless, current applications introduce extra, non-standard equipment to the VR system, making it difficult for general VE practitioners to experiment and make use of this knowledge. Besides, some literature indicates that PI could be positively influenced by mindfulness practices, but is rather un-explored empirically.

DESIGN CONCEPT: MINDSITION

To explore what effects mindfulness has on PI, it was examined how meditation techniques can be incorporated inside general VR experiences with standard hardware (i.e. just the Head-Mounted Display (HMD) and controllers). This resulted in a design called Mindsition that consist of two environments and uses guided meditation in the first to increase feelings of PI in the second. These environments are, respectively, based on the two steps described by Wirth et al. [30] that presents a model for the formation of PI. In the first step, a mental model has to be constructed from the mediated world by allocating ones attention and mental capacities to the VR experience, away from the physical environment. In the second step, one has to actually form the feeling of PI through experiencing the new place and understanding what action can be performed through testing the mental model formed in the first step.

To implement this model in a virtual experience, the first environment of Mindsition is a transitional VE, an environment that is used to transfer the user from the physical world to the VE where a task has to be performed [24]. Within this environment, users will be introduced to a guided meditation exercise to allocate attention and senses towards the VR experience with elements of interaction that are used in the second environment. The exercise focuses on emphasizing the modalities that are important in the VR experiences (i.e. vision, walking physically around in space and using the controllers) and suppressing senses that are less relevant, as described in the *psychological framework of immersion* [28]. Hence the name Mindsition, as referral to the transition of the mind from the physical world to the VE. The implementation of the exercise, closely resembles the work of Niksirat et al. [19], that presented the *attention-regulation framework* and their case study of the mobile application *Pause*. Their application is based on Relaxation Response (RR) - slow-paced repetitions of movements to keep users away from processing everyday thoughts - and Attention Restoration Theory (ART) - soft cognitive stimulus that promotes effortless attention - that are used to elicit a mindful state in the user. Mindsition uses a similar approach and techniques to elicit this state, except that it is tailored to VR technology. The second environment is the place where users can freely explore the virtual world and perform a specific task. Interaction in this environment is related to the first scene and should ease the establishment of the mental model of the task environment; this in contrast to an immediate exposure of the environment to users.

Transitional Environment

Design

The transitional environment would accommodate the first step of Wirth et al.'s [30] model for the formation of PI: allocating ones attention to the VR experience and blurring one's awareness of the physical environment. Figure 2 shows a few screenshots of this environment. The VE was designed as minimalistic as possible excluding visual cues of space (e.g. walls or corners) to make users forget their orientation relative to the physical space, and the sky was filled with slow-moving blue particles of different sizes to make the environment look endless. Within the space, a sphere was present that was the interaction point for the guided meditation exercise. Instruction for this exercise was given by written text that floated above the sphere, facing the direction of the user (Figure 2a). It was made sure that all the presented text was readable without the need of moving the head.

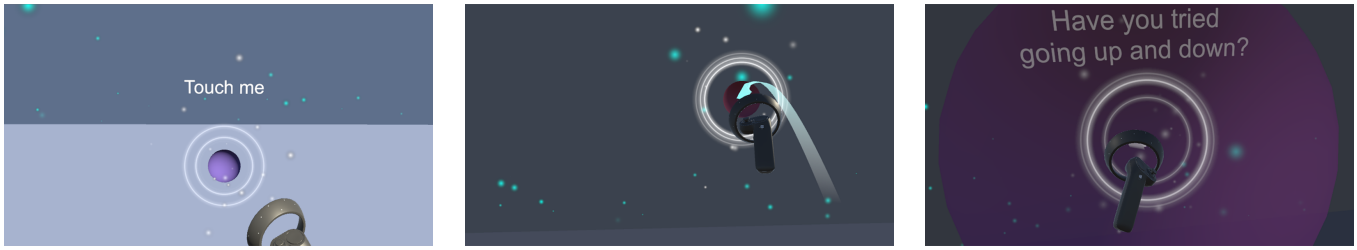
Interaction

The sphere was used to elicit RR by making the users interact with it through slow movements with the controllers. Interaction explorations were done between allowing the user to move the sphere around, but limiting the maximum speed of the sphere to induce relaxation response (resembling similar interaction as in *Pause* [19]), or giving the sphere its own trajectory that had to be followed by the user. By means of informal tests, it was found out that the second option gave more consistent and desirable results as users were imposed to make larger movement and move physically around in the space depending on the sphere's trajectory. When users controlled the sphere by themselves, they tended to only use their arm to move the sphere and guide it close to the head, resulting in small and fast movements that felt uneasy. Nonetheless, the first option gave the users more space for interaction exploration, instead of a pre-defined path. For the final design, a combination of both approaches was used to guide users towards a mindful state (a more detailed description of this can be found in the procedure section). In addition to the direct interaction with the sphere, elements of ART were used to enhance the meditative experience in form of visual and aural feedback. So was the sphere surrounded by particle effects, to make it a point of interest, and environmental feedback was given when the sphere was touched with the controller. Environmental feedback included darkening of the sky color and increasing the movement speed of the particles in the sky (Figure 2b). If the controller and sphere would detach from each other, the environment would return to its initial state. This would give the user more tendency to keep the controller close to the sphere, while it was moving around. Lastly, music and bird sounds were added and altered to emphasize these environmental changes by increasing the volume when the user touched the sphere or decreased when the environment changed back to its bright state.

Task Environment

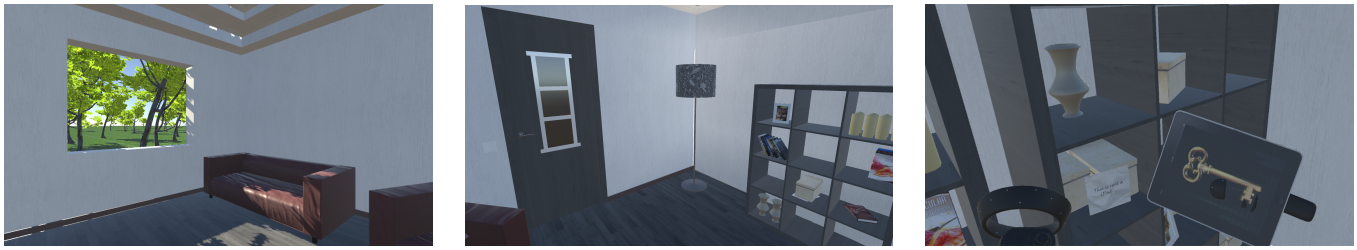
Design

The task environment would accommodate the second step of Wirth et al's model: experiencing the mediated world and form feeling of PI by interacting with the environment. Figure 3 shows a few screenshots of this environment. The room represented a virtual escape room in which users got the written task to *"find a key and escape through the door"* on a painting on the wall. No contextual information was given in why they were locked inside the room. The room was filled with regular



(a) (b) (c)

Figure 2. Screenshots containing the transitional environment of Mindsition. (a) Users were guided through the meditation exercise based on RR using a sphere in an endless environment. (b) To elicit RR, the user had to follow the sphere with the controller slowly. the sphere moved in a repeating pattern up and down within the VE. (c) At some point, the roles switched, and the participant had to guide the sphere around. If the participant did well, the size of the sphere increased until it completely encapsulated the user.



(a) (b) (c)

Figure 3. Screenshots containing the task environment of Mindsition. (a) This VE depicts a virtual escape room game in an environment with regular household items. (b) Participants had to find the key to escape through the door, which was hidden in the lamp next to the door. (c) Participants could interact with all the small items in the room using the controller, in the same as with the sphere in the transitional environment.

household items, like shelves filled with boxes and books as well as a chair and couch, coherently distributed within the room. A window was located in the wall opposite to the door, through which users could look outside upon a grass field populated with trees (Figure 3a). The key was located in a floor lamp located in one of the corners of the room, next to the door (Figure 3b).

Interaction

All small items that were located in the Virtual Escape Room could be picked-up by the user by means of the controller. However, the interaction was a bit different compared to conventional VR experiences. Instead of picking up an object by using the trigger button on the controller, objects would automatically float to the controller once the controller was in close proximity to the item (Figure 3c). If the controller moved at a steady pace, the item would follow the position and rotation of the controller without stopping. If the controller moved too fast, and the distance between the item and object was too big, the item would drop down to the underlying surface. This interaction is comparable to the interaction in the Transitional Environment but at a faster pace. As it was expected that users could transfer the interaction with virtual objects from the transitional environment to the task environment, this would strengthen their overall mental model of the environment, potentially increasing PI more in comparison to users that do not experience the Transitional Environment. Furthermore, the bigger items in the environment could not be moved (e.g. shelves and couch), except for the floor lamp in which the key was hidden. This item could be pushed away by the user if the controller was in close proximity to it, but could not be picked up like the smaller items. Within the environment also several notes were hidden that led the participants astray to different places inside the room, having written phrases on them like *"maybe under another box"* or *"no, not here"*.

METHOD

Experiment Design

A study was conducted to evaluate Mindsition in its effectiveness of guiding a person to a mindful state and if this experience influenced feelings of PI within the task environment. In a between-subject study design, participants were randomly assigned to either the mindful condition or a control condition. In the mindful condition, participants experienced the entire Mindsition design as described in the previous sections, whereas in the control condition participants would only experience the Task Environment.

During the VR exposure, Electrodermal Activity (EDA) and Breathing Rate (BR) of the participants were recorded, to measure psychological indicators for relaxation and could suggest the induction of a (more) mindful state [2]. In addition to this, task completion time and the movements of both controllers, as well as HMD, were recorded as indicators for task performance. After the VR exposure, participants were asked to complete the Igroup Presence Questionnaire (IPQ) [20], that measures a PI score based on 14 items. 13 items measure the three factors Spatial Presence (SP), the feeling of being physically in the VE; Involvement (INV), the amount of involvement experienced in the VE; and Experienced Realism

(REAL) of the VE, while the last item measures the general feeling of PI, and has a high loading on all three factors. The language of the questionnaire was English. In addition to the quantitative measures, participants were qualitatively measured by means of semi-structured interviews about their VR exposure. The focus of the interview was to understand how participants remembered and experienced the VEs as well as how it differed from real-life experiences. The questions of the interview can be found in table 1.

Pilot

As participants were freely allowed to explore the virtual environments at their own interest - without the interference of the researcher - a pilot was conducted with 6 participants (n=3 for each condition) to examine how participants would act in the VEs and if everything worked as intended. As result of this pilot, the written instructions in Transitional Environment were slightly improved so participants would better understand what was required from them, while for the Task Environment some small adjustments were made to improve overall playability. However, most importantly it was found that there was a huge difference between prior experience in VR that influenced the perception of the VR exposure quite a bit. Particularly, participants that were unfamiliar with the technology were afraid of moving around and using the controllers to interact with the VEs. For this reason, a baseline VE was added to both conditions to make participants feel safe to move around, and provide some basic understanding about how the technology worked. The baseline consisted of an empty room that had the same size and shape as the escape room, but with white walls and basic illumination. Within the room, four spheres were present (as seen in 2a) in the corners of the room. When touched directly with one of the two controllers - by walking towards it - the spheres changed color as feedback. Participants were asked to touch all four spheres to feel comfortable in VR. If participants asked about how to use the buttons that were present on the controller, they were clearly told that they had to find this out themselves during the actual experience.

Table 1. Interview Questions subsequent to the VR experience. Question 6 and 7 were only given to participants in the mindful condition.

#	Question
1	What is your general impression of the virtual experience(s)?
2	Can you describe to me, from to moment that you put on the headset till you took it off, what were the steps you took throughout the experience?
3	Where there moments during the experience(s) that something bothered or disturbed you?
4	From what you understand, can you describe how the virtual environment(s) worked?
5	In the escape room, what were for you the main consistencies and difference with a physical environment?
6	Were there for you any similarities between the first and second experience? *(mindful condition only)*
7	Can you describe in what way your previous experiences with meditation relate to the first experience? *(mindful condition only)*

Procedure

Participants were invited to a spacious room with the promise to play a VR escape room. Arrived in the lab, participants were informed about the general procedure of the study and were asked to sign a form of consent. Next, participants were equipped with an HMD of a HTC Vive, and were introduced to the baseline environment.

Once the participants felt comfortable in VR, the HMD was removed for a moment to inform them about the remainder of the study. First of all, wireless physiological measurement equipment (Bitalino (r)evolution) was attached to their arm, along with a respiratory band for the chest and two electrodes that measured the EDA of the hand palm. It was made sure that the wires did not constraint the participants movements during the VR exposure. Depending on the participants condition, participants were either told that they would first experience a preparation scene before they entered the virtual escape room (mindful condition), or that they were directly placed in the virtual escape room (control condition). Additionally, it was clearly instructed that during the stay in VR, the participants were on their own and had to explore themselves how interactions worked and what had to be done.

Before the participants entered VR for the second time, the EDA and respiratory rate were measured for one minute. During this period they were instructed to stand as still as possible. Once the measurement was over, the participants were equipped with the HMD, controllers, and headphones so they could start the fully immersed VR experience. For the participants in the mindful condition, the guided meditation exercise started with the user following the sphere in a circle around them, going up and down in the virtual space like a sinus wave. The radius was larger than an arm's length, so participants were also forced to physically move around the space in order to follow the ball. After a minute the roles switched, and participants had to guide the sphere in a slow pace around the virtual space. The maximum speed of the sphere was restricted, so that when participants moved too fast and the distance between the controller and sphere became too large, the ball would lose track of the controller and stop moving (as feedback towards the participant to move slower). At some point further into the experience, also the volume of the sphere increased, till the point, it completely encapsulated the participants, with the intention to make them lose focus and allocate attention elsewhere, e.g. feeling of the arm movements or remaining environment (Figure 2c). In order to prevent participants directing the sphere to their head, they were asked to move the sphere up and down in the virtual space, as this would change its color depending on the height towards the ground. This gave them more intention to explore larger movements up and down, rather than small movement close to the HMD. After another minute of having control over the sphere, it restored to its original size and the roles switched again. For another minute participants had to follow the sphere around, after which they were asked to close their eyes and count slowly to twenty. During this period the screen faded to black and the environment was swapped with to the Task Environment. Once the participants opened their eyes, they were free to explore the Task Environment at their own pace

and interest, without restrictions. Participants in the control group were immediately placed into the Task Environment, without experiencing the Transitional Environment.

After the task was completed and the VR equipment was removed, participants were asked to complete the IPQ questionnaire. Items of the questionnaire were randomized and presented with a 7-point Likert scale, each item having their specific anchors. Demographic information, like age and nationality, was collected after the IPQ was completed. Moreover, Participants also had to indicated on a 5-point Likert scale, labeled from *"Not at all"* to *"Extremely familiar"*, how familiar they were with VR and meditation. At last, the participants were interviewed.

Participants

The total number of participants was 24 participants, 12 for the control condition (M = 24.8, SD = 3.10) and 12 for the Mindfulness condition (M = 24.8, SD = 1.86). All participants were recruited through convenience sampling and included a wide variety of nationalities like Swedish (n = 4), Italian (n = 4), Chinese (n = 5) as well as many others. Moreover, 4 participants of the control condition were female, while this number was 5 for the Mindfulness condition. 2 participants in each condition also indicated to have much prior experience with VR.

Ethics and Sustainability

All participants were asked to sign an informed ethical consent prior to the experiment. Participants were informed that they would be required to wear equipment for recording physiological signals as well as an HMD and headphones. In addition, it was noted that if participants felt dizzy or sick (due to VR sickness) this had to be notified to the researcher immediately, so the experiment could be stopped in a safe manner. Consent was also asked for audio recording the interview sessions.

The results of this research could be beneficial for researchers in the field of VR to improve health-related issues in society, like VR therapy. By providing insight into how mindfulness (or similar attention increasing techniques) influence PI, advances can be made in how people should be immersed to effectively treat phobias or anxieties.

ANALYSIS AND RESULTS

Analysis of Task Performance

In order to confirm that task performance was not affected by the mindfulness exercise prior to the task in VR, completion time and movement speed was analyzed during the period the participants were in the task environment. For completion time, it took the participants in the mindfulness condition (M = 219, SD = 185) approximately 30 seconds longer to complete the escape room task, compared to the participants in the control condition (M = 188, SD = 92). However, the main reason for this difference is that two participants in the Mindfulness condition took both more than 500 seconds to complete task. An independent samples t-test was performed for the task performance times, but revealed no significant difference (t(20) = -.511, p = .615 (two-tailed), d = .047).

For movement speed, the sum of each distance between samples was calculated and divided over the entire duration of the task completion time for both the left and right controller as well as the HMD. The left controller was in the control condition (M = 35.0, SD = 9.33) slower than in the mindful condition (M = 39.9, SD = 13.2), while the right controller was faster in the control condition (M = 41.2, SD = 6.80) compared to the mindfulness condition (M = 38.2, SD = 7.30). For the HMD, the speed in the control condition (M = 23.4, SD = 5.20) was the same as in the mindful condition (M = 23.8, SD = 4.45). This might indicate that participants in the mindful condition experienced small fatigue in right arm due to the mindful exercise. An independent samples t-test was performed for the speed of the left controller (t(20) = -1.00, p = .329 (two-tailed), d = .069), right controller (t(20) = .994, p = .332 (two-tailed), d = .043) and HMD (t(20) = -.205, p = .840 (two-tailed), d = .009), but did not reveal a statistical significant difference. Hence, both measures suggest that the performance in the task environment was not influenced by the guided meditation exercise.

Analysis of IPQ Questionnaires

Table 2 shows the results of the reliability analyses for the IPQ questionnaire and reveals varying internal consistencies between subscales and conditions. Whereas the control condition has a high internal consistency for *Spatial Presence* and the mindful condition low, the opposite is true for Experienced Realism. The internal consistency of *Involvement* could have been greatly improved by removing the question "I was completely captivated by the virtual world. (INV4)" from the subscale (resulting in an $\alpha_{\text{mindful}} = .729$ and $\alpha_{\text{control}} = .814$), however, as this only includes 3 out of 14 items, the remainder of the analyses is performed on all the items individually.

Table 2. Cronbach's Alphas for each IPQ subscale in both conditions.

Subscale	Mindful condition	Control condition
Spatial Presence	.244	.687
Involvement	.522	.629
Realness	.716	.166
Overall	.585	.805

Figure 4 shows the mean ratings for each item of the IPQ. Some of the items show relative big differences between conditions but are contradictory. G1 and SP5 - items that directly asks about the participant feelings of PI - showed to be rated higher in the mindfulness condition. However, P3 - an item that directly asks about the participant's feelings of PI as well, but negatively formulated - indicates the opposite. For Involvement, INV1 to 3 - items related to the acknowledgment of the physical world - showed differences favoring the control condition, with INV2 showing the biggest difference. This seems to suggest that participants in the mindful condition were more aware of the physical environment than participants in the control condition. INV4 - an item about the captivation about the VE - deviates from this pattern, although the difference is small. Regarding Realism of the VE, participants in the mindful condition gave higher ratings for the items REAL2 to 4 - items corresponding to the realness of the VE compared to the physical environment. Surprisingly, however, REAL1 - an

Table 3. Independent samples t-test results for each individual item of the IPQ.

Question	Code	T-test (two-tailed)	Alpha
In the computer generated world I had a sense of "being there".	G1	t(18.7) = -.842, p = .410, d = .034	α
Somehow I felt that the virtual world surrounded me.	SP1	t(22) = .215, p = .832, d = .008	α/6
I felt like I was just perceiving pictures.	SP2	t(15.2) = -1.15, p = .268, d = .047	α/6
I did not feel present in the virtual space.	SP3	t(22) = 1.09, p = .286, d = .045	α/6
I had a sense of acting in the virtual space, rather than ...	SP4	t(22) = -.266, p = .792, d = .011	α/6
I felt present in the virtual space.	SP5	t(22) = -.596, p = .557, d = .025	α/6
How aware were you of the real world surrounding while...	INV1	t(22) = .164, p = .871 d = .006	α/4
I was not aware of my real environment.	INV2	t(22) = 1.28, p = .214, d = .052	α/4
I still paid attention to the real environment.	INV3	t(22) = .892, p = .547, d = .024	α/4
I was completely captivated by the virtual world.	INV4	t(22) = -.373, p = .713, d = .015	α/4
How real did the virtual world seem to you?	REAL1	t(22) = 1.24, p = .228, d = .051	α/4
How much did your experience in the virtual environment...	REAL2	t(22) = -.953, p = .351, d = .039	α/4
How real did the virtual world seem to you?	REAL3	t(17.1) = -.701, p = .493, d = .029	α/4
The virtual world seemed more realistic than the real world.	REAL4	t(22) = -.591, p = .560, d = .024	α/4

item that directly asks about the realness of the VE, without comparison - showed to have higher ratings in the control condition. Due to these contradictions, the overall PI score for the mindful condition (M = 56.4, SD = 7.25) was the same as the control condition (M = 56.3, SD = 9.47).

For each individual item of the IPQ questionnaire, an independent samples t-test against condition was performed to test for statistical significance (Table 3). However, as expected, none of the analysis revealed such a difference. Due to the pilot and interviews, there was also an indication that participant with much prior experience in VR have a different attitude to the VR exposure than participants for which the experience was new. To investigate this, another independent samples t-test was performed against the participants' indication of familiarity in VR with the PI score as the dependent variable. This analysis did reveal a statistical difference (t(22) = 3.52, p = .002, d = 8.14) showing that participants with much prior experience (M = 45.5, SD = 6.45) had significantly lower PI scores then the other participants (M = 58.5, SD = 6.79).

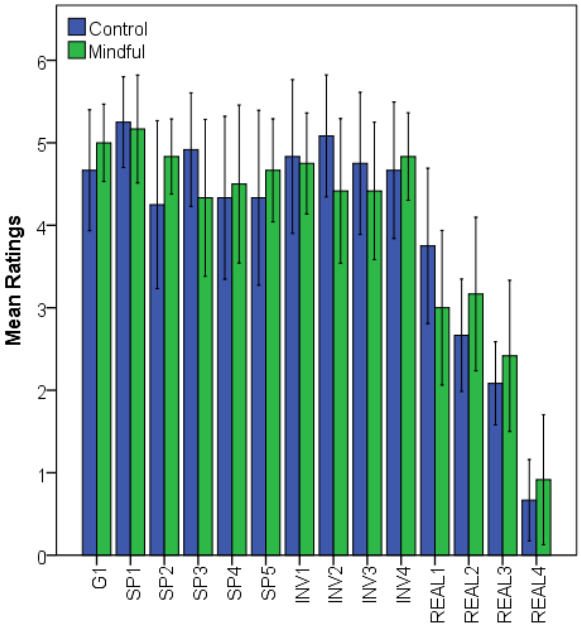


Figure 4. Means of each IPQ item, seperated by condition (item codes can be found in Table 3).

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Analysis of qualitative interviews

A thematic analysis was performed on transcriptions of the interviews with participants to identify themes that are related to PI and show differences between conditions [5]. Quotes of participants were extracted from the transcriptions and systematically coded based on coherent description or keywords, resulting in 13 themes that were often mentioned between participants and included topics like awareness of consistencies and differences with the physical world, feelings, and disturbances. These themes were independently checked by a second student for accuracy and relevance. Afterwards, both students reviewed the themes in relation to each other to generate an affinity diagram as presented in Figure 5. During the review of the themes, earlier topics identified for PI [22] were used as inspiration to identify relevance between themes but were not used as a basis for the affinity diagram. Based on the participant interviews, it was concluded that participants described topics in four main themes: (i) *Vividness*, liveliness of the VE in memory; (ii) *Awareness of action*, extracts that describe tendencies and reactions towards the VE; (iii) *Realism*, extracts describing controllable aspects of the VE, i.e. coherence of the virtual surrounding with the physical world, sensory awareness and interaction; and lastly (iv) *Feelings of Placeness*, extracts that indicate the participant's thoughts of reality and space [22]. The next sections describe the themes in more detail with specific focus on the differences between conditions. In addition to this, the last section describes the effectiveness of the mindfulness environment.

Vividness

The clearest differences between conditions were found between participants that mentioned aspects about the vividness of their memories, including in what form they perceived the experience (i.e. as pictures on a screen) and their feelings with the room. 6 participants in the control condition indicated that

they felt the VE could be distinguished from a real world because the experience seemed more like images to them, often expressed quite strongly. *"This is like I am looking at a screen, and not actually in something"* (P6). While in comparison, only 3 participants in the mindful condition said something similar, but in an indirect manner. *"I also know it was not reality reality. You can also understand it is a simulation, because of resolution etc."* (P24). Additionally, 5 participants in the mindfulness condition expressed feelings towards the atmosphere of the VE in relation to aspects escape room of the room often referring to the outside environment, sunshine or music. *"It was calming. It was comfortable. The birds singing, the window and green outside, it was a clean and orderly room"* (P18) or *"The sunshine and music and the furniture made me feel like home"* (P27). In the control condition, 3 participants expressed similar feelings but were more generic in nature. *"It was a friendly environment. It made me feel comfortable"* (P14) or *"Calm and music in the background. That made me feel peaceful"* (P8). This gives some indication that participants in the mindful condition are more observant of the overall scene and have the tendency to consider the VR experience as more lively, i.e. not a computer screen. This last observation is consistent with the IPQ item SP2.

Awareness of Action

Several participants mentioned awareness of action within the space, consisting of goals to be completed in the task environment and (not) having the tendency to physically interact with virtual objects. Between conditions, the most notable finding was that 5 participants in the control condition stated a clear goal in the task room. *"From your instruction, I knew I had to find a key somewhere in the room"* (P2). *"The goal of the game is to find the key, so I did not really care about other stuff"* (P6). Compared to only 2 participants in the mindful condition which stated a clearly different attitude towards the task. *"At first I was more exploring the room, but after the text I was more on a mission"* (P30). Suggesting that participants in the mindful condition were more in an exploratory mindset,

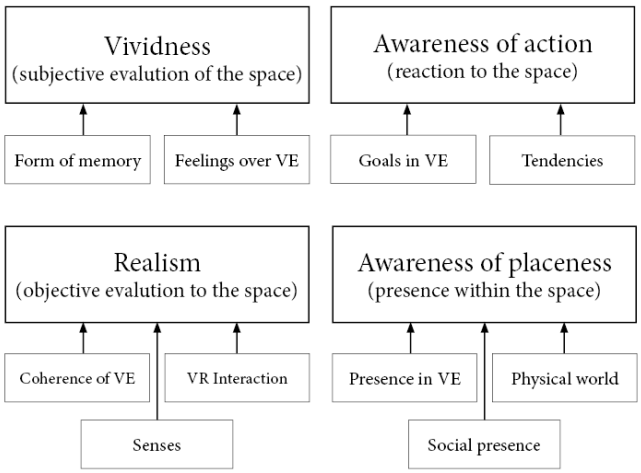

Figure 5. Affinity diagram of the participant interviews, containing 4 topics consisting of 10 themes.

while attention of the participants in the control condition was highly focused on the initially given task. This might explain why participants in the mindful condition were more observant of the VE, and aware of the physical surrounding as suggested by the IPQ questionnaire (INV 1 to 3). *"Whenever you have a goal, you forget about where you are, and you are just like 'I need to find that key'"* (P25, mindful). 3 participants in both conditions also mentioned tendencies to see the virtual objects as real, but no difference between conditions could be determined. *"Also with the sofa, I wanted to sit, but luckily I did not"* (P17, mindful). *"But when I took it of <the HMD>, I still wanted to pick up the things that I left on the floor."* (P8, control).

Realism

7 participants in the mindful condition mentioned difference of the VE in comparison to the physical world, ranging from the virtual objects inside the room to the illumination of the room. *"Difference, would be really symmetric and sharp edges and not that much noisy patterns, like scratches"* (P18). *"The green part outside also did not look consistent"* (P17). Similarly, 7 participants in the mindful condition mentioned consistencies as well. *"Consistencies, sunshine and music and the choices of furniture"* (P27). *"And also the window make it look more real. The light makes it look like something comes from outside"* (P30). In the control condition, 5 people mentioned differences about the VE and only 3 mentioned consistencies. The contents of these extracts are similar in nature although less detailed. *"the details of the room are not as detailed as the real world"* (P14). *"And things drop more slowly than in reality"* (P8). *"Realism was in the texture and lighting, because it was very bright"* (P13). Moreover, 3 participants in the mindful condition noticed that there was no keyhole present in the door, making them hesitant to complete the task. *"I also did not know what to do with the key, because there is no keyhole"* (P24). This difference was not noticed by any of the participants in the control condition. It was also found that, in general, participant often mentioned contradicting differences and consistencies in realism. For example, as showed in the first quotes of this paragraph, P27 and 30 considered the lighting as something similar to the real world, however P2 considered this a difference: *"Lighting and texture was obviously virtual created"*.

Regarding senses, participants in both conditions mentioned moving around in the physical space an important similarity, while the inability to feel virtual objects as an important difference. *"Consistency would be movement, the feeling of where you are in the room and the feeling of distance to something"* (P14). *"if you can make it like you can feel the object it would make it much better"* (P11). However, in the mindful condition, participants more often referred to the naturalness of interacting with the virtual objects. *"You use your hand, but not in the same way to grab something"* (P30). *"Interacting with the controllers was the least natural thing for me. I could not have a sense of interacting like with my bare hands"* (P28). For the mindfulness condition, 2 participants also mentioned the absence of sounds that virtual objects made, something not mentioned by participants in the control condition. *"Another*

difference was that when you touch an object there was no sound" (P18).

Only 3 participants in the mindfulness condition understood how to interact with the virtual objects in the Task Environment, of which 2 indicated to have much prior experience with VR. The remainder of the participant indicated to struggle with the controllers and went more with the flow rather than actually having control over the objects. *"I had a hard time figuring out how the function of the controllers are"* (P11). *"I also had a little hard time picking and dropping things, I did not exactly understand how to do that"* (P30)..

Feelings of Placeness

As expected, most participants indicated feelings of believe in the reality of the VE or acknowledged the presence of the physical world during the experience. Overall, participants in the control condition indicated stronger feelings of realness towards the VE, often actually indicating it 'real'. *"It felt quite real. How you can check things and walk around in the room"* (P3). *"I thought I was in this room, but I was aware of the fact that it was not a real room"* (P14). In the mindful condition, participants described stronger feelings of being inside the VE, rather than realness of the environment. *"I was really into that world. I really felt myself inside this room"* (P19). *"you could really feel inside the room, and you could play with the things"* (P28).

Several participants also indicated or mentioned feelings of social presence. 5 participants in the mindful condition indicated the feelings of not being alone in the virtual space, and/or acknowledged the presence of the researcher during the experience. *"I did not feel really alone. Because there was this whole part in me that I knew the place was not real"* (P19). *"I did not feel alone, because I know you were nearby"* (P17). In contrast, 3 participants in the control condition indicated that they felt alone in the VE and none acknowledged the presence of the researcher. *"I was obviously alone"* (P2). *"I was alone in this room, but it was a pretty light room with a window and birds"* (P14).

Mindfulness

2 participants (Turkish and Chinese) did not consider the guided meditation exercise relaxing. The remainder of participants in the mindfulness condition expressed relaxation due to the exercise and music. *"Following this ball was nice. I felt calming to make some slow movements and with the sound"* (P18). *"The scene with following the ball was peaceful and easy"* (P28). Although it was relaxing, eastern participants (and an Italian participant that indicated to have much prior experience with meditation) were more skeptical about the meditative nature of the exercise. *"I was more disturbed by the object then relaxing. Like freeing your mind was not in there, because I was following something and keep up with the speed"* (P24). *"I do not think this will go to a meditation state, because when I have to do something, I am not meditating anymore. For meditation, I have to clear my mind"* (P19). Participants that participated in yoga sessions before, or had no prior experience, were more optimistic about the experience. *"I think the experience could give me a similar feeling if it continued, although it did not happen for now. I think this can help you to get in that state more because you are guided, while with yoga you have to do it yourself"* (P30). *"I felt like the experience could initiate the whole relaxing, and from then it would be much easier to relax myself. But it does not go all the way through as yoga does"* (P25). Overall it seems to suggest, that acceptance of the exercise differs per person depending on nationality and prior involvement with meditation.

LIMITATIONS

The biggest limitation of the current study is that the Mindsition does not incorporate mindfulness into a VR experience in an isolated way. As participants in the mindful condition were exposed longer to the VR technology, some effects are caused due to forgetfulness and habituation. For example, that participants in the mindful condition were less focused on the task may result from the participant's forgetfulness when their attention was focused on the meditation exercise. Due to this, participants also took more time exploring the environment noticing more differences and consistencies with the physical environment.

In addition to the interviews, objective measurements in EDA and BR were done as well. However, due to the set-up of the study, these measurements did not give reliable results. EDA could be processed and showed some indicative results, however, a correct comparison with the control could not be done due to an inadequate amount of measuring moments. For BR, the movements of the participants during the VR exposure caused a severe amount of artifacts in the data, making it impossible to process it systematically. After all, a better approach would have been to take four measurements from the participants in each condition - before and after the baseline as well as before and after the task environment - with longer time spans. With this approach, the measurements could have been analyzed properly as it could confirm what effect exposure to (and moving in) VR has on EDA and BR, as well as if the mindful condition showed another pattern.

DISCUSSION

The results provide some tentative evidence that the feeling of PI did increase due to the Mindsition design, but did so in a trade-off with the participant's feelings of reality judgment, i.e. how veritable the environment felt [1, 23]. This distinction between PI and reality judgment is, however, often neglected or subsumed into a single concept like PI [1]. Furthermore, the fact that participants in the mindful condition observed more consistencies between the VE and physical world, but considered the VE to be less real, gives some indication that these two factors do not submerge into a single concept either. Or to put it in other words, the degree of realism that a VE conveys does not directly influence reality judgment of the VE [1, 23]. In this particular study, the IPQ seems to combine these constructs resulting in the low internal consistencies found between the different subscales and conditions. This means that for studies, as presented here, the IPQ might give a distorted representation of PI in a VE based on the overall score and subscales alone. In hindsight, a more suitable measure that reflects the user experience could have been the Reality Judgment and Presence Questionnaire (RJPQ) developed by Banõs

et al. [1], as this questionnaire acknowledges the described distinctions.

For this reason the results are inconclusive and conclusions are difficult to draw based on the current data, however the thematic analysis and IPQ sketch together a possible comprehension on how Mindsition influences the VR experience. Participants in the mindful condition seemed to feel more present in the VE, as attentional resources were more placed on the details of the Task Environment and less on the fact that the room was displayed through a screen. For this reason, participants in this condition felt more captivated by the environment and had a stronger overall feeling of 'being inside' the VE. However, at the same time, the mindful participants were also more aware that the VE co-existed with the physical world, resulting in more awareness of the physical environment and researcher.

The reason why participants in the mindful condition considered that the VE co-exists with the physical world can only be speculated, but it might be the visual integration of the Transitional Environment. The Transitional Environment was very abstract and had little to do with the main task of the experiment, most likely making the participants more aware of the mediated nature of the world. Some participants described the Transitional Environment as 'highly imaginary', possibly breaking the plausibility that the virtual world is another reality on its own. In contrast, studies with more realistic Transitional Environments showed to actually increase reality judgment of the Task Environment [24, 25]. This would mean the manner users are primed into VR, does have a strong influence in how a VE is perceived [11]. Future research could combine the two approaches, and research if a guided meditation exercise inside a more realistic scenario increases both PI and reality judgment simultaneously.

Nonetheless, the effects that Mindsition has on the VR experience seems to be in line with what is expected from Mindfulness practices as participants showed higher awareness of their present surrounding by remembering more details and impressions of the environment, indicated feelings of relaxation and peacefulness as well as having a more exploratory mindset [3, 2, 6]. This indicated that mindfulness can be evoked in a VR setting using standard hardware equipment. The state of mindfulness was however depended on the participant as well as his or her openness towards it, as cultural origin [14] and pre-conceptions about meditation negatively influenced the participants' attitude towards the guided meditation exercise. This opens up opportunities to explore mindfulness further within the context of VR with relative ease. As Mindfulness originated from healthcare-related research [3, 2], this approach might prove usefulness in VR therapy treatments for specific phobias and anxiety [4, 8, 17]. Adding a mindfulness exercise prior to the experience might enhance the effectiveness of the treatment as, for example, patients treated for phobias will be more relaxed when they are confronted with their fear.

In addition, it was found that prior experience with VR has a strong effect on the VR experience measured by the IPQ, as a statistically significant difference was found between participants with some and much familiarity in VR. This is further supported by the fact that only the 2 participants with much familiarity in VR could successfully transfer the unconventional interaction from the Transitional Environment to the Task Environment in Mindsition, whereas most other participants in this condition could not. The 2 participants with much familiarity with VR in the control condition considered the interaction 'weird'. Although more research is required on this topic, this might indicate that VR, as a medium, has some kind of perceptual learning curve and models, as presented by Wirth et al. [30], have more ground once this is completed.

Overall, some tentative evidence is found that Mindsition, as presented now, enhances the feelings of PI but compromises reality judgement, providing an indication that certain aspects of the VR experience can be enhanced by guiding the mind to a higher state of awareness (e.g. perceiving the experience more vivid), but also reinforces negative aspects of VR (e.g. perceiving the experience as mediated). Mindsition should be further improved to see if the reinforcements of the negative aspects can be prevented or reduced. Despite this, if implemented under the right conditions, practices that raise awareness of the mind could potentially increase feelings of PI inside VR.

CONCLUSION

The aim of this study was to investigate what effects mindfulness has on feelings of PI in VR. For this reason, a design was proposed, called Mindsition, that brings users in VR scenarios to a more mindful state using standard hardware equipment. In Mindsition, users experience first a VE that introduces a guided meditation exercise based on RR and ART to allocate attention and senses towards the VR experience. Afterwards, users are placed inside another VE to complete a specific task. The first VE can be seen as a Transitional Environment that brings users from the physical environment to the virtual world by means of altering their state of mind. The design was evaluated using a between-subjects experimental set-up in which half of the participants were exposed to the entire Mindsition experience, while the other half only experienced the VE in which a task had to be completed.

Results show that the effects that Mindsition has on the VR experience are in line with what is expected from Mindfulness practices. Participants were more aware of their present surrounding by remembering more details and impressions of the environment and indicated feelings of relaxation and peacefulness. This indicates that mindfulness can be evoked in VR settings with standard VR hardware. The mindfulness intervention also did not affect task performance, indicating that the guided meditation exercise did not negatively affect the completion of the task. Analysis based on participant interviews and objective evaluation of the experience is inconclusive but revealed tentative evidence that the feeling of PI increased due to the Mindsition design, but did so in a trade-off with the participant's feelings of reality judgment, i.e. how veritable the environment felt. Most likely the visual coherence of the transitional environment with the task environment should be more considered to make sure that reality judgment is not affected by the design. Overall, the study suggests that

Mindfulness has the potential to make users more observant about various aspect of the VE and place less attention on the fact that the environment is perceived through a screen, making memories about the VR experience more vivid.

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