# Hacking alternatives in 21st century: Designing bio-responsive virtual environment for stress reduction

Mirjana Prpa, Karen Cochrane, and Bernhard E. Riecke

School of Interactive Arts + Technology, Simon Fraser University, Surrey, Canada.
{mprpa,kcochran,ber1}@sfu.ca

**Abstract.** In this paper we present the initial exploratory design of SOLAR, an immersive virtual environment (VE) that assists novice users in learning the stress reducing practice of mindfulness meditation. The VE is generated by user's brain activity and respiratory rate. In addition, we give an overview of previous work, outlining the elements that we find effective and the gaps for each presented design. This is followed by a description of the design principles. Finally, we present the participatory design, design evaluation and iteration and discuss possible applications for the final design and future steps.

**Keywords:** Mindfulness practice, Virtual Reality, Brain-computer interface (BCI), Computer-supported mindfulness, Thought distancing.

## 1 Introduction

It can be difficult to avoid the stresses of daily life. Stress, as defined by the Canadian Mental Health Association, is "an overwhelming feeling and a belief that the demands of the situation are greater than [the] resources [we have] to deal with the situation". Examples include fast-approaching deadlines, traffic jams or personal relationships.

Meditation practice is known to reduce stress. Derthick's research showed that practicing meditation can change the mental function even in non-meditative states [8]. Other studies showed that meditation reduces stress levels and has a positive effect on stress-related disorders [5] such as anxiety and depression [9].

Mindfulness is a practice of meditation that is "a non-judgmental, non-conceptual, and accepting form of awareness of ones mental, emotional, and bodily sensory experience" [10]. The core practice focuses on breathing and letting go of strong thoughts of the past and future, especially those that trigger anxiety.The need to combine alternatives with current mindfulness approaches was recognized by many tech companies whose focus was on offering solutions to stress-related problems in modern society. This trend resulted in a number of computer-supported mindfulness [1] applications and devices that help users

[1] the term borrowed from [7]

learn how to meditate. From guided meditation videos posted on YouTube to Mindfulness-Based Stress Reduction (MBSR) therapy for war veterans implemented in Second Lifethe benefits of a guided computer-supported mindfulness meditation in stress reduction are widely recognized. However, it can be difficult to learn how to meditate individually without the guidance of a highly trained expert.

In this paper, we present SOLAR, an immersive computer-supported virtual system for learning mindfulness meditation. We focus on investigating how we can design a support tool that will teach novice participants how to meditate. Presented virtual environment (VE) allows users to stop, observe the thought, let the thought go and return to the practice (SOLAR) [6]. The main part of the system is an audio-visual VE that reacts to the mediator's breathing and EEG data in real-time. SOLAR is an expansion of the Sonic Cradle [17], immersive audio environment, and as such it was built in Unity3Dand Max6 while adding Emotiv [1] EEG sensors to Thought Technology's ProComp2 and Respiratory Sensors [4]. In SOLAR, the data is mapped to visual elements in VE and audio in Max6 in order to provide a feedback to the user in real time. Though difficult, meditating with one's eyes open is the preferred practice. Therefore, our tool will assist novice mediators with keeping their eyes open while practicing meditation.

## 2 Design Principles

In SOLAR we aim to accommodate different needs of users with a unique design, by following these design principles:

**Thought Distancing** is one of the techniques widely used in mindfulness meditation to help practitioners experience negative thoughts as mental events rather than self-critique or reflection of truth [16].The goal is to reach a state of awareness in which internal mental events are not judged, analyzed or responded to [18]. Practitioners are instructed to observe that they are having a thought, visualize a release from the thought, and focus on remaining detached from this internal mental event. However, many authors noted that for novice meditators thought distancing can be extremely difficult to achieve [11] [15] and may discourage further practice. We believe that building a meditative environment with both visual and auditory feedback will support the practice of meditation for users with a range of experience.

**Abstract Visual Elements** such as images and shapes are less distracting than concrete images (flower, sky, etc.) according to findings from the study by Karamnejad [13] which revealed that visual elements, abstract and of ambient value, help participants relax. The use of subtle visual elements as a reminder to focus on "positive coping strategies" is the preferred form of visible feedback [14]. For this reason, in SOLAR we included a visual representation of one's breathing in the form of abstract elements such as particles, expanding circle, and various lighting. The purpose was to create a pleasant visual feedback experience and to introduce an ambient quality to our computer-supported mindfulness system.

**Rewarding Practice**, we believe, can motivate users to meditate more often and for longer periods of time because of the enjoyment they feel. Some applications balance reward and "punishment" feedback by providing pleasant feedback when the meditation score is high, and unpleasant feedback when thoughts start wandering. Our design relies on pleasant sound and visuals only. We predict that the user's anticipation of an enjoyable soundscape that accompanies a proper meditation session will provide motivational feedback, signaling to the user that they are meditating properly, and will reinforce thought distancing techniques for longer periods of time.

**Immersion and Attention Restorative Environments - ARE** can positively affect user's attention, which was explained by Kaplan [12] in his Attention Restoration Theory (ART) that focuses on the correlation between the type of stimuli and the restorative potential of different environments. The environments with stimuli that modestly capture attention are preferred (subtle nature sounds are preferred over traffic noise, for instance), and the design of our system relied on this principle.

## 3 Design Evolution

Designing a virtual environment for meditation came with many challenges. Our aim was to design an environment that will enhance the mediation experience. Following that rationale, we decided to keep a minimal design and include elements that will directly provide feedback to its users. SOLAR was developed in phases. Following completion of the first prototype, we conducted a design activity to get feedback on the working elements. The feedback helped us reconsider some of the design decisions and redesign the model. In the following section, we explain the design decisions in more detail.

Internal processes relevant to mindfulness meditation include a still posture, breathing and thought distancing. We aimed to create an embodied connectedness between the user and the user's virtual representation by positioning the user's silhouette in the center of the scene.

The audio and visual elements of SOLAR were manipulated using two biofeedback input devices. We employed a non-invasive brain-computer interface device (Emotiv Epoc [1].) which uses 14 EEG channels to obtain EEG data that was then translated into a meditation score by Emotiv Epoc affective suite. We also used Thought Technology's ProComp2 with two respiratory sensors [3]. In order to collect and distribute collected data in the most efficient way, we chose The M+M: Movement + Meaning CANARIE Networked Enabled Platform (NEP) [2], a multi-sensor middleware platform that enabled us to distribute data in real time. Finally, we outputted the visual and audio elements for the SOLAR prototype using Unity 3D game engine and Max6.

Mindfulness meditation needs a focus for self-regulation of attention and thought distancing. SOLAR asks users to focus their attention on the visual representation of breathing, rather than just focusing on a mental representation of breathing. It is common for the users mind to wander during the medita-

tion, therefore we included user's meditation scores during the session in order to provide a gentle feedback to the user when their mind start to wander. This meditation score was mapped to an additional element in our virtual environment: meditation circle (positioned behind the silhouette) and to the silhouette's opacity. If the user is focused and the meditation score is increasing, then the "meditation circle" appears blue and the silhouette becomes more transparent (Figure 1 on the left). However, if the user loses focus and the meditation score decreases, then the colour of the circle will shift into a purple state and the silhouette will become less transparent.

The respiration sensors were placed on the user's thorax and diaphragm. The data received from the sensors was used for generating both audio and visual elements of SOLAR. In mindfulness meditation, it is suggested by the experts to practice deep diaphragm breathing [11]. In SOLAR, the user is rewarded with a complex soundscape when they are taking deep breaths from their diaphragm. If the user suddenly starts to breath from their chest (above their thorax) or starts taking shallow breaths, the soundscape becomes simplified. In the visuals, the respiration sensors are mapped to the "breathing circle" (in front of the silhouette). The breath circle becomes larger and smaller as the user inhales and exhales.

Solar consists of two scenes. First, an introduction scene has included audio instructions on how the user's breathing and meditation score interacts with the visuals. In the second - main scene, the audio consists of the Sonic Cradle soundscape and the visuals mapped to breathing and EEG sensors as described above. In addition, we added burst of particles on the user's exhale after we reconsidered design decisions of the previous prototype.

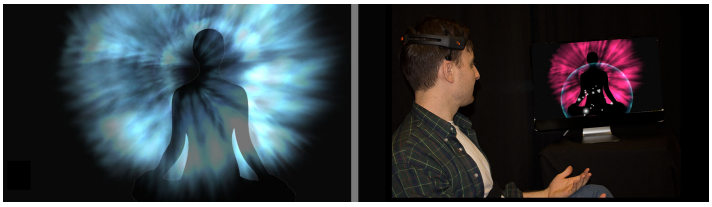

**Fig. 1.** Figure right: Silhouette's opacity decreased due to high meditation score. Figure left: The participant is meditating while using SOLAR

SOLAR can be used in lab, medical, or home environments as long as the user is sitting on a chair. The room should be as dark as possible with no auditory or visual distractions so the user can fully focus on the screen (Figure 1 on the right).

## 4 Discussion

In this paper, we present the prototype SOLAR, an immersive virtual system created to serve as a training to teach mindfulness meditation. Our goal was to create a system that will support novice meditators, with a unique design. The design of this system is grounded on four design principles (Thought Distancing, Abstract Visual Elements, Rewarding System, and Immersion and ARE) that emerged from current practices and experts' perspectives.

In design iterations, we faced new challenges in the final design. We added an introduction scene that included audio instructions on how to use SOLAR, and in the main meditation scene we replaced the mindfulness meditation track(from first prototype) with the Sonic Cradle soundscape. To address the issues of personal preference, we would like to add customizable visual and auditory elements in the next prototype.

With respect to limitations, although Emotiv and respiratory sensors are lightweight, they can become uncomfortable to wear for long periods of time. From our previous experience testing EEG sensors on participants, stress levels in participants can increase due to participants anxiety about what EEG sensors can or cannot do, therefore users need to be informed accordingly prior the session.

In the future, we would like to consult with expert meditators and medical professionals working within the mental health and neurodevelopmental fields, and conduct user-centered design studies to create an effective system that would benefit their clients. After incorporating feedback from iterative user testing and refinement starting with the current prototype we would also like to conduct a more extensive usability study and eventually more rigorous testing of the system's effectiveness in supporting novices to learn mindfulness practice, test for mental disorders (especially anxiety and depression), neurodevelopmental diseases (autism), and a comparison study between novices and experts. Concurrently with future studies, we will be working on system improvements to address recommendations and evaluate the effectiveness of visual elements, and the design guidelines will continue to evolve.

## 5 Conclusion

In this paper we described SOLAR, the virtual system designed to support novice meditators. By briefly reviewing previous work and similar projects, we outlined the omissions we found and made every effort to address these with our design. We explained the system design process and the principles that we used as a guide for our system design. This included the participatory design activity and the findings that will inform future designs. To conclude, we have presented revised and improved system design, and have suggested several recommendations for future work.

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