xR-Based Systems for Mindfulness Based Training in Clinical Settings

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

[1] Syracuse University, Syracuse, NY, USA
mrcosta@syr.edu
[2] Universitat Juame I, Castellón de la Plana, Spain
[3] University de València, Valencia, Spain

Abstract. Chronic and acute stress are persistent and troubling health concerns for many people and military veterans in particular. Clinicians are increasingly turning to mindfulness techniques to provide people with the skills they need to self-manage that stress. However, training and getting people to adhere to the practice is difficult. In this paper, we talk about a virtual reality based system designed specifically to help veterans learn mindfulness-based stress reduction techniques.

Keywords: Mixed reality · Virtual reality · Wellness · Mindfulness Meditation

1 Introduction

Mindfulness-based techniques (MBT) are useful for managing stress, anxiety, trauma, and pain, as well as for improving concentration and general mood. Practicing mindfulness techniques can help people reduce or eliminate reliance on pharmacological treatment and specialized mental health care treatment providers. Additional potential effects include higher levels of self-efficacy because MBT helps reduce trait anxiety, self-criticism and self-judgment [4, 5] and improves performance through increased ability to focus attention [21]. Practicing mindfulness can also improve interpersonal relationships, which are critical for emotional well-being. The effectiveness of mindfulness-based interventions is well established for physical and mental health. However, effectiveness requires both physical and psychological engagement in mindfulness-based practices.

Given the documented efficacy and breadth of benefits associated with practicing mindfulness, clinicians and researchers are increasingly incorporating mindfulness techniques in clinical settings. The main interest is to test the efficacy of the techniques on specific problems as well as identifying the challenges to implementing effective practices across a wider range of patient populations. Although mindfulness has many positive effects, patient adherence and quality of practice can be challenging. The benefits of mindfulness come through regular practice; that practice can be difficult at first and may even drain attentional resources. Helping patients develop sustainable habits, is a challenge for any person interested in promoting mental and physical wellness.

J. Y. C. Chen and G. Fragomeni (Eds.): VAMR 2018, LNCS 10910, pp. 31–39, 2018.
https://doi.org/10.1007/978-3-319-91584-5_3

This paper discusses our research, which focuses on using cross- or extended-reality (xR) technologies to address some of the challenges related to teaching people mindfulness and developing the necessary habits to make the practice a sustainable part of their daily lives. For this research, we focus on mixed reality and virtual reality xR mindfulness technologies to improve self-regulation and engage the parasympathetic nervous system (PNS).

2 Context and Challenges

Although clinicians apply MBT to a variety of patient populations and treatment problems, our work focuses largely on United States military veterans who use the Department of Veterans Affairs (VA) health care services. The VA patient population presents health care providers with many challenges, including high rates of post-traumatic stress disorder (PTSD) and other mental health problems, traumatic brain injuries (TBI) and musculoskeletal injuries which can present unique barriers to engaging in mindfulness-based practices which we will address in turn. For example, PTSD is characterized by hypervigilance, reductions in working memory, and startle response which can make it difficult to block out environmental distractions. Musculoskeletal injuries can present barriers to extended periods of sitting meditation; although mindfulness-based practice can effectively manage chronic and acute pain. Whereas TBI, PTSD and some mental health conditions reduce working memory and present barriers to engaging in focused attention and metacognitive training of the mind. In addition to the aforementioned potential barriers research has also found that drop out or non-completion rates of mindfulness-based programs may be 30% or higher and those who drop out may be the people who could benefit most (Banarjee, Cavanagh, & Strauss, 2017; Cavanagh, et al., 2014). Disengagement and non-completion of mindfulness programs may be particularly high for people with depression and rumination [3] feeling of being trapped in the long practices [13, 18].

Broadly speaking, the VA is split into primary and specialty clinics. Primary care is analogous to a general practitioner, while specialty clinics (e.g., mental and behavioral health) provide focused support for specific conditions. Understanding this distinction is useful because it highlights the difference in our previous work - much of the research on mindfulness practice focuses on specific chronic conditions and may involve prolonged support from specialized care. The aims of this paper are to examine the use of MBT to help primary care patients manage acute stress without having to visit specialty clinics. One of the driving questions of this research is - *How do we make mindfulness techniques more accessible to VA patients?* Our goal is to provide veterans with the skills needed to manage acute stressors in a limited number of sessions - approximately five over a period of several weeks and have those skills and seedlings of habit continue after the direct intervention.

One of the core problems veterans will face when attempting to learn MBT techniques in a clinical setting is managing external stimuli. In general, it is difficult for any person to tune out external stimuli when it comes to practicing mindfulness meditation. This is why many guided mindfulness meditation exercises start with the suggestion - "Find a quiet, comfortable place with few distractions." The VA's primary care settings are anything but quiet; sound infiltrates individual patient rooms from adjacent offices and hallways. The problem is further exacerbated by the high rates of hypervigilance in the veteran population. Therefore, exposure to external stimuli needs to be controlled to facilitate the mindfulness meditation practice.

Mindfulness-based meditation takes effort and requires ongoing practice. This may make it impractical for clinicians to teach individual patients or directly monitor their practice. Mindfulness based programs are most commonly conducted in a group setting which means that participants need to be available at the designated time and be able to get to the designated central location. This can present scheduling barriers and limitations for people who need child care. The xR mindfulness interface can be self-directed and enable participation for people who may be unable to travel to a central location at the designated time. An additional potential advantage of xR may be the customizability of the xR environment to enhance the cultural relevance and compatibility of the experience thus overcoming cultural barriers identified by researchers (Proulx et al., 2017).

We hypothesize that xR technologies are a solution to the problem of external distractions, stimuli control and access limitations of in-person clinic based training. One of the core capabilities of virtual and mixed reality is that the auditory and visual features of an environment can be precisely controlled. Also, because xR is now a consumer grade information and communication technology (ICT), it can be made readily available to diverse user groups relatively inexpensively.

Other researchers and developers have already identified the potential benefits of using VR for cultivating and training mindfulness [1, 9]. Additionally, virtual reality systems can be coupled with physiological sensors and supported by gamification mechanisms to promote sustained engagement. Popular sensors include heart rate and heart rate variability monitors, EEGs, and breath straps; these sensors are all commonly available in clinics and are increasingly available to consumers. What makes our systems different is that we focus more on designing the system to fit in to the social environment it will be embedded in. That is to say, we are building an xR-based meditation app that should not only work well for users, but also the clinicians supporting those users and the researchers interested in optimizing the experience and impact of the tool.

3 Needs and Design Requirements

In this section, we address the design requirements for our system from three different perspectives: the user's, the clinician's, and the researcher's. Our user population is veterans of the U.S. armed forces, specifically those veterans who use the VA's health care system. Clinicians include licensed clinical health care providers and other trained mental health care providers or team members affiliated with the VA. Researchers may include university and VA research staff who focus on building systems for mental wellness.

3.1 User Needs

Overall, our goal is to develop an xR-based mindfulness application that facilitates practice by providing an idealized, calming environment to meditate in. As authors pointed out, many novice practitioners would benefit from an environment that reduces or eliminates the distracting effects of stimuli present in most office and home environments. The application also needs to include interventions and feedback to maximize the effectiveness of individual sessions, most likely through customized biofeedback [8, 17], and a support system to promote sustained engagement in the practice over time.

We expect most of our initial users to be veterans who are referred to the system to deal with either acute or chronic stress. Access will not be limited to this particular subset of veterans, nor will it be limited to veterans entirely. However, we will be using participatory design techniques [15] to optimize the experience for our target population.

First and foremost, the environment needs to match the expectations and desires of the users of our system. [1, 11] found that users vary in terms of the environments they find naturally calming and conducive to meditation practices, which is why apps like Guided Meditation VR that give users a choice of scenes to meditate in are popular. Overall, we expect to provide a variety of nature inspired themes, based on research findings that have demonstrated the inherent calming effects of nature [19] and the potential of such scenes to support attention restoration therapy [14].

In addition to providing a calm environment, xR environments can be modified or made to be adaptive to the user to either gently direct attention to desired locations, to create optimal challenges to accelerate skill development, and to stimulate curiosity and selectively train specific aspects of mindfulness. We want the xR environments to be conducive to practice but also want the veteran to be able to transfer the skills [6] learned to the real world instead of needing to seek refuge in the virtual environment.

From the perspective that mindfulness is a skill honed through practice, any system intended to support the development of that skill needs to provide an infrastructure to promote sustained engagement and effortful practice. Gamification is a common and effective framework for incentivizing participation and engagement [12]. Popular meditation apps like Headspace use game mechanisms like data driven feedback and badges to encourage and reward practice and to provide feedback and recommendations for future action. Data driven feedback can also be used to guide individual sessions; one of the main advantages of having access to an expert trainer is that trainer can help the practitioner through his or her specific challenges via customized feedback. xR systems can provide customized feedback and guidance if they are coupled with sensors [9]. Users need feedback to enable them to make cognitive and physiological changes that strengthen self-directed mindfulness practices and the targeted neural networks. In terms of whether the sensors should be employed to promote curiosity of internal states or to identify and guide users towards an idealized state is an open question. Finally, we expect to incorporate self-report measures, both to inform our research (see below) and to serve as a limited journal for the users.

The genesis of this system emerged from a clinical need to provide quality care to veterans as well as the desire to provide those same veterans with the tools they need to excel in life. To that end, our system includes the capacity to enable and support clinical supervision of mindfulness practice (see next section). Consequently, our system will need to support patient privacy (HIPAA) rules. However, not all users will be patients and patients should be able to retain the right to use the system anonymously for any given session. Also, we support full user autonomy; therefore, the user should be able to sever the connection with the clinical system.

3.2 Clinical Needs

The main assumption going forward is that a clinician at a VA health care center will conduct a basic patient evaluation procedure and determine whether or not mindfulness-based stress reduction is the most appropriate intervention for that specific patient. If MBSR is the most appropriate choices, the clinician will suggest a 4–5 session MBSR training schedule in the office of the clinician, so s/he can supervise and guide the patient. The xR system will serve to reduce environmental stimuli, which generally makes it difficult for novices to practice.

The clinician will also want to maintain the capacity to override environmental variables in the xR system. There are two reasons for this oversight: first, the user may have little experience in xR environments; consequently, the immediate burden of learning to use the system will detract from the mindfulness experience. Secondly, the clinician may develop a better intuition of which environmental settings will most likely positively impact the users' experience.

Clinicians will also benefit from the data generated to improve user engagement. Common clinical practice is to give patients homework – exercises to strengthen the skill and promote habituation of the practice. But there is no reliable way to monitor patient compliance when practice is not dependent on a system; however, providers discovered that xR systems are very useful for tracking exercise compliance. Not only can the system track whether the patients are practicing, but also the frequency and duration of practices, the impact of the practice on the user's psychophysiological health. For example, sensors can be used to monitor indicators of the parasympathetic nervous system (PNS) with galvanic skin response (GSR) and heart rate during the exercise, track participant GSR and heart rate as an indicator of a state of relaxation and restoration [10, 20]; thus indicating de-escalation of the sympathetic nervous system and the stress response [16], and track attention and engagement of the task positive network (TPN) using as an indication of a state of mindfulness [22].

Ideally, all of the data discussed would be made available to the clinician via the VA's electronic medical record (EMR) system. The EMR system facilitates team care and would make the user's information readily available to other health care providers who may need it to provide the appropriate health care. For the monitoring mental health care provider, data based in the portal would make it easier for him or her to evaluate the patient using multiple data points, including some that are not associated with the xR system. Clinicians may want to take notes or share data with authorized personnel. Finally, clinical providers are responsible for discharging patients; therefore, the clinician also needs to be able to separate the connection to a user's data.

3.3 Researcher Needs

Researchers will need access to many of the same types of usage and environmental statistics that the users and clinicians have. Additionally, researchers will need to be able to explicitly limit the environment and the environmental settings to conduct controlled experiments. We anticipate most of the experimentation to be focused on the dynamic aspects of environments – attempts to instill calmness or focus by manipulating the speed and intensity of lighting, sound and textures, all of which can either serve as focal points or distractors yet are important for increasing the sense of presence we need [2].

In addition to the self-report measures that will serve as a log or diary for the user, researchers will want to collect survey data related to the specific research question. The collection and storage of that data needs to be done in an IRB compliant manner, which may include piping data from the user database to a research database while simultaneously anonymizing the data.

In terms of psychophysiological data, our labs are primarily interested in exploring the effects of mindfulness on the sympathetic and parasympathetic nervous systems, as well as the effects of mindfulness meditation on activation in the task positive network (TPN) versus default mode networks (DMN) [7]. Our core suite of sensors includes: EEG, fNIRS, EDA, HRV monitors, and breath monitors. From the adaptive system perspective, our system needs to be able to ingest streaming data, perform a classification function on the data to determine the user's state, and modify environmental variables based on the difference between the user's current state and idealized state. The classification model should be readily available, easily adjustable, and easily recorded for subsequent analysis.

Mechanisms of Mindfulness

Although it is well known that mindfulness is an effective technique for managing stress, increasing the well-being and improving emotional regulation, there is still room for improvement in how mindfulness is taught and in our knowledge about how the practice works at a deeper level. Specifically, we have gaps in our knowledge about the specific mechanisms of change and how the components of mindfulness work to affect that change. Additionally, it is difficult to get people to adhere to the practice, even when they believe practice will be beneficial.

According to research, beginning with the mindfulness practice can be difficult for novices. One of the main causes is that practice sessions may initially be exhausting, given that need a high demand for the attentional resources. Beginners have to struggle with the distractions in order to learn the attentional regulation skills required in mindfulness and to not be distracted by other stimuli or be able to attend and observe their own emotional states without getting caught up in them, whether the state is positive or negative (Lymeus, Lundgren, Hartig., 2016). This difficulty can cause a lack of adherence to the practice; therefore, there is a need to explore new and simple ways to bring the mindfulness benefits to these people.

In this context, cross- or extended- reality (xR) technologies can be a good tool for people without experience in meditation to begin and be committed to the mindfulness practice. Besides, virtual reality seems to be a perfect lab in order to train a mindfulness state in the mind, given its possibilities to manipulate the environmental stimulus. In this sense, through a VR environment the trainee can develop the skill by doing exercise according to her/his level, as for example a beginner could start the training in a controlled environment without a high number of sensor stimulus (e.g. noises, colors, movements), and progress in his/her training increasing the levels of difficulties. As already mentioned, the auditory and visual features of an environment can be controlled through these technologies and consequently reducing the attentional efforts and improve the skill acquisition. Different studies have already pointed out that the objective of these technologies should be to help beginning meditators to focus on the task of meditation and progressively develop the necessary skills to continue the practice in any noisier context (Kosunen et al. [17]).

In addition to VR being a training tool, it can also be used as an experimental testbed for learning more about and training the specific components of mindfulness, namely, focused attention, sustained attention, emotional regulation, and body scanning. In the previous section we talked about exploring the neural and physiological correlates of mindfulness. However, we do not know the relationship between the practitioner's current state, their ability to engage in the specific components of mindfulness and the effects those states have on their future states. For example, if a user is practicing mindfulness to help manage chronic pain, is it more important to focus on body scanning or attention regulation first? How would we manipulate the environment to emphasize that focus? When is it appropriate to begin transitioning the focus to other components of mindfulness and how do we implement that change?

As we better understand the relationship between the mechanisms of mindfulness practice and the neurophysiological manifestations of a mindful state, we can begin to develop interventions that support nervous system sensitization and to improve the training via a biofeedback system to facilitate the access to Mindfulness state. The general concept is to provide the user with a sense of self-efficacy regarding the practice as well as exposing them to the benefits of mindfulness, which should increase adherence to the training. Over time, we can scale back the utility of the biofeedback to prompt the user to rely more on their own skill to maintain the mindful state. Exactly how that can be done is contingent on developing a better understanding of the relationships between the components of mindfulness and the sustainment of a mindful state.

Transference is another critical concern. Here, we refer to transference as the ability to effectively move from practicing the technique in a structured environment to employing the technique in daily life. Challenges of transference are not limited to mindfulness, it is a common problem in the fields of psychology and education [6]. In contrast to many of the commercially available tools where the ability to transfer is expected or assumed to occur naturally from repeated practice, we are exploring ways to design our system to explicitly facilitate transference. For example, one experimental manipulation might involve progressively adding more stimulus to the training environment to better mimic daily life's distractors.

4 Conclusions and Future Work

Acute and chronic stress continue to be public health concerns, particularly for military veterans. Teaching veterans mindfulness has proven to be an effective approach to manage stress. However, there are still challenges to the process of teaching and practicing mindfulness. In this paper, we discussed some of those environmental and cultural challenges and identified how xR technologies might address those challenges.

Specifically, Virtual and mixed reality (xR) present viable solutions to overcome barriers to engaging in evidence based mindfulness practices. The xR technologies can reduce external distractions, control stimuli and provide flexibility in timing and location of participant practice. Moreover the customizability of xR environments can overcome cultural barriers with culturally relevant contexts and customizable auditory and visual features. The biofeedback interface can provide real time feedback to continue coaching and guiding participants to strengthen participant engagement and improve lifelong outcomes.

In addition to the inherent strengths of xR systems, the fact the xR is a form of ICT affords benefits related to behavioral tracking and feedback. The data gathered from behavioral feedback and tracking can be used by both veterans and their health care providers to encourage sustained engagement in the practice of meditation and monitoring of the efficacy of the intervention to ensure veterans are receiving the care they need. Our paper has outlined the core features xR-based meditation systems shoud have to support user, researcher, and clinician needs. Our next steps involve testing current versions and engaging relevant stakeholders via participatory design methods [15] of system development.

References

1. Andersen, T., Anisimovaite, G., Christiansen, A., Hussein, M., Lund, C., Nielsen, T., Rafferty, E., Nilsson, N.C., Nordahl, R., Serafin, S.: A preliminary study of users' experiences of meditation in virtual reality. In: 2017 IEEE Virtual Reality (VR), pp. 343–344 (2017). https://doi.org/10.1109/VR.2017.7892317
2. Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., Hansen, Å.M., Währborg, P.: Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study. Physiol. Behav. **118**, 240–250 (2013). https://doi.org/10.1016/j.physbeh.2013.05.023
3. Atkinson, M.J., Wade, T.D.: Impact of metacognitive acceptance on body dissatisfaction and negative affect: engagement and efficacy. J. Consult. Clin. Psychol. **80**(3), 416 (2012)
4. Bergen-Cico, D., Krishna Kumar, A.: Examining the processes of change associated with mindful-ness-based meditation and reductions in trait anxiety. Sci. Pages Depress Anxiety **1**(1), 1–11 (2017)
5. Bergen-Cico, D., Cheon, S.: The mediating effects of mindfulness and self-compassion on trait anxiety. Mindfulness **5**(5), 505–519 (2014). https://doi.org/10.1007/s12671-013-0205-y
6. Bossard, C., Kermarrec, G., Buche, C., Tisseau, J.: Transfer of learning in virtual environments: a new challenge? Virtual Reality **12**(3), 151–161 (2008). https://doi.org/10.1007/s10055-008-0093-y

7. Buckner, R.L., Andrews-Hanna, J.R., Schacter, D.L.: The brain's default network. Ann. N. Y. Acad. Sci. **1124**(1), 1–38 (2008)
8. Chittaro, L., Sioni, R.: Affective computing vs. affective placebo: study of a biofeedback-controlled game for relaxation training. Int. J. Hum. Comput. Stud. **72**(8), 663–673 (2014). https://doi.org/10.1016/j.ijhcs.2014.01.007
9. Choo, A., May, A.: Virtual mindfulness meditation: virtual reality and electroencephalography for health gamification. In: 2014 IEEE Games Media Entertainment, pp. 1–3 (2014). https://doi.org/10.1109/GEM.2014.7048076
10. Davis, W.B., Thaut, M.H.: The influence of preferred relaxing music on measures of state anxiety, relaxation, and physiological responses. J Music Ther. **26**(4), 168–187 (1989). https://doi.org/10.1093/jmt/26.4.168
11. De Kort, Y.A.W., Meijnders, A.L., Sponselee, A.A.G., IJsselsteijn, W.A.: What's wrong with virtual trees? Restoring from stress in a mediated environment. J. Environ. Psychol. **26** (4), 309–320 (2006)
12. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From game design elements to gamefulness: defining "gamification". In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments (MindTrek 2011), pp. 9–15. https://doi.org/10.1145/2181037.2181040
13. Dobkin, P.L., Irving, J.A., Amar, S.: For whom may participation in a mindfulness-based stress reduction program be contraindicated? Mindfulness **3**(1), 44–50 (2012). https://doi.org/10.1007/s12671-011-0079-9
14. Kaplan, S.: The restorative benefits of nature: toward an integrative framework. J. Environ. Psychol. **15**(3), 169–182 (1995). https://doi.org/10.1016/0272-4944(95)90001-2
15. Kensing, F., Blomberg, J.: Participatory design: issues and concerns. Comput. Supp. Cooper. Work (CSCW) **7**(3–4), 167–185 (1998). https://doi.org/10.1023/A:1008689307411
16. Khawaji, A., Zhou, J., Chen, F., Marcus, N.: Using galvanic skin response (GSR) to measure trust and cognitive load in the text-chat environment, pp. 1989–1994. https://doi.org/10.1145/2702613.2732766
17. Kosunen, I., Salminen, M., Järvelä, S., Ruonala, A., Ravaja, N., Jacucci, G.: RelaWorld: neuroadaptive and immersive virtual reality meditation system. In: Proceedings of the 21st International Conference on Intelligent User Interfaces (IUI 2016), pp. 208–217. https://doi.org/10.1145/2856767.2856796
18. Lomas, T., Cartwright, T., Edginton, T., Ridge, D.: A qualitative analysis of experiential challenges associated with meditation practice. Mindfulness **6**(4), 848–860 (2015). https://doi.org/10.1007/s12671-014-0329-8
19. Lymeus, F., Lundgren, T., Hartig, T.: Attentional effort of beginning mindfulness training is offset with practice directed toward images of natural scenery. Environ. Behav. **49**(5), 536–559 (2017). https://doi.org/10.1177/0013916516657390
20. Paul, G.L.: Physiological effects of relaxation training and hypnotic suggestion. J. Abnorm. Psychol. **74**(4), 425 (1969)
21. Zeidan, F., Johnson, S.K., Diamond, B.J., David, Z., Goolkasian, P.: Mindfulness meditation improves cognition: evidence of brief mental training. Conscious. Cogn. **19**(2), 597–605 (2010). https://doi.org/10.1016/j.concog.2010.03.014
22. Zhang, H., Dong, W., Dang, W., Quan, W., Tian, J., Chen, R., Zhan, S., Yu, X.: Near-infrared spectroscopy for examination of prefrontal activation during cognitive tasks in patients with major depressive disorder: a meta-analysis of observational studies. Psychiatry Clin. Neurosci. **69**(1), 22–33 (2015)