Increasing Meditation Efficiency with Virtual Reality

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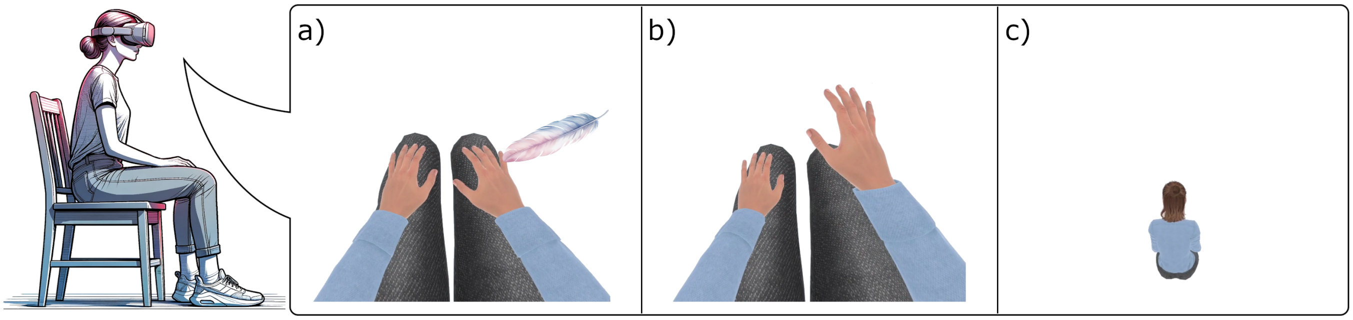

Figure 1: VR meditation practitioner experiencing scenario with a) visuo-tactile conflict; b) visuo-kinesthetic conflict; c) visuo-proprioceptive conflict (out-of-body condition).

ABSTRACT

Meditation, as a mental training for augmenting consciousness (by improving perception, cognition, and life satisfaction with mindful awareness), has been known for thousands of years and has numerous positive associations confirmed by contemporary research. The main issue with meditation seems to be the time it requires for enduring reconfiguration of the brain that leads to lasting benefits, such as the capacity to manage sustained mindfulness (often thousands of hours in meditation sessions). With mechanisms behind meditation increasingly more elucidated, it is time to research optimizations for the meditation procedure. The current theory behind meditation explains it as a process of optimization in the brain's predictive coding system. This article builds on this theory and describes the utilization of virtual reality for the development of sensory stimulation that seeks to a) facilitate meditation-related insights into the nature of perception, and b) increase the speed of changes in the brain's predictive models.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Applied computing** → **Psychology**.

KEYWORDS

Avatar Embodiment, Meditation, Multisensory Integration, Predictive Coding, Virtual Reality

CHI EA '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0331-7/24/05
https://doi.org/10.1145/3613905.3651003

ACM Reference Format:
Filip Škola and Fotis Liarokapis. 2024. Increasing Meditation Efficiency with Virtual Reality. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '24), May 11–16, 2024, Honolulu, HI, USA.* ACM, New York, NY, USA, 9 pages. https://doi.org/10.1145/3613905.3651003

1 INTRODUCTION

It is not necessary to be familiar with how the mind works to use it. However, according to the 2,500-year-old Buddhist teachings, insight into the construction of the phenomenological (subjective) experience and a better understanding of the mind's nature allows one to live a more fulfilling life [100, 108, 120]. The Buddhist texts offer a comprehensive manual for training the mind towards improved perception, cognition, and life satisfaction with the utilization of several kinds of meditation practices [24, 60, 91, 124, 125]. Buddhist teachings emphasize that human perception and behavior are heavily influenced and constrained by existing mental constructs and habits [77]. Meditation improves this condition by enabling access to a state of consciousness where the mental constructs and constraints are visible to the mind and can be mitigated and eventually transformed.

Seeing how conscious experience gets constructed moment by moment is facilitated by the cultivation of meta-awareness (characterized by a sustained awareness of the processes of consciousness [25, 107]). Maintaining meta-awareness about the momentary contents of consciousness prevents one from being automatically captivated by these contents and inner narratives (i.e., being experientially fused with what is experienced [22]). In Buddhism, meta-awareness is developed as the cornerstone of mindfulness [25, 50]. Mindfulness itself is an overloaded term with different meanings across fields (e.g., psychology, therapy) and the original Buddhist concept [102]. Here, mindfulness originates from the Pali (the language of the Buddhist texts) word *sati*, meaning awareness, attention, or remembering. Meta-awareness together with the skill of sustained attention is the common first stage of the meditative path, trained using focused attention (FA) and open monitoring (OM) meditation practices.

Besides meta-awareness, another important component of mindfulness is the non-judgmental and non-conceptual seeing of the perceived phenomena [8, 124]. Non-conceptuality of the phenomena and disconnection of the perceptual world of qualia from the conceptual world of things is one of the fundamental Buddhist themes, described in the later Buddhist traditions as *sunyata* [2] (commonly translated as "emptiness", denoting the observation that no phenomena exist as separate entities). Inquiry into the non-conceptuality is performed with insight practices (rooted in Theravada tradition, technically similar to the OM practice) and deconstructive practices (rooted in Mahayana and Vajrayana traditions, which often employ a more analytical meditative approach) [22].

Based on results of empirical and neurophenomenological studies conducted in the last couple of decades, the current theory links meditation (and similar contemplative practices) to transformations in the predictive coding models in the brain [21, 29, 59, 72, 77, 89, 90]. Predictive coding (or predictive processing) theory states that perception is an interaction between predictions, that are continuously produced based on prior experience, and the incoming sensory data [17]. Consequently, perception is primarily a construction generated from hierarchically organized priors, which are corrected by the inputs from the senses. The most general models sit at the top of the hierarchy, which includes a world model [37] (representation of the external environment) and a self-model [80] (representation of the self).

How does meditation contribute to the cultivation of mindfulness and freeing the mind from seeing through the lens of learned concepts? Training of attention and meta-awareness with FA and OM practices leads to upweighting of the sensory evidence (and weakening of the power of priors) within the Bayesian integration of priors and sensory data in predictive coding [77]. The insight/deconstructive meditations, which aim to dissect the stereotypes in the conceptualization of experience, flatten the hierarchy of predictive models. This manifests as a deconstruction of concepts in the mind and dereification (recognizing and dismantling the illusion of inherent existence in all phenomena) [72]. In both cases, meditation slowly reconfigures the prediction coding system, leading to a progressive reduction in conceptualization and abstracting away (creating additional counterfactual depth) from the sensory data comprising the present moment [72]. To achieve this, meditation leverages attentional modulation [17, 30] to induce neuroplastic changes in the brain [9].

Unfortunately, this process requires a lot of time before significant alterations to the predictive pathways are achieved. While some benefits are accessible within short timeframes (e.g., weeks of intensive practice in mindfulness-based stress reduction programmes [63]), lasting changes to the brain that enable trait-level benefits often require thousands of hours of meditation practice [43, 70, 94, 113, 119]. Moreover, even though meditation-related benefits profoundly improve life even for people who do not momentarily feel this necessity [14], people are often not aware that such augmentation of consciousness is possible [50]. Methods and tools for facilitating access to expanded states of consciousness would be immensely beneficial for society, for their potential to enduringly increase the quality of life [49, 65, 111, 115].

This article is concerned with using virtual reality (VR) to increase meditation efficiency. VR delivers targeted sensory stimulation based on the position and orientation of the user's sensory and motor organs. VR "works" for people for the same reason the physical reality "works" [47, 103]. The illusions making VR plausible lean onto the interplay of top-down predictions [51], bottom-up sensory processing [7], and sensorimotor self-awareness frameworks [42]. VR has been exploited as a sensory playground in extensive research on body ownership, such as partial [104] and full-body ownership transfer [105, 106], body schema flexibility [86, 110, 121], the sense of agency [5, 67, 88], or "Proteus effect" [123], manifesting as subconscious conformations of the self-image, behavior [66], and attitude [4] to match the assigned avatar.

The popularity of meditation and mindfulness interventions using VR has grown recently. Still, the designs seldom go beyond providing relaxing or awe-inspiring environments (see Döllinger et al., 2021 [27] for a review). Often, the VR mindfulness interventions have therapeutic aims directed towards specific outcomes [27], such as reducing anxiety [32, 69, 112], stress [19, 32, 64], pain [10, 48, 52], increasing concentration [95], or attempting to increase overall positive affect [46, 82, 84]. These works, however, do not seem to take into account the original goals of meditation and apart from partial successes (people meditating more with VR [85]) do not show improved efficiency over standard meditation (in terms of facilitating sustained access to mindful awareness) [1, 78, 85]. Apart from employing biofeedback (providing the users with real-time information about their physiological state) to facilitate the meditative states [68, 101, 117], research in VR meditation does not exploit the VR technology in attempts to directly increase its efficiency (accelerate the changes in the brain). VR-mediated meditations also rarely incorporate the body of the user [27].

We tackle the topic of using sensory stimulation with VR instrumentation to increase the efficiency of Buddhist meditations. Leaning on the current theory behind meditation mechanisms, we propose VR designs that aim to stimulate the reconfiguration of the predictive models. This is achieved by exposing the practitioner to stimuli that contradict existing priors. Our scenarios use sensory stimulation based on disturbed multisensory integration (the process by which the brain combines information from different senses to form a unified perception of the environment) and aim to prune predictive hierarchies by facilitating access to insight. We hypothesize that applying investigative attention to stimuli with contradicting conceptual phenomenology will facilitate faster transformations of the higher-level priors toward non-conceptual awareness. Standard meditation involves repeatedly becoming aware of the differences between low-level sensory stimuli and higher-level conceptual understandings, as counterfactual depth develops around these discrepancies. By adding another dimension of the conflict and thus error to be integrated, the prediction coding system will receive extra stimulation. From the perspective of the meditating mind, scenarios that cannot be replicated in the real world (often with avatar embodiment as a carrier illusion) are experienced, bearing the potential to mediate a perspective shift. This article presents the rationale behind our theory and proposals for concrete techniques exploiting the theory for increasing meditation efficiency using VR.

2 BACKGROUND

2.1 Predictive Coding

According to the predictive coding (processing) theory, the currently dominant theory that unifies perception, action, and cognition [18], people do not experience reality directly using their senses but their brains take an active part in the construction of perception [57]. Predictive processing is based on Friston's free energy principle [15, 33, 35]. At its core, the free energy principle works with the idea that all living organisms strive to resist entropy (maintain a boundary between the self and the world) to sustain, which is represented by the reduction of the free energy (represented by uncertainty or disorder) in the system [36].

In the brain, predictive coding combines the predictions (formed by previous experience, beliefs, and expectations) with the flow of sensory information (new evidence) using probabilistic reasoning. Specifically, the priors (prediction models) and the likelihood of the new evidence (weighted sensory data, i.e. how reliable the sensory data given the current conditions) are integrated using the Bayesian theorem and result in the posterior probability, representing the updated belief about the model of the situation [17, 74]. In each moment, the brain constructs hypotheses about the causes of sensory inputs, and these hypotheses travel across multiple layers of the cortical architecture [3], close to the source of the sensory input. The difference between the prediction and the sensory data is communicated back across the predictive layers as the prediction error [93]. Based on the weight (estimated precision) of the sensory evidence, the brain's models are either updated and new hypotheses are formed based on the sense data (passive inference), or the hypotheses do not change and instead more sensory data are gathered (the situation is resampled), usually after performing some motor actions (the process called the active inference) [38, 56].

2.2 Meditation in the Buddhist Traditions

Buddhism has been a subject of intensive research in the last decades [116], attracting the attention of research thanks to the preservation of the ancient texts and its empirical focus and non-authoritarian approach [50, 55]. Several fundamental concepts underlying the Buddhist insights into the workings of the mind are aligned with contemporary scientific models [122], such as the illusoriness of the concept of self [80] or the constructive nature of perception [37]. Mindfulness training has been associated with improvements in various aspects of life (cognition [125], well-being [14, 65], physical and mental health [20], reduced stress [49], and others). Although these benefits matter and various interventions based on mindfulness (e.g., mindfulness-based stress reduction programme [63]) aim for them, they are seen as preliminary steps on the broader meditation path that aims for long-term transformations towards an augmented consciousness (not only a state but as a trait) free from everyday psychological suffering [21].

Meditation practice starts with improving the attentional abilities with FA, followed by training in non-selective awareness with OM [98]. In OM, practitioners do not focus on a specific channel of stimuli but open their minds to any phenomenological content arising. OM can be considered either attention-oriented (when emphasizing the cultivation of meta-awareness) or insight-oriented practice (when inquiring into the nature of phenomena) [22]. Despite existing philosophical and methodological differences between the insight practices of Theravada (*vipassana*) and the later deconstructive practices of Mahayana and Vajrayana Buddhism, their aims are relatively aligned and we use the terms insight/deconstructive practices interchangeably for purposes of this paper. Dahl et al. (2015) [22] further identified three types of deconstructive practices; object-oriented insight (inquiry into the objects of consciousness; e.g., investigating the constantly changing nature of physical sensations [87]), subject-oriented insight (inquiry into the nature of perceptual, cognitive, and affective processes), and non-dual-oriented insight.

At the beginning of the meditation training, meditators typically practice "dualistically"; i.e., with the attention pointing from its imaginary locus (usually imagined behind the eyes) towards the objects of meditation; the practitioner perceives him/herself as meditating. This type of attention implies the distinction between the subject (observer) and the objects of meditation (the observed). Actualization that awareness does not have to be rooted in the self-model or even the world model, but that awareness is what gives rise to those models, allows for non-dual awareness (NDA) [41]. The state of NDA embraces seeing all arising and passing phenomena in a common space of consciousness without reinforcing the self-other distinction. The state of non-duality bears the potential to lead the practitioner towards the understanding of interconnectedness and unity. Apart from its increased potential in alleviating suffering through the means of insight [41], attaining the state of NDA helps to reach more concrete states of united compassion, replacing ego-driven goals with pro-social tendencies to alleviate the suffering of all sentient beings [99]. It should be noted that NDA is not strictly defined in terms of its depth and extent. Some Buddhist traditions (e.g., Dzogchen of Tibetan Buddhism) and authors [62] consider the state of NDA to be akin to Metzinger's minimal phenomenal experience [81]; i.e. when the practitioner's awareness registers its "background" where the consciousness contents (phenomena) standardly arise [61].

2.3 Meditation and Predictive Coding

Improving attentional skills with the FA practice lays the groundwork for developing mindfulness [76]. Maintaining skillful attention to the phenomena forms the basis of the majority of meditative practices. During FA, the sensory data in the lowest-level stages of the perception pathway are upweighted using attention as a weighting modulator [17, 72, 77, 89]. Lutz et al. (2019) [77] proposed that besides the attention-modulated upweighting of the low-level stimuli (a priori setting of the task-relevant goals), recognizing the distraction while practicing represents a peak in the prediction error, and thus forming an important phase of the FA meditation [77]. Accommodation of these prediction errors updates the models towards the goal and also leads to positive updates in the "epistemic" goal of the FA meditation; insight into the constructive and dynamical nature of mental function [77]. Analogically, in the OM, the effects were proposed [89] to be mediated by a combination of active inhibition, upweighting of the incoming sensory data via attention, and diminished top-down influence (by a priori setting the task-relevant goals). From the perspective of epistemic goals, the mind shifts from the position of the unexamined, reactive state of behavior towards increased meta-awareness, interoceptive awareness, and openness to new experience [89].

An important mechanism for the implementation of insights from meditation is fact-free learning [39, 72], which contributes to Bayesian reduction in complexity of the predictive models by finding "cheaper" explanations [39, 40]. This has been likened to reductions in complexity that take place while sleeping, which makes sense in the context of meditation, where the practitioner typically assumes a still posture and state of mind, allowing for this form of "in-active" inference [39, 72]. Interestingly, there is a link between perception of bistable images (e.g., the Necker cube) and feelings of insight, in terms of shared cognitive processing (likely employment of the conflict monitoring system [11]) [73]. This can potentially be exploited for increasing the likelihood of insight by priming with the presentation of conflicting stimuli [73].

The unifying element across the reviewed meditation practices is their aim at the reduction of the counterfactual depth, the process of creating additional layers of abstraction on top of the present-moment low-level percepts [45, 72]. The counterfactual layers correspond to the hierarchical nature of the brain [31, 34], where higher-level structures accommodate the higher-level concepts. The aim to reduce conceptual thinking is rooted in the Buddhist philosophy and typically also explicitly conveyed in instructions to the meditation practices, which emphasize something akin to "staying in the present moment" [72].

3 TOWARDS INCREASING MEDITATION EFFICIENCY WITH VR

We propose that VR technology can be used to create sensory stimulation that enhances the meditation-related transformation of predictive models. The VR content would contribute to these transformations by contradicting the practitioner's priors on an additional level. Standard meditations rely on careful examination of low-level aspects of sensations (before their multisensory integration, self-model mapping, world-model mapping, and further conceptual examination involving counterfactual narratives). VR allows for the construction of stimuli that break the prepositions of multisensory integration and/or conceptualization. While the learning in standard meditation can sprout from bringing the difference between learned conceptual understanding of things (e.g., feelings of breath, the appearance of the objects) and the actual stimuli reaching our senses into awareness, VR allows us to create stimuli that have this difference increased. Apart from meditative attention to conflicting stimuli, VR scenarios have the potential to mediate a perspective shift and facilitate insight (fact-free learning). Several of the proposed techniques exploit the avatar embodiment illusion as a carrier for stimuli presented as if on the user's body. With such manipulation, it is possible to dissolve the barrier between the bodily and the external, stimulating insight into the NDA.

From the technological perspective, techniques not requiring a user representation in the form of an avatar are readily exploitable even in the most basic VR set-ups (with rotational head-tracking paired with 3D audio). Standard VR with head and hand tracking enables the implementation of techniques that incorporate the avatar. Without body movement (or in seated set-ups with the movement of head and hands only), it is necessary to set only the initial avatar posture (e.g., sitting on a chair) aligned with the posture of the user and use inverse kinematics to estimate the rest of the body.

3.1 Unimodal Auditory and Visual Stimulation

The presentation of objects in auditory or visual sensory modalities separately can be exploited to facilitate the deconstruction of the sensory experience. VR can help to challenge the learned perception of sound; heard sounds are normally mapped to our world model (hearing sounds "at a distance"), even though the sounds can be perceived only after they reach the consciousness ("in the head"), regardless of the distance and orientation from the sound source. The implicit assumptions of world model-based sound perception can be challenged by attending to sounds originating at different sources in the virtual 3D space. Similarly to attending to sounds in standard OM, sounds produced in the controlled VR space can be exploited to help users realize how sound is formed in the consciousness, easing the deconstruction of the world model.

An analogical approach can be applied also in the domain of vision. With a head-mounted display (HMD), all visual content is rendered in the same plane, despite giving a sense of spatiality. This is in line with a common open-eyes meditation technique that encourages practitioners to perceive the visual field as a field of light with different colors, without interpretation into objects positioned at varying distances.

Meditation on external objects for purposes of cultivating attention or insight is not uncommon in Buddhism. Tibetan Buddhism tradition utilizes meditation on visual aids called *thangkas*, paintings containing mandalas or Buddhist deities [54]. Concentrating on these images aims to cultivate qualities like compassion and wisdom. Another traditional visual meditation can be found in *kasina* meditation, where the practitioner focuses on objects with certain characteristics (such as fire or water) and subsequently works with their afterimages after eyes are closed [23]. The aim of *kasina* meditation is similar to the interoceptive FA meditations; cultivating of attention [50, 83]. Attention-training meditations can be also designed within a unimodal VR stimulation framework.

3.2 Conflicting Visuo-Auditory Integration

Conflicting multisensory stimuli are proposed here for the cultivation of insight. Perception of the outlined ambiguous stimuli cannot rely on deeply rooted predictive models and forces the system to use the sensory evidence instead of relying on priors in the Bayesian integration in perception. Analogical scenarios can be created with the employment of other sensory modalities (disturbed multisensory integration including, e.g., haptic stimulation).

Disturbances to integration between auditory and visual sensory modalities can be easily produced in VR. One possibility is scenarios based on conventional associations that mirror real-world interaction, such as the display and sound produced when striking a triangle, while participants concentrate on a single sensory modality at a given moment (this would be a common meditation strategy). However, the association can be distorted to challenge the perception of the scenario holistically; i.e., the source of the sound in the VR environment is to be (progressively) disassociated from the visual stimuli representing the sound source, violating physical properties of sound propagation in space. The setup can evolve to systematically omit one sensory modality completely, or to replace the expected sound with a different one, further challenging the predictive model in use. Alternatively, the design can be exploited with unconventional associations. Environmental visual alterations, such as modifications to lighting conditions or object scales or textures, can be associated with synchronous auditory cues (e.g., the sound of bell chimes) and subsequently independently modified.

3.3 Disturbed Virtual Body Perception

The following techniques lean on the avatar embodiment illusion, where the virtual body is temporarily accepted as a surrogate for the user's real body. While VR embodiment is typically dependent on first-person perspective [92, 106] and sensorimotor synchrony [42, 96], it is a relatively robust illusion, as suggested by studies on out-of-body experience (OBE) disturbing the first-person perspective [28, 75, 79]. The proposed disturbances to the avatar embodiment always violate only part of the constituents of the illusion.

3.3.1 Conflicting visuo-haptic integration. Visual representation of the touch on body parts that is not accompanied by corresponding haptic stimulation (see Figure 1a) is known to elicit qualia reminiscent of an actual touch (illusory touch) [118]. It challenges the predictions in multisensory integration, where the priors modulate the seen touch to be accompanied by a haptic stimulus. In a VR design with objects "touching" the avatar body, the FA practitioner's prediction system should upregulate the sensory evidence (visual data) while suppressing the prediction (producing the illusory tactile sensation). The actual presentation of touch-like visual stimuli can vary; ordinary objects touching the practitioner's body, "light-touches" [26], or more suggestive stimuli such as insect landing and "tickling" the body parts. Non-touch illusory haptic stimuli suggesting sensations of temperature, vibration, or stimuli going beyond what is plausible in reality can be employed. For example, creating stimuli composed of objects (e.g., light particles) not only touching the body but entering a body part and penetrating it to the other side. This implausibility extends the challenges of the higher-level predictive models; it must tackle not only the illusoriness of the visually presented touch but also the arising illusory perception of unreal objects passing through the body.

A limitation of these scenarios in a traditional VR setting is their missing counterpart; i.e., haptic stimulation with missing or conflicting visual stimulation. One way of mitigating is to use redirected touch (leveraging self-touch after the position of the virtual limb is dislocated from the source limb position) to provide haptic stimulation without seeing the hand touching the other body part. Nonetheless, this would add active movement to the meditation, significantly altering its nature.

3.3.2 Body image manipulation. Presenting gradual changes to the physical proportions of the embodied body parts (e.g., hands/arms, legs, or their parts) in terms of manipulating their size, shape, or texture would lead the user to an entirely novel phenomenology. These qualia can be either consciously explored in their embodied context, or a focus on the actual bodily signals can be maintained, resulting in voluntary suppression of the visually-evoked sensations. Such scenarios have the potential to be useful for challenging the mechanisms of own-body perception and potentially guiding the user towards the NDA, by temporarily inducing an incongruent body (facilitating the disconnection of the interoception from the body map).

3.3.3 Conflicting visuo-kinesthetic integration (violating sensorimotor contingencies). Plausible manipulation of the avatar's body parts can be done by changing their position and rotation (the avatar's legs or arms can be gently moved, such as in Figure 1b). While attending to those events without producing any movement (thus actively overriding the dichotomy), the brain's mechanisms must compensate for the discrepancy between the visual perception (suggesting an intention to move) and the missing efference copy from the motor system. Observing an illusory self-movement can give rise to an illusory agency over the movement [97], even to the degree when the subconscious urge to move in an attempt to reduce the prediction error must be consciously inhibited [71]. Similarly to the scenarios in visuo-haptic conflict, it would be interesting to allow also counterpart of the conflict; allowing body movement without seeing the corresponding movement performed by the virtual body.

3.3.4 Conflicting whole-body visuo-proprioceptive integration. The position or rotation of the HMD camera in a VR scene can be changed without corresponding transformations to the avatar, leading to disconnection of the first-person view in the avatar embodiment. This has been exploited for inducing OBEs [12], where users keep their ownership over the body even in the condition of having the point of view transferred outside the body [75]. We propose that manipulation of this kind can be leveraged to facilitate an insight into the nature of the NDA. This can be achieved by a typical OBE set-up; by disconnecting the camera position from the avatar's eyes, and slowly moving it up and backward (depicted in Figure 1c). Although camera movement that is not bound to user action has the potential to induce motion sickness, making this movement very slow alleviates this issue. Alternatively, the camera position and angle of view can be changed instantaneously (e.g., mapped to a blink of an eye with eye-tracking-enabled HMDs). The latter approach is inspired by instructions given in the Dzogchen practice, suggesting to "project your awareness into a corner of the room and have it look back at itself" [44]. This approach provides less guidance and thus it is suitable for more advanced practitioners.

While attempting to perceive with the NDA, the practitioner is not trying to erase the body from perceptual experience, but to dissolve the subject-object duality in perception. While seeing the avatar body sitting (or acting, even if only head movements are performed) in synchrony with the felt body, the integration of proprioception with the seen body is disturbed. Supposing the embodiment illusion is not broken, this gives the practitioner a unique perspective. The practitioner maintains interoceptive bodily awareness but must integrate it with the visual domain where the body stops acting as a point of reference.

One of the limitations of this approach is its dependency on the avatar embodiment illusion and possibly high subjectivity in "believing" the performed disturbances to the illusion. As with standard meditation techniques for facilitating insight, there will be high variability in the effect of this "trick" on individuals.

4 DISCUSSION AND FUTURE WORK

Empirical validation of the proposed techniques is the next step in this research direction. Advances in mindfulness-related skills over time can be measured periodically with questionnaires [114], and direct verification of the changes to predictive processing is possible with neuroimaging (e.g., by evaluating changes to event-related potentials underlying subconscious responses to stimuli [58]). Instant verification of the more immediate insight-based effects (such as access to the state of NDA) can be performed subjectively using questionnaires [53], and the state of NDA seems to have established neurophysiological correlates [6, 61]. Consequently, it makes sense first to determine the effectiveness of the insight-aimed scenarios with novice meditators where an effect can be observed more quickly.

When conducting the experiments, researchers must be aware of the psychological health concerns possibly existing with standard meditations, such as depersonalization, derealization, changes in motivation, or emotional difficulties [109]. Even if they appear to be predominantly transitory [13, 16], screening for pre-existing psychological health problems should not be neglected in future studies. It is important to emphasize that the proposed techniques are just building blocks for usage in more complex scenarios that will provide comprehensive guidance in the meditation procedure.

While using FA/OM practices to facilitate upregulation of the sensory evidence in perception can be leveraged with our scenarios, most of the proposed techniques are suitable with the deconstructive practices for facilitating collapses of the prediction chains. The perception of the VR environment itself with its contents can also become powerful objects for looking into the "emptiness" (*sunyata*). Moreover, experiencing VR followed by residing in physical reality can be an interesting transition for fostering insight. More complex scenarios akin to the NDA one (Section 3.3.4) are another future direction for insight stimulation. Changes to the "way of seeing" that tend to arise after substantial meditation effort could be conveyed with artistic VR scenarios. VR as a medium for conveying surrogate realities seems like an ideal candidate for sharing the subjective "ways of seeing", which is exploitable for conveying the "emptiness" of the world and, while possibly taking advantage of the "Proteus effect" [123], also the self.

5 CONCLUSIONS

This article presented a theory for enhancing meditation efficiency with VR. Our hypothesis and the techniques offered are based on the current research in the fields of cognitive and contemplative sciences; the predictive processing theory applied to meditation, an approach that finds large support in empirical and neurophenomenological studies. While the benefits of meditation and mindfulness seem to be firmly established, mindfulness training is currently very lengthy. The work presented in this article can be classified as meditation engineering with VR; it aims to improve meditation efficiency using the means available thanks to the advanced human-computer interaction. While the convenience of the proposed techniques has yet to be verified, we hope the proposed theory will contribute to making mindfulness more accessible, helping people to improve their well-being and life satisfaction.

ACKNOWLEDGMENTS

This work has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 739578 and the Government of the Republic of Cyprus through the Deputy Ministry of Research, Innovation and Digital Policy. It has also received funding from the European Union under grant agreement No 101093159. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

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