Conscious or Unconscious Meditation? Haptic Interaction Design in Meditation Augmentation Using Physiological Sensing

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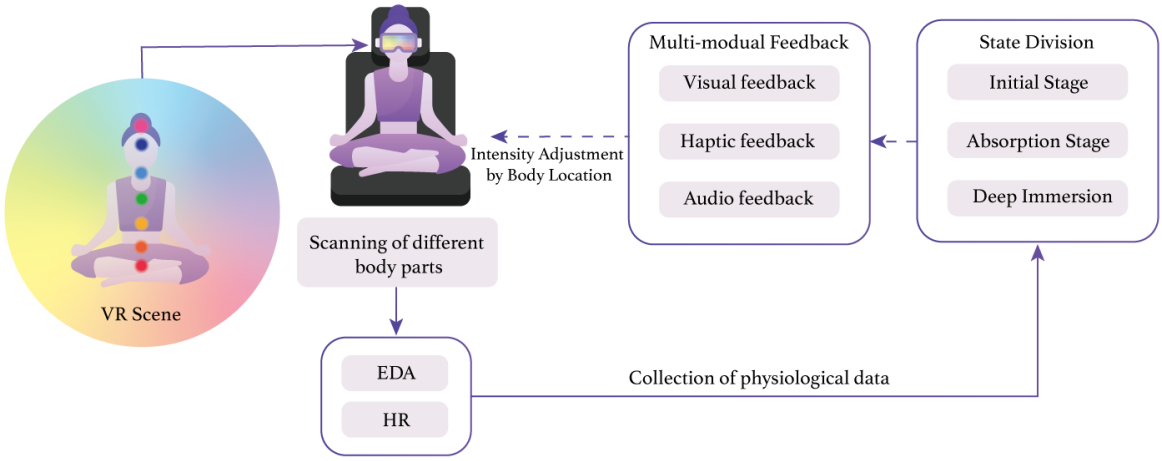

Figure 1: Biofeedback-Based Meditation System Framework (we use solid lines to represent the implemented work, while the dashed lines indicating the components planned for ongoing implementation)

Abstract

In this paper, we propose our framework to investigate how haptic feedback driven by physiological data can enhance mind-body connectedness in a multisensory meditation experience. First, we introduce a chakra-based meditation experience using a multisensory feedback system. Next, we collected initial users feedback (N=70) suggesting that the system can positively influence user perception, enhancing perceived helpfulness while reducing perceived disturbance during meditation. To further explore the mapping between perception and haptic design, we present our framework to use Shimmer-based sensing of electrodermal activity (EDA) and heart rate (HR) with the multisensory haptic-guided system. By interpreting real-time physiological signals to infer interoceptive states, the system can adaptively modulate haptic feedback in synchrony with visual and auditory cues, aligning the experience with users' bodily responses. Our goal is to support embodied self-awareness and deepen meditative engagement through dynamic, bio-adaptive multisensory interaction.

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CCS Concepts

• **Human-centered computing** → **Virtual reality**; **Haptic devices**.

Keywords

meditation, multi-sensory, virtual reality, haptic, biosensing

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1 Introduction

With the rapid advancement of ubiquitous computing technologies, there is a growing global focus on well-being and mental health. This trend offers unprecedented opportunities to leverage wearable technologies for continuous, non-invasive monitoring of human physiological data. Meditation, an ancient practice, has been widely recognized for its significant benefits to physical and mental well-being, including stress reduction and emotion regulation. However, during meditation, users often encounter challenges such as mind-wandering or distraction, which can hinder the depth and effectiveness of their practice [10]. Body scan meditation (BSM), as a core practice within Mindfulness-Based Stress Reduction (MBSR) and other mindfulness-based interventions (MBIs), aims to systematically and non-judgmentally direct attention to different parts of the body, thereby enhancing present-moment bodily awareness[5]. This practice can reduce conceptual thinking and facilitate the experience of bodily sensations as transient and ever-changing, encouraging individuals to perceive the self as a dynamic "event" rather than a static entity[3]. While commercial product such as shiftwave[1] emphasize outcome metrics like stress reduction, but there is still a gap worth discussing how multisensory feedback can shape users' attention and physical awareness during meditation.

To support beginners, recent studies have explored the integration of various sensory aids into meditation training, including the use of digital media and wearable technology [6, 9]. Although prior research has extensively explored light interaction modalities—such as auditory guidance, visualized breathing, and biometric based monitoring—the relationship between haptic feedback and users' physiological states, along with the potential for body-region-specific personalized meditation, remains underexplored.

In response, we propose a multisensory VR-based chakra meditation system that combines visual guidance with real-time haptic feedback, dynamically modulated by users' physiological states. Utilizing Shimmer sensors, the system continuously records heart rate (HR) and electrodermal activity (EDA) during meditation. These biosignals are analyzed in real time to adapt the intensity and timing of vibrotactile stimuli, thus enhancing immersion and promoting a more personalized and embodied meditative experience.

Our contributions include (1) a novel approach for facilitating the meditation and designing a culturally grounded, multisensory-driven meditation system, (2) preliminary users feedback (N=70) on its potential to support interoceptive focus through multimodal interaction, and (3) the implementation framework of adaptive haptic feedback based on real-time physiological signals.

2 Approach

Given that effective meditation experiences often depend on subtle internal focus and bodily awareness developed through concrete tasks, we approach haptic design as a staged exploration. First, we propose a multimodality chakra-based system that anchors vibration feedback to culturally and physiologically meaningful body points. Second, we conduct preliminary study to evaluate users feedback towards the multimocal meditation experience. Finally, we design the mapping studies to explore how different haptic patterns are perceived across specific locations, helping define intuitive stimulus-response associations, and using bio-sensing to further measure user states and support the development of adaptive, real-time haptic feedback.

2.1 Chakra Meditation

In line with our design objective of embedding training exercises within a narrative structure to facilitate sustained engagement throughout the virtual reality experience [2], we incorporated Chakra meditation, a traditional practice rooted in Hindu philosophy. The concept of chakras refers to energy centers distributed along the human body's midline, commonly translated as "wheels" or "cycles". According to classical doctrine, there are **seven** principal chakras, positioned along the body from the base of the spine to the crown of the head. [4]. Grounded in chakra-based cultural traditions, we co-desiged and iterated this ***Transcendental Chakra*** through participatory sessions with eight professional meditation tutors.

2.2 System Implementation

Figure 2: (a) and (b) shows that the user sits on our designed haptic chair, experiencing 'Transcendental Chakra'—a multisensory, VR-based meditation journey. (c) demonstrates an example of VR visual feedback, using avatar of user's virtual body and seven chakras in the virtual world.

The system was developed using the Unity Engine and provides users with a personalized avatar. The avatar's gender was intentionally obscured to maintain neutrality. The **seven** chakras are spatially mapped onto their corresponding anatomical locations on the avatar's body. Each chakra is also associated with a distinct virtual environment, designed using a monochromatic gradient corresponding to the color traditionally linked to that chakra. As the guided meditation progresses and prompts users to focus on different chakras, the surrounding environment dynamically transitions to the associated color, simulating the shifting fields of awareness experienced during chakra meditation[7].

Informed by the cultural context and procedural structure of chakra meditation, we collaborated with a meditation instructor to record the guided voice instructions. The script was designed to incorporate traditional background and symbolic meanings associated with each chakra. Additionally, elements of Tibetan singing

[1] https://shiftwave.co/

bowls were integrated into the audio to enhance the immersive quality of the experience and evoke a sense of sacredness often associated with meditative rituals.

To support beginners in developing body awareness during chakra meditation, we initially designed a wearable haptic device using VP2 actuators that convert audio signals into vibrotactile feedback. Each actuator was encased in a 3D-printed shell and embedded with LED lights to visually indicate chakra activation. However, preliminary trials and feedback from meditation experts revealed that the wearable configuration created a sense of constraint and discomfort during extended cross-legged meditation. In response, we redesigned the system by integrating all actuators into a meditation chair and added padded leg cushions on both sides to improve physical comfort and postural stability. This spatially embedded setup preserves the original chakra-aligned vibration mapping while allowing users to maintain a relaxed posture without distraction.

3 Preliminary Investigation

Study Procedure. To investigate the effectiveness of this multimodal, embodied meditation experience, we prepared a 5-minute guided practice showcased at SIGGRAPH Asia 2024 [8]. The experience comprised four stages: (1) breath awareness, (2) sequential chakra scanning, (3) all chakra alignment, and (4) reactivation. Vibrotactile feedback was incorporated in stages (2) and (3), though the feedback was pre-programmed and not dynamically adjusted in real-time.

To evaluate users' attitudes toward the multimodal meditation experience, we designed a brief questionnaire incorporating both positively and negatively worded items to assess users' attitudes toward the role of VR and vibrotactile feedback in meditation experiences. We invited participants to complete the questionnaire in two phases: first, before experiencing the demo, where they reported their expectations or attitudes toward the use of vibration and VR technologies in meditation based on their prior meditation experiences; and second, after the demo, where they reflected on their attitudes toward the application of vibration feedback and VR in meditation following their direct experience. Sample items included: *" I think the VR environment/vibration feedback will help my meditation practice.* (positive item), and *"I think the VR environment/vibration feedback will disturb me from meditation."* (negative item). Responses were rated on an 11-point Likert scale, where 0 indicated 'not at all' and 10 indicated 'very much'. A total of 76 participants consented to the data collection and completed the survey. After data cleaning, 70 valid responses were retained ($N = 70$; 30 female, 36 male, 4 preferred not to say; age $mean = 28.37$, $SD = 6.96$).

Based on self-reports, 13 participants had no prior practiced meditation experience, 20 were beginners, 25 were at an intermediate level, and 12 identified as advanced meditators.

Initial Results. A series of paired-samples t-tests were conducted to assess the effect of vibration and VR interventions on perceived helpfulness and disturbance during meditation. For perceived disturbance caused by vibration, there was a significant decrease before and after the interventionion (Before $Mean = 6.09$, $SD = 3.15$; After $Mean = 5.17$, $SD = 2.62$), $t(69) = 2.80$, $p = .007$,

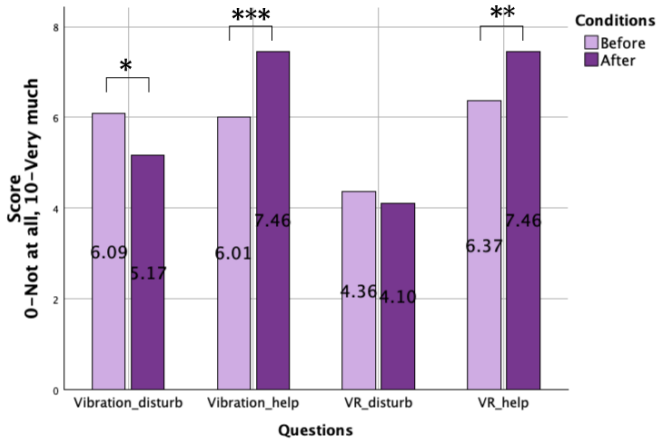

Figure 3: Users' attitudes toward the supportive or disruptive roles of VR and vibrotactile feedback in meditation. ($p < .05$, $p < .01$, $p < .001$; *, *, *** respectively)**

$Hedges'g = 0.33$, 95% CI[0.09, 0.57]. In contrast, ratings of helpfulness significantly increased after vibration (Before $Mean = 6.01$, $SD = 2.04$; After $Mean = 7.46$, $SD = 2.28$), $t(69) = -4.98$, $p < .001$, $Hedges'g = -0.59$, 95% CI [−0.84, −0.34]. The significant increase in perceived helpfulness and decrease in perceived disturbance suggest that participants developed a more positive attitude toward vibration feedback following a single session, indicating a high level of acceptability of vibrotactile cues in the context of meditation.

For the VR condition, no significant change was observed in disturbance scores (Before $Mean = 4.36$, $SD = 2.88$; After $Mean = 4.10$, $SD = 3.23$), $t(69) = 0.74$, $p = .46$, $Hedges'g = 0.09$, 95% CI [−0.15, 0.32]. However, perceived helpfulness significantly improved following the VR experience (Before $Mean = 6.37$, $SD = 2.16$; After $Mean = 7.46$, $SD = 2.29$), $t(69) = -3.32$, $p = .001$, $Hedges'g = -0.39$, 95% CI [−0.63, −0.15]. The significant increase in VR helpfulness ratings suggests growing user acceptance and perceived benefit of the VR-based meditation environment over repeated exposure. Although effect sizes were small to medium, they are meaningful in behavioral interventions where subtle perceptual shifts can significantly influence long-term engagement.

Insights. This pattern highlights an important shift in users' attitudes toward vibrotactile feedback: from a potentially distracting element to a beneficial sensory cue. Although the preliminary experiment had limitations, such as the lack of a strictly controlled setting and the absence of a no-vibration control group, the positive change in participants' perceptions of how VR and vibration supported their meditation after experiencing multimodal meditation provides valuable insights. Especially for beginners, multimodal meditation may serve as an effective tool to help them maintain attentional focus and cultivate interest in meditation practice. Therefore, when thoughtfully integrated, vibrotactile cues may serve as a valuable support for meditation practice rather than an obstacle.

4 Haptic and Perception Mapping

Despite the limitations of our preliminary investigation, we have gained initial insights into the effects of haptic feedback on body-scan chakra meditation. Building on these findings, we aim to further explore the following three research questions:

- **RQ1:** How do different vibrotactile feedback parameters affect users' physiological states during meditation?
- **RQ2:** What is the relationship between users' attentional focus on specific body regions during body-scan meditation and their corresponding physiological responses?
- **RQ3:** How can an intelligent feedback system be designed to deliver real-time, personalized, and multimodal meditation experiences?

To further explore the relationship between haptic feedback and user perception during meditation, we plan to implement a two-layered mapping framework: (1) perceptual mapping across chakra-aligned body locations and (2) physiological signal–driven feedback adaptation.

First, we aim to investigate users' sensitivity to vibration at each of the seven chakra positions along the spine. Future mapping sessions will involve delivering vibrotactile stimuli with varying amplitude and rhythm to identify perceptual salience and comfort in body regions. We hypothesize that certain areas may exhibit enhance densitivity or emotional resonance, which could inform the tuning of vibration profiles to balance effectiveness with comfort.

Second, we intend to develop a biosignal-to-haptic adaptation model using real-time electrodermal activity (EDA) and heart rate (HR) data based on a customized biosensing setup from our prior work [1, 6]. By applying a sliding analysis window, we plan to classify user states into categories such as initial stage, absorption stage, and deep immersion. Haptic feedback will be dynamically modulated in response, with the aim of gently amplifying or softening stimuli to align with the user's internal state.

Through this mapping framework, we seek to create a closed-loop interaction in which haptic feedback resonates with the body's physiological rhythms—supporting interoceptive awareness and deeper meditative engagement.

4.1 Discussion and Future Works

Prior physiological studies of meditation [11] suggest that effective meditative states are not solely characterized by parasympathetic dominance, but rather by dynamic shifts and a balanced co-activation between the sympathetic and parasympathetic nervous systems. This indicates that deep meditative engagement involves both relaxation and heightened attentional readiness.

Moreover, to further discuss whether meditation is a conscious or unconscious process, we raise some critical design considerations for personalized feedback. For novice meditators, consciously perceived haptic signals can act as explicit attentional anchors, supporting focus and awareness of bodily sensations. In contrast, experienced practitioners might prefer more subtle or even subliminal cues that blend seamlessly into their practice, sustaining deeper states of absorption without intrusive reminders.

In our next step of *Transcendental Chakra* design, we aim to measure the body-mind response of haptic feedback, and to design the adaptive haptic feedback using biosensing. Here, biosensing is not merely used to monitor user states but plays an active role in shaping the meditation experience. The system integrates heart rate (HR) and electrodermal activity (EDA) sensors to track users' physiological responses in real time. These signals dynamically modulate the timing and intensity of vibrotactile feedback delivered through a custom wearable along the spine. This closed-loop design allows the meditative environment to subtly adapt to the user's internal state—amplifying vibrations during heightened arousal or softening them during moments of calm.

Guided by insights from physiological research [11], our ongoing work explores how biosensing can inform a haptic interaction model that supports autonomic balance. Rather than suppressing physiological activity, we envision haptics as a soft interface that resonates with and reflects the body's internal tempo. By adjusting haptic feedback parameters such as rhythm, frequency, and duration, the system gently cues shifts in focus patterns, helping novice meditators become aware of subtle nervous system dynamics. Through this approach, we aim to support a more embodied meditative practice.

5 Conclusions

In this paper, we present our initial work to iterate the design of a multisensory meditation system that integrates physiological sensing and spatially mapped haptic feedback to support chakra-based meditative practices. Our preliminary findings suggests that vibrotactile and VR interventions can positively influence user perception, enhancing perceived helpfulness while reducing perceived disturbance during meditation. Our system shows promise in promoting interoceptive awareness and sustained attention, especially for beginners. Building on these insights, we believe that exploring adaptive haptic modulation informed by real-time bio-signals can deepen meditative states on supporting inward experience through closed-loop, body-aligned feedback. We hope to contribute to the workshop's discussion on how biosensing can shape more reflective, embodied forms of human augmentation.

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