Body Matters: Exploration of the Human Body as a Resource for the Design of Technologies for Meditation

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Figure 1. Three objects created in workshops to materialize the lived experience of meditation using distinct embodied and material metaphors: (left) "The Healing Journey" by P5, (center) "Mandala" by P19, (right) "Meditation" by P12.

ABSTRACT
Much research on meditation has shown its significant benefits for wellbeing. In turn, there has been growing HCI interest for the design of novel interactive technologies intended to facilitate meditation in real-time. In many of these systems, physiological signals have been mapped onto creative audiovisual feedback, however, there has been limited attention to the experiential qualities of meditation and the specific role that the body may play in them. In this paper, we report on workshops with 24 experts exploring the bodily sensations that emerge during meditation. Through material speculation, participants shared their lived experience of meditation and identified key stages during which they may benefit from additional aid, often multimodal. Findings emphasize the importance of recreating mindful physical sensations during moments of mind-wandering; in particular for supporting the regulation of attention through a range of embodied metaphors and haptic feedback, tailored to key transitions in the meditation process.

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CCS Concepts
• Human-centered computing ~Interaction design ~Interaction design process and methods ~User centered design

INTRODUCTION

Sit in a comfortable posture, as upright as you can, and let your shoulders drop. Close your eyes if it feels comfortable to do this. If not, then focus your sight on a spot in front of you. Bring your awareness inside you, to body sensations, by focusing your attention on the sensations of your body where it makes contact with the floor and whatever you are sitting on. Spend a few minutes just noticing these sensations. Try just to notice the sensations for what they are, without judging them. Bring your attention gently to your breathing, feeling your breathing flowing into your body on the in-breath and out of your body on the out-breath. Do not try to change you breathing, just pay attention to it. Keep the focus on your breathing, 'being with' each in-breath for its full duration and with each out-breath for its full duration. It is completely normal for your mind to wander when you are meditating. This does not mean that you are not doing it properly. Every time that you notice that your mind has wandered off the breath, softly note what it was that took you away and then gently bring your attention back to your breath.

This an adaptation of a short guided meditation by Kabat-Zinn [p58, 31], which has been extensively used in his Mindfulness-Based Stress Reduction program [27]. With roots in historical spiritual traditions, the practice of meditation has also been increasingly used in clinical settings and adopted by general population because of its significant benefits for physical and mental wellbeing when practiced regularly [15,21]. Nevertheless, learning to meditate can be challenging as it is a subjective experience while the traditional guidance is often generic rather than adaptive or personalized.

In this regard, a growing number of technologies have been designed with the aim of facilitating the practice of meditation, ranging from consumer applications [17] to interactive systems in HCI [64]. On the one hand, many commercial apps scaffold the integration of meditation as a regular daily practice, albeit they merely provide non-interactive audio-visual guidance which limitedly accounts for user's real-time performance [60]. On the other hand, most interactive technologies in HCI provide real-time feedback based on the changes in internal processes underpinning meditation, such as relaxation [48] or attention [53]. Still, the role of the human body in such designs has been limitedly explored [7,42], as the body has been mainly used to record physiological signals (e.g. EDA [57], breathing [48,49,70], EEG [3,40,53]) which were further mapped onto creative audio-visual feedback.

Despite the increasing HCI interest in embodied interaction [18] and the findings on the importance of embodiment in meditation practice [39], our understanding of how to leverage the body as an active ingredient to support meditation is still limited. In this paper, we explore the lived experience of meditation and its associated physical sensations. In particular, we aimed to identify:

- The key stages that may occur during meditation and whether they have specific bodily sensations.
- In what way could these bodily sensations could inform the design of novel technologies to better support meditation.
- The opportunities and risks of using technology to facilitate meditation.

We report on workshops with 24 experts in different meditation traditions exploring the bodily sensations that emerge during meditation, following a research through design approach. Through material speculation, participants emphasized the importance of bodily sensations during moments of mind wandering using different haptic qualities to support the regulation of attention. Interestingly, haptics have been limitedly accounted for in interactive technologies for meditation. The contributions of this paper are new design insights into the growing body of work on embodied interactive meditation, and adds to the emerging relevance of haptic interfaces to explore embodied experiences in interaction design and HCI research.

RELATED WORK

Interactive Technologies for Meditation

There is a growing interest in HCI regarding the design and development of technologies to support the training of meditation [59,64]. These technologies range from mobile applications [17] to novel interactive systems based on immersive virtual environments [48] or ambient installations that foster embodied experiences during meditation [49]. Most designs provide continuous feedback throughout the meditation session, which creatively maps current bodily states onto the digital system encouraging a shift of attention inwards [42,64]. A common approach to support such shift is to bring the attention to the self in the present moment by directing its focus to one's breathing using audiovisual cues [45,48,49]. However, there has been a limited exploration of distinct modalities of feedback that may enhance different human senses during meditation [42].

Previous work in psychology and neuroscience has shown that the practice of meditation enhances bodily awareness, as well as attention and emotion regulation [15,63,68]. In such work, bodily awareness refers to greater interoception (e.g. sensing visceral bodily sensations) [13,20,29], as well as perception of physical sensations (e.g. tactile sensitivity) [24,39,56]. Although less explored, the tangible interaction approach to support meditation has also started to receive attention in HCI [49,59,65]. Nevertheless, most of this work is still limited to augmenting applications for smartphones, for instance, by providing real natural elements in the interaction such as a water-based interface [69] or drawing from traditional meditation tangible aids such as praying wheels [72].

To sum up, although the human body has been used as a design element in interactive systems for meditation, it has been leveraged mostly for input (e.g. physiological signals, movement). Despite acknowledgements that meditation is a highly embodied practice [39], the way in which feedback could actuate directly onto the body to facilitate the meditation experience has been little explored. We argue that novel design insights could emerge when placing the body at both ends of the interaction experience (i.e. sensing and actuating), and by exploring also the potential of multi-sensory feedback to support meditation.

The Lived Experience of Meditation

Scholars in psychology and neuroscience have defined meditation as a dynamic process that consists of different stages [43] with distinct neuro-correlates [30,43,68]. Furthermore, research exploring the subjective experiences of meditation have suggested that different bodily sensations [39,74] may emerge in each of these stages: intention to begin, grounding, and mind-wandering moments, although work in this area is rather limited (e.g. pilot study investigating the experiences associated with mind-wandering [46]). Future HCI research can draw from this body of work to provide multi-sensory feedback tailored to each of the meditation stages.

Despite many designs acknowledge the role of the body in meditation, the exploration of multimodal feedback drawing from human senses to enhance bodily awareness during meditation has been limitedly explored. In this paper, we aim to contribute to this body of work by designing from, and for, the bodily sensations that arise during meditation.

Exploring Embodied Experiences in HCI

In recent years, a number of design approaches have emerged in interaction design and HCI with the aim of leveraging the interactions between the human body and technology [54]. For instance, somaesthetics design positions the body at the center of the user experience, cultivating an aesthetic appreciation of the bodily experience through guided attention inwards [31,58]. Such approaches tend to build upon first-person practices in order to design from, and for the experience of the self [61], by acknowledging the importance of embodiment in the sense-making of experience [44]. An example from this body of work is the soma mat [32], which uses directed heat stimuli to subtly guide and sustain attention to different body parts while the person is laying on top of the mat.

Particularly in tangible and embodied interaction research, there has been a growing exploration of how metaphorical representation of bodily experiences can be effectively implemented into interaction models [7,8,51,55]. For instance, such metaphors have been used for the design of tangible learning systems [10], to foster collaborative shared experiences [23], or to support the self-regulation of attention and affect [9,38]. Most recently, materials such as material food probes [25], thermochromic ink or shape memory alloys [67] have been used not only to mirror one's experience but also to promote the self-regulation of different internal processes, for instance, to communicate affective data metaphors-based visual and haptic feedback [1]. Nevertheless, the exploration of the affordances of different materials' qualities to enhance the understanding of abstract subjective embodied experiences has been limited.

METHODOLOGY

In this paper, we report on 10 workshops exploring the way in which experts in different meditation traditions perceive their meditation experience, paying particular attention to their bodily sensations. Each workshop lasted around 2 hours and was conducted in a group setting, with 2 to 5 participants at the time. The workshops followed a research through design methodology [75], particularly inspired by Andersen's Magic Machines [5,11] which facilitates the expression of personal experiences through an embodied process of making. Magic Machines have been particularly used to explore abstract concepts with experts, often external e.g. creating novel sounds with musicians, designing innovative spatial interventions to contribute to vocational education with architects [6]. The aim of the workshops was to explore bodily sensations during meditation as *internal* rather than external concepts by reflecting on the qualities of the materials that we provided for them.

Participants

Through purposive sampling, invitations were sent to different meditation centers in our local area to recruit participants, who got in touch with the authors by email. A subsequent snowball sampling emerged, with other experts in meditation being referred by previous participants. A total of 24 meditation experts participated in the workshops (18 identified as female, 6 as male) with different, nationalities, ages (48 years old on average, S.D. = 15, range: 26 to 85, with 4 participants being over 65 years old) and meditation backgrounds. The average meditation timespan is 12 years, ranging from 2 to 37 years; and participants practiced meditation at least 3 times per week, with most participants practicing daily for 10 to 60 minutes. Participation was incentivized with an equivalent of a $20 Amazon voucher.

Workshops' Protocol

We now describe the protocol of the workshops as well as data collection and analysis methods. Workshops consisted of four parts further described.

Part 1. Introducing the Design Space

At the beginning of each workshop, we asked participants to reflect and draw on a blank card their "*bodily sensations during meditation, paying careful attention to the difference between when they are being mindful and when their mind wanders*". The goal of this task was to provide an inviting introduction to the design space and set the workshop scene, which acts as a prompt in Magic Machine workshops [5,11].

Part 2. Crafting Material Speculations

Drawing from Andersen's Magic Machines methodology [5,11], participants were asked to individually build a magic machine: "*magic*, in this context, refers to the desired, not-yet-understood ability of future technology, and *machine* to its embodiment and physical interface to the human user" [p35, 2]. In particular, they were asked to create a physical artefact with imaginary functionalities that addresses their initial reflection on their evolving physical sensations during meditation.

Participants are provided with common non-technological, affordable everyday materials with the aim of encouraging an open and playful experimentation, e.g. by taking them apart and envisioning a novel set of functionalities [5]. We carefully chose a set of materials (Figure 2) meeting the following two criteria, after we experimented with their experiential qualities [26,37]. First, we included what we called "structural" materials allowing the construction of the magic machine such as plain cardboards, paper plates and cups, strings, and elastic bands; as well as tape, scissors, and a hot glue gun. Second, we provided a curated selection of materials to facilitate the focus on bodily, tactile experiences [33,34]. In particular, we aimed to foster haptic experimentation [41] involving variation in knismesis (i.e. tickling sensation), pressure and temperature. For knismesis we included materials such as wool, feathers or bowls with grains of different sizes; for pressure we used clothespins or straps; and for temperature pebbles and paper straws.

Howbeit, most materials did not fall under a single category. Then, the created objects become speculative artifacts though which "alternative stories emerge that operate in the space between rationality and reality" [p3, 63].

Part 3. Presentation to the Group

Once all participants finished crafting, they presented their creation in front of the group: "*can you tell us the name of your machine, and show us how it works?*". This is a sudden and unexpected task, hence, driven by intuition and improvisation, a sense of on-the-spot reasoning over their magic machine emerges during the descriptions [4,19]. The presentations become performative as participants were required to rehearse the use of their machine whilst describing it. The goal of this task was to perform a cognitive walkthrough, during which the other participants were encouraged to ask questions together with the workshop facilitator.

Participants were asked about the functionalities of their magic machine with questions such as: "*How is it switched on and off?; What materials is it made of?; When, where and with whom should it be used?"*; the interaction qualities: "*How do you interact with the magic machine during meditation?; What interaction qualities of each of the materials used have?";* and the meditation experience: "*What is the person's posture (e.g. sitting, laying down) while using the object?; Are the eyes open or closed?; Does the object recreate any bodily sensations that arise during meditations?; Do these arise on any particular part of your body?* This generated a conversation around what had been presented by the participant without judgment or evaluation attitudes, but with a focus on deepening the understanding of the concepts underpinning the magic machine.

Part 4. Personal Semi-structured Interviews

The aim of the semi-structured interviews was to explore the lived experience of meditation, as well as opportunities for technology to facilitate its training. Therefore, the initial set of questions revolved around the qualities of their meditation method [43] including questions about their preferred *style of meditation*, if any (e.g. Buddhist, Vipassana), as well as their *body posture* (e.g. open/closed eyes, posture while sitting, control of breathing). Secondly, we enquired about what kind of additional guidance they would find most useful during meditation. In particular, each interview included questions about *when* and *how* to provide feedback during meditation (e.g. continuously or based on events such as becoming mindful or during mind wandering moments). Finally, interviews included questions about participants' vision of the potential use of technology to facilitate the training of meditation, from traditional commercial apps to novel interactive systems. For example, we asked about their preferred *level of interactivity* (e.g. from passive audio tracks to real-time biofeedback-based feedback), the *context of use* (e.g. novices/experts, individual/group setting, public/private location), and possible *limitations*.

Figure 2. Illustration of the materials used in the workshops to elicit tactile experiences.

Data Collection

For each workshop, participants were gathered in a quiet room with a large central table where the workshop materials were placed (Figure 2). Only the group discussion and individual interviews were recorded on video, with participants consent.

Data Analysis

All qualitative data was anonymized and conversations were transcribed and coded following a hybrid coding approach [22] using Atlas.ti8 software for qualitative analysis. The development of the coding scheme was an iterative process involving both authors, drawing upon a conceptual framework developed from prior work on meditation (e.g. meditation strategies, stages of meditation) and codes that emerged from the data (e.g. bodily sensations, embodied and material metaphors).

FINDINGS

The Lived Experience of Meditation

The practice of meditation originated in historic contemplative traditions using different techniques and goals [43]. This diversity was present in our workshops, as participants had explored and currently practiced a range of meditation traditions such as Buddhist, Zen and Loving-kindness, although not everyone followed a specific tradition. Regarding their engagement in meditation practice, all participants acknowledged its benefits for well-being: "*it makes me feel better and I can explore myself and the world around me*" (P5), while over half of them also mentioned spiritual reasons informed by the specific meditation traditions. Nevertheless, despite having practiced for years, all participants acknowledged that meditation can still be challenging due to intrusive thoughts and mind wandering: "*when you start [to meditate] all sorts of thoughts come into your head and you'd be planning your shopping list, you'd be thinking about what your kids are doing"* (P1). As indicated by this quote, one of the main challenges is learning to accept the thought process without engaging with it.

Qualities of Different Meditation Styles

We will now provide an overview of participants' meditation practices drawing from Nash et al. meditation taxonomy [43], although we aim to highlight them between participants rather than to categorize a particular style. Regarding the followed cognitive strategies marked by distinct neuro-correlates [30,43,68], we found that focused attention was a common approach among all participants. In particular, we found that most objects of focused attention were physical (14 participants), such as focusing on their breathing patterns: "*stopping everything and just focusing on the breathing*" (P16), and 10 participants on a conceptual foci: "*I think of things I'm grateful for in the journey that I've kind of made to get me here at this point*" (P4). Besides focused attention, 13 participants practiced memorization and repetition of a mantra, which in some cases was also vocalized: "*keep repeating […] 'I am a peaceful being or I am a being of peace or I'm a peaceful soul and not anything else'*" (P12). We found that participants following this cognitive strategy usually practiced meditation as a spiritual practice.

The role of the body can be also explored from a third-person perspective. Findings indicate that all participants practiced static meditation, in which their body remain still either sitting (18 participants) or laying down (5 participants). Nevertheless, the postural position of the hands was important for 8 participants, particularly when sited:

> *You sit down with your feet on the floor, fairly back, fairly upright and the right hand on top of the left hand and the thumbs meet. […] So it represents body, speech and really, status of it and it creates that total connection of body, speech and mind* (P2).

As illustrated by this quote, participants found that this posture facilitates the connection between body and mind. With regard to the eyes, most participants did not have a preference although they usually practiced meditation with the eyes closed (20 participants): "*I find that [with my eyes open] I'm either staring at something -which is not very helpful- or I'm distracted by any movement, so I shut my eyes*" (P12). Therefore, most participants choose to close their eyes to avoid distraction.

Another aid that 16 participants used to practice meditation is audio guidance: "*guided meditation will start [by the teacher] commenting, and then you just keep doing what that [teacher] says*" (P18). Guided meditation is usually led by a teacher, either in person as stated in the above quote or via audio or video. Whilst some participants enjoyed having a narrator explaining the dynamics of the meditation processes, others (8 participants) preferred self-reliant meditation: "*I use silence, obviously there are the natural sounds around and I allow them to be part of the experience.*" (P3). This quote is interesting, highlighting the way in which things that occur in the moment outside the meditation experience, are actually integrated in the meditation experience.

Figure 3. Transition between different meditation stages by P1, with material metaphors representing their associated physical sensations: the meditation journey is vertical (*string*), grounding at the bottom (*scrunched up paper*), the targeted mindful stage at the top (*light air*), becoming mindful by going up (*soft wool*), and mind wandering at the bottom (*heavy beans*).

This was particularly stressed by 3 participants describing how they meditate near the sea and use the tide to guide their experience. This findings suggest that the restorative power of nature [36] can better support the practice of meditation, and such power has been recently explored as an audiovisual feedback for technology mediated meditation [16,17]. Finally, an important outcome is that patterns of bodily sensations consistently appeared at specific moments or stages during meditation experience, despite different meditation methods. Such patterns were particularly clear during material speculation part, as many participants used the same materials to materialize similar metaphors, as further detailed in the following section.

Meditation as a Sensorial, Staged and Dynamic Journey

Previous work exploring the experience of meditation has acknowledged each meditation session as a journey in which different stages are involved (Figure 3): *"I start my journey here [pointing at the scrunched-up paper on the left representing her initial state] and the little pecks [small wooden clips] are kind of where my mind wanders, so hiccups along the way, and I've deviated I've gone off track. But then I have really positive experiences in my meditation as well where actually it feels all nice and fluffy and I feel protected, I'm encircled [pointing at the cotton balls encircled by wool].* (P5, Figure 1 left). As illustrated by this quote, our findings confirm previous ones on meditation session as a dynamic journey [43], but also expand it by describing different embodied experiential qualities such as vertical and horizontal movement associated with different meditation stages (Table 1). For instance, a common metaphor used by 12 participants was the one describing the connection between meditation stages by using a soft, malleable string: "*this [pointing at wool string that goes through the plate] is the umbilical cord, and [pointing at the wool around the plate] connects the ones in there [the materials on the plate: beans as mind-wandering, cotton balls as becoming mindful, paper straws that represent balance being mindful]*" (P19, Figure 1 center).

We now describe, from a bodily perspective and using the objects created during the workshops, the stages of grounding at the beginning of the meditation sessions, and of becoming mindful. Moreover, we also further unpack mind-wandering and how expert meditators approach the transition from the stage of mind-wandering back to becoming mindful again.

Grounding: Increasing Body Awareness through Breathing

The first step to start the meditation session consists of a set of actions, commonly referred to as grounding, aimed to facilitate the subsequent stages, and in particular the achievement of a mindfulness state [43] . At the beginning of the session, people tend to feel disconnected from their bodies: "*[at the beginning] would be like fiddly. And then […] I would actually be more aware of them [hands and legs]*" (P6). As described here, the process of grounding allows meditators to ensure the mind-body connection.

Participants explained that there are two key elements during the grounding stage that are very much interrelated: body posture and breathing control. In order to slow down the mind, all participants start their sessions by focusing on their breathing: "*kind of diaphragmatic one, imagining with an image of a balloon. So as the balloon comes in, it inflates and deflates - that's your breath. So your mind just focuses on that sensation"* (P2). As described by the previous quote, breathing tends to be slow, controlled and located on the belly: "*hands are on your belly, feel the rise and fall of your belly"* (P4). This type of breathing is common in most meditation traditions and is used at the beginning of the session to elicit the relaxation response [50], a physiological ability to slow down the body and the mind by increasing blood flow to the brain. This process is also supported by relaxing specific parts of the body, particularly those in which tension is held but usually overlooked: "*a lot of people have tension here in their necks, but also in their mouth and we don't notice it. But then when, in the beginning, it happened all the time. […] we keep all our tension in mind, in our mouth, just relax your tongue*" (P1). Most participants (20) expressed the importance of bringing attention to the shoulders by bringing them down, jaw by relaxing the tong at the bottom of the mouth, and the breath within the lower part of the belly.

To conclude, the pattern of moving downwards both mentally and physically has emerged during this initial grounding stage of meditation session: "*my body is definitely different. It feels as if it's sinking down, but in a good way*" (P5). This is an interesting concept that can be used as a design input to facilitate grounding.

Becoming Mindful: Soft, Warm and Balanced

After grounding, the next meditation stage is becoming mindful by using specific methods such as: "*body sensations, emotions, cognition, spirit, divinity. They're just starting to flow instead of it all being blocked*" (P19). As stated by this quote, in this stage the mind-body connection is deeply established and body perception is enhanced: "*it comes back to that tangible feeling of all of those thoughts*" (P4). As described previously, participants followed distinct meditation techniques. However, we found that the body sensations that emerged from this stage were similar for most participants, irrespectively of their meditation tradition. Another important outcome is that in contrast to the grounding stage, most participants (22) expressed the experience of becoming mindful as *moving upwards*: "*as you meditate, you travel. […] And as you go higher and higher […] all your thoughts are sort of slowing down*" (P8). As this occurs, all participants described a general feeling of softness: "*you then move up to more relaxed, softer state*" (P2); a tingling sensation on top of the head (16 participants): "*like a current of positivity […] starts in the head*" (P21); and a warm feeling in the belly (18 participants): "*my belly feeling really comfortable and warm and calm*" (P6).

Furthermore, all participants expressed how one of the main goals of practicing meditation is achieving a mindfulness state. However, it appears that the physical sensations of the process of becoming mindful are very different from the ones when the mindfulness state has been reached: "*when you go up there [mindfulness state], you feel like your body, part by part, is detaching and you become something bodiless*" (P9). In that moment, the concept of balance emerges: "*you're not sinking […] perfectly balanced right onto it*" (P4); both physically and mentally: "*a state of balance of left-right brain, mind-heart-body*" (P19). Therefore, despite the important role that the body plays in the process of becoming mindful, the bodily sensations also quiet down when the mindfulness state is achieved. At this stage, body's role takes second stage and thoughts front stage. As a result, the interaction with the thoughts, is the most challenging aspect during this stage: "*I used to try and fight the thoughts coming into my mind. […] However, the more you let them come in, the more they'll bang out again"* (P4). As this quote describes, the skill of observing the thoughts and not engaging with them is challenging to develop, which in turn can easily lead to mind wandering moments.

Mind Wandering: Sharp, Tense and Heavy

The experience of mind-wandering during meditation, has been previously explored for instance by the landmark work of Petitmengin et al. [47] who employed micro-phenomenological interviews. In particular, they reported on the way in which body awareness fades when attention starts drifting. Findings from our workshops confirm and expand these previous outcomes: "*you only know your mind has wandered when you come back […] In the moment when your mind has wandered away, you aren't aware because your mind is there [with the thoughts]*" (P3, Figure 4). As described in this quote, all participants explained how when a thought appears, it takes the focus of attention and people no longer are in touch with their bodies and bodily sensations.

Figure 4. Magic machine by P3 recreating the soft (*wool, cotton*) and balanced (*aligned sticks*) body when being mindful, right before engaging with dismissible thoughts (*rice*).

It is only when they realize that their attention has drifted by engaging with a thought that they can actively bring their attention back to the body: "*it's feeling very, very tense my body and it's getting cold in different ways"* (P5). As described in this quote, the bodily sensations experienced when awareness is brought back, after getting distracted, are in sharp contrast to those of becoming mindful. Finally, most participants identified two different types of thoughts leading to different levels of mind-wandering. First, there are *dismissible* thoughts, mostly represented with rice (8 participants) or small wooden clips (6 participants): "*they're insignificant, you know, as soon as you're aware the thought has come, you can get back to your intense meditation again*" (P12). Second there are *distracting* thoughts, mostly represented with beans (5 participants), tensed elastics (2 participants) or metal clips (6 participants): "*these are the ones that tend to fully interrupt [mindfulness state]*" (P12). An interesting finding, is that some participants tried to overcome the dismissible thoughts by imagining and engaging back with a mindful sensation: "*if a thought comes in, then I will go immediately back to a sensation, a physical sensation*" (P3). Whereas with respect to distracting thoughts, these tend to become a train of thoughts that really disengage the person from the mindfulness state: "*when I get distracted, then here we are again with a few rocks […] and I breathe in, just focusing*" (P24). As described in this quote, in such cases, the meditators need to go back to the grounding stage, in order to slow down the thoughts and start becoming mindful again.

Design Concepts for Meditation Technologies

We now discuss different design concepts that emerged during the workshops through the magic machines, including their experiential qualities, functionalities, as well as the materialization of, and transition between meditation stages.

Intent: Representing for Experts vs Regulating for Novices

An important outcome is that the objects created during the workshop appear to be of two distinct types. On the one hand, 11 magic machines represented the meditation experience aimed to facilitate self-monitoring of attention (Figure 4): "*instead of visualizing your own body, you are visualizing an object, therefore, taking the emphasis away from yourself […] When you follow these thoughts [rice], the spine [aligned sticks] starts to lean [and] if you were to come back to the center here [body, focus of attention], then your spine realigns itself*" (P3). As illustrated by this quote, in this case, the goal was to materialize one's experience through an external object which, in turn, would enhance self-awareness and improve the meditation. Most participants (17) advised that representing the meditation experience after the practice, instead of providing feedback in real time, would benefit experts the most: "*I think it's also useful to know, to relate back to what thought patterns did come up*" (P14).

On the other hand, 13 objects supported regulation of attention by providing opportunities to achieve the aimed experience of mindfulness state: "*it's like a subtle reminder […] it helps you come out of all the other impressions […] it feels like someone giving you a hug […] that feeling of warmth*" (P7). As described in this quote, regulation of attention was fostered by providing subtle physical sensations at specific moments when the focus of attention is lost. All participants highlighted the fact that this would be very useful for beginners: "*this could really help a beginner, actually, because they might not even know that their mind has wandered*" (P3). Further, this would also be particularly beneficial for scaffolding the learning process of recognizing moments of mind wandering, which has been also identified as one of the main challenges aspects of meditation as described in previous sections.

Form: Tangibles to Encourage Embodied Interactions

During the workshops every participant created a different object to communicate their lived experience of meditation. These objects had distinct forms such as ambient installations (Figure 1, left); wearables (Figure 1, center); and ubiquitous displays (Figure 1, right). Interestingly, many participants designed tangible artefacts aimed to support the meditation when held: "*what is transferred to your hands, could be transferred to whole body"* (P2). This outcome is interesting, as in many meditation traditions, the hands are a key aspect of the practice: starting with the gestures (or Mudras) to set the intention [62], to the physical sensations that emerge in different stages of the meditation session.

Tempo: When to Provide vs When Not to Provide Guidance

A striking finding was that although participants found guidance during meditation important, 20 found the lack of guidance even more essential: "*I think it might be good to let the person's mind wander for a little while, but then to remind them that actually your mind has wandered. So therefore they can kind of, they wouldn't become that reliant on it [support], all the time [but] they [have to] figure out for themselves that "my mind has wandered, I need to bring it back"*" (P5). As stated by this quote, despite the affordances of technology for real-time monitoring of one's performance and provision of support to bring the attention back when distracted, such affordances limit participants' opportunity to practice the ability to recognize mind wandering moments by themselves.

All participants agreed that during the grounding stage, continuous personalized feedback to help relax the body, and to slow down the mind would be beneficial. This resonates with previous work in HCI supporting people become more aware of their bodies [32,64]. However, once the person starts employing their meditation method and enters the stage of becoming mindful, 22 participants expressed they would then benefit from a cyclic feedback pattern: "*almost on a loop, kind of send you there, something like waves*" (P4). During the moments of guidance, participants were excited by the potential of technology to provide personalized, targeted support: "*something that tells you, you're wondering now, come back!*" (P3).

Adaptivity: Mindful Sensations when Mind-Wandering

Most participants (18) had introduced technology to their meditation practice in the past by using smartphone applications. For instance, participants used them to track aspect of their meditation sessions: "*if I'm not using an app or something timed, then how do I know when it's ended?*" (P5). As stated by this quote, most participants liked to meditate for a specific amount of time, hence they rely on technology to provide reminders of when to stop the session. However, not all participants enjoyed the experience with meditation apps: "*I tried Headspace and Calm [smartphone apps for meditation] and […] found I didn't necessarily need that, it was a little bit too prescribed for me. And I think, I thought of meditation as being a bit more personal to me.*" (P4). This indicates that since each meditation session is a different journey, people may benefit from adaptive support, tailored to the specific meditation stages they are in.

In order to support the regulation of attention during meditation, most participants (20) suggested the value of providing feedback during moments of mind wandering by recreating mindful bodily sensations: "*you have to focus inward […], so it's like wrapping yourself into something"* (P17). For instance, they suggested encouraging an upward movement to support going back to the stage of becoming mindful, by leveraging touch: "*you could use touch, because that would automatically bring attention to that place [where touch is experienced], warmth in that place*" (P3). Therefore, we can imagine novel haptic feedback to be provided during meditation that uses subtle qualities of touch (e.g. warmth, pressure) to recreate the personal mindful bodily sensations.

Control: Meditation as a Personal Agentic Practice

Importantly, all participants emphasized their agency over their practice, and how technology should not take this control away by being too evaluative: "*technology could put a layer of pressure, which could make people scared […] but it might also help people develop a regular practice*" (P3). As stated by this quote, if the users felt that the technology was over-analyzing their practice, it would actually create an adverse effect. Participants also described that technology could be positively integrated into a meditation session: "*it works with your body, it's not imposing anything*" (P2) "*Yes [to P1], the machine can't bring you back [from mind wandering], you'll deal with it personally and come back*" (P1). This is a more nuanced view on the affordances of technology with the aim to enhance the meditation practice, as the main goal is to teach the person to become more aware of their experience by paying attention to their bodily experiences rather than just providing a continuous monitoring of and feedback on the performance without teaching how to act upon it. Finally, with regard to user control and technology, participants voiced ethics concerns about interactive technologies, particularly in terms of data management: "*my initial reaction would be 'what's happening with the rest of the data [biometrics collected during the session]?'*"" (P5). Therefore, despite being excited by the potential of novel biofeedback technologies to facilitate meditation training, most participants said that they would only use such systems if they were in control of their personal data and it was not shared with others, unless they chose to. These findings echo others regarding the ethics of self-tracking technologies, particularly for wellbeing or health [14,52,73].

DISCUSSION

In this section, we discuss the findings by revisiting the initial research questions regarding the bodily sensations that emerge in different meditation stages, how these can inform the design of interactive technologies for meditation, and which novel opportunities as well as risks should be considered when designing such systems. This discussion is informed by participants' lived experiences of meditation and by previous related literature.

Mapping Bodily Experiences to Meditation Stages

Previous work in psychology identified different stages that occur during meditation [43,46], such as *grounding*, following the preferred meditation method to *become mindful*, and *mind-wandering*. Our findings have expanded this body of work by providing an overview of different bodily sensations and embodied metaphors associated with each of these stages (summarized in Table 1). We argue that this represents an interesting topic to be further explored, and further detail how our findings may inform the design of novel interactive technologies for meditation.

Vertical Movement: Becoming Mindful vs Mind-Wandering

During the workshops, participants emphasized how their meditation experience differ both among individuals, and across time or meditation sessions in terms of how they transitioned between stages, despite the stages being the same. Interestingly, some physical sensations and embodied metaphors associated with each meditation stage were shared. For instance, related to the concept of *vertical movement*: grounding was described as a downwards movement, whereas becoming mindful was described as moving upwards. When realizing that mind-wandering had occurred, people found themselves as if they had moved lower –and how much lower depended on whether it was a distracting or dismissible thought.

MEDITATION STAGES		MATERIAL METAPHORS	EMBODIED METAPHORS	BODY LOCATIONS	PHYSICAL SENSATIONS
journey		maleable soft string	dynamic movement	-	-
grounding		scrunched up paper, sponge	downwards movement	shoulders, jaw, belly	slow rhytmic breathing, relaxing
becoming mindful		cotton ball, wool	upwards movement	head, belly, hands	softness, tingling, warmth
being mindful		light, air	balance	crown, hands	bodyless, radiating light
mind wandering	*dismissibile thoughts*	rice, small wooden clips	sharpness	-	-
	distracting thoughts	beans, metal clips, tensed elastics	heavyness	-	-

Table 1. Based on the Findings, this table shows how the lived experience of distinct meditation stages were described by participants using material and embodied metaphors as well as body locations and physical sensations.

We find this to be an interesting design input for meditation systems, as regardless of the feedback implemented in the system, the concept of vertical movement could be used to facilitate transition between meditation stages with the goal of achieving a mindfulness state. The introduction of vertical movement to assist the stage of becoming mindful has been explored in some interactive systems for meditation through audiovisual feedback in immersive virtual reality [3,48]. Nevertheless, we think that this could be enhanced by using haptic feedback recreating the physical sensations in particular body locations associated with each meditation stage (Table 1). For instance, we imagine an adaptive haptic feedback system like a smart modular necklace that signals distracting mind-wandering moments by rhythmically heating up its beads from the solar plexus to the collar bone.

Designing for Balance: Maintaining a Mindfulness State

Once the mindfulness state has been achieved, one of the main challenges is maintaining it. A concept that was recurrent when participants were explaining the experience of being mindful was *balance*, i.e. having your body and mind in balance. In order to stabilize their body and mind during meditation, participants described how they focused their attention on an object, usually with their eyes closed to facilitate bringing the attention inwards. That is, focusing on internal bodily processes such as breathing. The embodied metaphor of balance has been used before in HCI to explore, for instance, the concept of social justice through embodied interaction using an interactive tangible prototype that follows a twin-pan schema [2]. Similarly, we found that experts in meditation would improve their practice by experiencing balance (i.e. being mindful) and unbalance (i.e. getting distracted). Therefore, when starting to become unbalanced, interactive technologies could be designed to bring the attention back to bodily sensations when balanced (Table 1). In this way, the design would not be mapping the current but the aimed state i.e. being mindful. For instance, we can imagine the similar modular necklace described earlier which can provide subtle haptic feedback patterns recreating grounding after prolonged mind-wandering, or stimulating radiating sensations through gentle tingling to confirm a prolonged mindfulness state.

Cyclic Feedback Patterns to Support Meditation

Designs of interactive technologies for meditation usually provide real-time feedback on one's performance, by continuously mapping physiological signals into creative audiovisual outputs [59,64]. From our findings, we speculate that such systems could benefit from introducing cyclic feedback patterns to better support the meditation practice.

Continuous vs Targeted vs Cyclic Feedback

Traditionally, guided meditation provides a generic *cyclic* support (i.e. every few minutes the teacher will say "*if your mind wanders, bring it back gently by focusing your attention back on your breathing*" [35]) that is not tailored in real-time to one's performance. Novel technologies have facilitated the provision of personalized *targeted* feedback in real-time using, for instance, biofeedback (e.g. breathing, heart rate, brain activity) [64]. This is usually employed to monitor the meditation experience and provide *continuous* feedback, e.g. to let the person know when they are becoming mindful or being distracted. Despite its immediate benefits, overreliance on such support may limit the opportunity to also practice the ability of regulating attention such as becoming aware of mind-wandering and refocusing attention.

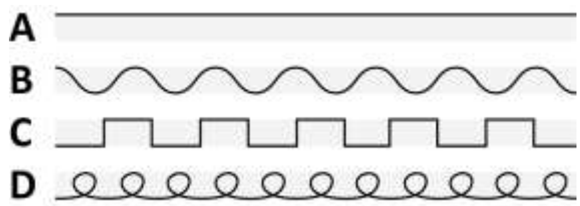

Figure 5. In each of the feedback patterns shown (A-D), the horizontal axis represents the temporal domain of the meditation session, and the vertical the amount of feedback.

We suggest that interactive technologies could draw from traditional guided meditation practices to provide both moments of guidance and moments without guidance in a cyclic manner. This comes from our findings on participants reporting their interest in targeted feedback based on one's performance, but reluctance about the continuous real-time mapping as it might be overwhelming and counterproductive for the meditator. During moments of guidance, nonetheless, the interactive system could augment traditional practices by providing targeted feedback based on one's performance rather than generic, non-interactive feedback.

Designing Cyclic Feedback Patterns for Meditation

Based on the nature of cyclic patterns and our findings, we can imagine how different feedback examples, such as the ones shown in Figure 5, would benefit the meditation experience when being used during distinct stages. Pattern A in Figure 5 represents a continuous feedback provided throughout the meditation session, as most meditation systems in HCI have been designed for [64]. We suggest this pattern would be beneficial when integrated into the design of the grounding stage, as it could provide real-time targeted feedback facilitating users to acquire the correct posture and relax different parts of the body before the start of meditation session.

Then, we envision that different patterns would better support different design goals. For instance, if the target users are novices, a smooth real-time transition from cycles of providing targeted feedback to cycles with no feedback would be most beneficial. That could be accomplished with the second pattern (Figure 5, Pattern B), which smoothly transitions between providing feedback to not providing it, similar to the transitions designed to adjust the level of difficulty or support in reinforcement learning systems [28]. The third diagram (Figure 5, Pattern C), which represents a way for providing feedback in binary fashion, similar to notifications systems on the phone [12], could be envisioned as an notification system that is only activated when the user has drifted completely into mind-wandering. Finally, as the person becomes more experienced with meditation, the system may start providing the feedback based on their performance over small windows of time rather than real-time (Figure 5, Pattern D), recreating the cyclic yet generic feedback patterns of traditional guided meditation. This may, in turn, allow users to be less reliant on the system and better develop the ability to self-regulate their attention.

Future work could further explore the amount of time needed between moments of providing feedback, to best support the meditation training. This may also be adaptive, based on one's performance: the better and less distracted the person is doing, the more time between periods of feedback. In the following section we will discuss how the feedback should be designed in terms of modality in order to best support the meditation practice in a non-obtrusive way.

Targeted Haptic Feedback from Mindful Body Sensations

Now, the next question would be: how could such targeted feedback be designed? Most HCI designs rely on ambiguous audiovisual feedback to map one's current internal processes related to meditation states into external objects. For example, the intensity of the light of a candle [3], the sounds of the sea [48], the amount of leaves on a tree [45]. Nevertheless, we found that mapping one's performance during meditation back to the body could be an interesting design concept. Our findings show that each meditation session can be framed as consisting of the same stages, and that each of these stages has been linked to particular bodily sensations (Table 1). Based on our findings, we suggest the exploration of an approach focused on recreating the physical sensations that occur when becoming mindful, at the critical times when the process of mind wandering occurs. In that way, the attention is gently brought back to the path of becoming more mindful rather than getting distracted and ruminate on the distracting thoughts. We argue for the importance of expanding this growing body of work by taking these bodily sensations as design inputs for future interactive systems for meditation. This could be done by relying on haptic feedback, such as warmth [32], pressure or vibration [66,67].

CONCLUSIONS

The practice of meditation has shown significant benefits for physical and mental wellbeing, including enhanced emotion regulation and bodily awareness. A growing number of HCI designs have focused on embodied interactive systems to facilitate meditation, however the body has mainly been used as a passive element from which physiological signals are mapped into creative audiovisual feedback. In this paper, we report on workshops with 24 experts exploring the bodily sensations that emerge during meditation. Through material speculation, participants shared their lived experience of meditation and identified key stages during which feedback should be provided. Findings emphasize the importance of recreating mindful physical sensations during moments of mind wandering. We conclude by discussing implications for designing interactive meditation technologies, such as supporting the regulation of attention through embodied metaphors, designing cyclic feedback patterns, and relying on haptic feedback to recreate mindful bodily sensations.

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