Exploring and Designing Embodied Mindfulness-based Interactive Technologies For Mental Wellbeing

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A thesis submitted for the degree of
Doctor of Philosophy

May, 2021

I would like to dedicate this thesis to my family and to all the friends who have supported me in this journey.

Declaration

I declare that the work presented in this thesis is, to the best of my knowledge and belief, original and my own work. Many of the ideas in this thesis were product of dicussion with my supervisor Professor Corina Sas. The material has not been submitted, either in whole or in part, for a degree at this, or any other university. This thesis does not exceed the maximum permitted word length of 80,000 words including appendices and footnotes, but excluding the bibliography.

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Abstract

Mindfulness practices have become increasingly popular due to their significant benefits for mental wellbeing. However, the required skills to sustain and regulate attention are challenging to develop. Both the benefits and the challenges of mindfulness training have attracted a growing Human-Computer Interaction (HCI) interest in designing interactive technologies for mindfulness. Most mindfulness-based technologies employ metaphorical mappings of mindfulness states to support awareness of such states and facilitate attention regulation, although the rationale for such mappings is seldom articulated. This thesis addresses this shortcoming, drawing on first-person experiences and embodied metaphors of mindfulness practices to design novel multi-sensory technologies for mental wellbeing.

This work concentrates on focused attention mindfulness (FAM) practices which involve sustaining selective attention moment by moment on a chosen object, and are considered the most widely accessible among novices. In particular, the research presented in this thesis is structured around two distinct FAM practices, in 6 different but interrelated studies. On the one hand, *mandala colouring* illustrates a non-static FAM practice with an external object of attention. On the other hand, *sitting meditation* represents a static FAM practice with an internal object of attention.

The first and second study investigate in-depth mandala colouring, respectively, by interviewing 21 people who regularly engage with this practice and through an auto-ethnographic and heuristic evaluation of the 14 top-ranked mandala colouring apps. Findings informed the development of Anima, a peripheral colour palette materialising EEG-based mindfulness states onto colours for mandala colouring. In the third study, Anima's design solutions were evaluated with 12 experienced participants.

The fourth study follows a research-through design and material speculation approach to understand the role of body during meditation with 24 experts. This is extended in the fifth study, in which the 16 most popular meditation apps are evaluated through auto-ethnography. An identified opportunity of designing for the physical sensations that arise during meditation was considered through the design of the WarmMind, that provide warmth patterns on the upper body. The WarmMind prototype was evaluated in the fifth study, through a user study with 10 participants experiencing thermal metaphors for mapping meditation states on the upper-body.

Besides the technological design contributions of Anima and WarmMind, the contributions of this thesis include the concepts of *intricate confines* to scaffold mindful movement to support non-static FAM practices with an external object of attention, and *interoceptive interaction* to facilitate focusing inwards during meditation to support static FAM practices with an internal object of attention; as well as a framework built on embodied metaphor theories to designing meditation technologies. Collectively, these studies highlight the value of the human body in mindfulness-based technologies in HCI, as well as theoretical and methodological contributions to designing around mindfulness for mental wellbeing in HCI.

Publications

Parts of the research contained in this thesis have been previously presented at academic conferences and were published in book and conference proceedings, or conference abstracts.

Contributing Publications

Daudén Roquet, C., & Sas, C. 2020. *A Mindfulness-Based Brain-Computer Interface Augmenting Mandala Coloring for Depression: Protocol for a Single-Case Experimental Design.* JMIR Protocols.

Daudén Roquet, C., & Sas, C. (2021). *Interoceptive Interaction: An Embodied Metaphor Inspired Approach to Designing for Meditation.* In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems.

Daudén Roquet, C., & Sas, C. *Exploring Anima: A Brain-Computer Interface for Peripheral Materialization of Mindfulness States during Mandala Coloring.* Taylor and Francis. Journal of Human–Computer Interaction.

Daudén Roquet, C., & Sas, C. (2020, July). *Body Matters: Exploration of the Human Body as a Resource for the Design of Technologies for Meditation.* In Proceedings of the 2020 ACM Designing Interactive Systems Conference (pp. 533-546). **(Honourable Mention Award)**

Daudén Roquet, C., & Sas, C. (2020, March). *A Scoping Review of Interactive Mindfulness Technologies for Mental Wellbeing: Considerations from HCI and Psychology.* In 25th annual international CyberPsychology, CyberTherapy & Social Networking Conference.

Sanches, P., Janson, A., Karpashevich, P., Nadal, C., Qu, C., **Daudén Roquet, C.**, Umair, M., Windlin, C., Doherty, G., Höök, K., & Sas, C. (2019, May). *HCI and Affective Health: Taking stock of a decade of studies and charting future*

research directions. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (pp. 1-17). **(Honourable Mention Award)**

Daudén Roquet, C., & Sas, C. (2019, May). *Digital Wellbeing: Evaluating Mandala Coloring Apps. In 2019 CHI Conference on Human Factors in Computing Systems*. Position Paper for the "Designing for Digital Wellbeing" Workshop.

Daudén Roquet, C., & Sas, C. (2018, April). *Evaluating mindfulness meditation apps*. In Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (pp. 1-6).

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Finally, I would like to give a huge thanks to all the people that have participated in the user studies: for sharing your personal experiences with mindfulness and mental well-being, and for engaging in valuable discussions that have inspired the research presented in this thesis. Also, thank you to everyone in SCC that has helped me and had faith in my research.

The past three years and a half have been an incredible experience, and I could not have gotten through all the ups and downs without the support and encouragement from those around me. I apologise to all that I have not mentioned. I have not forgotten about you, *thank you*.

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Chapter 1

Introduction

1.1 Overview

Mindfulness practices have become increasingly popular because of their significant benefits for psychological well-being [40], mental [16, 82] and physical [99, 134] health. Mindfulness has been conceptualised as actively bringing one's attention, non-judgmentally, to the unfolding experience in the present moment [157, 168, 246, 110]. The work presented in this thesis builds on Vago and Silbersweig's S-ART framework [277], in which they describe two distinct approaches to mindfulness training: focused attention through concentrative practices, often the starting point of novice meditators [168, 277], and open monitoring involving no specific object to focus the attention on, hence learning to observe the present moment without engaging with neither internal nor external stimuli [168]. Consistent findings in the literature indicate that the skills required to sustain and regulate attention, such as in mindfulness practices, are challenging to develop [145].

There are a wide variety of traditional focused attention mindfulness (FAM) practices that follow different approaches, which can be categorised in two dimensions: main object of attention (i.e. internal, external), range of movement (static , fine movements, full-body movement). Regarding the first dimension, in FAM practices with an internal focus of attention, practitioners tend to concentrate on bodily processes or sensations such as their breathing [84]; whereas when the main object of attention is external, it can take different forms such as a mantra sound, a visualisation or a tangible artefact. Regarding the second dimension, the most popular static FAM practice is sitting meditation [163], whereas non-static practices can rely on fine movements such as in mandala colouring or in full-body movements as in walking meditation or Tai-Chi. Depending on the approaches used, and despite all targeting the same goal of training mindfulness, these practices have distinct neurobiological underpinnings [188, 80, 261]. In other words, the exploration of FAM practices that

occupy different positions in the space set by these two dimensions, offers various pathways to obtain the benefits of mindfulness.

In recent years, there has been a growing interest in the fields of Human Computer Interaction (HCI) [252, 263, 228] and Psychology [43, 147] to design and develop interactive FAM technologies aiming to train mindfulness and, thus, enhance mental well-being. In this thesis, *interactive* refers to systems that provide real-time feedback based on one's performance during the mindfulness practice, commonly accomplished through biofeedback. Despite the broad range of traditional FAM practices, most work in HCI has focused on static FAM practices such as sitting meditation [263]. This is surprising given the acknowledged value of bodily movement in traditional mindfulness practices [239] and their growing interest in the general population (e.g. walking meditation, tai-chi, mandala colouring).

The most common biodata used in FAM interactive systems is respiration [212, 200], as it is a bodily process easy to monitor with sensing technology, understand the mapping and act upon to adjust one's conduct. Nevertheless, mindfulness states can be complex to accurately monitor as they have several processes underneath it (e.g. a mindfulness state involves being both relaxed and active [80, 151]). Hence the most interesting biodata to use in interactive systems is brain activity, as it can provide a rich overview of the state of these processes unobtrusively in real-time [151]. Recently, a few brain computer interfaces have been designed and used to support the self-regulation of attention during mindfulness practices [230, 5]. However, this is still a less explored space with potential to contribute to the design of interactive FAM technologies for mental well-being.

Furthermore, the way in which mindfulness states can be represented from biodata onto different creative outputs has not been properly established. Most FAM systems in HCI tend to use metaphorical representations of mindfulness states to scaffold the practice, but the design rationale of such metaphors is seldom articulated [11]. With the rich history of metaphors in HCI supporting designers research unfamiliar topics [29, 225] and the advance of metaphorical representations of biodata using different feedback, a framework providing conceptual theory on how to design for materialising biodata to support regulation processes is much needed. And especially in the context of designing for communicating brain activity, which has received less attention in HCI.

1.2 Research Aims

The main aim of this thesis is understanding the practise of and designing for focused attention mindfulness practises in order to support mental well-being. Therefore, the research objectives are the following:

1. To understand the motivations and challenges of practising focused attention mindfulness for mental well-being, as well as the qualities of the lived experience associated with such practises.

2. To explore the design of novel interactive technologies to facilitate the practise of focused attention mindfulness, with either external or internal main objects of attention, in order to mitigate the identified challenges.

3. To explore people's perceptions of metaphorical representations of mindfulness states in interactive technologies to successfully support focused attention mindfulness practises.

In particular, these objectives are intended to address the following main research questions:

1. Why do people engage in focused attention mindfulness practises, with internal and external main objects of attention? What are the main benefits and challenges they faced? How is the subjective experience of engaging in such practises?

2. How can the identified experiential qualities of such mindfulness practises inform the design of novel technologies to facilitate focused attention, with either internal or external main objects of attention?

3. What design qualities of the proposed embodied metaphorical representations of mindfulness states support focused attention mindfulness practises, with internal or external main objects of attention?

The table below (Table 1.1) offers an overview of the research aim, objects and research questions, and their interrelationships.

Research Aims			
Research Objective 1	Research Objective 2	Research Objective 3	
Research Question 1	Research Question 2	Research Question 3	
Sub-Research Questions 1	Sub-Research Questions 2	Sub-Research Questions 3	
Chapter 4 (Study 1) What are the motivations, benefits and challenges of engaging in mandala colouring practice? What is the socio-temporal-spatial context of practicing mandala colouring for regular practitioners? What materials and actions are key in mandala colouring practice, and what specific qualities do they have? *Chapter 4 (Study 2)* What are the main strategies implemented in mandala colouring apps to support the FAM practice? How is the experience of practicing non-static FAM with an external object of attention? What are the main challenges of the current technological solutions?	*Chapter 5* How should metaphorical representations of mindfulness states, captured from brain activity, be designed to be recognizable and open for interpretation during the practice of mandala colouring? What are the design elements that can support the practice of non-static FAM with an external focus?	*Chapter 6 (Study 3)* In what ways do people make sense of the metaphorical representations of their mindfulness states with the peripheral interface? How does the decoupling of focused attention and its monitoring impact on the mindfulness training supported by mandala coloring?	MANDALA COLOURING: NON-STATIC FAM WITH EXTERNAL FOCUS
Chapter 7 (Study 4) What are the key stages that may occur during meditation and do they have specific bodily sensations associated? In what way could these bodily sensations inform the design of novel technologies to support meditation? What are the opportunities and risks of using technology for meditation? *Chapter 7 (Study 5)* What are the main strategies implemented in meditation apps to support the FAM practice? How is the experience of practicing static FAM with an internal focus? What are the main challenges of the current technological solutions?	*Chapter 8* How should metaphorical representations of mindfulness states, captured from brain activity, be designed to support be perceived as interoceptive? What are the design elements that can support the practice of static FAM with an internal focus?	*Chapter 9 (Study 6)* In what ways do people make sense of the embodied metaphorical representations of their mindfulness states with aural and thermal feedback? How do the on-body thermal patterns impact on the focused attention mindfulness experience of sitting meditation?	SITTING MEDITATION: STATIC FAM WITH INTERNAL FOCUS

Table 1.1: Overview of the interrelationships of the overarching research aim, research objectives and research questions of this thesis.

1.3 Contributions

This PhD thesis provides four contributions to the HCI community: 3 theoretical and 2 technological design contributions.

1.3.1 Theoretical Contributions

Intricate confines: a strong concept for designing non-static FAM with external object of attention

Intricate confines is a concept proposed after the exploration of the practice of mandala colouring (Chapter 4) and developed in the following chapters (Chapters 5-6). This concept allows to successfully scaffold the slow and controlled fine movement required to colour mandalas, and that has been found key as it becomes the main focus of attention. Therefore, there chapters discuss how it can inform the design of novel interactive technologies drawing from non-static FAM practices with an external main object of attention. This work has been accepted at the journal of Human Computer Interaction, Taylor and Francis.

Interoceptive interaction: a strong concept for designing non-static FAM with external object of attention

The concept of *interoceptive interaction* is introduced and developed in Chapters 7-9. Drawing from the sense of interoceptive awareness, the proposed approach is to facilitate supporting focusing on internal objects of attention even when the experience is mediated by external technological interfaces. This work has been published at CHI2021 [70].

A framework for designing meditation technologies

This framework is built on existing theories of embodied metaphor design and FAM meditation practises with an internal object of attention. It highlights three design tensions, with qualities on one end supporting discoverability and on the other end supporting attention regulation: familiar - ambiguous metaphorical mapping, continuous - discrete feedback, rich - subtle sensory stimulation. The circles' size is proportional to the number of systems with that quality. This framework has scaffolded the design of the WarmMind prototype, which provides on-body thermal patterns to foster interoceptive awareness during sitting meditation (Chapter 8 and 9). This work has been published at DIS2020 [67] and CHI2021 [70].

1.3.2 Technological Design Contributions

Anima: Brain-computer interface materialising real-time mindfulness states onto colours to augment mandala colouring

This prototype is a design exemplar of an augmentation of a non-static FAM practise with an external object of attention provided through a peripheral interface. Furthermore, it also explores the mapping of mindfulness states during mandala colouring, captured from brain activity, onto colour-based metaphors. Finally, implications for designing expressive FAM technologies with an external object of attention for mental well-being are articulated (Chapters 5 and 6). This work has been is under submission at the journal of Human Computer Interaction in Taylor and Francis.

WarmMind Prototype: Design exemplar for interoceptive interaction during sitting meditation

This prototype is a design exemplar for augmenting the static FAM practise with an internal object of attention, by using on-body thermal patterns that recreate bodily sensations that arise during sitting meditation. Its design employs novel embodied metaphors to support interoceptive awareness, and the prototype explores how these are understood in comparison to nature-inspired audio metaphors (Chapters 8 and 9). This work has been published at CHI2021 [70].

1.4 Thesis Structure

The remainder of the thesis is structured as follows (Figure 10.1):

Chapter 2: Literature Review

This chapter presents the relevant related literature, drawing from three research areas: mindfulness interactive technologies in HCI, mindfulness practises for mental well-being, and embodied metaphor designs in HCI. A theoretical paper has been published based with the insights gained from this chapter [66].

Chapter 3: Methodology

This chapter highlights the relevant methodology applied in this thesis. Key research methods include interview studies, participatory design workshops and somaesthetic explorations.

Chapter 4: Understanding the practise of Mandala Colouring for Mental Well-being

This chapter presents the in-depth investigation of the design space for mandala colouring, as an illustration of a non-static FAM mindfulness practise. It presents the findings on the motivations and lived experiences of mandala colouring with two studies. It also discusses relevant theoretical and design implications. One paper has been published with the findings described in this chapter [69].

Chapter 5: Designing Anima: A Brain-Computer Interface for Peripheral materialisation of Mindfulness States during Mandala Colouring

This chapter presents the design of a prototype augmenting the practise of mandala colouring through a peripheral colour palette materialising EEG-based mindfulness states onto colours.

Chapter 6: Investigating the Metaphorical Representations of Mindfulness States with Anima as a Prototype

This chapter presents the initial evaluation of Anima's design solutions in a set of participatory workshops with 12 experienced participants.

Chapter 7: Understanding the Role of the Human Body in the Lived Experience of Sitting Meditation

This chapter presents an in-depth investigation of the practise of sitting meditation through a participatory workshop with experts and an evaluation of commercial meditation apps. It also discusses relevant theoretical and design implications for static FAM practises with an internal focus of attention. One paper has been published with the findings described in this chapter [67].

Chapter 8: Designing Interoceptive Interaction: Metaphor-based On-Body Haptic Patterns for Sitting Meditation

This chapter explores the design of novel interactions for static FAM meditation with internal object of attention through on-body haptic patterns in the form of two different prototypes, which we named WarmMind: a thermal necklace that provides warmth-based metaphorical patterns on the upper body to guide meditation. It also presents the concept of interoceptive interaction and discusses the implications for design [70].

Chapter 9: Investigating the First-person Experience of Sitting Meditation with Interoceptive Interaction Prototypes

This chapter presents the exploration of the designed solutions with the WarmMind necklace through a user study and auto-ethnographic approaches. One paper has been published with the findings described in this chapter [70].

Chapter 10: Discussion and Conclusion

This chapter discusses the overall findings, revisits the research questions, and unpacks the main contributions of the thesis. Finally, the conclusions chapter summarises the entire journey of this thesis. It also discusses limitations and proposes directions for future work.

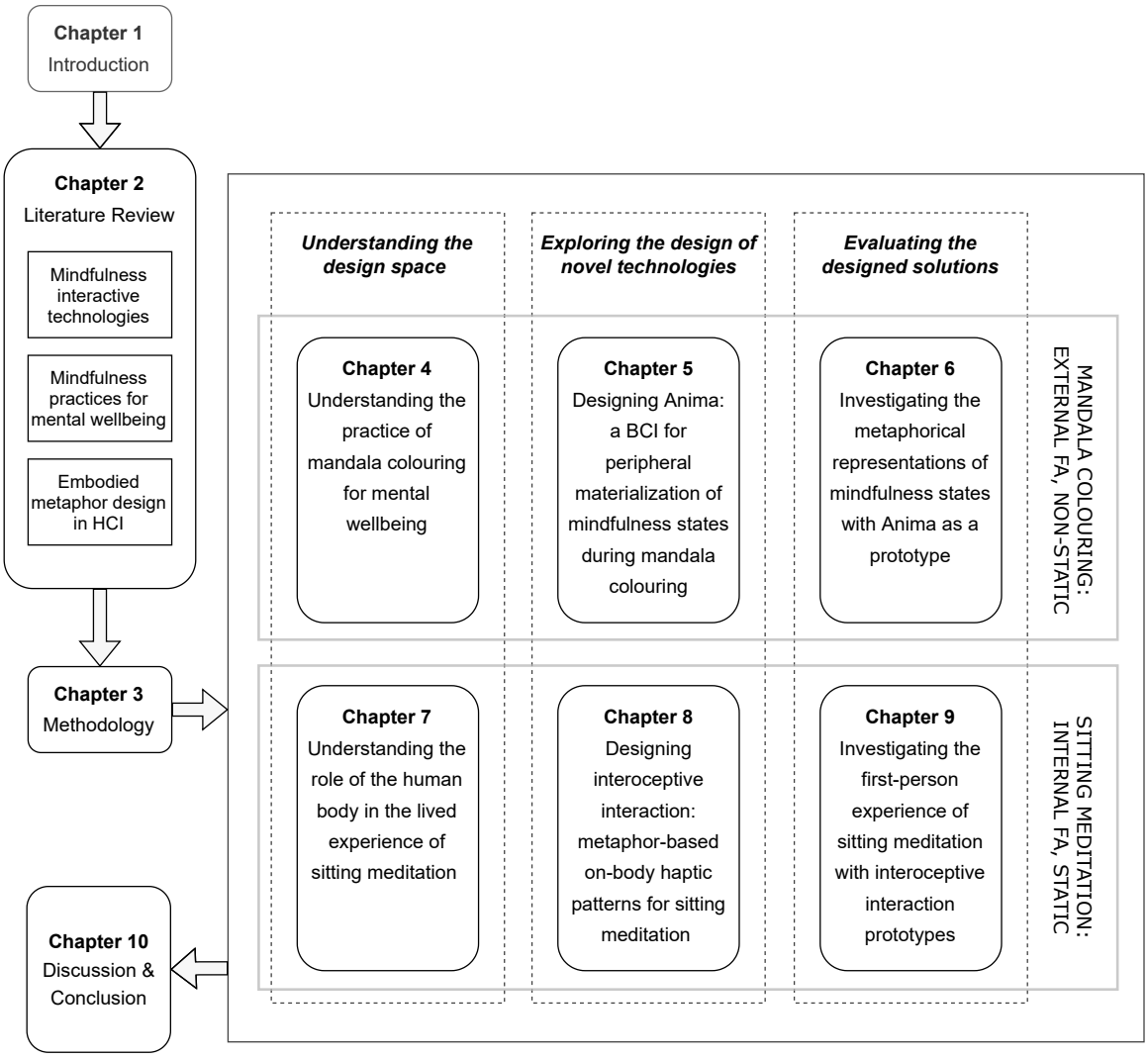


Figure 1.1: Structure of the Thesis

Chapter 2

Literature Review

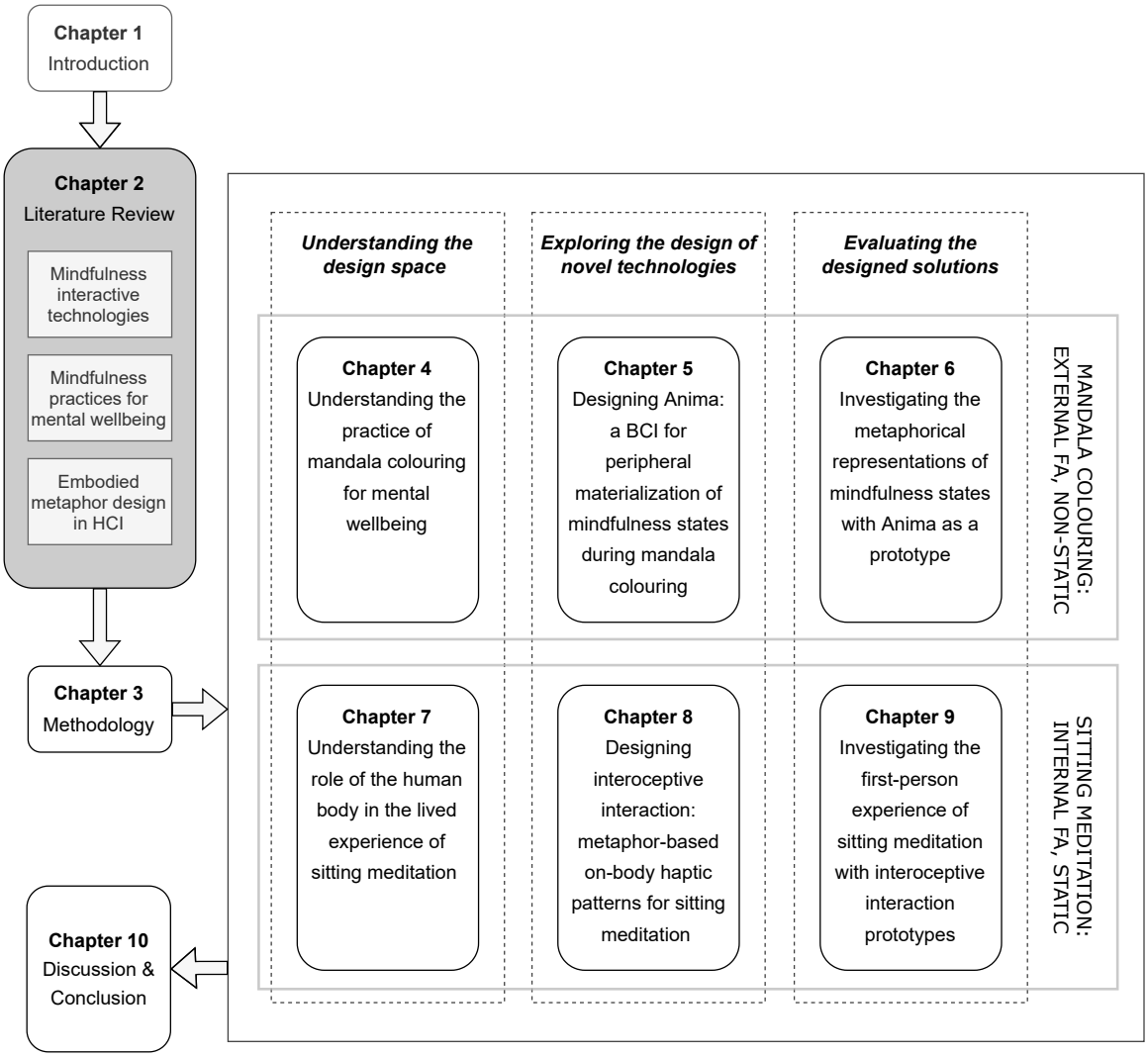


Figure 2.1: Chapter 2 of Thesis structure

2.1 Mindfulness practises for Mental Well-being

Mindfulness practises have become increasingly popular because of their significant benefits for psychological well-being [40], mental [16, 82] and physical [99, 134] health. Mindfulness has been conceptualised as actively bringing one's attention, non-judgmentally, to the unfolding experience in the present moment [157, 168, 246, 261]. There is growing evidence of the benefits of mindfulness-based interventions for mental health.

Landmark examples of well-established interventions include the Mindfulness-Based Stress Reduction (MBSR) program by Kabat-Zinn [135]. MBSR consists of an eight-week program that combines different types of experiential (e.g. sitting meditation, body awareness) and cognitive (e.g. exploration of patterns of behaviour, thinking, feeling and action) mindfulness practises to train a non-judgemental acceptance of the present experience. These secular, intensive mindfulness training has shown to assist people with stress, anxiety, depression and physical pain [135, 136, 283]. Similarly, Mindfulness-Based Cognitive Therapy (MBCT) adapts the MBSR intervention to focus explicitly on low mood and negative thoughts [135]. It uses the same eight-week structure that includes psycho-education, formal mindfulness practises (both static and movement-based) as well as daily home practises and exercises. MBCT was developed to prevent future episodes of depression in people with a history of recurrent depression, and research on this program has shown its effectiveness in preventing a relapse in major depression [153, 205] as well as an improvement on self-compassion, anxiety and mental well-being [109] and self-reported mindfulness [105].

Another example is Mindfulness-Based Art Therapy (MBAT) which combines mindfulness training within the structure of an art therapy framework, and was first formally introduced by Rappapport [142, 217]. MBAT has shown positive results to improve psychological well-being [182], emotional awareness and quality of life in individuals with anxiety [183] and depression [31].

Outside of formal psychological interventions, the practise of mindfulness has also shown benefits for well-being when practised regularly [40, 279, 277]. Nevertheless, consistent findings in the literature indicate that the skills required to sustain and regulate attention, key in mindfulness practises, are challenging to develop [145, 230]. Our work builds on Vago and Silbersweig's S-ART framework [277], in which they describe two distinct approaches to mindfulness training: focused attention through concentrative practises, often the starting point of novice meditators [38], and open monitoring involving no specific object to focus the attention on, hence learning to observe the present moment without engaging with neither internal nor external stimuli [168].

2.1.1 Focused Attention Mindfulness practises

Focused attention mindfulness (FAM) practises are considered the most widely accessible among beginners, as they facilitate stabilising the mind and decreasing mental proliferation by concentrating on a specific mental or sensory object. Therefore, the practitioner have to shift their attention from distractors -that can be internal thoughts and/or external stressors- to sustain it on the main object of attention.

Potentially, the main object of attention could be anything, but in traditional FAM practises they fall under two main categories. One the one hand, are *internal* objects of attention. For instance, it is common in sitting meditation practises that the focus of attention is oriented towards one's breath or bodily sensations [168]. On the other hand, the main object of attention can also be *external*. In this context, traditional FAM practises tend to rely on tangible artefacts, such as a candle for sitting meditation in which the practitioner needs to focus on the continuous movement of the flame [202]. Interestingly, most external objects of attention are fine skilled movement mediated by the tangible artefact [239]. For example, the Baoding Balls are two little spheres that need to be rolled in the palm of the hand, constantly switching the relative position of both balls whilst trying to avoid them to touch each other. Similarly, the Tibetan Prayer Wheel also relies on small continuous movement of the hand as the cylindrical wheel spins clockwise whilst visualising a mantra. Mandala colouring is another interesting example in this space, in which the object of attention is the fine, slow and controlled movement of the hand to create and colour in the intricate geometry.

According to neuro-psychology literature, internal objects of attention integrate conscious awareness with ongoing, dynamic viscerosomatic function [277]. Hence fostering interoceptive awareness, an ability to receive and attend to the signals originating in our bodies, which is shown to improve attention task performance as well as emotion regulation [82, 81]. Whereas external objects of attention involve an underlying framework of motor learning that functions to strengthen non-conscious, associative memory processes [277]. The instructions for practise (e.g. baoding spheres have to be rolled without touching) form an executive set that is created and sustained by working memory processes, while attention processes operate to focus and sustain concentration on the external object (i.e. fine, controlled and continuous movement). This "mind-body" connection has been suggested to have benefits to improve cognitive function and attention by coordinating executive goals, sustained attention and motor plans [57].

Therefore, FAM mindfulness practises can be categorised on two different axis: (i) internal - external main object of attention, and (ii) level of movement involved. The work presented in this thesis focuses on two practises that occupy two distinct spots within that space. On the one hand, *sitting meditation* is explored as a static FAM practise with an internal focus of attention. On the other hand, *mandala colouring* is explored as a non-static FAM practise with an external focus of attention. These are further detailed in the following sections.

2.1.2 Sitting Meditation: FAM with Internal Focus, Static

> *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, [135]), which has been extensively used in his MBSR program [135]. With roots in historical spiritual traditions, the practise of meditation has also been increasingly used in clinical settings and adopted by general population because of its significant benefits for physical and mental well-being when practised regularly [16, 40]. Meditation practises have been long explored in the fields of psychology and neuroscience, however, 'meditation' is generally used as an umbrella term encompassing a wide range of practises [189] that engage different psychological mechanisms and neural circuitries [168]. Therefore, in this thesis 'meditation' will refer to the practise of sitting meditation following a focused attention approach, and this review will focus on literature that uses a similar definition. That is, research investigating static, contemplative traditions.

Previous work in psychology and neuroscience has shown that the practise of FAM meditation enhances bodily awareness, as well as attention and emotion regulation [40, 261, 277]. In such work, bodily awareness refers to greater interoception (e.g. sensing visceral bodily sensations) [37, 83, 103], as well as perception of physical sensations (e.g. tactile sensitivity) [90, 145, 239]. Scholars in psychology and neuroscience have defined meditation as a dynamic process that consists of different stages [189] with distinct neurocorrelates [110, 189, 277]. Furthermore, research exploring the subjective experiences of meditation have suggested that different bodily sensations [145, 295] may emerge in each of these stages such as intention to begin, grounding or mind-wandering moments , although work in this area is rather limited (e.g. pilot study investigating the experiences associated with mind-wandering [203].

Nevertheless, learning to meditate can be challenging as it is a subjective experience and the traditional guidance is often rather generic. In this regard, a growing number of technologies have been designed with the aim of facilitating the practise of meditation, ranging from consumer applications [174, 207] to interactive systems in HCI [252, 263]. On the one hand, many commercial apps scaffold the integration of meditation as a regular daily practise, albeit they merely provide non-interactive audio-visual guidance which limitedly accounts for user's real-time performance [174, 207]. 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 [212, 150] or attention [230, 223]. Still, the role of the human body in such designs has been limitedly explored [181], as the body has been mainly used to record physiological signals (e.g. EDA [223], breathing [212], EEG [230]) which were further mapped onto creative audio-visual feedback. Although less explored, the tangible interaction approach to support meditation has also started to receive attention in HCI [223, 252, 267].

Yet, most of this work is still limited to augmenting applications for smartphones with external objects of attention, for instance, by providing real natural elements in the interaction such as a water-based interface [282] or drawing from traditional meditation tangible aids such as praying wheels [287].

2.1.3 Mandala colouring: FAM with External Focus, Non-static

> "*I sketched every morning in a notebook a small circular drawing, a mandala, which seemed to correspond to my inner situation at the time. With the help of these drawings I could observe my psychic transformations from day to day. Only gradually did I discover what the mandala really is: 'Formation, Transformation, Eternal Mind's eternal recreation.' (Faust, II). My mandalas were cryptograms in which I saw the self–that is, my whole being–actively at work. To be sure, at first I could only dimly understand them; but they seemed to me highly significant, and I guarded them like precious pearls.*" – C. G. Jung (page 107, The Red Book)

The psychotherapist Carl G. Jung was the first to bring the practise of creating mandala images into psychotherapy as an aid to focus on the self and the present moment, as exemplified in the quote above. With its origins in Eastern spiritual traditions [273], mandalas have been widely adopted by psychotherapists to cultivate self-awareness and improve mental well-being through mindfulness-based art therapy [182, 142]. In Buddhist traditions, mandalas are used both as a process and symbols to convey wholeness and harmony: always starting from a central point, mandalas build up in circular layers representing the universe [13]. Their geometry represents symbolic aspects of harmony, wholeness, and the self [273].

Mandalas were brought to the Western culture and therapeutic context by Carl Jung [251], whose work suggested that the structure of mandalas facilitates focused attention and meditative states, as well as their benefits for mental well-being [144]. As a result, mandalas have been extensively used in art therapy for processing emotional experiences [142], expressed either consciously or unconsciously through the art materials [184], the way they are applied [167], and the use of colours [142]. Indeed, the coloured mandalas embody subtleties, and layers of expression which may be difficult to articulate through words [173]. Nevertheless, similar to other somatic practises, the evaluation of mandala colouring's impact on well-being and mental health has been limited; probably due to the traditional Western mind-body dichotomy still dominating cognitive sciences [103]. Efforts to capture such impact have started to emerge within art therapy as an aid for relaxation [142], anxiety reduction [28, 44], improvement of negative mood [14], and mindfulness training [142].

Findings have shown that through the use of colours and the fine, slow and continuous movement of colouring within geometric structures, mandalas require focused attention to the present moment and disengagement from any other thoughts or emotions [44, 64]. In HCI, the art therapy and its affordances for self-expression and bringing attention to the present experience have been particularly explored with people experiencing communication difficulties [160] or living with dementia [146, 160], indicating benefits for their well-being. For instance, craft activities have been used to scaffold self-expression to support memories [235] and reminiscing in old age [233]. Despite its link to traditional practises such as mandala colouring, the exploration of self-expression through craft and arts in the context of mindfulness practises has been limited. Emerging work in both HCI and psychology [50, 147] have highlighted the importance of supporting digital mindfulness practises through expressive aesthetic experiences that are non-static and rely on external objects of attention [69, 296]. However, there is limited integration of embodied aesthetic experiences supporting self-expression in mindfulness training technologies as a means of monitoring and interpreting one's experience.

2.1.4 Section Summary

Mindfulness, understood as intentionally and non-judgmentally paying attention to the experiences arising in the present moment, can be trained through a wide variety of practises. Research from psychology and neuroscience has shown that the regular practise of mindfulness can have important benefits for mental and physical well-being. However, learning the key mindfulness skill of regulating one's attention is not trivial. Thus beginners tend to start with focused attention mindfulness practises, in which the individual trains sustained attention by concentrating on a single object of attention that can be either internal (e.g. a bodily sensation) or external (e.g. a tangible object). Furthermore, FAM practises can also be categorised based on the level of bodily movement involved. This section provides an overview of two FAM practises occupying two distinct yet very interesting spaces: sitting meditation as a static FAM with an internal object of attention, and mandala colouring as a non-static FAM practise with an external object of attention. Despite most HCI work has focused on the former (e.g. guided breathing meditation), the outlined benefits of FAM practises relying on fine movement mediated by tangible artefacts and self-expression open the design space for novel mindfulness technologies.

2.2 Mindfulness Interactive Technologies

Mindfulness is generally defined as a state of mind that actively brings one's attention, non-judgementally, to the unfolding experience in the present moment [137]. Both the benefits and challenges of mindfulness practises (detailed in section 2.2 below) have attracted a growing interest in HCI regarding the design and development of mindfulness-based technologies [252, 263]. This section covers a review of interactive technologies for mindfulness training (Figure 2.2), focusing on: the type of technology used, the way in which the mindfulness states were mapped onto the experience, and the modality of feedback employed.

2.2.1 Type of Technologies

The increasing interest in mindfulness technologies is grounded in a wealth of findings showing the important benefits of mindfulness practises for both mental [40, 47, 262] and physical health [134, 294]. This is reflected in the growing range of technologies supporting mindfulness training from commercial smartphone apps [69] to interactive systems [252, 263]; most of which are tailored to support focused attention practises, and often through guided meditation.

HCI research on focused attention practises for mindfulness training (further detailed in section 2.4 "Mindfulness practises for Mental Well-being" below) has looked at both external objects of attention such as tangible artefacts [239, 277], and internal ones associated with bodily responses such as heart rate [267, 296], electrodermal activity [247] or breathing patterns [277]. These have been mapped into generative soundscapes [230, 284] and elements in virtual environments [212, 223], to provide real-time feedback and support for the mindfulness practise.

Neurofeedback has also been explored for mindfulness training, although to a lesser extent. Such work leverages findings on neuro-correlates of mindfulness training [27, 154, 281], as well as advances in wearable BCI technologies [108, 187, 196] through which brain activity is used to represent changes in mindfulness states [219]. For example, systems such as Relaworld [150] and PsychicVR [4] use EEG data related to focused attention mindfulness training to control elements in virtual reality environments; while MeditAid [230] supports attention regulation in open monitoring through real-time, binaural beats-based feedback on mindfulness states.

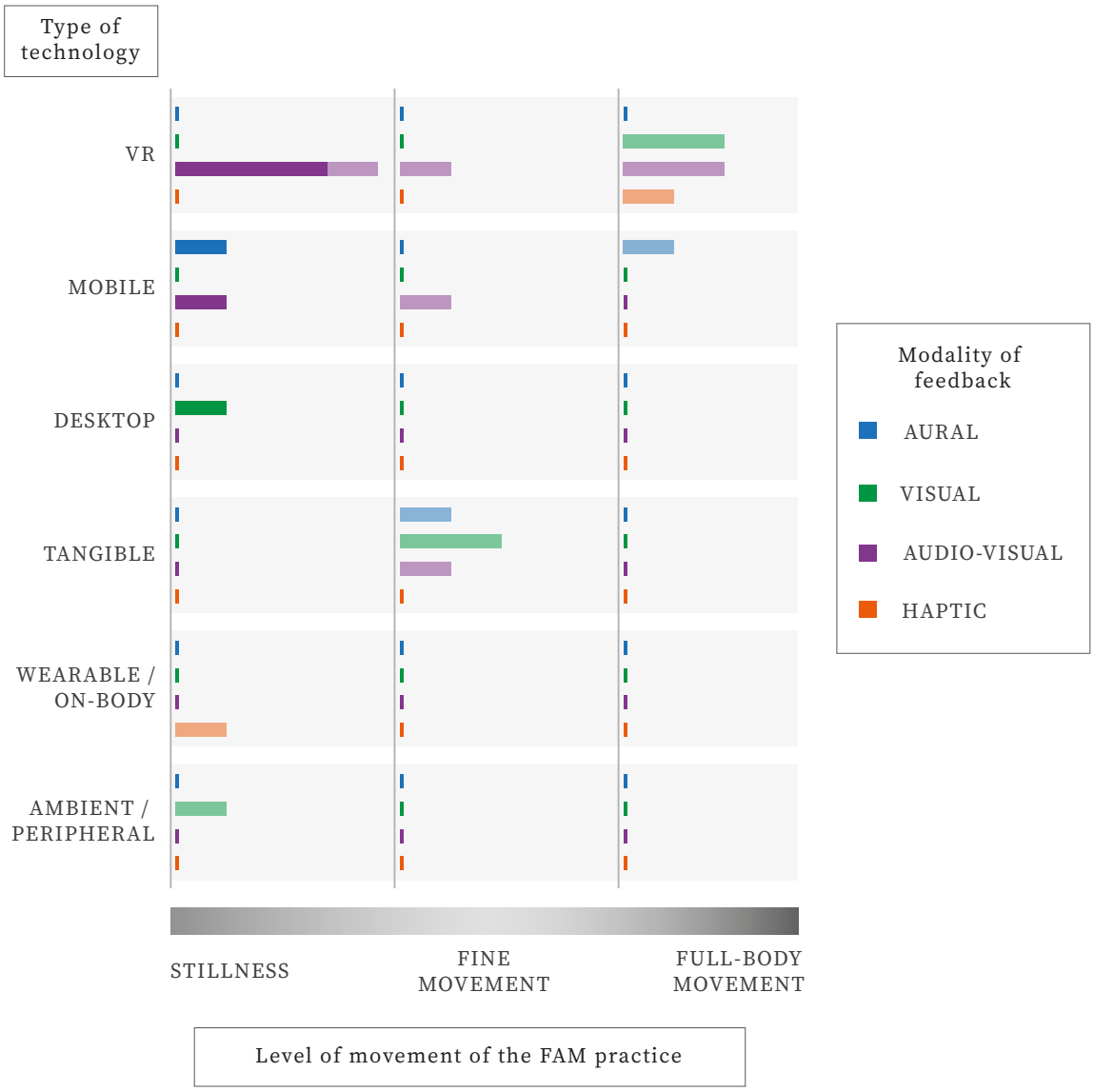


Figure 2.2: Summary of previous work on interactive systems facilitating FAM practices, mapped onto three dimensions: level of movement of the FAM practise, type of technology, and modality of feedback. All the systems reported use metaphorical representations of mindfulness states from biodata, those using brain activity data are represented with a solid colour [230, 127, 8, 150, 59, 55] and the rest are represented with a pastel colour [267, 287, 52, 98, 102, 125, 209, 223, 53, 89, 212, 282]

Emerging HCI work has also looked at tangible interfaces to enhance the embodiment aspects of mindfulness practises [145]. Examples in this space include PAUSE, a smartphone app for training mindfulness focused attention through the finger's gentle interaction with the touchscreen [52, 226]; or the Channel of Mindfulness [287] which, inspired by the Tibetan praying wheel, consists of a tangible add-on to the smartphone that needs to be kept spinning in a steady rhythm. Both these systems provide adaptive audio-based feedback for monitoring the practise based on the maintenance, or not, of a gentle and continuous movement on the smartphone's interface. Other examples of tangible technologies for mindfulness training are the Mindfulness Spheres [267], Inner Garden [223] or Mind Pool [164], which map physiological or brain signals into creative audio-visual outputs. Inner Garden [223], for example, provides two distinct interfaces with different feedback modalities to support the mindfulness training: a tangible augmented sandbox and an immersive virtual environment. However, the use of peripheral interfaces to simultaneously support distinct aspects of mindfulness has not been yet explored.

2.2.2 Mapping Mindfulness States

The review identified two classes of meditation technologies in relation to the mapping of mindfulness states. The largest of these classes consists of systems mirroring user's mindfulness states in real-time through *familiar representational metaphors* (e.g. nature-inspired) in visual or aural modality [8, 12, 55, 59]. In the other class, mindfulness states are mapped through abstract representations such as colour properties e.g. hue [210] or opacity [150, 210], as well as spatial metaphors e.g. low vs high pitch binaural beats [230] and central vs peripheral position [127].

The other class of technologies explored by HCI scholars map mindfulness states through *abstract representations*. Examples of visual metaphors mapping mindfulness vs mindlessness include those using colour properties such as hue or opacity [284, 210]. Auditory metaphors in this space include for instance those using low vs high pitch binaural beats to represent mindfulness vs mindlessness states [230], while spatial metaphors can take the form of location within shapes like a spiral where the centre of a spiral represents mindfulness and the periphery represents mindlessness [127].

As illustrated above, a common characteristic of neurofeedback-based mindfulness technologies shared by both these classes is the reliance on polarity to represent the two distinct mindfulness states: being mindful vs mind-wandering. Another important characteristic of most mindfulness technologies is the common use of external visual or aural interfaces for mapping the metaphorical representations of the two key mindfulness states. However, this can be problematic given the importance of paying attention to and regulating one's bodily sensations arising during the mindfulness practise, which is key for this embodied practise [67, 145, 203].

Alternative modalities that can support internal representations of mindfulness states have been less explored. A good candidate here are haptic interfaces. Indeed, findings shown that haptic biofeedback could support awareness of internal bodily experiences, also called interoception , and in turn the self-regulation of internal processes [81].

While HCI work on haptic feedback for mindfulness technologies is limited [41, 181], useful related work has explored vibro-tactile and thermal biofeedback for emotional awareness and regulation [2, 276]. In this respect, findings indicate that the inherent affective quality of thermal sensations is reflected in abstract and subtle of thermal feedback [132]. A landmark example is SomaMat [115], which uses directed heat stimuli during Feldenkrais exercises [175] to subtly facilitate sustaining attention on different body parts while laying down. Its evaluation indicates the subjectivity of heat experience in terms of sensitivity and aesthetic appreciation, as well as heat's "potential to permeate the skin and be perceived inside the body" (p. 114, [112]) helping some participants bring their attention back to the body from mind wandering. A more recent example is ThermalWear [77], an on-body interface that augments affective voice messages using thermal stimuli on the chest. They found that although cold stimuli were easier to perceive than warmth, participants found it to be very intense and less comfortable than warmth. Another example is the heating band reflecting changes in physiological arousal through increase in heat, with findings indicating that heat pads are subtle, less responsive and inertious hence better suited to signal the lingering quality of an emotional response subsiding [264, 288].

In these examples, findings suggest that thermal haptic feedback is perceived as a pleasurable, yet subtle and unobtrusive form of feedback in which warmth is mapped to positive and nice sensations, and cold is the opposite. To conclude, most work on mindfulness technologies has focused on either abstract or representational metaphors of both mindfulness and mindlessness states, predominantly through external visual or aural stimuli. In contrast, limited work has explored the metaphorical mapping of mindfulness states on internal stimuli e.g. through thermal actuators and their potential to support mindfulness practises, given their subtle and pleasurable qualities.

2.2.3 Section Summary

To conclude, most work on interactive technologies aiming to support focused attention mindfulness practises has focused on static and external objects of attention. And there has been very limited explorations of other spaces in this context, for instance, practises that are non-static and/or with internal objects of attention. Therefore, 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 practise [145], the way in which feedback could actuate directly onto the body to facilitate the meditation experience has been little explored. Most work on mindfulness technologies has focused on either abstract or representational metaphors of both being mindful and mind-wandering states, predominantly through external audiovisual stimuli. In contrast, limited work has explored the metaphorical mapping of meditation states with distinct modalities of feedback that may enhance different human senses during focused attention mindfulness practises with internal stimuli; for instance through thermal actuators and their potential to support meditation, given their subtle and pleasurable qualities. 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 multimodal feedback to support a wider variety of focused attention mindfulness practises.

2.3 Embodied Metaphor Designs 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. For instance, Somaesthetics designs position the body at the centre of the user experience, cultivating an aesthetic appreciation of the bodily experience through guided attention inwards [115, 248]. These designs tend to build upon first-person practises in order to design from and for the experience of the self [259], by acknowledging the importance of embodiment in the sense-making of experience [195]. An example from this body of work is the Soma Mat [115], 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 [8, 11, 238]. For instance, such metaphors have been used for the design of tangible learning systems [18], to foster collaborative shared experiences [86], or to support the self-regulation of attention and affect [12, 141]. Most recently, materials such as thermochromic ink or shape memory alloys 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 [276]. Nevertheless, the exploration of the affordances of different materials' qualities to enhance the understanding of abstract subjective embodied experiences has been limited.

Metaphors have a rich history in HCI [29] from supporting designers research unfamiliar topics or get inspired by novel associations, to communicate their ideas [225] and ultimately the mental model of systems to users [48]. The theory of conceptual metaphor that builds on the embodiment tenet according to which bodily perception, movement, and experience of the physical world (including gravity and force dynamics) underpin our conceptual and abstract thinking [156]. When such bodily experiences across a range of scenarios get structured as recurrent patterns, they become image or embodied schemata [128].

The grounding in sensory-motor experiences makes image schemata multimodal, which means that they can also be represented in different modalities, the most researched ones being aural, visual, and haptic. Lakoff [156] argued that embodied schemata support abstract thinking, as people build metaphors that extend schemata from the physical to the abstract domain, such as Better is Up, Worse is Down [158]. Metaphors that extend image schemata are called embodied metaphors [11] and emerge through repeated connections of their image schemata with the subjective judgements of the respective abstract domains such as affect or morality [120].

Regarding their qualities, image schemas and embodied metaphors tend to be intuitive [120] or easily understood, often without the need for words [169]. This quality has been linked to the discoverability of the underpinning mapping of the image schema [169, 225] which can be represented in different modalities. However, some are more ambiguous than others depending on the content being mapped from the source to the target domain [120]. Hence, a main challenge of designing with embodied metaphors is identifying the best content to be mapped and the instantiation of embodied schemata [120]. Among different classifications of metaphors, those relevant for HCI include a distinction between orientational or spatial metaphors emphasising bodily orientation through space and time: up-down, front-back, near-far, left-right, and ontological ones underpinned by bodily interactions with physical objects, i.e. desktop metaphor, that can be used to communicate abstract concepts in terms of physical ones [155]. Previous work has suggested that spatial embodied metaphors may be easier to understand [9], particularly those organised along the vertical axis to map abstract concepts such as emotions, although limited empirical work has explored this.

2.3.1 Embodied Metaphors in Tangible Interaction

Apart from the theoretical work outlined above, much of the HCI applied work on embodied metaphors took place in tangible interaction research, for instance to explore the bodily understanding of intangible and / or unfamiliar concepts such as music [10] or food production[169]. Antle and colleagues [10] built Sound Maker, an interactive learning environment integrating camera vision system to capture movement with percussive audio output.

The system was explored by 7-10 year old children to enact in pairs bodily movements in order to manipulate three abstract sound concepts generated by the Sound Maker: volume, tempo and pitch through both embodied metaphors (i.e. volume was mapped to activity reflected in moving arms, stomping feet through more is loud and less is quite) and non-embodied metaphors (i.e. volume was mapped to proximity to each other through near is loud and far is quiet). In their tasks, children had to understand changes in the parameter and how to control these changes through movement. Authors expected that the embodied mapping was more intuitive or easily understood compared to non-embodied one which would require learning, and indeed they found that the former led to more accurate movement enactment for controlling the three abstract concepts through the interface; and that children could better demonstrate through movement than verbalise their mapping between movement and sound concept . In order to identify the movement qualities that best map each of the abstract sound concepts, authors interviewed experts and selected movements that could be easily recorded, and for each experts agreed on.

Experts also confirmed the mapping polarity [11] through the distinct movements for the two levels of the abstract concepts, i.e. more activity for high volume vs less activity for quiet volume. Antle and colleagues [10] targeted the Music is Body Movement as an ontological metaphor: "abstract concept as something concrete and physical: object, person, body, or substance in the environment" [p 180] assuming its benefits over orientational ones. While the latter was acknowledged for their value in interpreting music and its emotional impact, the conceptual understanding of music and its abstractions appeared more relevant to the former type of metaphor. Findings indicated however children's inclination for initial reliance on spatial behaviour to explore the physical environment of the speakers before enacting the ontological metaphor, suggesting that potentially orientational metaphors may precede ontological ones for new learning activities. Sound Maker employed only one embodied metaphor for each sound concept, while children appear to have more than one.

In a subsequent study [19] authors have looked at 7-9 year old children's understanding of 8 abstract sound concept including beside volume, tempo and pitch, also rhythm, timbre, harmony, articulation, tone duration. In this study, rather than eliciting the mapping from experts and design them in the interactive Sound Maker system, authors played sound samples reflecting significant changes of one of the abstract sound concepts, and asked children to first verbalise and then enact them through both full body movement and the use of a flexible plastic ring as a tangible artefact. Findings indicate that children enacted a range of movements to represent changes in these concepts underpinned mostly by ontological metaphor Music is Body Movement (i.e., tempo is linked through slow-fast schemata; rhythm to structured-chaotic schemata) and to some degree by the orientational metaphor, underpinned by up-down embodied schemata (i.e., for pitch). Most concepts were linked to more than one metaphor and schemata, albeit children did enact fewer metaphors for the concepts they have not yet experientially understood such as articulation. Timbre also was challenging, most likely because it cannot be described in terms as polarity or by two opposites like for instance high vs low volume; which in turn may makes it less suitable to be understood through metaphors.

Another interesting exploration of embodied metaphor is Springboad, a whole body system integrating camera vision which maps users' position in space and its balance to sets of two images depicting different states of environment preservation and food production [3]. Authors explored the impact of three input-control mappings on usability, engagement an intuitiveness: metaphoric mapping, i.e., twin-pan and point balance with balance achieved in the middle position, isomorphic mapping, i.e., two triangle areas, one for each image, whose vertical height represents the abstract amount it its counterpart image, with balance achieved in the centre of triangle, and conventional mapping, i.e., circular path whose different points mapped to different images, and balance achieved at 6 o'clock. Findings indicate that metaphoric mapping supported performance, but lacked discoverability so people may have understood it at subconscious level but probably without forming an explicit understanding of it.

2.3.2 Section Summary

To conclude, most HCI work on embodied metaphors emphasised their support for intuitive understanding of abstract concepts such as sound concepts or social justice through bodily movement. Such work highlighted metaphors' qualities such as polarity and easier enactment than verbalisation. The embodied metaphors were elicited from both experts or users to discover the best physical movements representing abstract concepts, and evaluated through studies where the enactment of movement was used to control changes in abstract concepts represented through sound or images.

There has been however less exploration of the different modalities for the same abstract concepts including those about interoceptive senses such as thermoception. Moreover, tangible interaction work on embodied metaphors explored the physical to abstract mapping, with image schemata usually enacted through bodily movement. The exploration of embodied metaphors in mindfulness technologies unpacked metaphors highlighting the body to mind mappings that link bodily experiences to one's mental states instead of abstract concepts [8], enacted though attention regulation to external or internal stimuli. The aim of the two domains are different: body and movement to interact with tangible artefacts vs to train attention regulation. Hence, metaphors' properties such as polarity, multimodality [120], and discoverability [11] could play different roles in other classes of technologies such as those challenging habits, supporting reflection [118] or in our case, supporting mindfulness training.

Chapter 3

Methodology

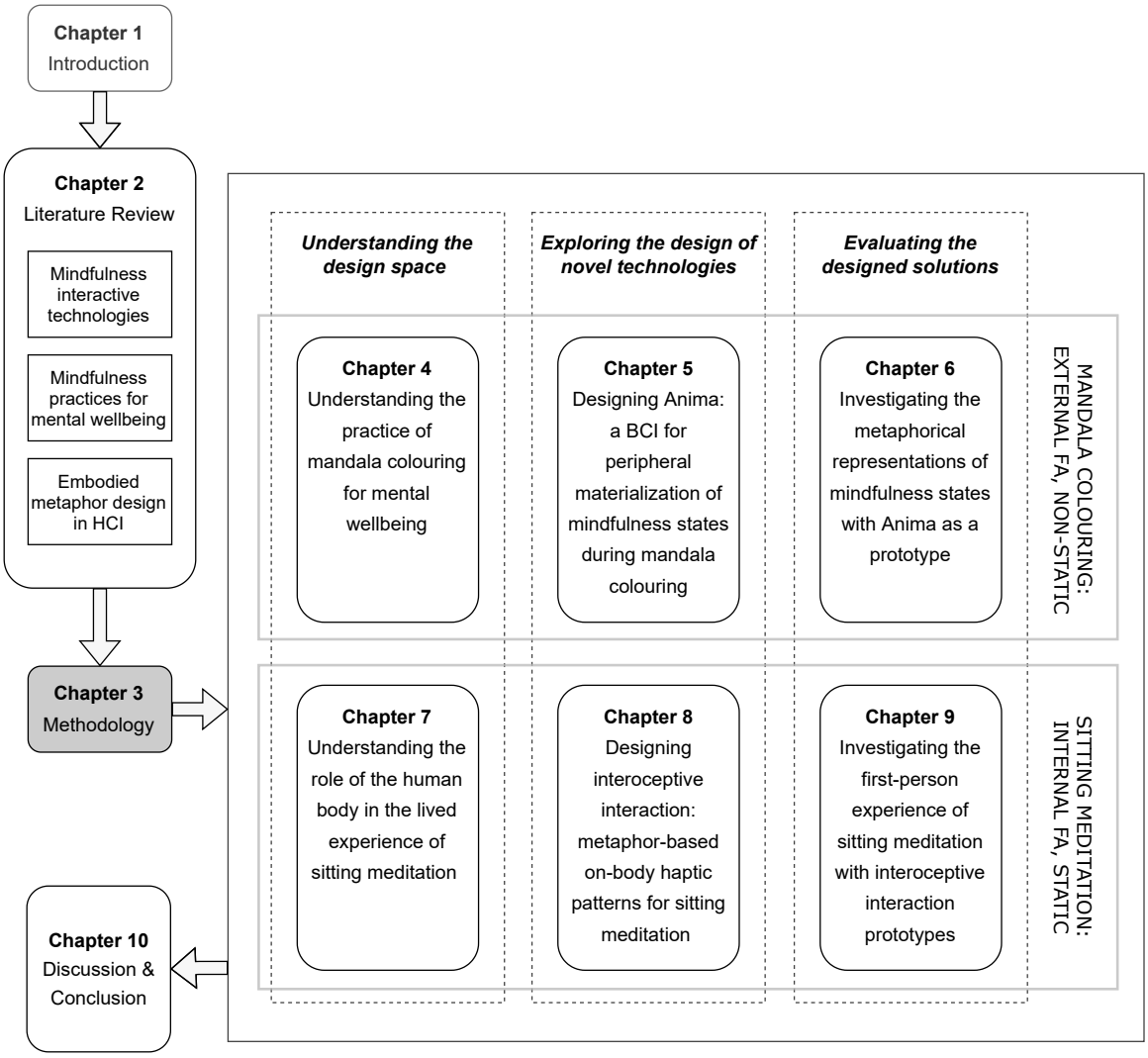


Figure 3.1: Chapter 3 of Thesis structure

3.1 Introduction

The methodology adopted for this thesis is a human-centred design approach to explore, design and evaluate embodied mindfulness-based technologies for mental well-being placing personal experiences at the centre. First, to understand the design space, auto-ethnography, interviews and material speculation methods were employed. Then, to explore the design of novel technologies based on the highlights of the initial studies, a prototype for mandala colouring and two prototypes for sitting meditations were developed following iterative design methods. Finally, the experiential qualities of the prototypes were evaluated through participatory workshops, user studies and auto-ethnography methods.

This chapter provides an overview of human-centred design and first-person research methods; and then describes the specific methods employed in the research presented in this thesis, together with the rationale behind each choice.

3.2 Human-Centred Design

Human-centred design (HCD) is an approach to systems design and development that carefully identifies stakeholders and contexts of use by applying creative processes [96, 152]: "*human centred design is based on the use of techniques which communicate, interact, empathise and stimulate the people involved, obtaining an understanding of their needs, desires and experiences which often transcends that which the people themselves actually realised*" ([96], p610). Similar to user-centred design (UCD) [1, 218], both approaches are focused on providing the end user with a design that is highly usable and accessible for them. However, UCD and HCD's methodologies differ slightly: user-centred design tends to focus primarily on the tangible ways users interact with a system [1, 218], whereas human-centred design also incorporates more intrinsic motivations such as emotional or psychological preferences [96, 152].

The most frequently deployed HCD tools and methods [172] can be organised in three main categories, along temporal dimension. The first category is based on whether the technique involves historical data, such as cognitive, psychological or emotional data sets and models. The second category consists the tools used to capture needs, desires and meanings, both verbally (e.g. interviews, metaphor elicitation, or focus groups) and non-verbally (e.g. technological probes, physiological measures, or material speculation). The third category includes techniques used to simulate possible futures (e.g. co-design workshops, experience prototypes). These methods have been used in a variety of contexts, particularly regarding research with a number of complex and interrelated factors such as designing for well-being and healthcare [24, 21].

3.3 First-Person Research Methods

In HCI, first-person research methods provide a deep understanding of the interplay between people and technology by investigating the embodied and felt-like experience of designing and living with the technological system [115]. This embodied approach to interaction was brought to the forefront with the third wave in HCI [33], which acknowledges the importance of the embodiment in the sense-making of the experience. Generally, first-person research methods tend to focus on exploring the tacit experience of the designer and/or the users.

When first-person research methods are used by the *designer* can provide a rich and in-depth understanding of the tacit experience designing for. In turn, this reflective approach supports an empathetic understanding of the user's needs and motivations, which generates design insights difficult to reach otherwise. In this context, designers and HCI researchers commonly employ autobiographical methods [190] such as autoethnography [63] and somaesthetics [112].

Autobiographical design is also commonly employed to explore the first-person experience of *users*. Therefore, researchers can gain an in-depth understanding not only of the user's experience using the system, but also capture the nuances and complexities around such subjective experiences. Common participatory methods employed in HCI to tap onto user's first-person experience include phenomenological approaches [92, 211], as well as embodied practices to facilitate the exploration of abstract or unfamiliar concepts such as somaesthetics [112] or material speculation [6].

3.3.1 Semi-structured Interviews

Interviews are an umbrella term for qualitative methods that aim to gain in-depth knowledge about specific experiences, opinions and perceptions on a particular idea, by having focused conversations with participants [72, 30]. The questions asked by the interviewer require to be specific while remaining open-ended enough to construct a complete picture of their views on the research topic.

There are three main interview formats: structured, semi-structured, un-structured. On the one hand, structured interviews are conducted following a set of questions in a specific order that are delivered equally to all interviewees [214]. Thus answers can be reliably aggregated and enables researchers to compare them among participants with confidence. On the other hand, un-structured interviews do not have a pre-arranged set of questions, hence tend to be more flexible and free-flowing than a structured interview [72, 214].

The qualitative data collected tends to be richer and more detailed than the answers from structured interviews, however, the data analysis is more time-consuming. Semi-structured interviews provide a hybrid approach in which an interview guideline is prepared, but additional questions to ask for clarification and to allow the interviewee to talk in more depth are also considered [165, 93].

3.3.2 Autoethnography

Autoethnography is a qualitative research method that aims to describe and analyse personal lived experiences [78]. This method allow researchers to observe and describe their reality by producing reflexive first-person recounts of their experiences. Therefore, autoethnographies are generally reported as stories and narrated in the first person [76]. With epistemological roots in social sciences, autoethnography has also been widely used in HCI when a deep understanding of one's experience is critical to inform the design or evaluation of a technology [216, 73]. Examples include research on usage of interactive systems [280, 197] and exploring non-technological experiences [113, 206].

3.3.3 Somaesthetics

Somaesthetics is grounded in pragmatists philosophy and phenomenology, and offers an overarching conceptual framework and methods to better understand our somatic experience and to improve body consciousness [248]. This approach encompasses an integrative structure encompassing discourses from different fields, as well as a pragmatic orientation to improve the somatic practice being directed primarily at the individual practitioner or at others.

In HCI, somaesthetics methods have been increasingly used to intimately explore the interaction between humans and our bodies with technology. For instance, Somaesthetic Appreciation design focuses on facilitating the articulation and discrimination of different bodily experiences, promoting body awareness [114]. The qualities that allow for this process to unfold are: subtle guidance, making space for reflection, feedback and interactions need to follow the rhythm of the body, and providing means to articulate the experienced bodily sensations [114, 112].

3.3.4 Participatory Design Workshops

Participatory design methods actively involve the users in the design process to ensure the result meets their needs through a progressive refinement of prototypes [242, 34]. A very common approach in participatory design are workshops to engage users in different states of the design process, from requirements gathering to the implementation and evaluation of a design solution.

In the initial stages of the design process, participatory design workshops typically involve co-creating solutions with stakeholders. For instance, Andersen proposes workshops in which technology is treated as a 'magical unknown' to foster the exploration of ideas from a new perspective, by asking participants to build Magic Machines that answer a research question [6]. These workshops have been particularly used to explore abstract concepts with experts, such as creating novel sounds with musicians, and facilitate the expression of personal experiences through an embodied process of making.

To inform the implementation and evaluate current design solutions, participatory design workshops commonly involve the use of prototypes enabling designers and stakeholders to iteratively reflect on the designed solutions [162]. In this context, Lim et al. describe prototypes as "*filters intended to traverse and sift through a design space and as manifestations of design ideas that concretise and externalise conceptual ideas*" (P3).

3.4 Methodological Approach in this Thesis

The research paradigm for this thesis is interpretative and consists of 7 studies which can be categorised in three sections: understanding the design space, exploring the design of novel technologies, and evaluating the designed solutions. One of the primary goals of the work presented in this Thesis was to investigate the lived and personal experiences of different mindfulness practices with experts, novices and myself (the researcher).

First, semi-structured interviews allow me to explore the lived experience and perceptions around specific aspects of mindfulness practices with participants, in a methodical yet open manner. In Chapter 4 I use semi-structured interviews to understand the practice of mandala colouring with experts, and in Chapter 7 the practice of meditation with experts in different traditions; and in Chapter 9 I employ semi-structured interviews to explore the first-person experience of using the WarmMind prototype, both with novices and experts in meditation.

Second, I carefully selected two methods to explore myself the first-person experience I was investigating. This was important to gain a deeper understanding of the design space and to explore the design of novel technologies in a meaningful way.

Therefore, I followed an autoethnography approach to gain first-hand insight on the state of the art technology (i.e. smartphone apps) for mandala colouring (Chapter 4) and meditation (Chapter 7). And I employed somaesthetics methods to explore using warmth-based patterns in the upper body to communicate mindfulness states, for the design of the WarmMind prototype (Chapter 8).

Finally, I used different methods of participatory design workshops, which provided tailored outcomes for two distinct phases of this research. On the one hand, prototypes were used in participatory design workshops to evaluate the design solutions for augmenting mandala colouring with Anima (Chapter 6) and sitting meditation with WarmMind (Chapter 9) prototypes. On the other hand, participatory design workshops inspired by the Making Magic Machines [6] methodology were used to explore abstract concepts that are otherwise difficult to tap on and communicate, even with other methods such as interviews [203]. That is, to explore the bodily sensations that arise during meditation (Chapter 7).

3.5 Chapter summary

This chapter presented an overview of the methodological approach used in this thesis, detailing the specific research methods for each study. As shown in Figure 3.1, results from understanding the design space for mandala colouring (Chapter 4) and sitting meditation (Chapter 7), informed the design of novel embodied technologies to support non-static and external (Chapter 5) as well as static and internal (Chapter 8) FAM practices. Lastly, the initial evaluation of the working exemplar prototypes of the designed solutions are reported on Chapter 6 and Chapter 9. The detailed descriptions of each study are further outlined in the Research Method sections in the relevant chapters (Chapters 4-9).

Chapter 4

Understanding the Practice of Mandala Colouring for Mental Well-being

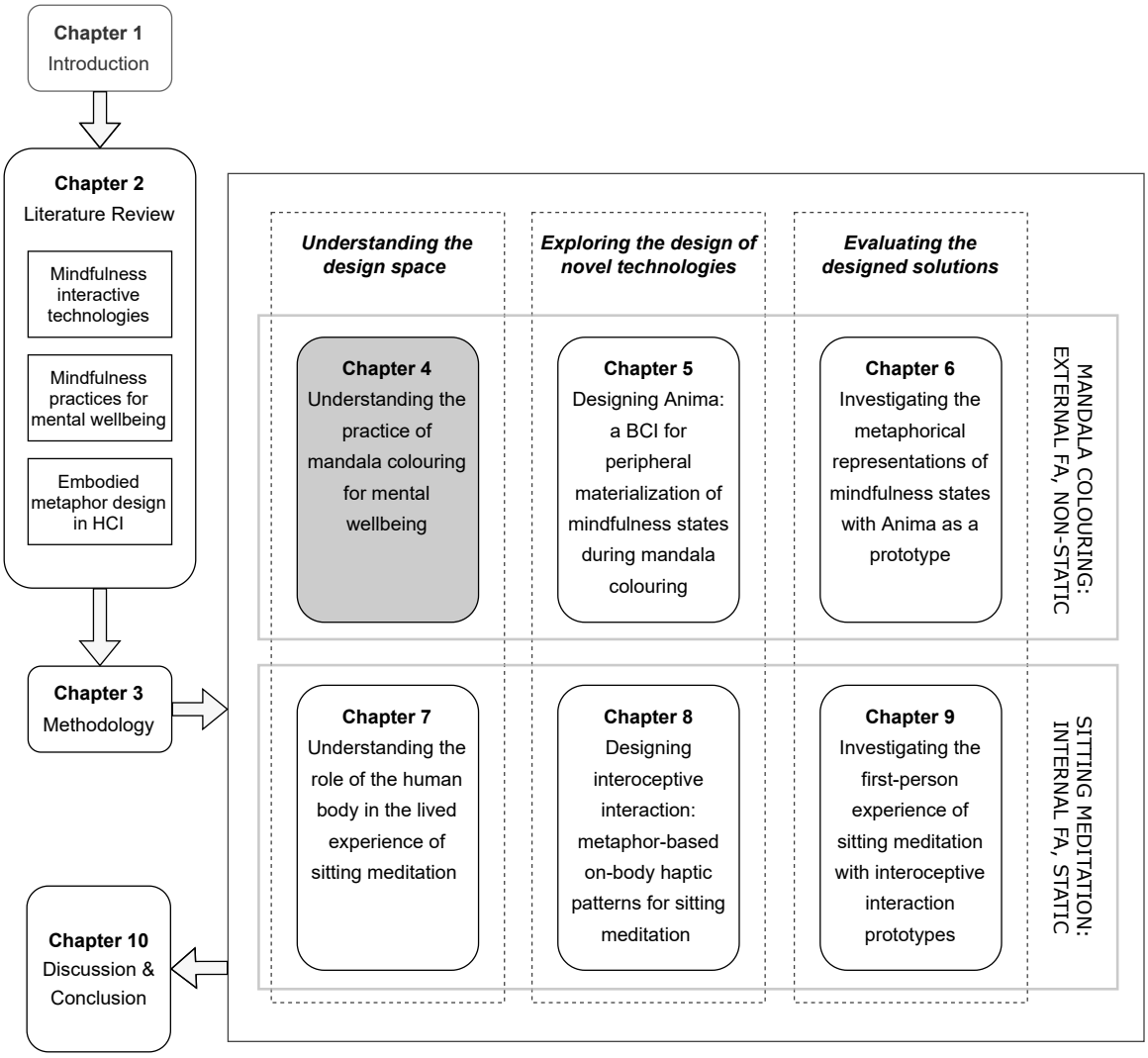


Figure 4.1: Chapter 4 of Thesis structure

4.1 Introduction

Colouring books geared towards adults have been particularly in demand for the last five years, with 12 million copies being sold in the U.S. alone in 2015 [193]. Adult colouring books are generally filled with a wide variety of black-and-white illustrations from pop culture to nature-based or abstract patterns, usually with the goal of reducing daily life stress [245]. This trend, however, seems to have its origins in the artistic mindfulness practice of mandala colouring, which has been used in spiritual [107] and clinical [88, 144] practices to slow down and bring the attention to the self. The creation of mandalas requires intense focus and attention to the present moment, which are key components of mindfulness [17, 40, 144].

This chapter investigates the practice of mandala colouring (Figure 4.2) to inform the design of novel expressive and movement-based mindfulness technologies. The two studies presented build on each other and intended to gain a better understanding of the main qualities of mandala colouring, as well as how technologies for mental well-being and mindfulness training can support and benefit from these qualities. The first study explores the motivations, context, and properties of mandala colouring, by interviewing 21 people who had been colouring mandalas for at least one year prior to the study. In the second study, the aim was to investigate the digital affordances for mandala colouring that these apps provide, and how such apps support the main qualities of mandala colouring that we have found from literature and from the first study. For that reason, we evaluated the most downloaded free colouring mandala apps for iPhone and evaluated them using auto-ethnographic and heuristic methods. Finally, I discuss opportunities for the HCI community to leverage fine movements, imperfections and metaphorical representations of mindfulness states when designing for focused attention mindfulness systems with an external object of attention.

Figure 4.2: One participant's illustration of mandala colouring process: starting from the centre with the desired colour, here felt tip (left), colouring in each concentric layer (middle), and partially completed mandala at the end of the session (right).

4.2 Interview Study with Experts

In this study, we explored the practice of colouring in mandalas as an illustration of movement-based mindfulness training (Figure 4.2). Mandala colouring has been explored mostly in Psychology as a task with non-experts to evaluate its impact on well-being [215, 44, 64]. Our work provides a fresh, complimentary perspective by qualitatively exploring mandala colouring as an intrinsically motivated practice with long term practicants. We report on interviews with 21 people who had been regularly colouring mandalas for at least one year prior to the study, with the aim to draw novel design inspiration for mental well-being technologies. In particular, we focused on the following research questions:

- What are the motivations, benefits, and challenges of engaging in mandala colouring practice?
- In what spatio-temporal context is mandala colouring practised?
- What materials and actions are key in mandala colouring?
- What physical and digital affordances support or hinder mandala colouring practice?

4.2.1 Research Method

The aim of our interview study was to explore the practice of mandala colouring and how this may inform the design of movement-based mindfulness technologies. We report on an interview study, partly completed online and partly face-to-face, with 21 participants. In this study we refer to them as practicants, since according to the inclusion criteria, they have been colouring mandalas regularly i.e. for at least once per month for a year prior to the study commencement.

4.2.1.1 Participants

We employed purposeful sampling [198] and recruited participants both by advertising the study in social media dedicated to mandala colouring (i.e. Instagram and Facebook pages and groups), and locally via the University's mailing lists and posters in campus and the city. Everyone who responded and met the inclusion criteria of having colouring mandalas at least once per month for the last year, was included in the study. In total, 21 people participated in the study, with 11 interviews completed online and 10 face-to-face. The latter were compensated with a 10 worth Amazon voucher as they had to commute to University to participate in the study, which also took longer due to the in-lab session of mandala colouring.

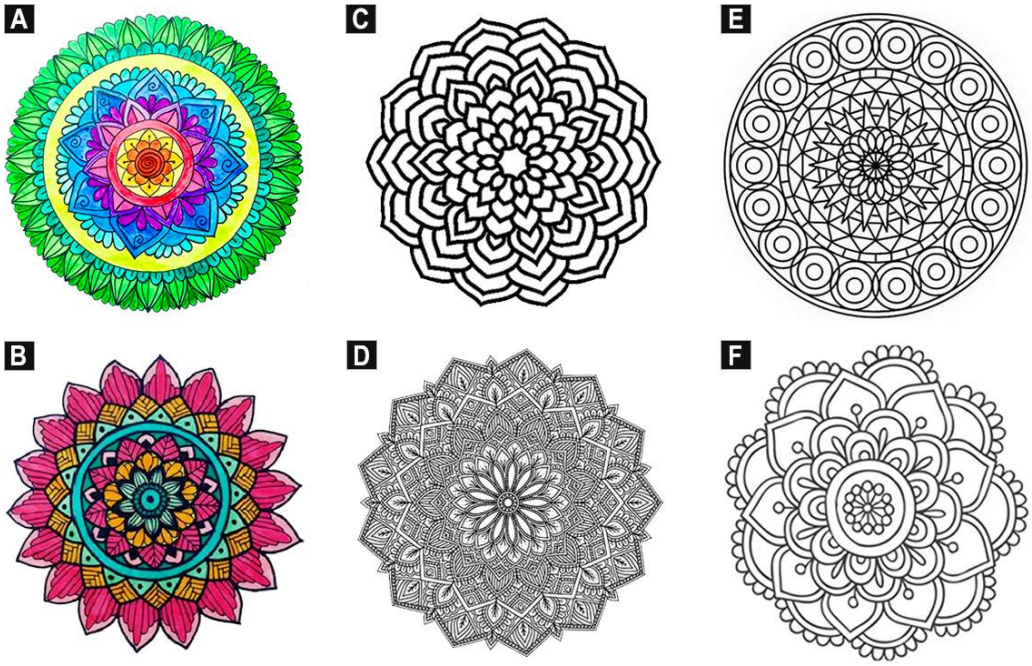


Figure 4.3: Mandalas coloured by our participants from the online interviews P5 (A) and P4 (B), and the choice of four distinct mandalas to colour in the face-to-face interviews (C-F).

From the total of 21 participants, 4 had over one-year experience of practising mandala colouring, 14 between 1 and 5 years, and 3 over 5 years (Mean = 3.3 years, SD = 2.9), and none reported discontinuing the practice at any time. All participants also described how mandala colouring is their regular self-care ritual: 15 reported colouring mandalas several times per week, and 6 several times a month. In terms of demographics, 12 participants were between 16 and 25 years old, 3 between the ages of 26 and 35, 3 between 46 and 55, and 3 were over 55 years old (Mean = 31.5, SD = 14.7). All 21 participants identified themselves as women, and regarding occupation 13 were students, 5 clerk workers, and 3 support workers. Interestingly, three participants (P16, P18, P19) did not only practice mandala colouring for themselves, but they also regularly used mandalas as healthcare professionals, as a tool for training mindfulness and enhancing mental well-being of their clients.

4.2.1.2 Study Design

We now describe the study design, which consisted on three distinct parts to better delve into their personal experience and understanding of mandala colouring: (1) investigating the process of selecting a mandala geometric pattern to colour in, (2) colouring a mandala, and (3) exploring the participant's view on mandala colouring. Parts 1 and 2 of the study were intended to bring the practice forward to be explored further in depth during the semi-structured interviews in Part 3. As not all participants could attend face-to-face, the part two of the study was modified to fit both online and face-to-face participants, as detailed below.

Part 1: Selecting a mandala geometry to colour in. The main goal of this task was to bring the participants into the space of mandala colouring by firstly exploring their process of choosing a mandala to colour in. Therefore, we provided them with a choice of 4 mandalas (Figure 4.3, mandalas C-F) with distinct geometric characteristics (e.g. sharp versus rounded edges, thinner versus thicker outlines, distinct size and amount of details). Whilst they were choosing which mandala they would prefer to colour in, we encouraged them to verbalise their thought process. Therefore, we asked them questions about the differences between the mandalas such as: What do you like the most about each mandala and why? What do you like the least about each mandala and why? Which mandala would you like to colour in?.

Part 2: colouring in a mandala. For the face-to-face participants, we asked them to colour their preferred mandala from Part 1 either with the art materials provided (i.e. colour pencils and felt tips). The colouring session lasted between 20 and 30 minutes [64, 215, 44], 25 minutes on average, and the process was photographed (Figure 4.2 shows a mandala being coloured by P14). For the online participants, as we could not provide them with a physical copy of their chosen mandala form Part 1, we asked them to colour one of their mandalas and send us a photo of it once finished (Figure 4.3, mandalas A and B). In this way, we ensured that participants had a recent lived experience of mandala colouring prior to the interview study, despite it being in a lab setting rather than their regular space and context of practice. Furthermore, it allowed us to observe their colouring process and refine the questions of the semi-structured interviews based on their personal practice.

Part 3: Personal experience of mandala colouring. Finally, we employed semi-structured interviews which included questions about the practicants' understanding of mandalas, their benefits, and challenges: *Which is your motivation for this practice? What benefits does it have for you? Do you perceive any challenges associated with it?, as well as their experience and context of practice: Where and when do you usually colour mandalas?.* We also enquired about the process itself, from preparing for colouring to finishing a mandala: *How do you choose which materials and colours to use?, What happens if you make a mistake?, What do you do when you finish and why?.* Lastly, we explored the role of current technology in mandala colouring:

Have you ever used an app for colouring in mandalas? If so, what did you like and dislike? If not, why not? How do you perceive the role of technology in this practice?. All interviews lasted between 20 and 60 minutes (Mean = 30 minutes), were audio-recorded and fully transcribed.

4.2.1.3 Data Analysis

Interviews were fully transcribed and analysed following an iterative and hybrid approach to coding [85], drawing upon a conceptual framework and its informed deductive codes. Codes from previous work included concepts such as materials and colours for self-expression, and the object of focused attention during the practice. The coding scheme was refined as new codes emerged from the interview data such as the significance of imperfections, qualities of movement, and context of practice. The authors revised the coding scheme weekly for several months to ensure consensus.

4.2.2 Findings

The findings indicate three main themes including first-person perspectives into the motivations for engaging in mandala colouring practice, together with its main perceived benefits and challenges; the context of mandala practice; and colouring - as a progressive emotional expression. These are further described with examples from participants' quotes, together with the presentation of the value of mandalas both analogue and digitally.

4.2.2.1 Motivations for Engaging in Mandala colouring: well-being and Mindfulness

Findings indicate that people perceive mandala colouring as a self-care activity beneficial for their emotional well-being such as relaxing when stressed, and also for their mental health as a tool for depression or anxiety. These two reasons can be positioned on the ends of a continuum from well-being to mental health, with focused attention being key throughout.

Colouring Mandala for Emotional well-being. All participants mentioned the value of mandala colouring for emotional well-being as it allows to express themselves freely, and facilitates sense-making of their thoughts and experiences, as illustrated in the following quote: "*projecting something [you're feeling] into something so visual it's very helpful [. . .] it's almost as a projection of whatever it is that I'm feeling, so it kind of helps me understand and go through my thought process a little better*" (P14). As a result, the practice of colouring mandalas is for most interviewees a deep and highly personal activity, which they become attached to: *"the more you go through the process, the more you connect [with your emotions]*" (P15).

Another participant gave a more detailed account of this relationship, suggesting that mandalas offer a safe space to process feelings otherwise difficult to communicate, which in return requires nurturing: *"I'm expressing and processing that emotion that's stuck inside [...] the mandala is giving something to you because it's something beautiful that's there for you to work with, but then you are giving something back as well because you are colouring it"* (P18).

Colouring Mandala for Mental Health. A significant finding is that more than two-thirds of participants started colouring mandalas for mental health reasons. Unexpectedly, almost all explicitly mentioned starting this practice because of conditions such as stress (14 participants) or severe ones such as depression or anxiety (5 participants). In particular, two participants openly talked about their experience with depression. For example, P18 started with a therapist who encouraged to express herself through mandala colouring. Despite the initial resistance to disclose her negative emotions, mandala colouring became a recurrent activity providing a safe space for self-expression: *"once you start the process, then it can become something you can go to, it's like a support"* (P18). In her case, the process of colouring mandalas helped self-regulate emotions through expressive strategies like using different colours and materials that would fit her affective state.

From Expressing to Regulating Emotional States. Apart from expressing emotions, mandala colouring offers also the benefit of regulating emotions, for both well-being and emotional health purposes. Another important outcome is that participants' choice of materials and colours, and the ways in which they are used that relate to their emotional states. This indicates additional embodied ways of monitoring one's focused attention: *"if they are pressing really hard, they could be frustrated, or if they are doing it very delicately they might be calmer"* (P18). As shown by the findings, the choice of colours is particularly important serving two both emotional expression and emotional regulation. The former is supported by participants' choice of colours, so that they reflect their emotional states at the start of mandala colouring: *"it depends on what I'm feeling; I think if I'm mellower I'd probably choose blues or greens, whereas if I'm angrier would be reds and pinks"* (P14). This quote indicates the potential value of such coloured mandala to provide emotional information of how they felt at the time. Mandala colouring also supports emotion regulation [215, 142, 44] when participants choose colours not to express how they feel in the moment but how they would like to feel: *"if I had a bad day I would choose something really jolly and nice so that I could shed away all the stresses from the day"* (P15). Such outcome confirms findings on how mindfulness-based arts and expressive practices can support emotional regulation for decreasing symptoms of distress [215, 142, 44].

Mandala Colouring as an Expressive, Movement-based Mindfulness Practice. We now describe participants' accounts of mandala colouring that resonate with mindfulness training, as mentioned by 10 participants. In this respect, findings indicate aspects of mindfulness training such as the practice of focused attention on the present experience as relevant also during mandala colouring. Focused attention is a key aspect that each participant agreed on, in particular as colouring helps anchor their mind by focusing attention on the process of slowly colouring the intricate details of the mandala's geometry: *"you are being very careful -filling the little spots with colour- and thinking ahead to the next colour you're going to put around, and that you need to let it dry"* (P17). With respect to movement-based qualities of mandala colouring, all participants described it as an active mindfulness training: *"instead of being like a guided meditation in which you have to listen, it is more active and you can see then what comes out*" (P13). Thus, through their intrinsic and symmetrical pattern mandala provides sufficient scaffold to ground the practice: *"because it has more structure, it's less exposing"* (P18). Participants also found that mandala colouring becomes a safe space to practice non-judgemental acceptance of one's colouring and its associated emotional experience which can, in turn, be generalised to their everyday life. For example, for P17 mandalas were recommended in her Cognitive Behavioural Therapy treatment for depression [153], and she found they offered a safe space to practice reappraisal and acceptance when making colouring mistakes: *"if you make a slight mistake you have to live with it, and you might have to rethink where you go after that"* (P17). Such non-judgemental acceptance of mandala colouring process in its entirety suggests participants' ability to take the observer's perspective and to attend to the present experience without active evaluation, which is an important aspect of mindfulness training [277]. An important outcome related to the non-judgemental acceptance of mistakes is their role in indicating less mindful moments, as further described.

Mistakes as Tangible Feedback of Mindless Moments. Findings suggest that colouring mistakes play two main roles in this practice, as reported by 8 participants. Firstly, as detailed before, is the way in which they facilitate the development of non-judgemental acceptance. Secondly, through their immediate visibility, colouring mistakes provide participants with the opportunity to monitor their training of focused attention as mistakes act as tangible indicators of mindless moments: *"Making sure how you stay in the lines, I wouldn't do that if I were thinking about other things too much. But mind wonders sometimes, I'm not always that focused"* (P12). Such mistakes (Figure 4.4) include crossing the boundary of a pattern, or breaking the symmetry of the mandala's colour pattern by filling a gap with the wrong colour.

Figure 4.4: Mandalas coloured by P18 (left) and P13 (right), with colouring mistakes highlighted.

Indeed, although generating frustration, colouring mistakes are particularly important to help people recognise mindless moments and to shift attention back to the colouring activity: *"I always make mistakes when I am not focused. If this happens, I try to find a way to avoid it being noticed"* (P4, mandala shown in Figure 4.4). As shown in this quote, practicants do not try to erase their mistakes, but instead make them fit within their current colouring pattern, further practising acceptance and learning to let go as core concepts of mindfulness [277]. This is also exemplified in P13's mandala shown in Figure 4.4, highlighted with a double circle as the mistake has not only been accepted but accommodated into the whole mandala. In this case, P13 started colouring a space with a wrong colour and then decided to combine both colours throughout the mandala's layer: *"you just have to carry on, you can't undo, it needs to go with the mandala"* (P13). This is an important finding highlighting the values of acceptance and reappraisal that come from mandala colouring [40].

4.2.2.2 Temporal Unfolding of Mandala colouring Sessions

We now describe the way in which practicants prepare for their mandala colouring sessions, the social context of this practice, and the range of practices they engage in with their completed coloured mandalas.

Preparing for Mandala colouring. In order to start colouring, people roughly plan materials and colours as indicated by 5 participants: *"I lay them out, that is part of it [. . .] and they (art materials) have to go back once you're finished!"* (P17). This resembles a ritual-like process that marks the entering into a special time and sacred place, which allows the intimate connection with mandala colouring to unfold: *"I have what everybody calls my corner. So it's just where I sit and I've always sat since my children were small. I can have a cup of tea next to me and [...] got a lovely view over the trees, so it seems to be very nice and peaceful for me"* (P5). With respect to the choice of colours, findings suggest that most mandalas tend to be coloured with a limited set of 3 to 5 colours (Figure 4.2): *"I kind of like to experiment in mixing tones, and sticking with one particular colour palette and theme"* (P14). Regarding the geometry, all participants mentioned that selecting the mandala to colour, based on their geometry, tends to be somehow open: *"I usually get them from a book; I don't go systematically but choose the one I like the most in that moment"* (P4, Figure 4.3). This quote indicates the value of browsing a set of uncoloured mandalas in order to choose the one that participants resonate with in the moment. Interestingly, from the choice of the four mandalas given to the participants in the face-to-face interviews shown in Figure 4.3, mandalas C-F, all chose mandala F with the exception of P13, who chose mandala C. Participants reported that mandala C was generally avoided because of its outline: *"I don't like how thick the lines are, it looks a little less delicate"* (P14), *"seeing the lines like that, it feels almost angry"* (P15). This outcome brings up the importance of the mandala's geometry, as for example participants found mandala D too intricate and challenging to colour in: *"I find it far too busy"* (P12), and mandala E too enclosed and with geometric spaces such as triangles that would make them feel uncomfortable to colour in: *"I don't like this one, it's too geometric"* (P16). On the other hand, mandala F offered better opportunities for self-expression: *"I like the combination of borders, and the dots, and bigger spaces there"* (P17).

Sharing the Practice and Space with Others. The way in which practicants prepare their environment prior to colouring was described by 16 participants. The setting up stage seems to be what helps them get grounded and ready for the practice. Such safe space is predominantly within one's home (19 participants), but we also found accounts of nature-based places that people consider sacred: *"at home, I do them all the time. But sometimes if I'm not in a great place, I will go down to the beach [to create the mandalas]"* (P16). This illustrative quote is interesting, suggesting that the restorative power of nature [139] can be leveraged within the mandala colouring practice.

With respect to the social context, participants mentioned the presence of trusted others with whom they share the space of mandala colouring but not the practice itself. The typical example is colouring a mandala in the living room while one's partner reads a book. Only occasionally, people would colour in group settings: *"everyone had their own personal little bit [parts to colour] but it was a part of the whole"* (P18), or alongside trusted others: *"I love looking at what my grandma's colouring because she uses some colour combinations I wouldn't think of, and I wonder what made her choose that"* (P21). Interestingly, participants mentioned that they would not feel comfortable with unfamiliar people. In particular, most interviewees (16 participants) considered mandala colouring an activity during which they open themselves up, and therefore would not like to do something that personal, for example, in public spaces: *"I had surgery and I took the mandala colouring in [the hospital setting] but it's not the same, I'm not relaxed enough, I'm just on edge because is not my colouring place"* (P10). Therefore, the spatial and temporal context in which the colouring of the mandala takes place is important, as this should be a space and a time in which the person feels safe. In contrast with previous work that suggests mindfulness training on the go [252, 69, 207, 52], these findings imply the need for a sacred space so that colouring mandala properly unfolds.

Completed coloured Mandalas. Most participants mentioned that they like to finish each mandala in one session: *"I try to finish the mandala in one sit. If I have to leave before, I feel like I should've finished it and I want to go back and finish it"* (P21). This interest in completion suggests the need for closure and the importance of supporting it through mandala's size and geometry, i.e. not too large that would need more than one session. Findings also indicate that almost all participants keep hold of their completed coloured mandalas as organised collections. They store them within precious boxes or albums in private spaces within one's home, and often in chronological order: *"I always date it with a nice pen, with the date I finished it"* (P17). By capturing the metadata of the colouring experience and then storing the mandalas, people attempt a sense of continuity within the practice. These collections of coloured mandalas can serve important remembering and reflecting functions. Indeed, over two thirds of participants mentioned that they would occasionally browse through their old coloured mandalas and that in doing so they remember how they were feeling whilst colouring: *"as if the mandala could convey the feeling you had while colouring it"* (P21). This is an unexpected yet relevant finding suggesting mandala's value for capturing and storing emotional memories.

4.2.2.3 Analogue vs Digital Affordances for Mandala Colouring

An appetite for technology to be used for mandala colouring came up during the interviews, with 17 out of 21 participants having used mobile applications to colour mandalas. However, such interest in the digital space does not seem to be fulfilled with current commercially available apps. Interestingly, the main affordances of the analogue practice on paper and using colour pencils were further unpacked while participants described their negative experience with such apps. We now describe them together with the main digital affordances and challenges as identified by participants, and how they can inform novel designs for movement-based mindfulness technologies more broadly, and mandala colouring technologies in particular.

Instantaneous, Perfect Colouring of Digital Mandalas. When inquired about colouring mandalas digitally, most participants expressed an interest. Nevertheless, the 17 participants who had tried mandala colouring apps such as Pigment or colorfy failed to enjoy and to adopt them as their experience with such apps was often problematic: *"I don't like that you can just colour by tapping on the screen, I like to work it out myself, slowly colour it"* (P12). A main limitation of such apps relates to how the mandala colouring practice is mapped onto the digital space with a focus on the final image rather than on the process of colouring: *"you're thinking more about... I think because then you're thinking more about what it looks like, as opposed to how it is just to do it"* (P5). Generally, such apps seem to deliberately eliminate the colouring's slow and continuous movement supporting, instead, the quick generation of a coloured mandala with no imperfections [68]: *"I think the colouring movement is very important [...] there is much more of a connection: [tap] is different [than] when you write or colour which is softer or more continuous [...] actual physical act is important to me, and that's how I remember"* (P15). The avoidance of imperfections was further supported by allowing users to undo actions [68], which prevents the acceptance and accommodation of mistakes. Nevertheless, these are mandala colouring affordances that participants found key in their analogue practice and missed in the digital experience: *"I don't like [the app] because of the [way it can erase] imperfections [...] because [mistakes are] very organic and surprise you as beautiful"* (P16). Similarly, the colouring of the mandala was facilitated digitally by allowing to zoom in, yet this disrupted the structured geometry hence the colouring rhythm. Furthermore, we found that the colouring affordances are at the core of mandala colouring practice. However, the limited used of materials for colouring in digital mandalas hinders such experience: *"I think I'm missing the pens (the smell, choosing them, holding them)"* (P20). These echoes previous findings on the role of different art materials and their properties for expressing intimate sensations and emotions [160].

Augmenting Mandala Colouring via Tailored Experiences. One of the main motivations to use mobile applications for mandala colouring was to access a wider range of mandala geometries, which would also be less expensive than mandala colouring books. Moreover, participants expected technology to increase the potential for personalisation. For example, by allowing to modify pre-drawn mandalas or to draw bespoke ones from scratch: *"the benefit of an app would be that you could build the mandala, and then you could make it the whole thing: production and design"* (P17). This quote illustrates similar views expressed by more than half of participants who perceive the drawing of a geometric mandala as a high-skilled process. While lacking skills for drawing mandala's geometry, participants would, however, like to be able to do it, in order to increase their sense of agency and expressiveness while colouring a mandala: *"if I could get the images out of my head, through my eyes, onto a piece of paper"* (P20). Yet, 14 participants never attempted to draw a mandala due to lack of skills.

To conclude, findings indicate strong mental well-being benefits of the act of colouring the mandala's geometry, as well as those linked to the ritualistic aspects of the practice. Participants also expressed growing interest in digital technologies for mandala colouring. According to the interviews, such technologies are expected to allow them expand the affordances of the analogue practice. Interestingly however, our findings also suggest that the current mobile apps purposefully designed for mandala colouring fail to account for its key qualities. Since the exploration of digital affordances for mandala colouring has only been touched upon briefly in this first study, an in-depth investigation could shed more light into the digital affordances and constraints for mandala colouring practice, and how they can be used to inspire more broadly the design of movement-based mindfulness technologies. Given the limited range of technologies available for mandala colouring, we will focus on colouring apps with free mandala patterns available, the only technology that a few of our participants have used. Therefore, the second study presented in this study aims to further explore in-depth the strengths and limitations of current digital approaches of mandala colouring by evaluating mandala colouring apps.

4.3 Analysis of Commercial Mandala Colouring Apps

The advent of applications for smartphones has created new opportunities to broaden the delivery and accessibility of experiences for social communication [42, 191], entertainment [244, 293] and well-being [194, 213] among many others. Mindfulness-based apps have been gaining interest both in research and private sector [69, 207, 263] as they have the potential to expand its contexts of practice, target wider audiences, and facilitate the larger adoption of mindfulness practices. Nevertheless, most of these apps tend to merely support guided meditation, overlooking other traditional practices with the potential of not only supporting the training of mindfulness but also mental well-being such as mandala colouring. In this study, we investigated how the traditional practice of colouring mandalas is mapped into the digital realm by evaluating the best ranked free apps for mandala colouring in the UK iOS AppleStore (Table 4.1). A preliminary analysis of these findings were captured in a short position paper at Designing for Digital well-being CHI'19 Workshop [68]. Here, we extend these findings by focusing on the digital affordances of mandala colouring apps that both support and hinder this mindfulness practice.

4.3.1 Research Method

The aim of this study was to evaluate mandala colouring apps to identify the state of the art of translating a traditional and popular practice into the digital domain. The evaluation was grounded on Nielsen's heuristics [192] while employing also an auto-ethnographic approach [73], a combination that has been commonly used in app evaluations [69, 213, 250].

4.3.1.1 App Selection

We now describe the selection process of the mandala colouring apps. A systematic search of free mandala colouring apps accessible from the UK for iPhone was conducted in January 2018. The search was done in the iTunes app store, including the following keywords: mandala, mandala drawing, mandala colouring, mandala colouring, mandala painting, mandala art therapy, mandala mindfulness, mandala meditation, adult colouring book mandala, adult colouring book mandala, art therapy, sand mandala. This resulted in 200 apps, which were then screened based on the inclusion criteria: have at least 500 review on the app store, and a minimum average score of 4 in a 5-point scale. We further excluded those apps that did not allow for free mandala colouring within the app, as some had in-app purchases. The final 14 apps that met the inclusion criteria were analysed in this review (Table 4.1).

App id	App Name	Number of Ratings	Average Rating
1	Colorfy: Coloring book	69095	4,5
2	Color Therapy Adult Coloring	6250	5
3	Pigment - Adult Coloring Book	5485	4,5
4	Recolor - Coloring Book	4745	4,5
5	ColorFly: Coloring Book	3750	4,5
6	Adult Colouring	2970	4,5
7	Colouring Book for Me	1744	4,5
8	Lake: Colouring Books	1702	4,5
9	ColorArt Coloring Book	1177	4,5
10	Coloring Book for Adults - Adult Coloring Book	1095	4,5
11	Tap & Color - Coloring book for adults & kids	1055	4,5
12	Colorme: Coloring Book for Adults	800	4
13	Adult Colouring Books Anti Stress Cats Pages Games	552	4,5
14	Mandala Coloring Book Adults Calm Color Therapy	550	4,5

Table 4.1: List of evaluated iOS apps including number of ratings and average rating.

4.3.1.2 Data Analysis

The mandala colouring apps (Table 4.1) were reviewed in iOS 11 with an iPhone 6s. Apps were tested by at least one author, with the first author having over 5 years of experience in colouring mandalas regularly. Each app was used for a couple of days in a real time setting involving the process of finishing the colouring of minimum one mandala. To facilitate the illustration of the user experience and comparison among the apps, and inspired by previous work on heuristic evaluations [106], Nielsen's heuristics were used to find usability issued during the practice of colouring mandalas with digital apps.

4.3.2 Findings

In this section, we report on the evaluation of the mandala colouring apps by describing the main strengths and problems found using heuristic and auto-ethnographic methods. Findings include the digital journey of mandala colouring using the apps, from the way in which apps allow to select a mandala to the colouring environment and the final functionalities once it has been coloured completely. Further, we discuss the experience of colouring a digital mandala by comparing the digital to the analogue affordances such as presence of continuous hand movement, and the variety materials for self-expression.

4.3.2.1 Digital Journey of Mandala Colouring: From Choosing a Pattern to Sharing the Mandala Online

The process of colouring a mandala can be broken down in distinct phases, as found in the previous study: from preparing for the colouring of the mandala to its completion. Here we describe the experience of this journey of mandala colouring when using the digital apps, and discuss the functionalities and main issues that appeared during each of these colouring stages.

First, the preparation of the practice takes place by choosing a mandala with a specific geometry, the art materials and, for instance, setting some goals or preparing the space in which the colouring session will unfold. All the apps provide a broad selection of mandala geometries or designs to colour, however, navigating through them to select the desired mandala is not easy as most apps do not offer organised collections. Furthermore, although we only evaluated free apps, all apps except for 6 (ids 2, 6, 9, 10, 11 and 13 in Table 4.1) only had a small selection of free mandala geometries available to colour. The option of creating or importing custom designs was supported by three apps (ids 1, 3 and 7 in Table 4.1), although they did not provide any particular support to generate mandala geometries. Once a mandala was selected to colour, most apps provide tutorials in the form of info-graphics or short videos to explain how to use the art materials of the app to colour the mandala in the most effective manner.

The identified functionalities for colouring the mandala include a combination of traditional artistic practices with their materials, and different ways of applying them to the mandala based on common technological features such as undoing, zooming and saving. The description of the process of colouring the mandala geometry is detailed in the following section, whereas we now describe the experience of using the apps for colouring in the mandala. For instance, we found that in most apps the overall experience was not allowing to wind down and focus on the self as the screen was too cluttered by providing too many options and visuals in a single screen.

In particular, interactive advertisements distract the experience by either popping up as full-screen every couple of minutes or by appearing at the top and bottom of the screen with loud sounds and flashy colours. As we understand that these advertisements are what allow most of these apps to be free to use, the way these adds are embedded in the use of the apps makes the experience stressful and overwhelming, opposite to what analogue mandala colouring is found to be.

In relation to the art materials provided to colour the mandala, most apps offered different tools. The most common ones available in all apps were the pots of paints, providing solid colours manipulated by tapping with the finger on the colour and then on the space of the mandala geometry where the colour was to be applied. Other tools recreated the textures of pencils, brushes, markers, sprays, or crayons and allowed for colouring by sliding the finger on the screen, yet in most apps these tools were free of charge to use. Some apps also recreated the sound of the material being used such as a scratch for the pencil and an air-pressure sound for the spray, but no app provided haptic feedback through the phone e.g. vibration to enhance the tactile experience of digital colouring. Regarding the selection of colours available, we found that a very common approach by the mandala colouring apps was to provide a set of default palettes from where to select the colour to colour with. We found that self-expression was not well supported in such apps, as the colour palettes could rarely be customised to have an easy access to the preferred colours. Furthermore, in many cases the app suggested what colours to use in each mandala pattern.

Therefore, although the user is provided with a wide range of possibilities in terms of colours and materials to colour the mandala with, these apps do not seem to support a sense of agency over one's practice. Once the mandala is completed, most apps suggested to apply an artistic filter to change the look of the mandala into a specific style such as pop art, graffiti or oil paintings. Finally, all apps prompted the user to share their completed mandala on their social media, download it to the phone and save it in their app's personal collection, making it available to be re-coloured in the future.

4.3.2.2 Mandala Colouring with an App: Focus on Aesthetics, Disregarding Imperfections

We now focus on reporting the issues that arise during the app evaluation in relation to the specific experience of colouring mandalas digitally, in comparison to the analogue practice. Drawing from the literature on mandala colouring and the previous study presented in this study, we can say that the main aspects in the practice of colouring mandalas are the slow and fine hand motion to colour in the structured and intricate geometry, and the use of colouring materials as an embodied expression of internal processes. First, half of the apps (ids 6, 9-14 in Table 4.1) did not allow the presence of fine and controlled movement to colour in the mandala, as the different spaces could be digitally coloured by merely tapping in. That is, with a single tap the space would fill in with the colour selected from the provided palettes. Further, some of the apps that allowed the continuous motion to fill in the different spaces, permitted blocking the target space to avoid colouring outside the lines (ids 3,4). Hence there was no need for the colouring movement to be fine neither controlled in order to avoid mistakes, whereas the traditional approach benefits from the mindful colouring movement.

In addition, the training of attention has also been linked with well-being and self-regulation processes [277]. In mandala colouring, the level of attention needed to colour is usually determined by the level of detail of the geometry. colouring complex geometries requires high level of attention while also fostering motivation as they provide a challenge (i.e. colour within a limited area). Surprisingly, all apps evaluated aim to lower this challenge by allowing to zoom in. And although this might be done to leverage the smartphone small screen estate and digital affordances, as the mandalas are coloured in the phone's screen usually with the finger which restricts precision, the balance for skilled attention is then broken. Furthermore, and also supported by the functionality of undo-redo provided by most apps, the possibility of making mistakes and including such imperfections as part of the coloured mandala seems to be highly avoided in this domain. We find this to be an important issue when colouring mandalas digitally as it does not match the motivations and values of the analogue practice. While dealing with mistakes and imperfections is an important aspect of the analogue practice, mandala colouring apps seem to discourage them by allowing for their easy erase. This common digital functionality that aims to improve performance seems to be a limitation in mandala colouring apps, as it does not support the slowness that allows for the acceptance and incorporation of such imperfections.

To conclude, although the apps evaluated were the top ranked ones, they fail to adequately map the practice of mandala colouring for well-being into the digital realm. Most apps translated colouring a mandala into mobile interface as the creation of a perfect and beautiful image that resembled a colour-by-numbers exercise, which consist on dividing the artwork into spaces with specific colours intended for each of them.

Therefore, we found that the digital translation of mandala colouring into apps seem to overlook the main qualities of this traditional practice, which have been shown to promote self-awareness and mental well-being [44, 144]. Hence, when the first author tried these apps, she felt that the experience was completely different and did not provide the positive well-being outcomes. Although colouring on the screen of a smartphone with a finger has many restrictions, it also offers affordances to support well-being through mandala colouring that have not been leveraged in these apps. Therefore, we make the argument that the digital experiences that draw from traditional practices for well-being should incorporate in their design the key features that support the positive outcomes, adapted to their new interaction medium.

4.4 Discussion

We now revisit the initial research questions and highlight the theoretical significance of our findings. We discuss mandalas as a movement-based expressive mindfulness practice for mental well-being, and how our findings open up the design space for novel movement-based mindfulness technologies within HCI.

4.4.1 Experiential Qualities of Mandala Colouring as FAM for Mental well-being

Despite the acknowledged benefits of mandala colouring for well-being [14, 64, 87] and its use in psycho-therapeutic settings [87, 241, 251], a striking finding was its extensive and prolonged use as a self-care tool for mental health. Indeed, more than two-thirds of participants started colouring mandalas for reasons such as depression or anxiety and engaged with this practice for over four years. well-being and mental health can be seen as part of a continuum [268], with mandala's ability to support self-expression, acceptance and emotion regulation contributing to them both [144, 142]. This is a striking finding, particularly since despite its benefits, mandala colouring and design opportunities inspired by this practice have been largely unrecognised within the growing body of HCI work in well-being and affective health [268].

While non-static FAM practices have been successfully incorporated in health care contexts [16, 145, 239], most HCI work on mindfulness training for mental well-being appears limited to static practices [69, 252, 263]. Within this space, our findings identify mandala colouring as an expressive movement-based mindfulness practice for training focused attention: it scaffolds and restricts one's colouring movements while providing a safe space for self-expression.

Participants' extended and frequent engagement with the practice can relate to the state of flow through which their actions and awareness merge as grounded in the present moment [62]. In turn, such qualities may be further explored to inform future designs intended to mitigate the high attrition in mental health interventions [143] and support stronger adoption of their underpinning technologies.

4.4.1.1 Embodied Self-Expression through Colouring

Mandalas offer a space for self-expression where the chosen materials and colours become active parts in an ongoing communication with the person colouring it. The process of self-expression through embodied interactions has been widely explored in art therapy [160], with findings indicating its support for increased agency over the object being crafted [253]. However, this value of mandala as a vehicle to capture emotional memories and for supporting reflection has been largely unrecognised in previous work on mindfulness. Such reflection allows for shifts of perspective and increased understanding of the initial emotional memories, usually towards their more positive reinterpretation. These benefits are similar to the ones of mood-reflection tracked by mobile apps such as Echo [123], AffectiveHealth [227], or wearable systems [274, 275], suggesting the value of integrating mindfulness and reflection technologies, so that the content being produced through movement- and focused attention, can be later used for reflection on its emotional meaning.

4.4.1.2 Focused Attention and Acceptance of Imperfections

While colouring mandala one's mind can wander, and such failures to sustain focused attention often result in colouring mistakes. However, rather than being perceived as something negative, mistakes are seen as opportunities to practice the acceptance of imperfections and how things can rapidly and unexpectedly change. This is an important finding, as feedback on the failure to sustain attention is usually limited in traditional mindfulness training practices such as meditation [171, 230]. During mandala colouring, mistakes are not just noticed but worked through so that they become integrated into the entire mandala, rather than erased or discarded. This accommodation of mistakes supports people to reappraise the situation, leading in turn to the acceptance of imperfections.

In this way, mandalas seem to provide a safe space for the practice of emotion regulation strategies [49, 82] which future designs can benefit from. Our findings also support previous work on imperfections as a resource for design [224, 272], especially regarding reflection on, and acceptance of impermanence. The difference is that mandala colouring embraces imperfections as outcomes of a process, rather than imperfections as traces of long-term use of a material good.

Also, the imperfections' particularities of form [224] are not as important as the awareness that arises from making a mistake. This is an important distinction, as imperfections in mandala colouring are a result of an action (i.e. shift in focused attention) instead of, for example, limitations of the design [272]. We further contribute to the field by calling attention to making mistakes an active support for the cultivation of mindfulness, in the way that they scaffold the training of focused attention and encourage acceptance of its failures.

4.5 Implications for HCI

Whilst smartphone apps may seem to facilitate the introduction to the practice of mandala colouring as they are ready-to-use without buying any new art supplies, we found that the current technological translation of this practice does not allow the same experience as the analogue mandala colouring. On the one hand, in our first study, we have shown how mandala colouring is adopted as a practice for mental well-being as it allows for self-expression through slowly and mindfully colouring an intricate pattern, which becomes a safe space to make and accept mistakes and imperfections as part of the experience. On the other hand, in the second study, we found that these qualities of the practice were not supported by popular smartphone applications for mandala colouring as they mostly focused on the creation of colourful fast on-the-go visually perfect images. Hence, colouring mandalas in the analogue and digital domain currently seem as two very different and opposite practices. We now discuss three implications for designing for mindful movement including design for intricate confines, for expressiveness, and for recolouring mandala as fluid material.

4.5.1 Designing for Intricate Confines: Slow, Continuous, and Structured Movement

A key contribution of our work is a deeper understanding of mandala colouring, as an illustration of a movement-based and structured activity to cultivate focused attention. The HCI exploration of traditional movement-based practices of mindfulness training has been rather limited. One noticeable exception [52] explored the design of movement-based mindfulness practice as mobile apps through free finger-based movements on the phone's screen, promoted to be slow and continuous through adaptive audio-visual feedback. Instead of supporting such free movement, mandalas restrict and structure the hand's fine movement through its layered geometry. The complex geometry challenges hand-movement required to colour in the different spaces, specially the small ones. Therefore, a high concentration level is required, which in turn facilitates grounding in the present moment [145, 273].

Inspired by this, one can think of novel forms of mindful interaction providing both space and boundaries for restricting the hand movement; which we call intricate confines. In this way, the interaction gently scaffolds the user towards a particular course of action without having to rely on willpower alone, while at the same time demands focused attention. To further develop this concept, we also found useful drawing on its similarity with the concept of subtle guidance from Somaesthetic Appreciation Design [2, 114], defined as gently directing one's attention towards specific bodily sensations albeit without grabbing. A key distinction is that instead of focusing on a specific object of interest such as body part, sensation, thought or emotion, intricate confines direct the focus of attention within defined physical spaces and to the mindful movement within them. While subtle guidance tends to be open, intricate confines involve a more structured training of focused attention where internal experiences arise and are expressed through the slow and controlled movement. Another similar idea is the one of microboundaries as interventions which deliberately introduce small challenges in the interaction with the technology, in order to support the shift from automatic to more mindful behaviour [61]. The key distinction is that for mindfulness training intricate confines prevent slipping out of mindfulness states while microboundaries facilitate slipping out of mindless states.

4.5.2 Designing for Expressiveness: Making the Intangible Tangible

Findings indicate participants' strong preference for mandala as a highly expressive form of interaction with materials. This is reflected in people's choice of colours and interest in personalising mandalas' geometry. Expressivity preferences can open up new design opportunities, for example through applications that provide collections of novel digital mandalas, i.e. a mandala for each mood, or supporting different emotion regulation strategies; as well as the provision to scaffold the process of drawing mandala's geometry. These design implications support the preparation stage of mandala practice, and their outcomes can then be both digital and printed personalised mandalas ready to be coloured. For the colouring process, we have seen the paradox of people's interest in technology, and the serious limitations of currently available mandala apps. We argue that there are design opportunities for innovative mandala colouring technologies that should be built on the design principles suggested by our findings: intricate confines and expressiveness.

The latter has been already explored within HCI, with findings indicating that expressive interfaces emphasise the human body, emotions, meaning-making and multi-modality [227], all sensitising concepts valuable also for designing for mandala colouring. In particular, we can think of novel tangible interfaces augmented with physical computing-based input devices.

This would address people's preference for the mediated input, i.e. pens or brushes instead of finger. In addition, as suggested in art therapy [142, 182, 160], different materials offer richer opportunities for communication and expression. Therefore, such tools could also adapt to ensure multiple expressive choices resembling those for gel pens, felt tips or pencils, range of choices much enjoyed by our participants. Furthermore, digital augmentation of mandalas coloured with rich expressive materials could also support the important stage of reflecting on them once finished. We could think of novel strategies to support such processes of attention regulation and reflection over one's mindfulness training. Distinct processes could be decoupled on separate interfaces, for instance, having a main interface for the attention training task, and a secondary one for its monitoring, possibly through brain-computer interface technology. This decoupling could facilitate a better understanding of the mindfulness practice and reflection on its otherwise abstract and less visible processes.

We can imagine novel mindfulness technologies providing real time feedback on mindfulness states through subtle visual guidance which would leverage ambiguity through metaphorical mapping and form of delivery (time or event based), or through leveraging peripheral displays as site for such subtle guidance which would not distract attention from the main technology where the focused attention is trained through slow continuous and restricted movement.

4.5.3 Design for Re-colouring: Mandala as a Fluid Material

Study outcomes suggest two important and previously unrecognised roles of the mandala: capturing emotional memories and reflecting on them. We argue that both these roles, and in particular the later, could be supported by technology in ways in which paper-based mandalas are less equipped to do. As participants noted, they would much prefer to re-engage with their completed mandala at the reflection stage. In addition, they declared their longing to even recolour them, often in more positive colours. It may be possible that through the personal involvement required by the colouring activity, this emotional memory is better encoded and processed. Hence, as a result, mandala serves as a powerful cue for remembering both the mandala colouring process and more importantly, the emotional event or memory that triggered it. Browsing through the completed mandalas and remembering their associated emotional experiences can also facilitate reflection.

Such reflection allows reinterpreting the initial negative experience and re-framing it in a more positive way. Special emphasis was put on the time-lapse between mandala colouring and the moment of reflection, as it allows participants to gain both distance and perspective for positively reinterpreting past emotions. This concept resembles the pictorial equivalent of Pennebaker's expressive writing process, well documented for its mental health benefits [201]. Previous work indicates that repeated writing about an emotional event allows for better emotional processing or the rewriting of its narrative.

Our outcomes indicate a different approach for such envisaged recolouring; to be performed directly on the completed coloured mandala rather than a new one. It may be that, unlike text, the expressive qualities of mandalas render them suitable for this temporally-layered approach, which digital interfaces are ideal to support. For instance, we can imagine new tangible interfaces on which the coloured mandala may become fluid material of past emotional experience. People could dynamically reshape such fluid material by slowly and continuously adding new layers of content and change the initial emotional meaning.

4.6 Summary

This chapter provides a rich overview of the non-static FAM practice of mandala colouring detailing the motivations, benefits and challenges of regularly engaging with this practice, the qualities of the context in which mandala colouring unfolds, and the opportunities and challenges of technology-mediated mandala colouring. My contributions to the HCI community include providing novel insights from an in-depth study reporting on interviews with 21 people who regularly engaged with the FAM practice of mandala colouring, as well as an heuristic and expert evaluation of the best rated mandala colouring apps in the UK. These two studies have shown that through its movement-related qualities and expressiveness, mandala colouring can support self-expression, non-judgemental acceptance, and emotion regulation. Mandala is also used as an emotional memory cue that people engage with for later reflection and meaning-making. Finally, it discusses the design implications deriving from this work such as the concept of intricate confines to support slow, continuous, and limited movement; expressiveness to support a more tailored practice; and recolouring mandala as a fluid material, and for reconstructing emotional meaning. These implications are developed in the next chapters (Chapter 5 and 6), which delve in the design of an interactive prototype for mandala colouring to enhance its benefits (e.g. interaction mediated by intricate confines, use of colouring mistakes to practice acceptance) and mitigate the challenges (e.g. become aware of one's mindfulness state in-situ instead of on-reflection after the practice).

Chapter 5

Designing Anima: A Brain-Computer Interface for Peripheral Materialisation of Mindfulness States during Mandala Colouring

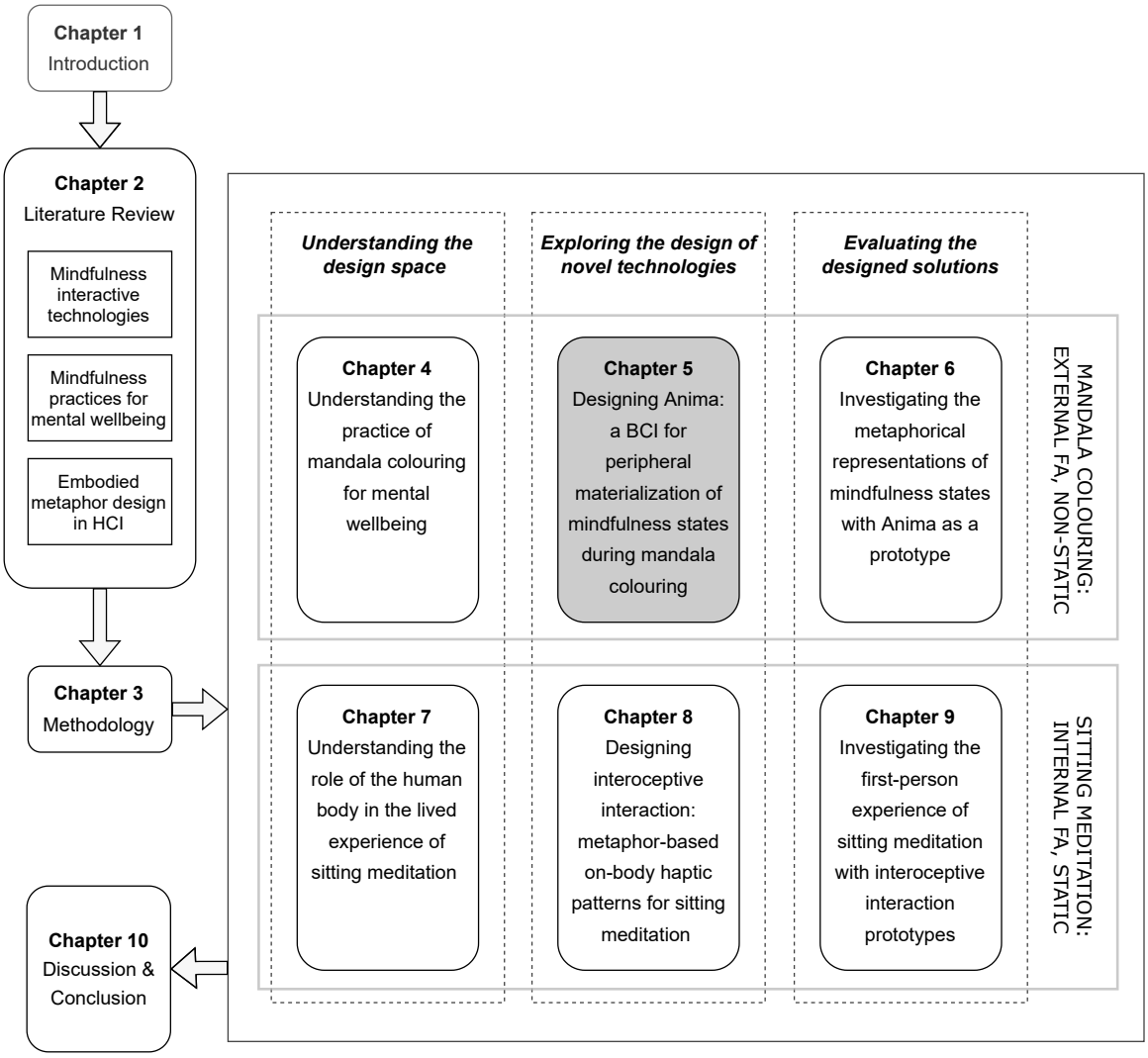


Figure 5.1: Chapter 5 of Thesis structure

5.1 Introduction

With its origins in Eastern spiritual traditions [273], mandalas have been widely adopted by psychotherapists to cultivate self-awareness and improve mental well-being through mindfulness-based art therapy [182, 142]. Mindfulness practices have become increasingly popular because of their significant benefits for psychological well-being [40], mental [16, 82] and physical [99, 134] health. Mindfulness has been conceptualised as actively bringing one's attention, non-judgementally, to the unfolding experience in the present moment [157, 168, 246, 261]. Our work builds on Vago and Silbersweig's S-ART framework [277], in which they describe two distinct approaches to mindfulness training: focused attention through concentrative practices, often the starting point of novice meditators [38], and open monitoring involving no specific object to focus the attention on, hence learning to observe the present moment without engaging with neither internal nor external stimuli [168]. Consistent findings in the literature indicate that the skills required to sustain and regulate attention, such as in mindfulness practices, are challenging to develop [145, 230].

Both the benefits and the challenges of mindfulness training have attracted a growing HCI interest in designing interactive mindfulness technologies [67, 252, 263], with a special focus in designing and developing systems to improve well-being [74, 166, 228, 268]. Most of the work within this space has drawn from static mindfulness practices such as sitting meditation [168, 277]. Although sitting meditation is a very common approach to training mindfulness, there are a wide variety of traditional mindfulness practices that rely on other strategies such as practices emphasising attention on movement -what we call movement-based mindfulness training-, yet these have received less attention in HCI [159, 239]. This is surprising given the acknowledged value of bodily movement in traditional mindfulness practices [239] and their growing interest in the general population (e.g. walking meditation, tai-chi, mandala colouring), as well as the embodiment and somatic practices [43, 45, 117] core to the third wave in HCI [33, 91]. Hence, this less explored design space offers untapped design opportunities for novel mindfulness technologies.

This chapter therefore explores the design of a prototype augmenting the practice of mandala colouring, informed by the understanding of the design space provided in Chapter 4. The prototype, Anima, is a peripheral colour palette materialising EEG-based mindfulness states onto colours during mandala colouring. It provides a detailed explanation of the design rationale of Anima, including the exploration of different metaphorical mappings of brain activity to represent mindfulness states as well as the form and structure of the user interface (i.e. external object of attention for the FAM practice).

5.2 Design of a Working Exemplar Prototype for Augmenting Mandala Colouring

Anima is a working exemplar prototype [234], defined as an instantiation or design exemplar illustrating an abstract principle. The main role of working exemplar prototypes, such as Anima, is both to inspire designers' thinking of such principle, and to act as possible placeholder (rather than design solution) within a novel and yet to be explored design space [234]. Such working exemplars have generative rather than evaluative purposes [111, 121, 236] emphasising their playful exploration, while offering the advantage of being easy to understand by naive users [35].

Therefore, the goal of the Anima is to bring forward the exploration of a novel design space for non-static focused attention mindfulness technologies, with an external focus of attention. The key design principle Anima illustrates is the decoupling of two main aspects of FAM practices: the training of focused attention and the monitoring of mindfulness states during the practice. Furthermore, we aimed to explore the way in which brain activity could be materialised in order to guide the mindfulness practice, which has been little explored in HCI.

5.2.1 Design Rationale

The design of the working exemplar prototype was inspired by the traditional practice of mandala colouring, in which the interactions between the mandala and the used colours are key. In Jung's theory, the psychotherapist that introduced mandala colouring to the Western culture for mental well-being, Anima represents the inner personality that allows bringing attention towards unconscious parts of the self [251]. Similarly, Anima aims to bring attention inwards through the materialisation of mindfulness states on the peripheral colour palette, in order to facilitate the FAM practice of mandala colouring [87, 173].

Its design was also inspired by traditional colouring and its interaction with the materials, representing the setting of using a colour palette to paint on a canvas: colours placed within reach, there when needed, yet peripheral. I now provide an overview of the system and describe the design choices regarding colours, their aesthetic appearance and spatial arrangement on the peripheral palette.

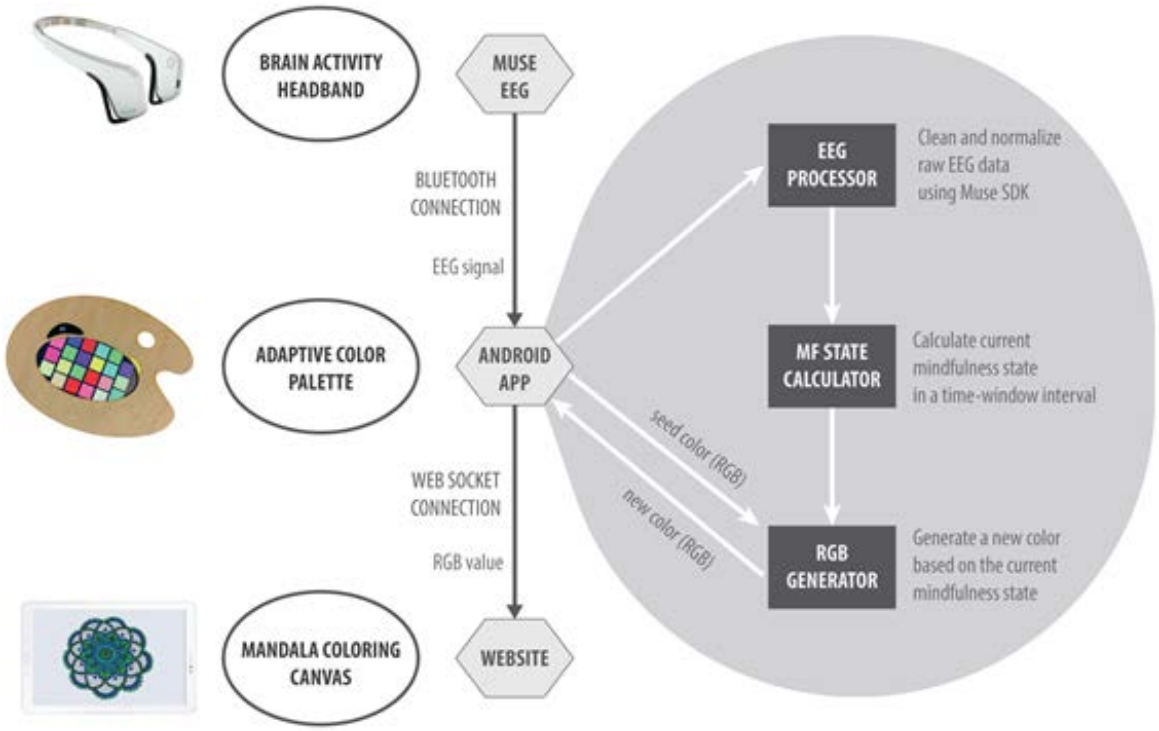


Figure 5.2: This diagram shows an overview of the system by describing the three components of Anima (i.e. brain activity headband, adaptive colour palette and mandala colouring canvas on two Android tablets respectively) and the way they function together monitoring the mindfulness practice with a peripheral adaptive colour palette.

5.2.2 Overview of the System

Anima working exemplar prototype consists of three components: a brain activity headband, an adaptive colour palette, and a mandala colouring canvas. Each of these components was carefully designed to fulfil a specific goal, as detailed in Figure 5.2. First, the brain activity headband is used to non-obtrusively access the person's mindfulness states during mandala colouring. Second, the tablet-based adaptive colour palette is used as a peripheral interface for monitoring the FAM practice, as it provides new colours that are generated based on the current mindfulness state. Finally, the tablet-based canvas aims to recreate the traditional practice of mandala colouring to train focused attention by colouring with conscious, slow and continuous hand movements. The design of each of these components is described in the following sections.

5.2.2.1 Sensing mindfulness states using a wearable brain activity headband

The first component of Anima is Muse [186], a wearable, commercial EEG headband for monitoring brain activity in order to infer mindfulness states in real-time. Through its four cutaneous channel electrodes capturing alpha, beta, gamma, and theta brain waves [151], Muse has been shown to provide valid and reliable measurements of event-related brain potentials [151, 219]. Previous work has also linked each of these brain waves with specific mental states [219], particularly during mindfulness training, from which mindfulness states can be clearly identified [110, 230].

The second component is an adaptive colour palette, for which we designed a hybrid artefact consisting of a tablet enclosed in a bespoke, wooden laser cut made painter palette (Figure 5.3). The aim of the palette is to act as a peripheral display to facilitate the open monitoring of the mindfulness practice during mandala colouring, as it provides new colours based on the unfolding mental states throughout the session. The interface was developed as an Android app that was installed on a Samsung tablet. Besides the generated colours, the palette also includes the original four seed colours selected by the user (see Figure 5.3 and section 'Mapping Brain Activity onto colours' below), an indication of the current selected colour with which the mandala is to be coloured on the canvas, and an icon showing the connection status with the Muse's headband, as shown in Figure 5.3. Figure 5.2 describes the way in which the new colours are generated based on the mindfulness states sensed by the brain activity headband, and is further detailed in the section 'Mapping Brain Activity onto colours' below.

5.2.2.2 Training focused attention through mandala colouring

Finally, the third component of Anima is a digital canvas for mandala colouring. The main goal of the canvas was to recreate the analogue practice of mandala colouring in order to facilitate the training of focused attention and self-expression. Therefore, we developed a website which provided the geometry of a mandala to be coloured in with a stylus as if it was on paper [68]: no eraser or undo actions, no zooming in and out, and no colour by tapping into the spaces. To select a colour, the user would simply tap on that preferred colour from the adaptive colour palette. Then, it would be automatically loaded on the canvas by sending the RGB value from the Android app to the website using web sockets, as shown in Figure 5.2.

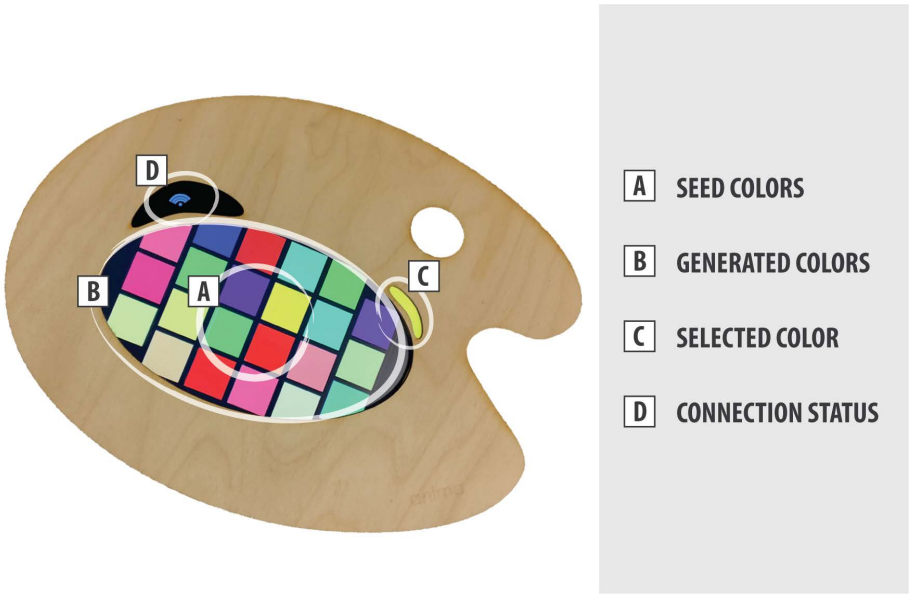


Figure 5.3: Close up diagram of Anima's colour palette identifying its main parts: (A) four seed colours originally selected by the user, (B) generated colours based on the mindfulness states, (C) current selected colour to use on mandala colouring canvas, and (D) connection status with brain activity headband.

5.2.3 Mapping Brain Activity onto colours

An important design decision focused on how mindful versus non-mindful states could be distinctively represented through colour. Here, the design was informed by Gombrich's concept of beholder's share [148], in which one's prior experiences and emotional memories guide the process of decoding visual information, determining its meaning and interpreting it . For that reason, the colour-based metaphorical representation of mindfulness states was based on an initial user selection of colours (Figure 5.3).

Drawing from mindfulness literature and the traditional practice of mandala colouring indicating that mandalas are traditionally created using four core colours [273], our initial choice of colours consisted of a set of four colours –which we call seed colours (Figure 5.3). The seed colours were chosen by each participant at the beginning of the mandala colouring session and used as a yardstick to represent their initial mindfulness state. Subsequent state changes (i.e. becoming more or less mindful) were materialised as changes applied to these seed colours.

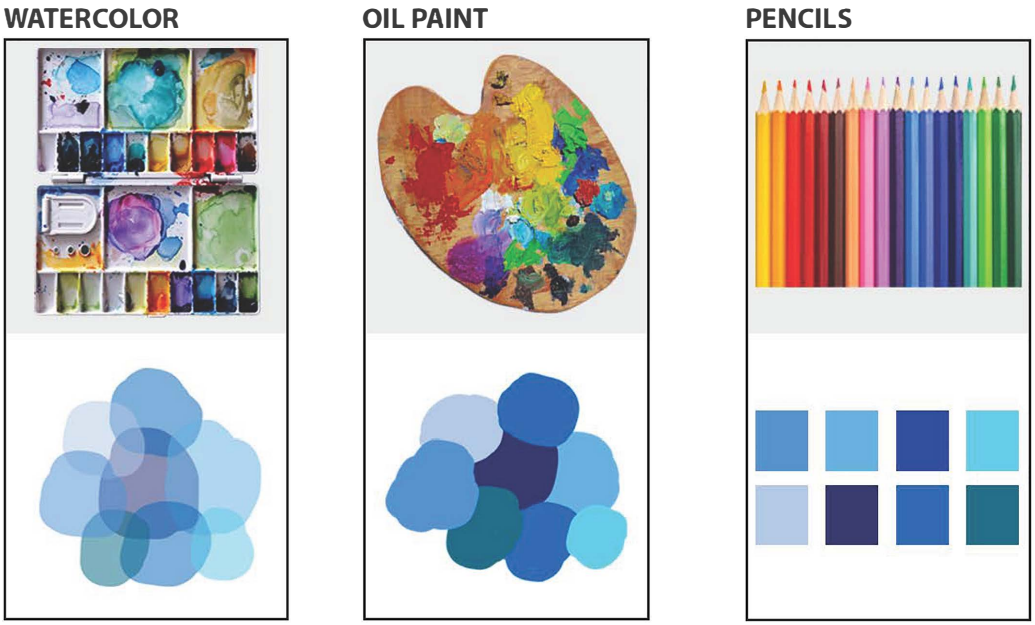


Figure 5.4: This image shows the design exploration of the mapping of mindfulness states into colours, by drawing from different materials: watercolour (left), oil paint (middle), pencils (right).

For the colour modification, we draw further inspiration from work on colour theory [56] suggesting that hue, saturation, and brightness can increase expressiveness in information visualisation [65, 161]; and that low saturated colours with low hue can support calm states [22]. While saturation and brightness levels were open for modification, we kept the hue constant to limit the range of distinct colours. Generation was deliberately ambiguous and subtle to not distract from the main focus of colouring the mandala [94], yet informed by participants' mindfulness states [219].

To monitor mindful and non-mindful states, we used alpha and beta brain activity frequencies as increases in alpha and beta frequencies have been linked to attention modulation in focused attention practices in related neuroscience work [122, 285]. Thus, when a participant reached a more mindful state (i.e. increase in alpha and beta), the system generated a more muted colour. This was done by lowering the saturation and increasing the brightness of a seed colour. Accordingly, to represent a less mindful state (i.e. decrease in alpha and beta), the system generated a new stronger colour by increasing the saturation and lowering the brightness of a seed colour.

5.2.4 Palette Design: Colour Choice, Appearance Placement

Regarding the interface of the Anima's adaptive colour palette (Figure 5.3), we conducted a series of design iterations to find the appropriate design for the working exemplar prototype. For this, we draw inspiration from the traditional painter's colour palette while aiming also to provide support for open monitoring during the mindfulness practice of mandala colouring.

For instance, we explored colours' physical appearance on the palette in terms of their shape and size. Inspired by work on materials for self-expression [95, 160], we looked into art materials such as watercolours, oil paint, and pencils (Figure 5.4). We decided to use digital colouring due to its simplicity to programmatically augment the practice, and its use of the metaphor of pencil colouring via the stylus. Digital colouring also leads to distinct, atomic colour generation and selection which can be associated with distinct mental states.

In terms of colour appearance, we considered a variety of shapes, like the ones shown in Figure 5.4, and decided to display colours as solid cells as the interaction and meaning-making processes were best facilitated with the grid. The cells were squares of 1 x 1 inch, ensuring that the number of displayed colours resembled the number of colours provided by a case of colouring pencils. Indeed, based on the palette's screen state and the size of the cells, up to 22 colours (4 seed and 18 generated) could be displayed on the palette without erasing any previous colours.

For the frequency and temporal addition of new colours, we initially tried to replace old colours with new ones. However, this felt like the system was erasing one's prior experiences. After initial testing, we chose new colours to appear every 30 seconds, until the 22-colour palette was full. Thus, half way through a 20-minute colouring session -average time of mandala colouring according to study 1 presented and previous literature [64]- the user would have access to a full-colour palette, which is no longer evolves.

Finally, we experimented with colours' spatial placement on the palette. After a few design iterations, we decided to place colours in random locations rather than chronologically aligned to make difficult the identification of the most recently generated colour, and to ambiguously link it to the current mindfulness state. We expected that this choice would limit the user's adoption of a judgemental attitude towards one's performance (e.g. "I am not doing it right" thoughts), while still providing subtle monitoring of one's FAM practice.

5.3 Summary

This chapter explores the notion of designing to facilitate through technology the practice of mandala colouring, a non-static focused attention mindfulness with an external object of attention. It contribute to the HCI community by outlining design recommendations for two under-explored spaces: peripheral interfaces for mindfulness training, and mappings of brain activity data onto metaphorical representations of mental states. Specially, drawing from the findings in Chapter 4 to design a brain-computer interface prototype that builds on the core beneficial components of mandala colouring: movement that is slow, continuous and structured through the intricate confines to colour the mandala, allowing for mistakes to occur as traces of mind-wandering moments and opportunities for self-acceptance, with a range of colours to support self-expression that are placed on the periphery but within reach. The colours available, however, are continuously evolving in an adaptive colour palette with metaphorical representations of the mindfulness states to facilitate the monitoring of the practice through an external object of attention without being too cognitive demanding. In the next chapter (Chapter 6), the experience of using the prototype and the design solutions proposed to support mindfulness training for mental well-being using Anima are explored in participatory workshops with experts in mandala colouring.

Chapter 6

Investigating the Metaphorical Representations of Mindfulness States with Anima as a Prototype

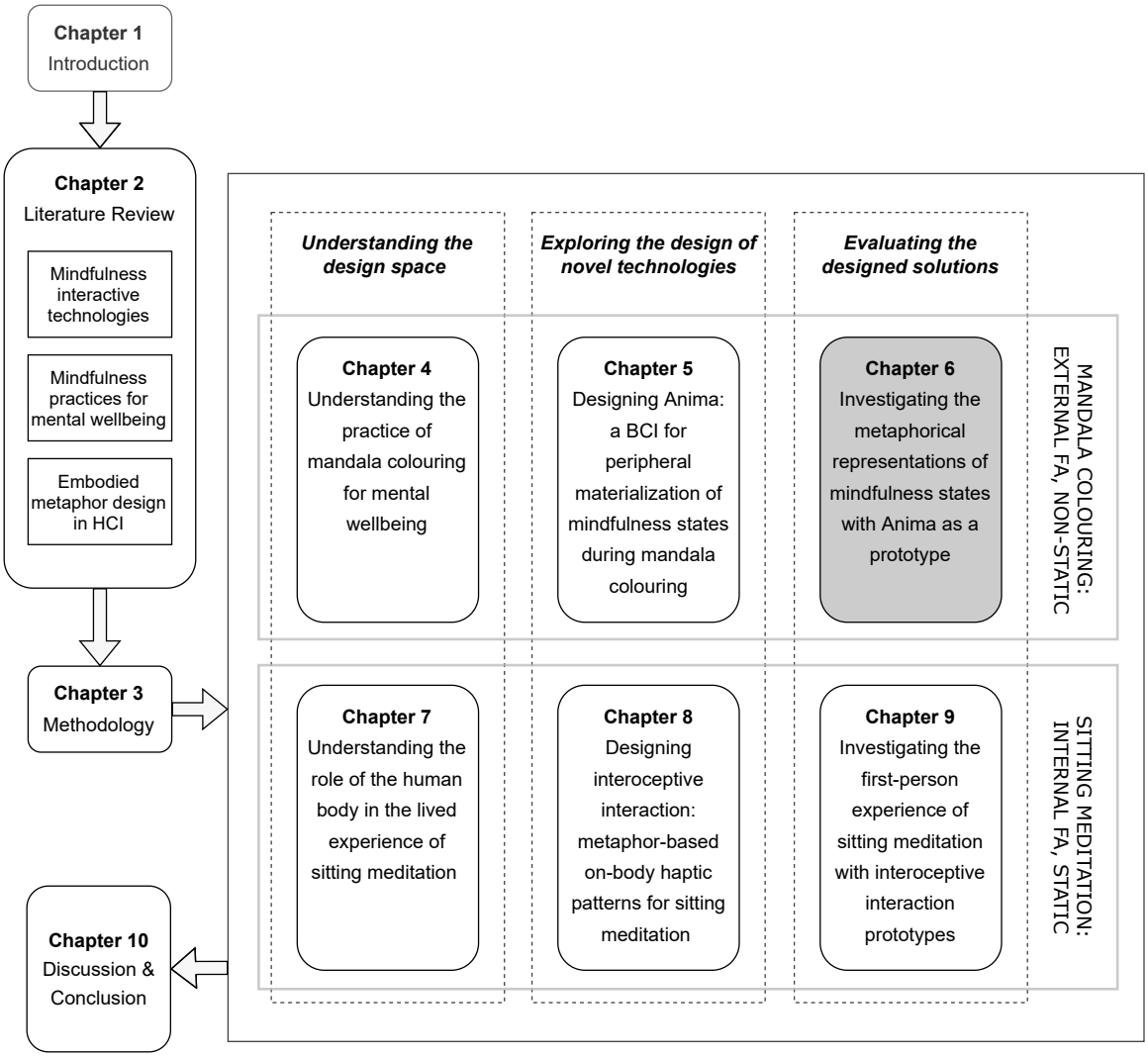


Figure 6.1: Chapter 6 of Thesis structure

6.1 Introduction

In previous chapters I have provided an in-depth overview of mandala colouring to understand the design space of non-static FAM practices with an external object of attention (Chapter 4); this has informed the design of a novel prototype, Anima, to augment the practice of mandala colouring with a brain-computer interface that provides in-situ colour-based metaphorical representations of mindfulness states on the periphery (Chapter 5).

This chapter reports on participatory workshops with 12 practicants (i.e. people that engage with the practice of mandala colouring regularly) to explore their experience using Anima for mandala colouring as a FAM practice. In particular, it delves into the participants' perceptions of the metaphorical representations of mindfulness states during mandala colouring, and their insights on using a peripheral interface to facilitate the monitoring of mindfulness states.

6.2 Participatory Workshops to Explore Anima

Anima was developed to explore a novel design space for mindfulness technologies in which the training of focused attention and open monitoring are decoupled into two distinct, yet connected, interfaces. Because of this, the purpose of the workshops was twofold: not merely Anima's evaluation but the exploration of its generative role to help us understand key design principles underpinning this new design space [234]. We conducted a total of five workshops with two to three participants in each (Figure 6.6), 12 participants in total, focusing on the following research questions:

- How should metaphorical representations of mindfulness states, captured through brain activity, be designed to be both recognisable by users and yet open for interpretation?
- How do people make sense of the metaphorical representations of their mindfulness states?
- How does the decoupling of focused attention and its monitoring impact on the mindfulness training through mandala colouring?

Figure 6.2: Photograph of the group discussion during a workshop exploring Anima.

6.2.1 Methodology

6.2.1.1 Participants

We recruited a total of 12 participants through university mailing lists and posters around campus. Participation was incentivised with an equivalent of a 15 Amazon voucher. All participants had regularly practised mandala colouring previous to the study, with 2 participants having coloured mandalas monthly, 5 more than once a month and 5 on a weekly basis. Furthermore, all participants had engaged with mandala colouring long-term for at least the last year, with 7 participants having been colouring mandalas regularly for 1 to 2 years, 3 for the past 3 to 5 years and 2 for over 5 years. Regarding participants' demographics, 9 identified as women and 3 as men, with an average age of 32 years old (SD = 10.02). Participants' nationalities were varied, with 4 participants identified as British, 2 Nepalese, 2 Peruvian, and 4 other (i.e. Costa Rican, Greek, Russian and Turkish).

6.2.1.2 Study Design

Upon arrival, each participant was provided with a Muse EEG headband [186]. After the setup, participants were asked to select the four seed colours, and individually colour the digital mandala provided to them (all participants had the same mandala) (Figure 6.3) using Anima's canvas and palette. This activity took place in a separate room for each participant to explore the working exemplar in a private space. The inner working and mapping of the working exemplar prototype were not disclosed at this stage in order to encourage Anima's unbiased exploration. After 20 minutes (time allocated based on findings from Study 1 and following previous studies on mandala colouring [13, 64]), participants were notified and given the choice to either stop colouring, or to spend 5 more minutes to finish up.

Then, all participants were brought together to start the group discussion, where they could share their final colour palette with the group to be used as a starting point for discussion (Figure 6.6). Before disclosing the mapping of mindfulness states to the generated colours, participants were prompted to share with the group their motivations for colouring mandala and to explain their own understanding of how Anima worked. After the Anima's colour-based representations of mindfulness states were disclosed to the group, participants were invited to discuss Anima's mapping of mindfulness states to colours, the colours' frequency of appearance and their placement, shape and size. We also provided alternative design choices for the mapping through different shapes, size and colour arrangements identified through our previous design exploration, and encouraged participants to design their own palette to materialise mindfulness states during mandala colouring.

6.2.1.3 Data Collection and Analysis

All workshops were audio and video recorded, and the design materials such as coloured mandalas, and generated palettes were photographed. Conversations were transcribed and coded using Atlas.ti/8 software for qualitative analysis. We followed a hybrid approach of coding and theme development [85]. For the deductive coding, we draw upon a conceptual framework developed from prior work including codes such as materialisation of mental states, focused attention, open monitoring, attention regulation in focused attention. For the inductive coding, we used the new codes that emerged from the data such as mapping of mental states to the colour palette, and its spatio-temporal arrangement. All brain activity data was stored and processed locally on the tablet of Anima's colour palette. EEG data was analysed using power analysis to detect the dominant brain waves [151, 219].

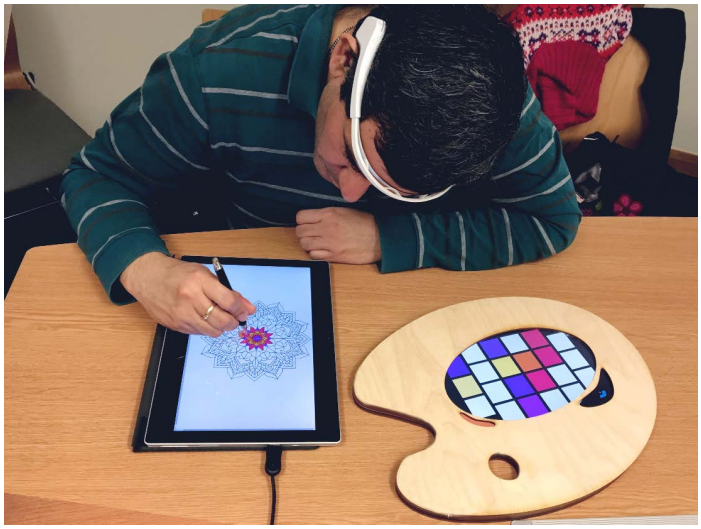


Figure 6.3: Photograph of a participant using Anima to colour a mandala.

6.2.2 Findings

We now report the findings from the workshops highlighting participants' motivation to colour mandalas regularly in their everyday live, and the ways in which their experience of mandala colouring has been impacted by the use of Anima. Further, we describe how participants made sense of Anima and how their mindfulness states were materialised into colours on the peripheral interface. They also provided suggestions for future brain-computer interfaces for mindfulness training during mandala colouring.

6.2.2.1 Motivation for colouring Mandalas

Findings indicate three distinct motives for mandala colouring (Figure 6.4): mindfulness benefits, spiritual motives, and artistic ones. The most prevalent motive was for the mental well-being benefits [64, 44] entailed by this form of mindfulness training (P2, P3, P4, P6, P7, P10, P11, P12): *"for me, I never see mandala as a piece of work. It's just an instrument for me to relax and be more mindful"* (P2), *"it gets you to see how you're feeling on a page, without having to necessarily be too explicit, like writing"* (P3). The other two motives were less emphasised, being shared by two participants each, and included spiritual reasons from Nepalese Buddhism (P8, P9), which embeds mindfulness training but not as the main goal: *"having the base colours as they should be (red, green, yellow and blue), because maybe we are trained that way"* (P9);

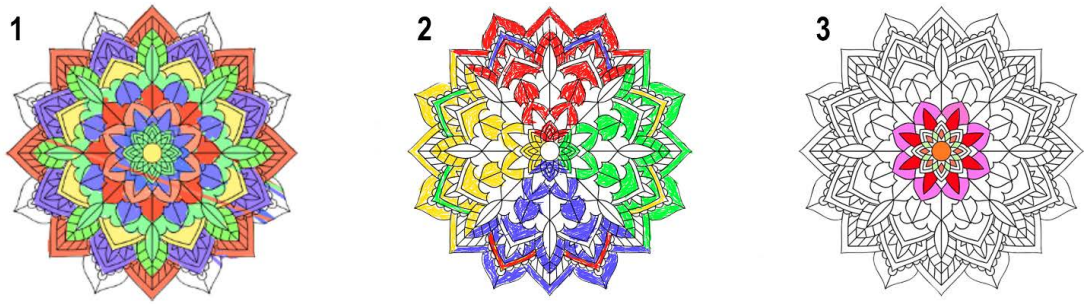


Figure 6.4: Mandalas coloured during the workshop by participants with different motivations: mandala 1 is by P7 for mindfulness training; mandala 2 is by P8 for spiritual tradition; and mandala 3 is by P1 for artistic purpose.

and artistic purposes (P1, P5) with the goal of creating beautiful images: *"with mandalas I don't have a specific idea or goal in mind as ideas flow more naturally [than when I do other types of art]"* (P5).

Findings also indicate how these motivations are reflected in different ways of colouring mandala. Participants who colour for mindfulness benefits and spiritual tradition fill in the mandalas layer by layer, as illustrated in Figure 6.4. They aim for completeness and have a specific approach to handling mistakes: going over the lines, by allowing, accepting, and integrating mistakes in the mandala colouring: *"if I make a mistake, I have to incorporate it"* (P10). This is an important outcome indicating the value of mistakes in signalling less mindful moments, as well as the opportunities they offer for practising non-judgemental acceptance [57, 277]. In contrast, in P1's mandala we can see that the goal was to create a detailed and aesthetically perfect image, with few mistakes whose acceptance has not been emphasised.

Regardless of their motivation, all participants expressed how the colouring of the mandala allowed them to express themselves in a non-judgemental way that facilitated self-reflection: *"you can reflect and see it through the colours, because sometimes you have so much in your brain you can't keep it all in –it's like a release"* (P11). These outcomes are important, indicating that mandala colouring, as a mindfulness practice rooted in Buddhist traditions [273], is predominantly used for mental well-being [144], although our participants' recruitment did not focus on this vulnerable user group.

6.2.2.2 Interactions with the Anima's Peripheral Palette and Digital Canvas

Most participants reported that they really enjoyed the experience of using Anima: *"It really felt nice, when I was colouring I didn't want to stop, and when you came earlier I thought 'it's only been 5 minutes, how... why?'"* (P8). Although 6 participants found it initially challenging to move from colouring on paper to colouring on a tablet (P1, P2, P5, P8, P9, P10): *"I loved getting patient with it (the digital canvas) and getting good at it, which was really rewarding... it's not great, full of mistakes, but I was quite happy with it"* (P10), in a couple of minutes all participants mentioned that they reached a more mindful state, and seven even wanted to continue colouring for longer (average Anima colouring time among participants was 23.5 minutes). We now describe participants' experience with the peripheral palette and the digital canvas, and how different motivations for engaging in mandala colouring impacted on their use.

Findings from the analysis of participants' interaction with the palette, indicate that from the 22 provided colours (4 seed colours, and 18 generated) the average number of colours selected to use was 5.9, including in average 2.8 seed colours, and 3.1 generated colours. This suggests that we may have provided more colours than needed, however as we shall see later, the number of generated colours provided both richer choices to select the colour to use, as well as real-time feedback on the mindfulness states. To explore the latter, we calculated the number of colours mapping mindful vs less mindful states, and findings on the palettes' colours indicate that an average of 11.7 out of 18 generated colours represented mindfulness states. This suggests that for the first half of the session, while colours were generated, participants experienced mindfulness states about 65% of the time.

Another interesting finding is that despite this rather limited use of merely less than a third of the colours provided on the palette, seven participants across all three motivation-based groups expressed a desire for more colours. A closer look into this revealed two main reasons. First, there was a preference for colours varying both in saturation/brightness level, and hue: *"I wanted more variety"* (P11). On reflection, we deliberately constrained the breadth of colours' hues so that they would not distract attention from the main colouring task. This design decision was notably supported by three participants: *"it's boring when you have so many options"* (P5). Driving the colour generation solely on the basis on mindfulness states, and the 4 seed colours, meant that some of the colours were similar and difficult to differentiate, which in turn restricted the range of diverse generated colours. Moreover, most participants across the three groups made use of bright colours, which were also less represented on the palettes.

The second reason for this preference of fewer colours to use relates to the duration of colour generation. Our design choices led to the palette being filled up with colours before the colouring session ended, which was perceived as less satisfactory by six participants: *"I think they [the colours on the palette] filled up very quickly"* (P7). This concern relates to the desire to have a complete materialisation of mindfulness states over the entire colouring session as expressed by eight participants, rather than merely for the first half of the session.

We also looked at how the interaction with the palette was impacted by participants' motivation to colour mandala. Differences in the use of colours across participants with different motivations was also found, with the reason of colouring for mindfulness benefits involving the greatest use of colours in general and of those representing mindfulness states in particular: on average they used 7.4 colours, of which 2.7 were seed colours, and 3.6 generated colours reflecting mindfulness states and 1.1 reflecting less mindful states. Interestingly, participants motivated by the benefits of mindfulness training have used not just muted colours, but also at least one bright colour (in average 1.1) mapping less mindfulness states, which may appear as counterproductive. However, as shown in their coloured mandalas (Figure 9), such choice was mainly due to the desire to move between mandala's layers rather than to colour in significant areas, so arguably they were used briefly for aesthetic reasons.

As shown in Figure 6.4, participants interested in artistic expression tend to cover smaller areas of the mandala with a balanced choice of muted and bright colours (average number of colours 4.5, from which more than half, 2.5, were seed colours and 2 generated colours reflecting mindfulness states). Participants following spiritual tradition used predominantly the same 4 prime colours of green, red, blue and yellow, considered symbolic of enlightened qualities in spiritual tradition (Tucci, 2001); making limited use of the generated ones (average 4, with 3.5 seed colours and 0.5 reflecting mindfulness states). As participants motivated by spiritual tradition used almost exclusively the seed colours, they arguably benefited less from the large range of generated colours.

6.2.2.3 Reflection in vs on Action on Mindfulness States

In this section, we describe how participants made sense of the mapping of mindfulness states to generated colours, both during, and after the mandala colouring session, and this understanding was supported by the colours themselves as well as their spatio-temporal appearance. Drawing from Schon's seminal work [240], we found useful the concepts of reflection-in-action that refers to the habit of observing one's thoughts in the process of action and adapting ones actions on the fly towards the goal, and reflection-on-action that takes place once the action has finished, through an effort of stepping back from the experience to gain a better understanding [240, 289].

This is relevant as a non-judgemental reflection over one's experience is also a core process of mindfulness practices [110, 277, 289].

Findings suggest that the palette supported reflection-in-action, as indicated by four participants: *"it really helped [me] become more aware [of my mental states as] through colour I try to organise a little bit of myself"* (P6). This quote indicates not only the value of Anima's generated colours for communicating mindfulness states, but also colours' potential to support or further regulate oneself towards mindfulness states. Such outcomes confirm findings in experimental psychology on the impact of low colour saturation and low brightness (no higher than Munsell brightness value of 43) on decreased arousal [278] or calming down. This also suggests people's interest on affective interfaces supporting not just awareness of emotional states, but also their regulation when such states are less than ideal [275]. These findings are also supported by the EEG's data analysis. A repeated-measures ANOVA with Greenhouse-Geisser correction shows that the dominant brainwave differed significantly between time points ($F(1.792, 17.920) = 7.679$, $p < 0.005$). Post hoc tests using the Bonferroni correction revealed a significant change in the dominant brain wave from dominant alpha (at the start of the colouring session) to dominant beta (at the end of the colour generation) which was maintained until the end of the colouring session. Both alpha and beta brainwaves are indicators of enhanced mindfulness sates [219], with dominant beta commonly relating to focused attention [150], and dominant alpha to open monitoring [230].

With respect to reflection-on-action, a key finding is that seven participants reported Anima's value for supporting awareness of mindfulness states and that this value emerged particularly after the colouring session as shown in this illustrative quote: *"I can feel the contrast of my state of mind at the beginning vs at the very end [and while looking and pointing at muted colours another participant's palette] Yes, definitely"* (P7). This quote refers to the intuitive understanding of the mapping of mindfulness states to muted colour during reflection-on-action. This would happen not just for oneself but also for others' palette.

The above findings indicate how the fully generated colour palette has becomes after the mandala colouring session has ended, a tool for reflection on the experienced mindfulness states. Indeed, although most of the generated colours from the palette were not used during the mandala colouring, they were definitely key during the post-colouring experience of sense-making as further described. Looking more in-depth at this sense-making process, findings indicate three main strategies employed in reflection-on-action: (i) identifying a known mental state and looking for its materialisation on the colour palette, (ii) identifying salient colours on the palette and inferring their mindful states, and (iii) negotiating the challenge of colours' random appearance.

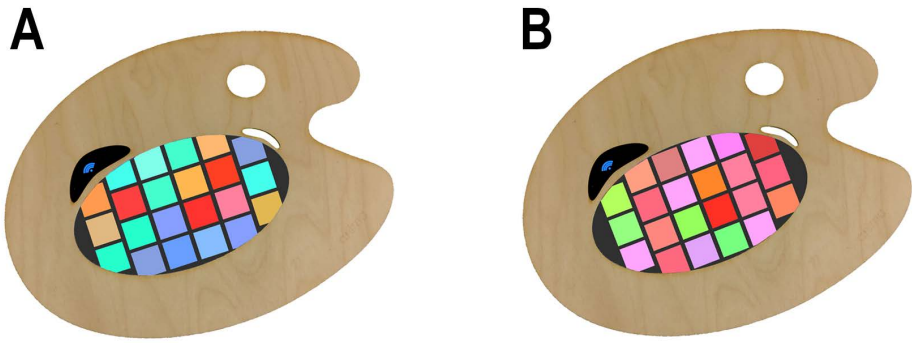


Figure 6.5: Interface of Anima's palette with the seed colours placed in the centre (A: P10, B: P11).

6.2.2.4 Identifying a Mental State and Looking for its Mapped Colour

Findings indicate that that the sense-making process was facilitated by the identification of a salient mental state. Since all participants successfully reached mindfulness states during mandala colouring, such salient states were most likely associated with memorable less mindful states. As it happened, one such state has been experienced by most participants as the initial frustration of learning to colour in digitally on a tablet with the stylus: *"I think I'd need to get accustomed to use a tablet, but the opportunity of me displaying different colours that reflect my brain activity helps me become more self-aware"* (P4). Indeed, the availability of this salient experience of frustration was particularly useful for facilitating the sense making of the overall mapped colours, both before and during the workshops: *"yours [to P11's palette, in Figure 6.6] is a really good example [of evolving towards a mindful state], where actually getting those kind of paler colours. I have [P10's, in Figure 6.6] quite a dark red plus poppy red and a scarlet red [as it took me longer to let go the initial frustration]"* (P10). As most of the generated colours were muted, the most salient ones were the colours with high saturation and brightness. Another way to make sense of the complete palette was during reflection-in-action, when participants identified such salient colours and attempted to link them to mental states experienced during the mandala colouring: *"when you see that your colours become not so bright, then you can like see you're doing ok"* (P2). As this quote indicates, the increase in the saturation of the generated colours was instrumental in helping participants linking them to specific mental states and in particular less mindful ones.

6.2.2.5 Negotiating the Ambiguity of colours' Random Appearance

A third strategy of sense-making of the colour palette was by confronting its ambiguity regarding the random generation of colour. We purposefully designed for this ambiguity so that it supports a non-judgment stance during mandala colouring: participants may not easily identify the last generated colour and hence, its mapping to the current mental state. In this context, the absence of a timeline led to a particularly challenging temporal ambiguity: *"because it was more random, I was more focused on the mandala [colouring] rather than on the colours coming up"* (P9). This was also supported by findings from the video analysis, which revealed that participants only shifted their attention to the palette when they wanted a new colour after they had completed the colouring of a full layer of mandala's geometry, rather than when colours appeared on the palette. Yet, they spent very little time selecting the next colour. This is an important outcome, confirming that the open monitoring of mindfulness states on the peripheral display through adaptively generated colours has been sufficiently subtle to not distract attention away from the main task of mandala colouring: *"when I finished with one colour I looked again and saw if new colours had appeared"* (P7), *"I didn't notice that they changed"* (P2). This outcome is important as it confirms the value of peripheral interaction for the design of mindfulness technologies, and in particular for open monitoring.

This extends the current approaches [129, 141] by enabling passive awareness of one's mental states via a near periphery interface providing subtle notifications through ambiguous EEG-based colour mapping. Furthermore, participants handled this ambiguity in their use of Anima for reflection-on-action: *"you can see when I started doing it they [the generated colours] were bad [less mindful, stronger], but later I could see they [the generated colours] were getting better [more mindful, muted]"* (P10). Moreover, by zooming out and looking for patterns in their palettes, participants reflected on their overall session. This is an interesting outcome indicating that temporal ambiguity in this context outweights the difficulties of understanding the colour mapping, although previous work has framed ambiguity mostly with respect to real-time visual mapping [227].

6.2.2.6 Opportunities and Challenges of using a Peripheral Interface for the Open Monitoring during Mandala colouring

In this section, we describe the outcomes of participants' engagement with Anima and their suggestions for the design of novel technologies for mindfulness training. We further describe the decoupling of mindfulness training for focused attention from that of open monitoring, as well as the mapping of brain activity onto colours to represent mindfulness states.

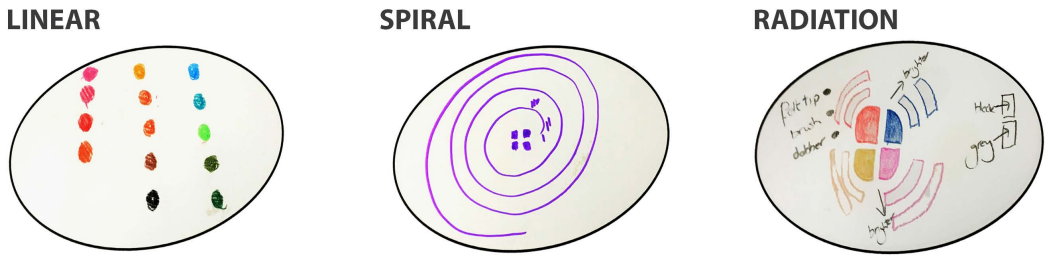


Figure 6.6: Proposed interface designs being: linear colour evolution (P5), outward-growing spiral (P6), radiating colours (P10).

Colour Variation: Saturation, Brightness and Hue. In the workshops, participants provided rich input into the materialisation of mindfulness states on the colour palette exploring both what states can be materialised, and through what colours' properties (e.g. hue, saturation, brightness). Participants also indicated the desire for less similar colours generated on the palette, and preference to select both muted and bright colours: *"with a dark side, and a light side"* (P12). Unlike muted colours which both materialise and help regulate mindfulness states, bright ones support materialisation of fewer mindfulness states. They can also support self-expression for infusing aesthetic qualities in mandala colouring not only for people interested in artistic purpose, but also for those interested in mindfulness practice. Indeed, the latter would use bright colours to provide accents among layers needed for contrasting the predominantly muted colours. All participants expressed a strong interest in the palette and its metaphor: *"it feels like you are using a paint box. It feels better than just using a tablet"* (P9). Because the colours were provided on a wooden palette (Figure 6.6, left), five participants enacted striking interactions resembling the use of a painting brush by tapping for instance several times on the colour as it would load more material and increase its intensity: *"applying more pressure to create different tones"* (P4). This suggests the value of extending Anima with additional art materials with tactile properties such as digital brushes and watercolours to enhance participants' potential for self-expression.

Colours' Generation: Frequency and Rationale. Another theme highlighted in the workshops was the colour generation process. If temporal ambiguity relates to the random order of generated colour whose chronology cannot be inferred from the palette, this topic concerns the frequency of the colour generation. Although eight participants enjoyed the provided time-based design, ten participants suggested three new approaches. First is colouring-based generation of colours, suggested by seven participants along the line that colours should be generated at a higher frequency at the start of colouring session: *"at the beginning, [the palette could] suggest more colours, then towards the end maybe just one or two, the final colour"* (P5) or after the completion of a mandala's layer. Second is a mental state-based generation of colours, suggested by six participants: *"when something happens [in the brain activity] the colour needs to change, but if I'm stable there's no need to change"* (P2). This suggestion came with the expected benefit to help people become more aware of mind-wandering moments, and facilitate bringing attention back to the present moment: *"if you get distracted then colours start appearing more suddenly"* (P6). The third is performance-based generation of colours was, suggested by three participants through new colours that could represent rewards for accomplishing focused attention goals such as colouring without mistakes: *"if I finish an area in the mandala and I didn't go beyond its line [avoiding mistake], more bright colours can appear in the palette"* (P1). This is interesting since bright colours are used to map less mindful states, suggesting that the focused attention may not be continual throughout the session but organised according to the mandala's geometry, allowing thus for brief moments of relaxation following the completion of a layer.

Session Monitoring: Organization of Generated colours. The way in which the unfolding mental states should be openly monitored to better support mindfulness training was also discussed during the sessions. Findings indicate that through their exploration of Anima, participants were challenged by the temporal ambiguity of the generated colours that were randomly placed on the palette. Five participants revised the random choice entirely by suggesting a transparent chronological placement of the generated colours. In turn, this would facilitate a more explicit open monitoring of attention (new interfaces' design suggestions are shown in Figure 6.6): *"a timely pattern, so we can see how our brain is functioning"* (P8). This suggestion would not only support reflection-on-action but also in-action by providing a less ambiguous real-time mapping. While Anima offers representations of current mental states, participants also looked into representations of their targeted deeper mindfulness states. This would leverage gamification principles by identifying both the desirable deeper mindfulness states as rewards, and the less mindful ones as penalties, as part of their initial choice of seed colours: *"So you're playing a game with yourself, you're challenging yourself"* (P10), or *"you have to earn that [original seed] colour, rather than be presented with it at the start"* (P11).

This suggestion, advanced by four participants, is interesting as it would also make the open monitoring more explicit. However, explicit monitoring of the mindfulness practice was considered more problematic by three participants. They were concerned about its risks towards non-judgemental acceptance, a key tenet of mindfulness practice: *"It would freak you out wouldn't it?"* (P12 to P11). This position is also supported by the tradition of mandala colouring as mindfulness practice with no attachment to an end goal (Daudén Roquet Sas, 2019; Fincher, 2000; Zhu et al., 2017). Although these participants appreciated the current design choice to provide a subtle open monitoring: *"because it was more random, I was more focused on the mandala rather than on the colours coming up [...] seeing a pattern maybe you sort of start thinking about why is this pattern coming up"* (P9), they agreed that rewards could be valuable only if administered in a subtle way to not distract from the mandala colouring.

6.3 Discussion

In this section, we revisit the initial research questions and discuss the value of our findings both within and beyond the practice of mandala colouring. Despite this study being an initial exploration of Anima, and future work will investigate its value in the wild, the outcomes contribute to the field of HCI and, in particular, the design of novel mindfulness technologies. We further elaborate how metaphorical representations of brain activity can benefit from representational and temporal ambiguity to facilitate mindfulness training. Such design implications can be extended to the design of peripheral visual feedback to support a subtle real-time feedback during focused attention practices, which also supports the more advanced practice of open monitoring.

6.3.1 Metaphorical Representations of Mindfulness States

One of our research questions focused on how to design metaphorical representations of mindfulness states that are both recognisable and open for interpretation. Findings indicate the importance of evocative balance [116] irrespective of one's motivation for mandala colouring, but in particular for its use as a mindfulness practice for emotional well-being. However, if previous work has framed such ambiguity mostly with respect to visual metaphors of discrete bodily states through different colours and shapes [227], or what we would call representational ambiguity, our outcomes extend this to include also temporal ambiguity. We define the latter as the concealment of the chronological occurrence of the mindfulness, or broadly bodily, states for instance through the random placement on the palette of their metaphorical representations.

6.3.1.1 Facilitating Mindfulness Training through Representational and Temporal Ambiguity

With respect to the representational ambiguity, findings suggest that the use of colour saturation and brightness to metaphorically represent mindfulness states, rather than merely hue, has supported participants' intuitive understanding, thus striking the right evocative balance. This extends the current work on colour-based metaphors of emotional states which have leveraged mostly discrete colours and their hue [108, 177, 181] for expressing rather than regulating emotions.

During mandala colouring, the painter palette adaptively generated muted (about two thirds) and high saturated, bright colours (about one third). During colouring, when most participants experienced mindful states, the former was selected more indicating the ability of these colours to communicate such states. Participants also highlighted colours' potential value to further regulate them and therefore to subtly support the training of focused attention. Interestingly, the more saturated, brighter colours were also used by all participants, albeit predominantly for aesthetic purposes to support self-expression and occasionally even by participants interested in mandala colouring for mindfulness benefits. They used such colours mostly for small touches among the mandala's layers. Our outcomes indicate the value of leveraging a broader range of colours' properties for exploring representational ambiguity of their evocative balance, both for mindfulness and art purposes, which in turn has the potential to increase the expressiveness of the metaphorical representations.

The value of temporal ambiguity comes into play in the case of monitoring the training of focused attention on the peripheral display which is in fact desirable, becoming a quality of peripheral interaction. This flexible use of temporal ambiguity in the design for reflection on bodily states has been limitedly explored before, with the exception of recent studies [276] on temporal unfolding of physiological arousal. The temporal aspect of evocative balance is particularly important in real-time monitoring of mindfulness states, but less so on later monitoring. This can be extended to the design of peripheral visual feedback for other types of technologies monitoring mindfulness training on a main display, for which we can imagine wristbands on which real-time visuals may appear in random order as subtle indication of one's mindfulness state, or as colours on embedded in environmental objects (e.g. backlit mouse pads). These would go beyond the current predominant focus on immersive experience to train focused attention, towards supporting also the more advanced practice of open monitoring of attention.

These findings extend previous somaesthetic approaches emphasizing the role of bodily experiences and their aesthetic appreciation to guide attention inwards [112]. In particular, our findings extend the communicative value of affective data mapped to visual and haptic feedback to brain activity data mapped to visual feedback whose exploration allowed our participants to engage in sense making, a process through which the EGG-based biodata become meaningfully rich somadata [2].

6.3.2 Making-Sense of Ambiguous colour-based Metaphorical Representations

Through the second research question, we explored how people made sense of the metaphorical representations of their mindfulness states. The findings highlight how people made sense of the metaphorical representations through the open exploration of their evocative balance that occurred, not during the colouring session, but after its completion. Limited HCI work has explored in detail the specific approaches that people take to make sense of such representations, which we argue are important if we want to better support them. Our outcomes provide fresh insights into how the sense-making evolves and its emerging strategies consisting of identifying either a salient mental state, or a salient colour, and link them to their counterpart mapped colour and mapped mental state, respectively.

This allows a causal connection between the two, enabling the understanding of how Anima works and how, in the light of their new understanding, people may improve their mandala colouring as mindfulness practice. While the representational ambiguity was successfully balanced, allowing for intuitive differentiation of mindfulness states from less mindful ones based on colour saturation and brightness, the temporal ambiguity was particularly problematic for the reflection on the focused attention practice. This suggests the value of enabling both a random colour generation during the use of the palette as a peripheral display, and the chronologically reorganization of the generated colours for reflection-on-action.

6.3.2.1 Preferring Reflection "on" rather than "in" Action

Although Anima could support monitoring both during, and after the mandala colouring session, an important outcome is participants' strong preference for its latter use which –unlike reflection during the practice- was considered key for not distracting from the practice and for not judgementally hindering it. Reflection-on-action requires complete and temporally non-ambiguous representations of mindfulness states as they occurred during an entire session; alongside more informative, event- rather than time-based colour generation triggered by changes in mindfulness states such as loss of focus or brief moments of relaxation following the completion of a mandala's layer.

Our outcomes provide a more nuanced understanding of the value of mandala colouring for reflection on one's experience [87], and extend findings on reflection-on-action for increased appreciation or positive interpretation of one's experiences [50, 123, 254]. Indeed, findings suggest benefits of "after" or "on" monitoring of mandala colouring practice, such as understanding the overall focused attention and how it may compare to one's other sessions or even other participants' sessions.

In contrast, the benefits of monitoring "during" or "in" attention focused training through mandala colouring are more nuanced requiring future exploration. For example, future work may look into if and how the peripheral generation of colours may impact on the training of focused attention, supporting for instance self-regulation by seeing, selecting and colouring with muted colours [167].

6.3.3 Decoupling the Main Focus of Attention from Open Monitoring

With respect to the third research question of decoupling the mindfulness training, a significant outcome was Anima's flexibility to support two distinct goals: the training of focused attention and the open monitoring. Thus, the digital canvas supported predominantly the focused attention training through the mandala colouring; while the painter palette supported the open monitoring of attention. Our outcomes suggest the benefit of decoupling the two activities on separate displays, so that the colouring mandala remains the focal activity, while its open monitoring becomes a secondary one, supported on the peripheral display. With respect to open monitoring, however, an important outcome is the tension regarding when it is best to occur: during or after the practice of focused attention, and the subsequent change of the palette's role from peripheral to focal display during the reflection-on-action. Peripheral Interaction for Real-Time Open Monitoring Findings indicate Anima's flexible use of the palette for real-time monitoring as well as for historic open monitoring. On the one hand, the painter palette is a peripheral display during attention training and thus a real-time open monitoring device, demanding ambiguous representation to prevent judgment. On the other hand, it is also a focal display for open monitoring after the mindfulness training session has been completed, which demands less ambiguity to facilitate interpretation.

The value of peripheral displays in HCI has been discussed mostly in terms of limiting the distraction of its content on the main task [129, 176], or for supporting unconscious persuasion like in the case of public displays leading people to use stairs [221]. This body of work found that interfaces placed in the near periphery [129] that use dynamic design elements such as intensity or rhythm [199] provide passive awareness i.e. without distracting the primary focal task. Seldom, however, such work has focused on strongly inter-related tasks.

We argue that this decoupling of displays with the use of near periphery for real-time monitoring of the activity on the main display is an important design principle that can be beneficial for mindfulness technologies, in particular, by providing a subtle monitoring of the main task using ambiguous mapping in an interface in the near periphery, e.g. colour-based representations of mental states. This could also inform the design of technologies to support meta-awareness in everyday activities, i.e. time management, screen time, and physical movement.

6.4 Summary

This chapter details the perceptions and experiences of using Anima from 12 people that regularly engage with mandala colouring. It highlights the way in which motivations for practising mandala colouring can inform the way the mandala is coloured, and outlines a number of specific design recommendations that the HCI community can further develop and evaluate (building on prior discussion on main components and challenges of this practice in chapters 4 and 5): designing for reflection in-action and reflection on-action to facilitate the transfer of skills onto everyday life, negotiating the temporal and representational ambiguity of the metaphorical mappings of mindfulness states, and decoupling the two main processes of mindfulness training (i.e. maintaining a focus of attention, e.g. on the mandala, and monitoring the mindfulness states, e.g. bring the attention back when the mind wanders) onto two different interfaces. Specifically, uncovering the value of colours' spatio-temporal appearance for understanding metaphorical representations of mindfulness states; and the value of decoupling mindfulness training and monitoring, through ambiguous representations on the peripheral display and less ambiguous ones on the focal display, respectively.

Chapter 7

Understanding the Role of the Human Body in the Lived Experience of Sitting Meditation

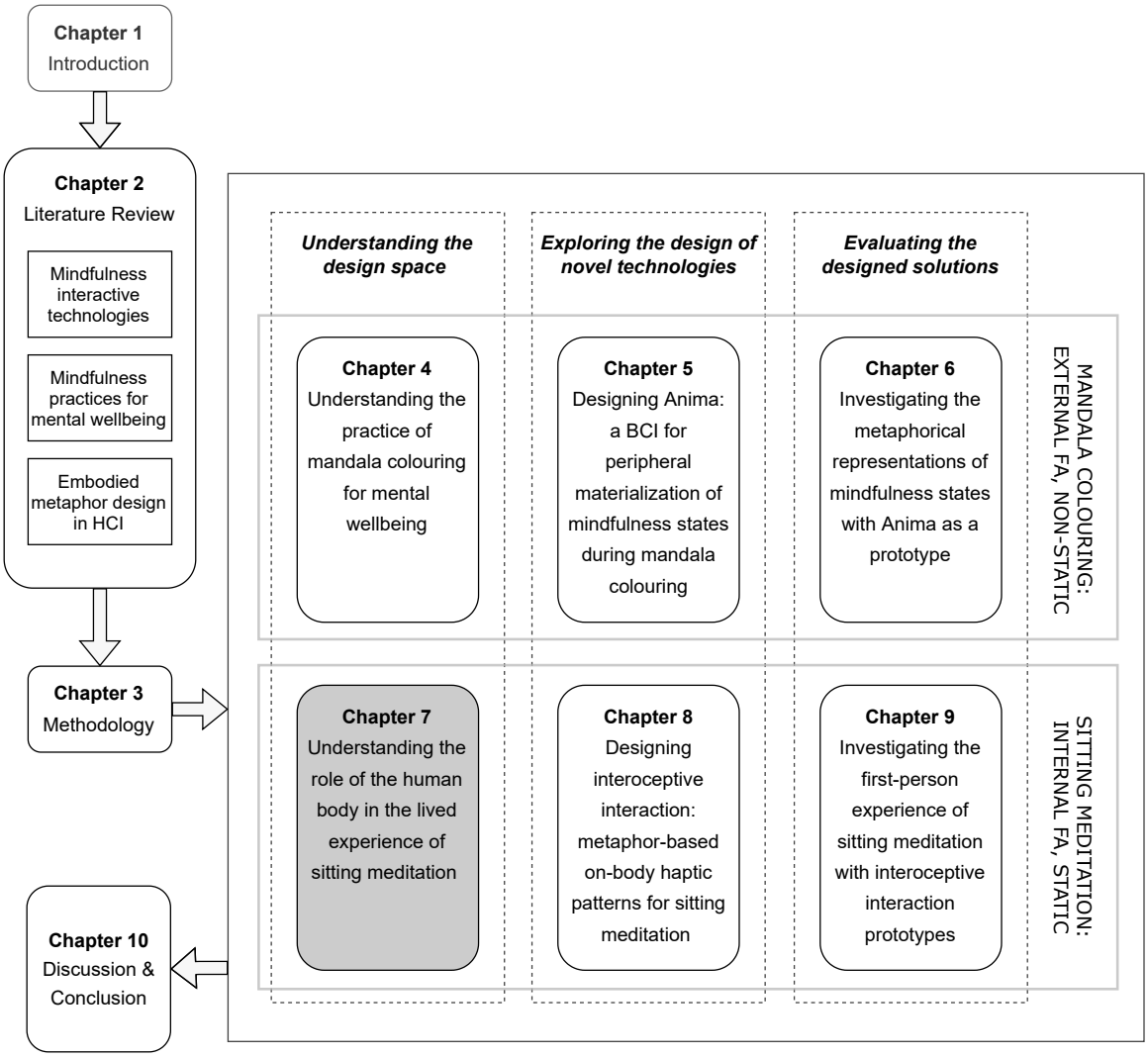


Figure 7.1: Chapter 7 of Thesis structure

7.1 Introduction

Focused attention meditation is a mind-body practice that relies on the regulation of attention to support the non-judgemental awareness of the ongoing present experience; both internal such as sensations, thoughts or feelings, and external to limit mind-wandering and enabling being mindful [80, 81, 137]. The importance of attending to bodily sensations has been long acknowledged in meditation and more broadly in mind-body practices [81, 97, 103, 271] to facilitate the regulation of emotions or attention [179]. Nevertheless, the skill of regulating attention during meditation is difficult to master.

This chapter explores the FAM practice of sitting meditation with an internal object of attention and, more specifically, the role of the human body when engaging with it. The two studies presented build on each other and intend to provide an in-depth understanding of the current approaches with and without technology for sitting meditation. Furthermore, they contribute The first study (section 7.2) consists on an auto-ethnographic and expert evaluation study of 16 most popular iPhone mindfulness apps in the UK. The second study (section 7.3) reports on participatory workshops with 24 experts in different meditation traditions exploring the bodily sensations that emerge during meditation, following a research through design approach. For each study, the opportunities for HCI researchers to design novel systems for sitting meditation that leverage the felt experience of meditation and its associated physical sensations are discussed.

7.2 Review of Mindfulness Meditation Apps

Mindfulness has been defined as the awareness that arises through paying attention on purpose, in the present moment without judgement [137]. While this practice has shown significant benefits for health and well-being, and especially for stress reduction and depression [40, 15], the term mindfulness usually covers a family of self-regulation techniques e.g. sitting meditation, movement meditation (yoga or tai-chi), or breathing and visualisation exercises. A landmark work for categorising such techniques has been proposed by Nash and Newberg based on neuroscience findings [189].

The prevailing interest on mindfulness and the accessibility of mobile applications in daily life has increased the amount of commercial mindfulness-based applications (MBAs). Recent findings indicate their effectiveness on stress reduction [46, 54], and improving well-being [119]. For example, a recent evaluation of MBAs has shown that only 4% provide mindfulness training, while the majority mostly offer time reminders for meditation [174].

This work however only explores the general qualities of MBAs (i.e. user interface, functionalities) providing limited insights into their design informed by mindfulness meditation literature. HCI scholars have also developed interactive technologies to support mindfulness training. Findings indicate the value of integrating wearables [230] and virtual reality [247, 284] in enhancing self-awareness and self-regulation of attention, which are two of the main processes involved in mindfulness meditation [229]. Thus despite mindfulness-based applications create new opportunities to target wider audiences and to expand their contexts of use, an outstanding challenge is understanding their underpinning techniques and design guidelines for more efficient mindfulness training and compelling user experience.

This study draws from HCI and commercial work on mindfulness and MBAs, which have the potential of offering alternative delivery medium and of fostering adoption of meditation practice in everyday life. There has been however limited investigation of the specific meditation techniques addressed in MBAs, which limits our understanding of their effectiveness. To address this gap, this section explores the meditation techniques underpinning the most popular iPhone MBAs in the UK. Although these apps represent a small portion over all MBAs available, our work aims to encourage a more nuanced discourse of MBAs and their relative effectiveness. With findings from an auto-ethnographic and expert evaluation of the apps, I then discuss implications for design [234] including bodily aspects to mindfulness meditation and a call for developing a framework for evaluating MBAs.

7.2.1 Research Method

The apps were identified by performing a search of free mindfulness-based meditation applications on the UK iTunes app store. The search included keywords such as mindfulness, meditation, mindful, and well-being. From the 280 apps initially identified, only the ones mentioned in the Health and Fitness category were retained.

From these,those with more than 100 ratings in the iTunes app store were selected, and an average rating higher than 3 on a 5 point scale. With the exception of Meditation Timer and 3 Minute Mindfulness apps, the other 14 apps are also available for Android OS. The final 16 apps (Table 7.1) were evaluated through both an auto-ethnographic approach and expert evaluation study. For the former, all apps have been used by the first author on an iPhone 6S for at least 30 minutes including several meditation sessions in a real-world setting. For the expert evaluation, the Nielsen's heuristics and MARS scale [256] were used first. However, given that the findings were quite generic focusing mostly on the usability of the interface rather than on the training content, I employed the meditation taxonomy proposed by Nash and Newberg [189] grounded in neural correlates of different techniques [270] and their underlying mechanisms [26].

App Name	Meditation Type	Cognitive Strategies	Objects of attention	Closed / open eyes	Static / kinetic	Verbal / non-verbal	Intrinsic / extrinsic	Body Posture	Control of breathing	Avg Duration	Sound Landscape
Headspace	Guided Meditation	Focused attention, Introspection	Body	Closed	Static	Non-verbal	Extrinsic	Sitting on a chair	In nose, out mouth. Focus on rhythm.	10 min	none
Calm	Guided Meditation	Concentration, Introspection, Noting	Body	Closed	Static	*Verbal*	Extrinsic	Sitting on a cushion or chair	Gentle breathing. Count breaths.	3 min - 10 min	nature
Relax Meditation	Guided Meditation	Focused attention, Introspection	Body	Closed	Static	Non-verbal	Extrinsic	Sitting on a chair	In nose, out mouth. Expand belly.	10 min	none
Insight Timer	Self-reliant Meditation	Concentration	*Sound*	-	Static	Non-verbal	*Intrinsic*	-	-	5 min	kangse bell
Digipill	Guided Meditation	Introspection, Passive observation	*Body, Sound*	Closed	Static	Non-verbal	Extrinsic	-	-	13 min	white noise
Relax with Andrew Johnson Free	Guided Meditation	Conscious awareness, Introspection, Body scan	Body	Closed	Static	Non-verbal	Extrinsic	Sitting on a chair	Deep breathing	14 min	music
Mindfulness Daily	Guided Meditation	Introspection, Focused attention	Body	*Any*	Static	Non-verbal	Extrinsic	Sitting, hands on stomach	Breath in deeply, exhale slowly	5 min	none
10% Happier	Guided Meditation	Passive observation, Introspection, Noting	Body	*Any*	Static	*Verbal*	Extrinsic	Sitting still	Inhale straigthen the spine, exhale soften the body	10 min	none
Simple Habit	Guided Meditation	Passive observation	Body	*Any*	Static	Non-verbal	Extrinsic	Sitting on a chair or laying on the ground	In nose, out mouth. Make outbreath sound.	5 min	none
Omvana	Guided Meditation	Focus on the self, Visualization, Body scan	Body	Closed	Static	Non-verbal	Extrinsic	Sitting	Deep breathing	8 min	none
The Mindfulness App	Guided Meditation	Passive observation, Intronspection, Compassion	Body	Closed	Static	Non-verbal	Extrinsic	Posture that reflects dignity.	Expand breathing in, back to center breathing out	10 min	none
Pacifica for Stress & Anxiety	Guided Meditation	Focused attention, Intronspection, Imagination	Body	*Any*	Static	Non-verbal	Extrinsic	Sitting on a cushion or chair	Breathing into stomach.	9 min	nature
Meditation Timer	Self-reliant Meditation	-	-	-	-	-	*Intrinsic*	-	-	10 min	bell
Breethe	Guided Meditation	Focused attention	Body	Closed	Static	Non-verbal	Extrinsic	Sitting on a chair	Deep breathing. In nose, out mouth.	10 min	noise
3 Minute Mindfulness	Guided Meditation	Focused attention, Intronspection, Self-awareness	Body	Closed	Static	Non-verbal	Extrinsic	Comfortable position	Deep breathing. In nose, out mouth.	3 min	none
Tide: Focus, Relax, Meditation	Self-reliant Meditation	-	-	-	-	-	*Intrinsic*	-	-	25 min	nature

Table 7.1: Summary of the meditation techniques used in the evaluated MBAs, based on meditation taxonomic keys [7].

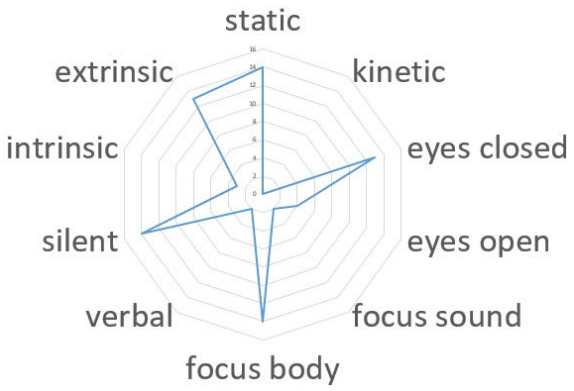


Figure 7.2: This graph indicates that most MBAs train sitting voice-guided meditation with the eyes closed (Table 7.1). Only two apps focus on sound and two support an internal verbal process, while the rest are silent target the attention to the body experiences.

The key dimensions of this taxonomy include: specific cognitive strategies (i.e. focused attention, concentration); object(s) of attention (i.e., conceptual and/or physical foci); description of required beliefs; as well as bodily aspects such as eyes are closed or open during meditation; the process is static (stationary but not necessarily immobile) or kinetic (prescribed movements); a specific body poster is suggested; recommendations for breathing; meditation is silent or auditory, which includes inner speech; the process is intrinsic (self-reliant) or extrinsic (dependent on an outside person or process).

7.2.2 Findings

Findings indicate that there is a lack of diversity on the techniques offered by MBAs (Figure 7.2), as well as in the context they are employed.

7.2.2.1 Two Main Classes of MBA

An important finding is the prevalence of MBAs supporting guided meditation echoing [174]. Furthermore, such apps focus on extrinsic and static processes, leveraging audio output. In contrast, only a small number of apps were identified that relied on intrinsic processes with limited external stimuli (such as Insight Timer, Meditation Timer, and Tide apps). In these cases, the user had no audio guidance but merely a bell sound announcing the start and end of the meditation session. This outcome is surprising, as consistent findings have shown the effectiveness of intrinsic processes in meditation practice [16], indicating a less explored design space.

7.2.2.2 Bodily Aspects of Mindfulness Meditation

With a few exceptions (Insight Timer, Digipill, Meditation Timer and Tide app), the majority of apps ask users to focus their attention on their body (Figure 7.2). In particular, guided meditation apps commonly start with breathing exercises in which users have to focus on feeling how “the air enters the lungs and expands the belly”. Calm and 10% Happier apps use a technique for sustaining attention by counting the breaths, i.e. noting. Other cognitive strategies often prescribed were passive observation and conscious awareness, as shown in the third column of Table 7.2. For instance, Headspace app asks to "do not worry about achieving anything, just sit back and enjoy being present in the world". Four apps (Mindfulness Daily, 10% Happier, Simple Habit, and Pacifica) let the user choose whether to keep the eyes open, but the general recommendation is to keep them closed. While visualisation, compassion and imagination are less employed approaches, when used they also focused on the body feeling experienced during meditation.

7.2.2.3 The Context of Mindfulness Meditation

The majority of the identified applications recommend meditating daily for about 10 minutes, in a quiet place while sitting still and comfortably on a chair or cushion (as shown in Table 7.2). Relax Meditation app specifically suggests to practice always at the same time in the same calm and private space. While the voice and pace of the delivery of guided meditation vary across apps, there is a gender balance in the meditation instructors. With respect to the sound landscape, Calm, Pacifica and Tide apps provide nature-inspired sounds; Relax with Andrew Johnson app has music, while Digipill and Breethe apps have white noise. Nonetheless, most MBAs only have the voice of the teacher guiding the meditation, which allows focusing on the surrounding sounds and present experiences.

7.2.2.4 Monitoring the Meditation Practice

While a few MBAs allow sharing messages on social media (Headspace, The Mindfulness apps) about the mindfulness experience, a general understanding of the meditation practice is less supported. Despite their popularity, the evaluated MBAs provide limited mindfulness education. The only exception is Headspace app, which supplies video infographics to explain mindfulness concepts in simple terms such as “watching thoughts pass by, without attaching to them”.

In addition, the effectiveness of each meditation experience is also difficult to evaluate with MBAs. During meditation sessions, they give general messages such as "when your mind wanders, bring it back gently", instead of feedback based on one's performance. Moreover, MBAs do not provide tools to measure the performance neither during meditation nor afterwards.

7.2.3 Discussion

7.2.3.1 Beyond Guided Meditation: Supporting Intrinsic Processes

Findings from Study 4 indicate the prevalence of MBAs for guided meditation, which is a less effective technique in terms of health benefits as it supports relaxation rather than mindfulness per se [16]. Designing for intrinsic processes is withal difficult, and mobile technologies with their audio or visual output may pose more challenges for supporting them. This offers up an exciting new design space for undesigning [204] for intrinsic processes, arguably by leveraging other technologies such as tangible interfaces.

7.2.3.2 New Tangible Interfaces for Supporting Bodily Aspects

While the body plays an important role in mindfulness meditation by being the object of attention, it tends to be limitedly accounting for in interface design and UX. Traditional meditation techniques often employ tools such as baoding meditation balls or the Tibetan wheel for supporting slow and continuous movements fostering mindfulness state. Yet all evaluated MBAs involve static rather than kinetic processes. To address this limitation, we can think of new design opportunities such as novel tangible interfaces augmenting MBAs to support movement. Bodily aspects have been also suggested important in supporting well-being during grief [231].

7.2.3.3 Developing Guidelines to Evaluate MBAs' Effectiveness

A striking finding was that only Headspace app was evidence-based [119], with no reference to the evaluation of health benefits for the other MBAs. I argue for the importance of developing a framework for evaluating the effectiveness of such apps, so that users can make informed choices based on their effectiveness. This can inform policy makers such as current efforts of the UK National Institute for health and Care Excellence (NICE) for developing an evidence-based system for evaluating health apps.

Figure 7.3: Three objects created in workshops to materialise 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.

7.3 Participatory Workshops Exploring the Role of the Human Body during Sitting Meditation

This section reports on 10 workshops exploring the way in which experts in different meditation traditions perceive their meditation experience, paying particular attention to their bodily sensations. In particular, the aims were to identify:

The key stages that may occur during meditation and whether they have specific bodily sensations.

In what way could these bodily sensations inform the design of novel technologies to better support meditation.

The opportunities and risks of using technology to facilitate meditation.

7.3.1 Research Method

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 [297], particularly inspired by Andersen's Magic Machines [7, 6, 32] which facilitates the expression of personal experiences through an embodied process of making. It has been previously 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 [7]. 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 were provided for them.

Figure 7.4: Illustration of the materials used in the workshops to elicit tactile experiences.

7.3.1.1 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 (18 identified as women, 6 as men) with different meditation backgrounds, nationalities and ages (48 years old on average, SD = 15, with 4 participants being over 65 years old) participated in the workshops. The average meditation time-span is 12 years, ranging from 2 to 37 years; and the least participants practised meditation was 3 times a week, with most participants practicing daily for 10 to 60 minutes. Participation was incentivised with an equivalent of a $20.

7.3.1.2 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 is used as a prompt [7, 32].

Part 2. Crafting Material Speculations. Drawing from Andersen's Magic Machines methodology [7, 32], 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, [7]]. 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 [7]. We carefully chose a set of materials (Figure 7.4) meeting the following two criteria, after we experimented with their experiential qualities [95, 140]. First, we included what we called "structural" materials allowing the construction of the magic machine such as plain card-boards, 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 [126, 133]. In particular, we aimed to foster haptic experimentation [170] 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 sises; 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, [286]].

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 [6, 79]. 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 walk-through, during which the other participants are 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 judgement 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 [189] 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.

7.3.1.3 Data Collection

For each workshop, participants were gathered in a quiet room with a large central table where the workshop materials were placed (Figure 7.4). Only the group discussion and individual interviews were recorded on video, with participants consent.

7.3.1.4 Data Analysis

All qualitative data was anonymised and conversations were transcribed and coded following a hybrid coding approach [85] 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).

7.3.2 Findings

7.3.2.1 The Lived Experience of Meditation

The practice of meditation originated in historic contemplative traditions using different techniques and goals [16]. This diversity was present in our workshops, as participants had explored and currently practised 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 practised 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 [189], although we aim to highlight them between participants rather than to categorise a particular style. Regarding the followed cognitive strategies marked by distinct neuro-correlates [110, 189, 277], 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 practised memorisation and repetition of a mantra, which in some cases was also vocalised: *"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).

Figure 7.5: 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).

We found that participants following this cognitive strategy usually meditated as a spiritual practice.

The role of the body can be also explored from a third-person perspective. Findings indicate that all participants practised 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 practised 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.

This was particularly stressed by 3 participants describing how they meditate near the sea and use the tide to guide their experience. These findings suggest that the restorative power of nature [139] can better support the practice of meditation, and such power has been recently explored as an audiovisual feedback for technology mediated meditation [60, 69]. 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 materialise similar metaphors, as further detailed in the following section.

7.3.2.2 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 7.5): *"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 7.3 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 7.2).

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 7.3 centre).

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 [189]. 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 [226], 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, irrespective 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. [203] 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 7.6). 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.

It is only when they realise 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.

Figure 7.6: Magic machine by P3 recreating the soft (wool, cotton) and balanced (aligned sticks) body when being mindful, right before engaging with dismissible thoughts (rice).

7.3.2.3 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 7.6): *"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 materialise 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 7.3, left); wearables (Figure 7.3, center); and ubiquitous displays (Figure 7.3, 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 [260], 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 recognise mind wandering moments by themselves.

All participants agreed that during the grounding stage, continuous personalised 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 [112, 263]. 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 personalised, 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 emphasised 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 [39, 228, 290].

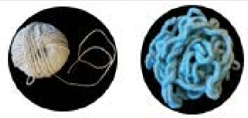
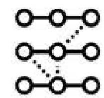
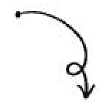
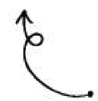
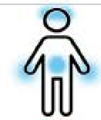
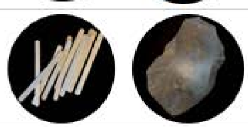
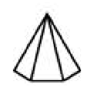
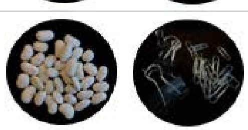
MEDITATION STAGES		MATERIAL METAPHORS		EMBODIED METAPHORS		BODY LOCATIONS		PHYSICAL SENSATIONS	
journey		maleable soft string		dynamic movement		-		-	
grounding		scrunched up paper, sponge		downwards movement		shoulders, jaw, belly		slow rhytmic breathing, relaxing	
becoming mindful		cotton ball, wool		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 7.2: 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.

7.3.3 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.

7.3.3.1 Mapping Bodily Experiences to Meditation Stages

Previous work in psychology identified different stages that occur during meditation [189, 203], 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 (summarised in Table 7.2). 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 emphasised 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.

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 [4, 212]. 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 7.2). 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.

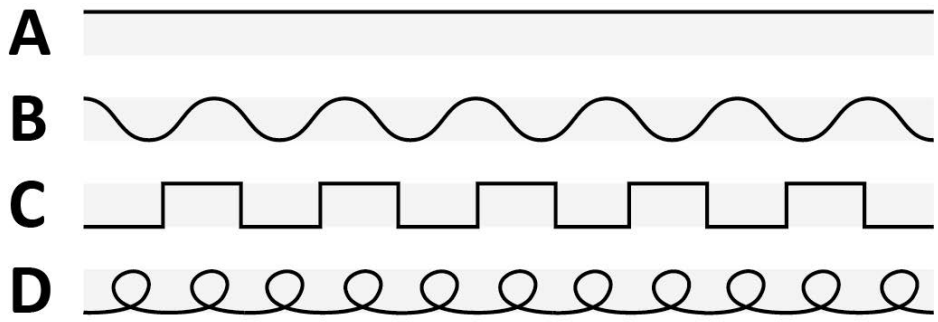


Figure 7.7: In each of the feedback patterns shown (A-D), the horizontal axis represents the temporal domain of the meditation session, and the vertical the amount of feedback.

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 stabilise 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 [3]. 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 7.2). 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.

7.3.3.2 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" [137]) that is not tailored in real-time to one's performance. Novel technologies have facilitated the provision of personalised targeted feedback in real-time using, for instance, biofeedback (e.g. breathing, heart rate, brain activity) [263]. 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, over-reliance 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.

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 [263]. 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 7.7, 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 [100]. The third diagram (Figure 7.7, Pattern C), which represents a way for providing feedback in binary fashion, similar to notifications systems on the phone [36], 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 7.7, 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 [4], the sounds of the sea [212], the amount of leaves on a tree [200]. Nevertheless, we found that mapping one's performance during meditation back to the body could be an interesting design concept. Chapter 7 shows 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 7.2). 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 [115, 132], pressure or vibration [276, 275].

7.4 Summary

This chapter illustrates the felt experience of sitting meditation in different traditions with an internal object of attention, and the challenges to scaffold these experiences with technology. The first study outlines that mindfulness apps focus mostly on guided meditation practices, with limited support for monitoring intrinsic meditation processes and measuring the effectiveness of the training. A more nuanced discourse around such apps concluding with implications for design is proposed; including new tools for supporting intrinsic meditation processes and bodily kinetic aspects fostering mindfulness, together with the call for developing guidelines for evaluating the effectiveness of such applications.

The second study analyses the experience of 24 experts in different meditation traditions exploring the bodily sensations that emerge during their practise. Through material speculation, participants emphasised 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 to HCI include new design insights for designing interactive meditation technologies with a focus on embodiment, such as supporting the regulation of attention through embodied metaphors, designing cyclic feedback patterns; and adds to the emerging relevance of haptic interfaces to explore embodied experiences in interaction design relying on haptic feedback to recreate mindful bodily sensations. In the next chapter (Chapter 8), the outcomes presented in this chapter inform the design of WarmMind: a prototype using on-body warmth actuations recreating the felt experience of meditation to facilitate focusing inwards.

Chapter 8

Designing Metaphor-based On-Body Haptic Patterns for Sitting Meditation

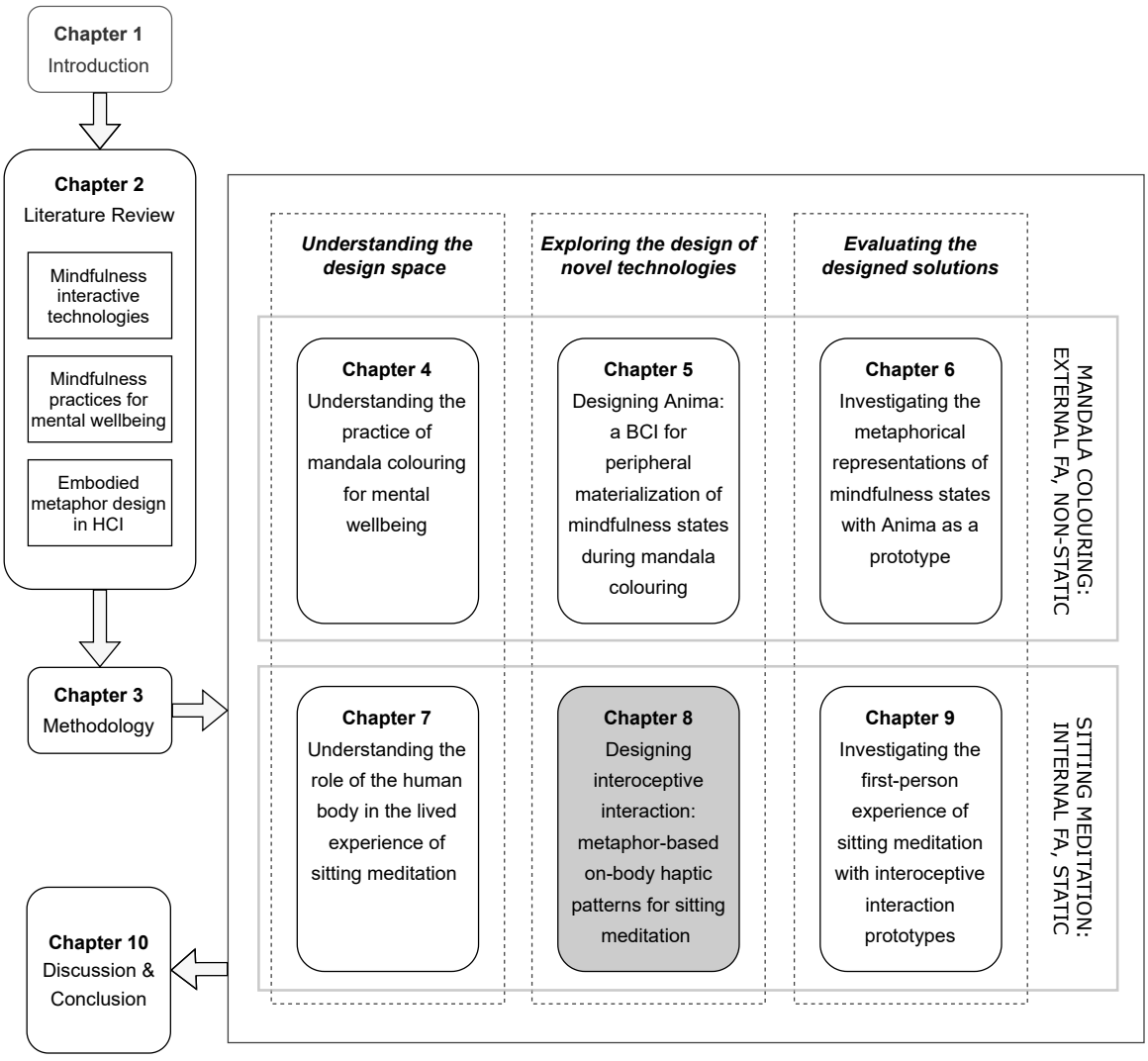


Figure 8.1: Chapter 8 of Thesis structure

8.1 Introduction

With roots in historical spiritual traditions, the practice of sitting 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 practised regularly [40, 81]. 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 (as detailed in Chapter 7 [69]) to interactive systems in HCI [263] (Chapter 2).

The advent of wearable biosensors and actuators has provided opportunities to push forward research in this space by capturing and communicating bodily experiences back to users. Yet a key challenge here is mapping bodily experiences to the interface modality and its content design [2, 227], particularly when designing meditation technologies where the aim is to support attention regulation. One of the main reasons is that being mindful and mind-wandering states involved in meditation training are more difficult to identify when compared to changes in physiological arousal accompanying, for instance, emotional responses to stress –particularly for novice meditators. Moreover, the mapping needs to support the awareness of such physiological responses, whilst also being subtle enough to not distract attention from the internal object of attention [67, 277]. Thus, it has to strike the right balance between ambiguity and clarity, so that the mapping is understood without demanding focus of attention or engendering self-judgement when mind-wandering states are identified.

A common approach used in interactive systems for meditation is mapping meditation states captured by electroencephalography (EEG) brain activity data to visual and aural interfaces [137]. In these systems, meditation states tend to rely on spatial orientation or sound pitch metaphorical mappings, generally with being mindful represented as "high" and mind-wandering as "low". However, the design of such mappings of bodily experiences to interface modality and content has been limitedly described, with a few exceptions [230], and limited efforts have been made to link these mappings to the embodied metaphors underpinning them. Furthermore, meditation's bodily experiences are often mapped onto external stimuli using visual and aural interfaces, and how they could be supported on the body, for instance through embodied metaphor inspired haptic stimuli [132], have received less attention. Hence, despite the growing research in biofeedback technologies and particularly neurofeedback systems for meditation, the field is yet to develop a theoretically informed framework to support the design of metaphor-based mappings of physiological data.

This chapter addresses this gap, by exploring the value of the contemporary theory of metaphors as one of the possible theories informing such a framework. For our design exploration, we have purposefully chosen Muse [151, 186], an increasingly popular commercial brain activity application providing nature-based metaphorical soundscapes in real-time mapping one's meditation experience. Moreover, we designed and implemented WarmMind (Figure 8.2), a research prototype providing counterpart mappings to Muse's using thermal patterns on the upper body -drawing from the outcomes of Chapter 7. As detailed in the following sections, the mapping of WarmMind's on-body haptic feedback differs from Muse's aural feedback in three important ways: (1) WarmMind targets bodily internal senses by recreating bodily sensations, namely thermoception or perception of bodily temperature, rather than using external stimuli e.g. nature-based sounds; (2) it provides discrete, rather than continuous feedback, and (3) through the mapping is more abstract and ambiguous, rather than familiar.

8.2 Exploring Embodied Metaphors of Meditation States

In this section, we describe the preliminary work informing our design rationale to explore thermoception-based embodied metaphors for meditation states, and their comparison with counterpart sound-based metaphors. We agree with the view that identifying appropriate metaphors is not trivial, and can benefit from multiple sources [120]. For the exploration of interoceptive-based metaphors, we triangulated three methods which are detailed below: review of HCI work on embodied schemata for mindfulness technologies (detailed in Chapter 2), work on cognitive linguistics on metaphors related to meditative practices, and the phenomenology of meditation.

8.2.1 Cognitive Linguistics Research on Meditation Metaphors

The exploration of meditation in cognitive linguistics has looked at corpus of text often from Buddhism discourse to explore the different embodied metaphors, common ones being those involving water and movement. Ontological dynamic metaphors include those of the ocean and its waves, for instance, waterscapes whose stillness relates to calm mind or being mindful states, and wind-induced waves or agitation which relates to troubled mind or mind-wandering states [138, 249]. Another common metaphor is that of meditation is a journey, and the meditator is an observer of one's body, thoughts, sensations or feelings [249]. Despite their richness and consistency, these metaphors capture less the lived experience of meditation, which we briefly review below.

8.2.2 Phenomenology of Lived Experience of Meditation

The lived experience of meditation has been explored mostly in mindfulness research and more recently in HCI. In novice meditators, Basnett [23] found that their most common subjective experiences included bodily sensations such as tingles, light/heaviness, a quarter reported feelings of warm, and two reported awareness of heart-beats. Another study of meditators' phenomenological experience explored across four practices (i.e. breathing, body scan, loving-kindness and observing-thought) has shown that and meditators across all practices experienced increased feelings of warmth and interoceptive awareness [149]; particularly in the upper body such as chest and throat [203].

Recent HCI work also explored the bodily experiences associated with key meditation states [67, 203]. Findings abound in metaphorical language indicating that meditation is experienced as a sensorial journey consisting of five key stages with specific bodily experiences: grounding is downwards movement, becoming mindful is upwards movement and warmth in the belly, being mindful is being in balance, and mind-wandering is loss of bodily awareness. Expert meditators suggested the value of recreating such bodily sensations through downward movement for mind-wandering, or of upwards movement to facilitate being mindful [67].

The above outcomes complement previous work on the importance of bodily sensation in meditation [81, 97, 103, 271]. They also provide additional phenomenological evidence for the value of designing interoceptive stimuli to support bodily awareness, and in particular novices' bodily awareness through FAM. These findings also shed light on specific bodily sensations characterising each meditations stage and the involvement of two interoceptive senses [220], namely breathing and thermoception [237], alongside metaphors related to movement. Compared to breathing, thermoception has been less explored in mindfulness technologies, presenting thus the opportunity to open up this design space.

To conclude, findings on the lived experience of meditation identified metaphors involving bodily sensations as emphasising warmth and movement, hence more suitable to be perceived through interoceptive senses such as thermoception (Table 8.1). In contrast, findings on cognitive linguistics indicated metaphors involving external objects and processes such as water and movement that appear more representational, hence better suited to be communicated through external senses such as vision or sound. The identified metaphors from both sources offer an exciting space for design exploration as they share movement as a process, but also warmth and water respectively which can be communicated to internal and external senses, respectively.

8.2.3 Analysis of Muse: Audio-based Metaphors

In Focused Attention Meditation (FAM) [168], the focus of attention is on an explicit, clear and unwavering (calm and stable) stimulus such as candlelight, mantra sound, or one's breath. If the stimulus is not visual, a common instruction is that meditator's eyes are closed to limit potentially distracting external stimulation. Although the explicit stimulus can be either external or internal, most work on meditation technologies has focused on external stimuli, commonly images or sounds.

In this section we describe the audio-neurofeedback provided by Muse, emphasising our analysis of its associated embodied metaphors and image schemata underpinning them, as well as the sound properties and how they vary among the meditation states. Muse [186] is a wearable headband monitoring brain activity through 5 cutaneous channel electrodes which infer real-time meditation states. Previous work has shown the validity of Muse headband measuring event-related brain potentials [151, 219] and meditation states [59, 151]. The Muse app provides a continuous forest soundscape adapting in real-time to the current mental state. It instructs users to focus on breathing, with their eyes closed while listening to the soundscape. The app identifies three meditation states: being mindful (when the person is fully focused and relaxed), mind-wandering (distracted mind when attention is fluctuating), and change from one to another (moments in which attention is not fluctuating, but there is no deep focus present). Table 8.1 (top) shows the embodied metaphors for each state, soundscape descriptions, and associated sound properties we identified.

8.3 Designing WarmMind: Somaesthetic Exploration of Warmth-Based Metaphors for Meditation

The design of the WarmMind prototype was intended to extend the design space of meditation technologies through interoception-based interaction. Albeit, in doing so, we also wanted to better understand in what fundamental ways such design may differ from the one for exteroception-based interaction. Hence, our intention to ensure a comparable design of WarmMind to that of Muse app was also grounded in the movement-based metaphors underpinning them both. Thermal sensations can be generated through heat pads which is a novel material for meditation technologies, both for us as designers and meditators.

AURAL FEEDBACK

Meditation State	Embodied Metaphors	Soundscape description	Soundscape properties				Image Schemata
			Timbre	Tempo	Volume	Pitch	
Being mindful	Calm / settled weather	Bird sounds	Birdsong-timbre	Fast	Medium	High	Slow-fast
	Still / unmoving water	River	River-timbre	Slow	Low	Low	
Change of state	Moving water	Rain shower	Rain shower-timbre	Medium	Low	Low	
Mind-wandering	Moving water	Heavy rain	Heavy rain-timbre	Fast	High	Low	

THERMAL FEEDBACK

Meditation State	Embodied Metaphor 1	Embodied Metaphor 2	Thermal pattern description	Thermal stimuli		Image Schemata
				Rhythm	Intensity	
Being mindful	No movement	Radiating warmth	Simultaneous activation of all heat actuators (subtle pulsating sensation)	Structured	Medium	Structured – unstructured
Change of state	Movement	Less warm	Ordered activation of heat actuators (downwards movement from chest to belly)	Structured	Low	
Mind-wandering	Movement	Less warm	Random activation of heat actuators (random movement)	Unstructured	Low	

Table 8.1: Top: Muse embodied metaphors for each meditation state, their soundscape descriptions, associated soundscape properties, and image schemata. Bottom: WarmMind design of embodied metaphors for each meditation state, their soundscape descriptions, associated sound properties, and image schemata.

Given the highly exploratory nature of our work, the emphasis was less on building an effective meditation aid but rather on better understanding the dimensions and qualities of designing for thermoception modality. Thus, we allowed ourselves to experiment, compare, and purposefully stretch some dimensions of the design space to increase their impact on the meditation experience so that we learn more about them. Such understanding could then lay the foundation for designing effective thermoception-based meditation technologies, and interoceptive ones more broadly.

The rationale for this less explored interoceptive sense, whose receptors respond to temperature changes within one's body [257], is to better support novice meditators' focus of attention on the inner experience of meditation and their associated bodily experiences, rather than on external visual or aural stimuli as most mediation technologies have explored. This further aligns with the aim to limit unnecessary stimulation and to allow for the focus of attention on breathing to be sustained, rather than being distracted by any other stimuli, thermal ones included. This meant a clear choice from the start for a rather subtle form of neurofeedback, unlike the continuous one in the Muse app. Thus, we explored discrete feedback, only when the transition points between the three states are experienced: for instance from being mindful to change state, or from change to mind-wandering state.

8.3.1 Overview of the WarmMind Prototype

We now describe the WarmMind prototype we developed to better understand the above metaphors and how they can be instantiated in design. Informed by our initial metaphor exploration outlined above, the WarmMind prototype is an on-body interface in the form of a necklace for providing the thermal patterns during meditation. The necklace has four actuators made of Nichrome wire heating pads placed on the upper body from the chest to the navel. To account for different body shapes, each pad was integrated with the necklace with an individual and adjustable string ($>$ 55cm). To ensure the stability of the placement, pads were attached using single-use surgical tape. The outer part of the pads was covered with insulating tape to minimise the heat-transmission impact regardless of clothing (Figure 8.2).

Nichrome wire heating pads are low-power, inexpensive, and malleable material, which gets warm when powered with a 5VDC. To support experimentation with the actuators we developed a tangible interface consisting of an Arduino baseboard microcontroller, 4 MOSFET modules, and 4 LEDs -one for each heating pad-, as well as a joystick to select, control, and change in real-time the thermal patterns (Figure 8.2). The WarmMind's baseboard was connected to the researcher's computer during each session to be able to manually control the pattern activation (no automatic input) and to save the preferred temperature of each user. The heat range was calibrated by modifying the current received by each heating pad via the MOSFETs.

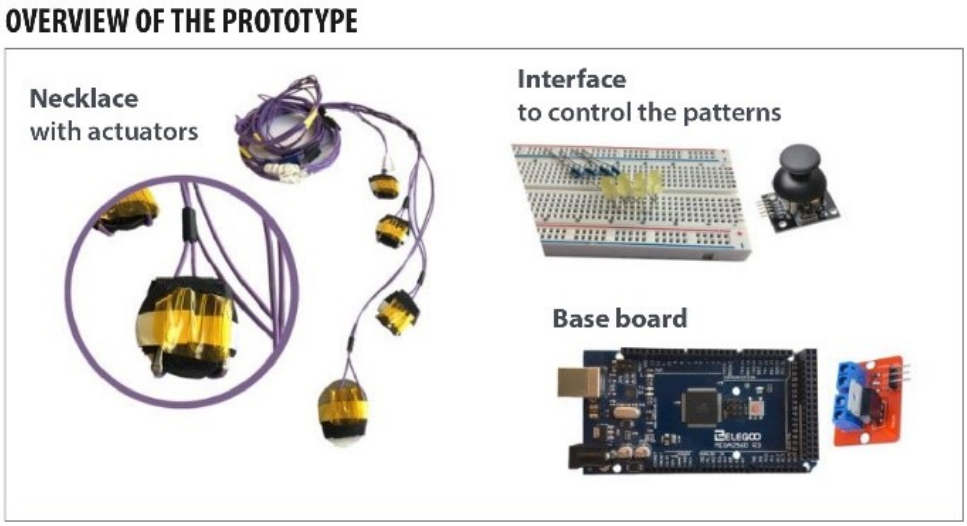


Figure 8.2: Overview of the WarmMind prototype, including: (i) an adjustable necklace with 4 Nichrome wire heating pads, (ii) an interface to control the patterns with a joystick to select the pattern and 4 LEDs to visualize the actuation, and (iii) a base board with 4 MOSFET modules to control the temperature of each heating pad.

8.3.2 Somadesign Exploration of Movement- and Warmth-based Metaphors

We employed a somadesign approach [114] to explore our first-person bodily experiences while interacting with the WarmMind prototype, a design exemplar used to articulate design knowledge and push the dimensions in this space [234]. This first-hand exploration was shaped by thermal actuators and our interaction with them to experience the temporal unfolding of temperature changes on our bodies, our understanding of thermal patterns, and how they can be better designed for increased expressiveness and communicative power. This exploration involved a group of 3 researchers (2 female, 1 male) meeting over several weeks to experiment with different sizes and placements of the heating pads on the body, their temperature intensity, duration, and pattern orchestration.

8.3.2.1 Integration of Movement- and Warmth-based Metaphors

Movement-based metaphors consistently link being mindful to stillness, and mind-wandering to movement or agitation [249]. Thus in designing the metaphor for the mind-wandering state, we started exploring the idea of a property that can capture chaotic patterns, and such property is rhythm, associated with structured-

unstructured image schemata [11]. It has been previously explored in tangible interaction research through metaphors mapping the abstract concept of sound's rhythm to movement's structure [11]. Thus, we decided to explore the metaphor mind-wandering is chaotic movement. Both upwards and downwards movements are vertical movements experienced during meditation on the front upper body [67], e.g. when following the breath moving from the chest down to the belly, and back up [137]. Thus, we started thinking about the placement of heat actuators on a vertical line from the chest to the belly.

As a proximal sense, thermoception will be supported through heat actuators whose placement on the body needs to be carefully considered. To design for the vertical movement and its physical form, we draw inspiration from the traditional meditation beads necklaces. Such necklaces consist of 108 beads placed on a string and are used to help the mind focus on meditation, for example, by repeating a mantra for each bead [222]. In order to create a vertical movement along a vertical axis of the front upper body, the necklace would need to consist of at least three collinear beads (or heat actuators). With the necklace concept in mind, we turned our attention back to the metaphor mind-wandering is chaotic/unstructured movement. However, we found that only three points may not be sufficient to create a feeling of chaotic movement and to increase the expressiveness of the mind-wandering metaphor, we considered a necklace consisting of four beads on a vertical string. Therefore, we designed a thermal pattern that randomly warms up one actuator at a time to better communicate a sensation of randomness or lack of pattern, as described in the next section.

8.3.2.2 Exploration of Thermal Stimuli for Meditation

Our exploration was guided by key aspects underpinning thermoception. Neutral thermal state is the range at which human skin usually rests (usually 28^{o}C- 40^{o}C), and within which thermal changes are difficult to detect [130]. This range is stable within an individual but can differ across individuals, i.e., 30-36°C, 28-34°C. Just noticeable differences is the minimum amount of change from current skin temperature that is required to be detectable [20, 58, 265]. These two parameters were initially adjusted for each user by calibrating each of the four actuators to ensure they were all noticeable and safe. For convenience, we started exploring the temperature intensity on more accessible body parts such as our arms and found out that the feeling of comfortable warmth meant different temperatures for each of us. Then we moved to explore them on our upper body, starting with one actuator at a time.

We particularly looked at the temperature range which the upper body would detect as pleasurable, without being too subtle or too hot. We found that nice warmth was perceived around 40ºC when applied for 6 seconds (Figure 8.3, left), although individual differences emerged with comfortable temperature ranging from 35ºC to 45ºC. Because a narrow temperature range made it more difficult to distinguish between different temperatures on the skin for which warmth felt pleasurable, we decided to keep this full temperature range consistent for each actuator and to generate the thermal patterns by altering their temporal aspects.

8.3.2.3 Creating Movement with Warmth: Location, Size and Duration of Actuations

With respect of bodily location of the actuations, we felt how different areas of our upper body responded differently to warmth: chest was by far the most sensitive one, while belly the least. For instance, temperature intensity over 45ºC, was felt as a sensation of stinging on the chest, and as a diffuse feeling of warmth on the belly. Such felt sensations provided us with a more nuanced understanding of previous findings on the increased thermal sensitivity of the upper body [131] and sensitized us to the importance of personalizing the temperature intensity and particularly for each one of the four heat pads and their bodily placements.

Regarding the size of the heating pads, we started with actuators of circular shapes of 5cm x 5cm, which felt comfortable on the skin. However, along the vertical string on which we placed them, such rather large pads could fit at most 2 cm apart, which led to the feeling of warmth radiating around them in almost contiguous areas. This led to the entire upper body feeling warm, with limited ability to recognize the location of each actuator. In this way, we felt on our bodies the property of the skin to summate the intensity of warmth over space and the rather poor spatial resolution of thermal interfaces [66]. This is a challenge limiting the ability to recognize the thermal patterns and to distinguish them from each other, which we addressed by exploring smaller sizes for the heat pads. We found that circular-shape 1.5cm x 1.5cm placed at least 2 cm apart can be individually perceived without blending into each other (Figure 8.3, left).

When it came to exploring thermal patterns, we found two temporal aspects that mattered most, namely the duration of actuation (long enough to be noticed, and not too long to stop being pleasurable), and time between consecutive actuations. We found that the actuation was unnoticeable when applied for less than 4-seconds and uncomfortable when lasted longer than 8 seconds, consistent with previous findings on on-skin warmth perception [132].

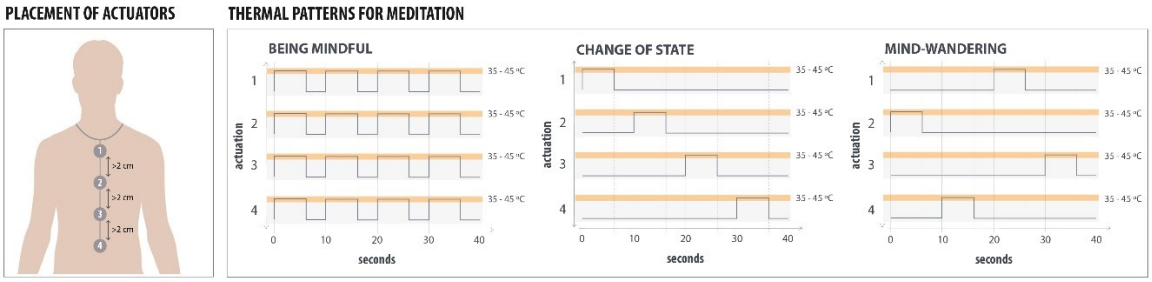


Figure 8.3: Left: Placement of the WarmMind's actuators on the upper body. Right: Diagrams of the WarmMind prototype's thermal patterns designed to map meditation states of being mindful (left), mind-wandering (right), and change of state (center).

Based on this, we designed each actuation to be on for 6 seconds, and have 4-seconds off before the start of the next actuation to allow for the warmth to dissipate. This actuation was the building block for each of the three thermal patterns, that were formed of 4 actuations to make sure that all actuators warmed up at least once within each pattern. Further, each pattern was designed to be felt distinct from the other, whilst keeping the same aesthetic quality of subtleness.

8.3.3 Metaphorical Representation of Meditation States with Thermal Patterns

Movement-based metaphors consistently link being mindful to stillness, and mind-wandering to movement or agitation [249]. We now describe the metaphors used (Table 8.1, bottom) and the first-person experience to design the thermal patterns mapping meditation states (Figure 8.3, right).

On the one hand, the being mindful state was mapped to 4 simultaneous activations of all heat actuators as a subtle pulsating sensation. We implemented this as shown in Figure 8.3 right, by simultaneous activations of all actuators for 6 seconds at their specific personalized temperature, repeated 4 times after 4-second intervals. We aimed to create no vertical movement so that stillness is properly communicated. For increased expressiveness, we considered however a pulsating pattern of each actuation, similar to the metaphor of a beating heart. This pulsating pattern is also consistent with previous work, which found that when being mindful people experience a sensation of warmth around the heart area, similar to a beating heart [67, 145]. When experimenting with this pattern, it felt like waves of warmth coming and going at a slow beating pace. We liked this pattern as it felt like augmenting the natural movement of breathing on the upper body.

On the other hand, the mind-wandering state (Figure 8.3, right) was mapped to random activation of the 4 actuators, with each of them being activated only once in random order at their specific personalized temperature. Although during meditation we found it difficult to identify the order of the actuations being activated, this pattern generated a nice and subtly agitated warmth sensation moving on the upper body. It also felt very distinct to the pulsating sensation of the being mindful state, which was important to us, since being mindful and mind-wandering can be conceptualized as being polar, each one placed on the ends of a continuum.

Finally, the change of state was mapped to ordered activation of heat actuators to represent a downwards movement from chest to belly. For this, we actuated each heating pad for 6 seconds, with the actuation starting 4-seconds after the heat pad, which was placed immediately above on the vertical string, has finished its activation (Figure 8.3 right). We experimented with different vertical movements to link the states of being mindful and mind-wandering and found it difficult to recognize the direction of movement as up or down. This may be because of the less thermoception accuracy on the belly area, and the dissipation of warmth around the actuation. Therefore, we chose just one direction of movement: to start on the chest and move down to the belly as we found the chest to be the more sensitive area and, this way, the sensation moved from being more intense to more diffused. We found this to be a nice middle point between the pulsating sensation associated with being mindful and the random actuation associated with mind-wandering, by moving attention to the vertical line within the front of the upper body in a structured manner.

8.4 Summary

This chapter provides an overview of the contemporary theory of metaphors and suggested how this body of work can inform the design of novel interactive systems for meditation in HCI. Followed by an analysis of the metaphors used in a popular commercial application (i.e. Muse) mapping brain activity into a natural soundscape to facilitate meditation, detailing how such qualities could be transferred into other feedback modalities. To illustrate this, the design of a WarmMind is presented, a prototype that integrates warmth-based patterns for FAM meditation with an internal object of attention -inspired by the bodily sensations identified in Chapter 7. The design process involved a somaesthetic exploration of warmth on the body, which can how to design embodied metaphors with them e.g. integrating movement as metaphorical representation of mindfulness states. The next chapter reports on the felt experiences of participants practicing sitting meditation with aural-based metaphors (using Muse) and warmth-based metaphors (using WarmMind).

Chapter 9

Investigating the First-person Experience of Meditation with Interoceptive Interaction

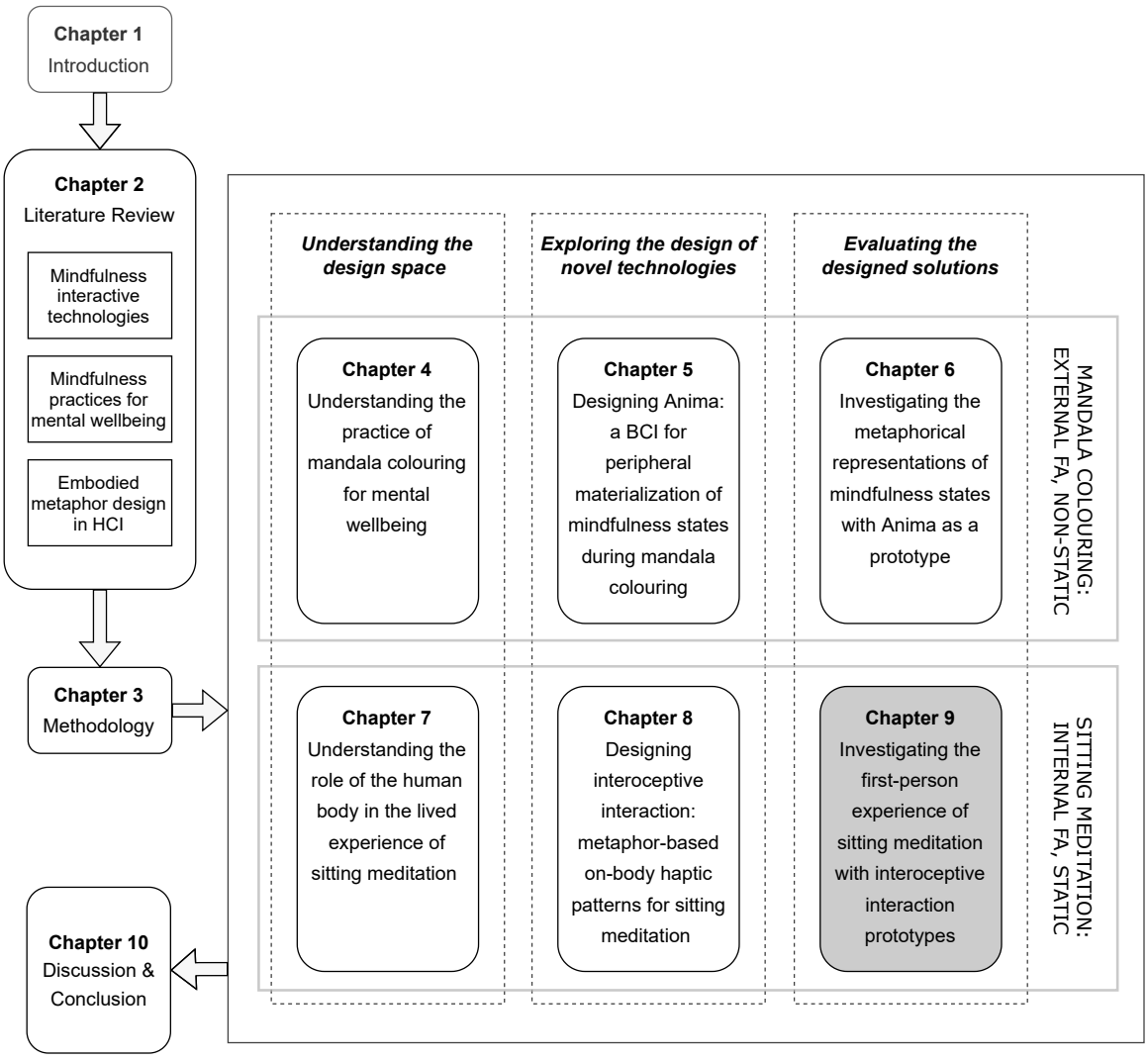


Figure 9.1: Chapter 9 of Thesis structure

9.1 Introduction

Most meditation technologies employ metaphorical mappings of meditation states to visual or soundscape representations to support awareness of mind-wandering and attention regulation, although the rationale for such mappings is seldom articulated. Moreover, such external modalities also take the focus attention away from the body. 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 [258]. 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 [212] or attention [230]. Still, the role of the human body in such designs has been limitedly explored [181], as the body has been mainly used to record physiological signals (e.g. EDA [247], breathing [212, 223, 284], EEG [4, 150, 230]) which were further mapped onto creative audio-visual feedback. Despite the increasing HCI interest in embodied interaction [75] and the findings on the importance of embodiment in meditation practice [145], our understanding of how to leverage the body as an active ingredient to support meditation is still limited.

This chapter advances the concept of interoceptive interaction and employs embodied metaphor theory to explore the design of mappings to facilitate the FAM practice of sitting meditation with an internal object of attention. I report on an exploratory study with 10 participants comparing our novel thermal metaphors with the WarmMind prototype for mapping meditation states with comparable ones, albeit in aural modality, as provided by Muse meditation app. To our understanding, this is one of the few instances of a cross-modal comparison of meditation technologies.

9.2 Exploratory User Study of WarmMind

The user study, approved by the University's ethics board, aimed to compare the two modalities for meditation: aural and haptic thermal neurofeedback provided by Muse app and WarmMind prototype, respectively. The study's aim was foremost exploratory to understand how to design embodied metaphors with different feedback modalities, and not intended at this step to assess their impact on meditation performance. I run individual sessions with our 10 participants, each session lasting about one hour. The feedback modality order was randomly assigned to ensure no learning effect on the understanding of the metaphors, as the aural and haptic thermal feedback was experienced individually and at separate times.

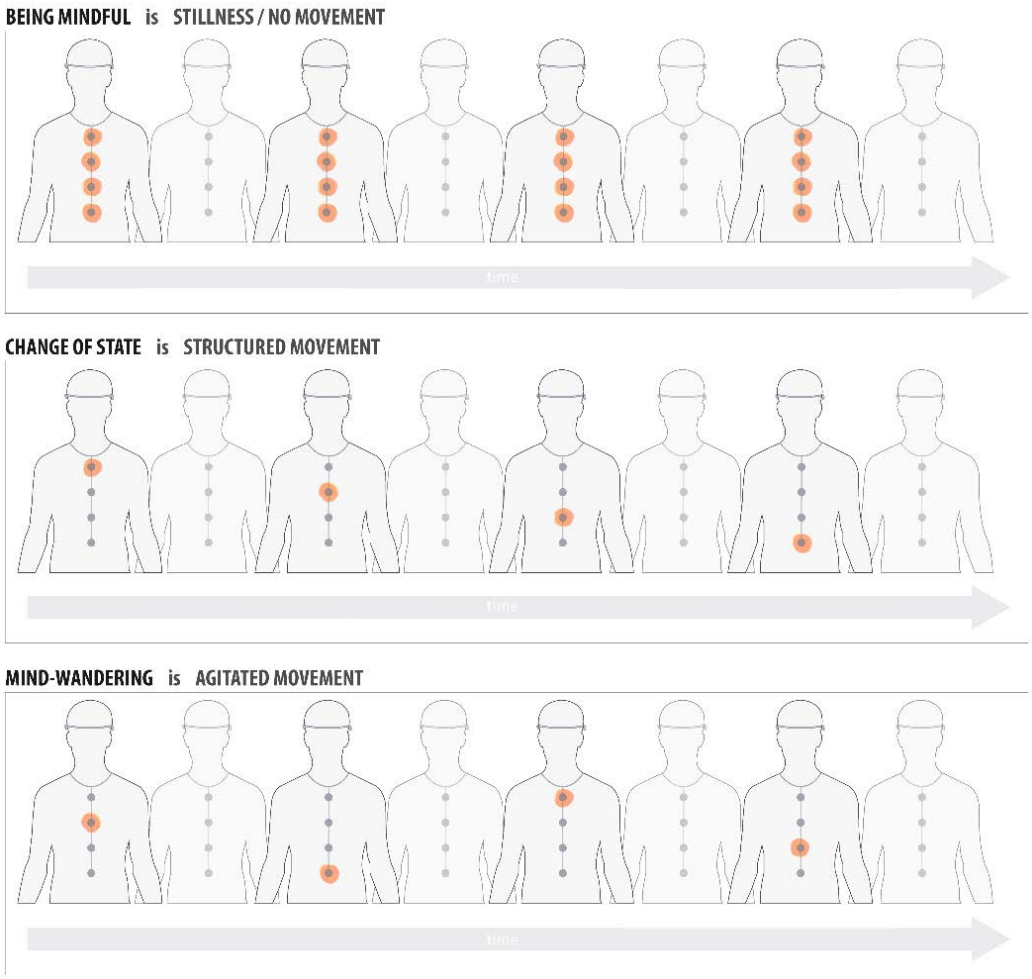


Figure 9.2: Thermal patterns based on embodied metaphors for meditation provided by WarmMind: being mindful is stillness / no movement (top), change of state is structured movement (middle), and mind-wandering is agitated movement (bottom).

The contributions of this study are threefold. First, I introduce the concept of interoceptive interaction, which extends the design space of meditation technologies to interoceptive modalities as outputs for metaphorical representations. Second, I present WarmMind, a design exemplar I developed to illustrate interoceptive interaction with on-body thermal patterns recreating embodied metaphors for meditation which were experienced as originating from inside the body (Figure 9.2). Third, I propose an initial framework capturing the tensions underpinned by three qualities of embodied metaphors: sensory stimulation, feedback temporality, and ambiguity.

9.2.1 Methodology

9.2.1.1 Participants

A total of 10 participants (5 female 5 male, range 19 to 25 years old, average age 21) were recruited through university mailing lists and notices posted on campus. A total of 4 participants had previous experience with meditation, of which 2 started the study with the haptic condition and the other 2 with the audio neurofeedback condition.

9.2.1.2 User Study

Upon arrival, each participant was given the study description and a short presentation introducing the practice of FAM and neurofeedback, and the two systems: WarmMind prototype and Muse [186]. The study started after participants signed the consent form and consisted of four parts as detailed below.

Prototype Setup and Calibration. The first step was to set up the WarmMind prototype (Figure 9.3). To respect privacy, participants were instructed on how to place the actuators and were left by themselves in the room to set it up. Then, a calibration test was conducted to adjust the temperature range of each actuator so they were both noticeable and comfortable. This consisted of turning on each individual heating pad at the lowest intensity for 6 seconds and then turning it off for 4-seconds. Participants were asked to say when they felt any warmth coming from the pads. The customised thermal range for each actuator (full range across the study sample was 35 ºC to 45 ºC) was saved for the duration of the study. This was also an important step to ensure safety as the thermal threshold on different body locations can vary between people [265].

Exploring Meditation with Aural and Thermal-based Neurofeedback. For both feedback modalities, participants were asked to meditate for 5 minutes, with their eyes closed while sitting comfortably on a chair. The baseline meditation state was automatically calculated by Muse at the start of each meditation session.

Participants were also instructed to pay attention to their breath, slowly filling their chest and belly, facilitated by the common FAM posture of placing one hand on top of the chest, and another on the belly which encourages deep, controlled breathing [104]. Between meditation sessions, participants had a 5-minute break to diminish the carryover effect.The aural feedback by the Muse's app was played through Audio-Technica M40X studio-grade headphones. The thermal patterns were provided through the WarmMind prototype, as described in the previous section, and the integration with the headband was by proxy through a Wizard of Oz approach. The researcher was listening to the participants' Muse [186] soundscape in real-time and provided accordingly the corresponding thermal feedback. To control for the effect of the mere presence of different devices and to ensure consistent experience regardless of feedback modality, the Muse headband and app were used in both conditions, alongside the headphones and the WarmMind prototype. Since the use of Muse headband in conjunction with the Muse app prevents access to real-time EEG data, I used self-report measures of state mindfulness (not trait), before and after each meditation session. Mindful Attention Awareness Scale (MAAS) for state [266]. This is a standardized instrument widely used to assess state mindfulness, as a receptive state of mind in which attention, informed by a sensitive awareness of what is occurring in the present, simply observes what is taking place [40].

Semi-structured interview. The semi-structured interviews aimed to explore users' perception of the two neurofeedback modalities, their understanding of the two mappings of meditation states to the soundscape and thermal patterns, and their impact on meditation experience. I asked whether they preferred audio or thermal condition and why, as well as what were the main benefits and challenges in each condition. I further asked about their perception of meditation states when meditating with audio and thermal neurofeedback, by enquiring about how each condition impacted the recognition of e.g. being mindful and mind-wandering moments. I also asked about the experiential qualities of the thermal patterns, the on-body location of the actuations, whether they could identify distinct thermal patterns and the potential integration of this feedback modality in meditation technologies.

9.2.1.3 Data Analysis

Interviews were fully transcribed and coded, following a hybrid coding approach [85] using the Atlas.ti8 software for qualitative analysis. The development of the coding scheme was an iterative process involving all authors. Drawing upon a conceptual framework developed from prior work on meditation [67, 189, 226], the initial codes included the main strategies for meditation, key meditation stages, and the physical sensations associated with meditation, as well as qualities of embodied metaphors (e.g. polarity, discoverability, ambiguity, discrete, continuous). Then, I refined the scheme to include codes that emerged from the interviews such as new qualities of embodied metaphors and about the meditation experience, such as: main focus of attention (i.e. internal / external), support or hindering for attention regulation (i.e. ambiguous / familiar, subtle / rich), and maintaining non-judgemental stance (i.e. abstract / representational).

9.2.2 Findings from the User Study

We now detail the qualitative analysis of the semi-structured interviews, organised in four main themes: (1) the main focus of attention, (2) recognition and understanding of the embodied metaphors for meditation states, (3) supporting regulation of attention, and (4) supporting non-judgemental attitude during meditation.

9.2.2.1 Focus of Attention

External: The Soundscape Becomes the Focus of Attention with the Muse App

An important finding regarding Muse App is that most participants (7) mentioned that the rather engaging quality of the soundscapes attracted their attention. This was usually due to the representational feedback and immediate communication in changes of meditation states: *"I did find that, like, with the sound, it would do something immediately and I would be like 'okay I know what caused that to happen'"* (P9). Because of this quality, participants mainly focused and maintained their attention on the feedback provided: *"I was focusing on the sound, the sound was really helpful thing when I hear birds I was trying to just maintain as long as I can."* (P2). However, most participants (8) did not like the fact that the soundscape became the only focus of attention as it distracted them from their meditation experience, as shown in this illustrative quotes: *"[the soundscape] it was just a bit too direct I think, and I don't know, hearing it made me a bit distracted"* (P7), *"the noises were annoying, when it started raining more heavily I got annoyed, so it was hard to focus again. [...] although the sound was clearer [easier to understand the mapping] [...] I don't think the feedback helped me"* (P8).

Figure 9.3: Participant wearing the WarmMind prototype -on top of the t-shirt for the purpose of the illustration, but during the study the actuators were attached to the skin on the displayed locations- and the Muse headband.

Having the focus of attention on the soundscape meant that the regulation of attention back to the breathing was not direct, but mediated by the sound: *"my brain would stop [engaging with distracting thoughts], and then my mind would be like 'Okay, I'm focusing on my breath, I'm doing something right'. And then I would lose my focus and the rain would start again"* (6). As illustrated in this quote, with the Muse app the breathing becomes a secondary focus of attention to the soundscape.

Another highlighted aspect of Muse App, mentioned by 5 participants was how the audio feedback allowed them to disengage from external stimuli such as environmental noise and focus on the soundscape: *"I feel I liked sound, because sound is more isolating. Not only do you focus on what you are listening to, but also tune out everything else around you"* (P4). Other 3 participants highlighted that the soundscape allowed them to also disengage with internal stimuli, such as their thoughts: *"because of the sound of the water, you don't focus on your own thoughts so much, you isolate more [...] it made you unaware of everything that's around you"* (P5).

Internal: The Body Becomes the Focus of Attention with the WarmMind Prototype

Findings indicate that whilst audio feedback was perceived as an external stimulus for the attention, both engaging or stimulating but mostly distracting, the warmth patterns were sensed as internally, coming from inside the body, allowing participants (7) to focus attention inwards on their personal meditation experience: *"I think the audio is more about the technology, and the heat is more about coming back to yourself [...] and focusing on your body. [. . .] It's kind of like turning on your all different senses"* (P1). This illustrative quote indicates that thermoception feedback supports increased awareness of one's senses, which contrasts with the common experience of isolation enabled by the audio feedback.

As a result, with the thermal patterns, the body takes a central role, becoming the focus of attention during the meditation: *"I feel like [WarmMind] also makes you more aware of your body. Because I don't usually focus on that type of change - [. . .] basically the temperature of different parts of your body; we're not really focused on that. So I feel like this also helps you build awareness in that aspect"* (P5). This quote and the following one also illustrate how the thermal actuation is perceived as internal to the body rather than from an external source i.e. our prototype: *"it felt like it's quite a natural thing"* (P9). An important consequence of the internal focus of attention is the direct access to the breathing pattern felt within the body, without being externally mediated by sound, like in the Muse app. As mentioned by 7 participants, the thermal feedback allowed for the deep breathing to be maintained within the focus of attention: *"it's quite good in the torso, especially with the breathing out to the breathing on the top"* (P3).

9.2.2.2 Recognising and Understanding the Metaphorical Mappings

Familiar Sounds Facilitate Identification of Meditation States

Regarding the identification of the distinct metaphors representing different meditation states, 6 participants identified three main sounds: *"there was that kind of heavy rain, light rain, birdsong"* (P3). which was particularly useful to recognise the metaphors. Findings particularly show d that the moments of being mindful and mind-wandering were the easiest ones to become aware of and understand during meditation: *"when I sort of started letting my mind go, I could start hearing the rain stop and the birds singing"* (P10). As illustrated by this quote, all participants easily understood the metaphor of rain for mind-wandering, and no rain and birds singing for when being mindful. Nevertheless, although the change of state metaphor was also usually identified: *"the water was quieter for a long periods"* (P5), it seems that it was less easy to map when compared to the other two: *"the actual different sounds for being not concentrated I didn't quite get"* (P3). To summarise, the two polar states were easier to map because the heavy rain was higher in tempo and volume compared to light rain, which also had new distinctive sounds of birds singing at a high pitch.

Thermal Ambiguity Difficults Differentiation of Patterns

Concerning the WarmMind prototype, findings indicate that the perceived ambiguity of the warmth patterns made it difficult to understand their mapping to meditation states: *"I couldn't really link what I was thinking with what the feedback [thermal pattern] was giving"* (P9). Thermal patterns were more difficult to differentiate as participants could not immediately recognise which actuator was warming up at the time: *"I didn't really distinguish like 'is it the middle one, the third one, the fourth one, or the first one; which is heating?'"* (P2). However, participants distinguished between a full warmth (i.e. being mindful) and a random pattern (i.e. mind-wandering): *"the pattern was kind of noticeable when my mind was wandering. It was absence of the same warmth as when I was concentrated"* (P3). As with the soundscape, the change of state metaphor was not as clearly understood compared to the two states of being mindful and mind-wandering. Besides, 6 participants identified changes in thermoception as something that requires bringing back attention to the breathing, without being able to discriminate its meaning: *"I was only really paying attention to this [heat] and the breathing"* (P9).

9.2.2.3 Supporting the Regulation of Attention

Rich Stimulation Hinders Attention Regulation

An important finding reported by most participants was that, although the audio-based feedback allowed them to easily identify their meditation states, they also struggled to regulate their attention in order to maintain it: *"although the sound was clearer [easier to understand the mapping] [...] I don't think the feedback helped me, because when I understood that I was doing good, I got back to the start and lost focus"* (P8). Findings indicate that most participants found the regulation of attention with the aural feedback challenging as the soundscape was perceived as distracting due to three main issues.

First, the soundscape was perceived as intense, particularly at moments of being mindful and mind-wandering: "*I feel like [audio] is also more distracting because it's more intense [...] With the sound, I had a problem where I started drifting off and I heard the sound was louder. So I tried to go back to make it quiet, but I was focusing on it too much"* (P5). As described in this quote, participants perceived the volume of the feedback to increase or becoming louder as they tried to focus their attention to get back to being mindful. Second is the continuous audio feedback meant that each change from one meditation state to another was mapped through the changes in the soundscape. However, such changes in meditation states can occur rather frequently, particularly in novice meditators, and thus, the continuous mapping may lead to fast changes which can hinder focus of attention: *"I found the sounds to be a bit maybe too disturbing the way they were changing [...] it was it basically too rapid"* (P10). Finally, the soundscape was also found to be rather sensorially rich, or overwhelming: *"the sound just overtook all my senses"* (P4). Together, intensity, rapid continuous change, and sensorial richness made the soundscape mappings both enjoyable and easier to identify albeit distracting.

Subtle Warmth Calls for Bringing Attention Back to the Body

A key outcome is that thermal feedback allowed participants to keep bringing the attention back to bodily sensations and breathing. In turn, this facilitated disengaging from distracting thoughts and achieving a being mindful state: *"I couldn't really tell [the patterns]. It was there, and I didn't really pay more attention to it, as I was focusing on my breathing, and my mind, rather than focus on what feedback I'm getting that makes sense, which sort of was just in the background"* (P10). This is a significant finding indicating that although the metaphorical representations of meditation states with thermal patterns were more difficult to understand than aural ones, the thermal patterns better facilitated the regulation of attention during meditation.

It particularly illustrates the subtle, almost peripheral presence of the thermal neurofeedback, which does not distract, nor engage attention away from meditation, albeit implicitly supported the focus of attention on breathing: *"it's [the heat] quite good in the torso as well, especially with the breathing out from the bottom [belly] to the breathing on the top [chest]"* (P3). The fact that such support was perceived by participants with and without previous experience with meditation is particularly important. Indeed, they both reported that thermal patterns fostered bringing attention back to the body, despite the fact that interoceptive awareness or awareness of bodily sensations is a skill that develops in time: *"it was just like, 'oh its warm, so I have to come back to myself"* (P1). Therefore, the embodied qualities and openness to interpretation of the thermal feedback were found to facilitate the regulation of attention at one's pace, whilst subtly suggesting to bring the attention back to the body.

Findings show that all participants perceived the warmth as a subtle form of interaction: *"I feel like [the audio] it's also more distracting because it's more intense, whereas the heat was more subtle and just felt like [the warmth] was suggesting, and the water was more of a guide like hard guiding you"* (P5). As illustrated by this quote, most participants felt like the thermal patterns were not as intense as the soundscape and allowed them to re-focus their attention without overtaking or overwhelming their senses: *"I really liked that it does get your attention but it wasn't like it was distracting"* (P9). Interestingly, if aural patterns were at times perceived as too intense, thermal ones were perceived by 6 participants as being too subtle: "I like the heat because it was subtle. [...] Although the heat might have been a bit too subtle maybe" (P4).

For the results of the MAAS questionnaire, I run a paired t-test to compare the effects on the state mindfulness, when meditating for 5 minutes with thermal feedback compared to an auditory soundscape. Although there was an increase in the state mindfulness for both conditions when compared to baseline (an increase of 0.3 on average with SD = 3.9 for the thermal, increase of 1.4 on average with SD = 3.5 for the audio), it was not statistically significant.

9.2.2.4 Metaphors' Expressiveness Fosters judgemental Attitude

As described above, the rainforest soundscape provided by the Muse's apps was perceived as easy to understand and particularly expressive due to different sound timbres (rain, river, birds), decreasing volume and tempo level from mind-wandering to being mindful, and increased pitch associated with birdsong in the being mindful state. Nevertheless, this was found to be a negative aspect of the audio condition for two main reasons.

First, participants found the metaphors for being mindful and mind-wandering states too representational and affect-charged. For instance, participants were familiar with the metaphors used and linked the heavy rain for mind-wandering with negative feedback: *"the heavy rain was kind of negative, and in the heat it wasn't anything negative"* (P1). Hence, the birdsong representing the state of being mindful were linked to positive feedback: *"when I heard them [the birds] I just went 'yeah, I got it', and then I just immediately lost it [being mindful]"* (P8).

Unfortunately, such easy recognition of meditation states with the aural feedback fostered a judgemental attitude towards meditation session: *"the water was nice but I think I was trying to like figure out the pattern [during the meditation], so maybe it was a bit too much"* (P4). As a result, 7 participants have shown a more performance-oriented stance of their meditation, looking for the positive feedback, instead of experiencing the present moment in a non-judgemental manner, a key aspect of meditation training [40]: *"it stressed me out when I had more rain, and when I didn't hear the birds I was like, oh I should be hearing the birds"* (P7), *"with the sound, I could hear the birds more when I was concentrated, so it kind of made me want to listen to the birds"* (P3). As illustrated in these quotes, applying gamification principles such as rewards and punishments to meditation technologies may support awareness of meditation states but can be counterproductive as they hinder attention regulation. This is due to the fostered judgemental attitude rather than the non-judgemental one, as an underlying principle of meditation [137].

In contrast to the judgemental stance emerging in aural condition, the warmth metaphors, with their ambiguous quality did not lead to it. In fact, the thermal patterns facilitated a non-judgemental attitude towards the experiences that arise during meditation: *"I could kind of tell if I was losing focus [with the soundscape] and I felt I felt that pressure with it [during the meditation], [...] the heat was more gentle"* (P4). As illustrated by this quote, the audio feedback was perceived as more disruptive hence added that layer of judgemental attitude towards being mindful, whereas the warmth was perceived as a gentler guidance in which they could choose whether or not pay attention to it: *"It can help us [thermal feedback for meditation], I think, in some way without relying on it too much"* (P1).

9.2.3 Discussion

We now discuss the findings by revisiting the initial research starting by introducing the concept of interoceptive interaction, which I further extend through a discussion of the qualities of the embodied metaphors explored with the aural and thermal feedback.

9.2.3.1 Interoceptive Interaction

The exploration of the design space of meditation technologies through the Muse app and WarmMind prototype allowed the understanding of their distinct metaphors and qualities underpinning them. WarmMind is an illustration of a less explored class of technologies leveraging a specific form of interaction which I call interoceptive interaction. I define interoceptive interaction as interaction with bodily data through interoceptive senses aimed to bring the attention inwards to increase awareness of bodily states. Although the heat was placed on the skin rather than within the body, I use the term interoceptive because the stimuli were perceived as originated from inside the body. This can have important wellbeing and health benefits, as interoceptive awareness is needed for regulation processes from emotional regulation to mindfulness meditation [81, 97, 103, 149, 220, 271].

Bodily data could include meditation states measured through brain activity, as well as emotional responses measured through skin conductance or heart rate, most of these explored in HCI. The main distinction of this new class of technologies that I propose is that interaction with bodily data takes place through interoceptive senses rather than the predominantly used external senses via visual or aural interfaces (Figure 9.4) to communicate, for instance, embodied metaphors of meditation states [4, 212, 230, 284]. In contrast to the external senses which support interaction with the environment, interoceptive senses receive information from inside the body namely the viscera (i.e. respiratory, cardiovascular, and gastrointestinal organs) and the skin (i.e. thermal and pain receptors) to support bodily optimal balance or homeostasis [220], as well as from the autonomous nervous system to support emotional awareness and regulation [178].

While modalities for interoceptive interaction have been less explored compared to traditional exteroceptive interaction, a rich starting point is haptics. Our exploration was focused on thermoception for attention regulation, while parallel HCI efforts have just started to emerge to communicate breathing through vibration patterns [180] or physiological arousal through heat [274] to support affect regulation. A landmark example in this space is Jonsson and colleagues' exploration of the aesthetics of heat [132], in which they use different thermal actuations to increase awareness of body parts during the practice of Feldenkrais exercises.

Our work goes beyond that of [132], by exploring the use of metaphorical mappings for meditation with first-person experience methods across two separate feedback modalities (audio and heat). With consistent findings from our soma exploration and the user study, our work also extends [132]'s through the effort of conceptualizing the underlying qualities of heat and audio that may foster such perception.

We suggest that interoceptive interaction can open a new design space for meditation technologies, in which the human body is not only used to monitor internal processes but is also used as a canvas to communicate meditation states via subtle actuations perceived to come from inside the body, and inspired by embodied metaphors such as our thermal patterns.

9.2.3.2 Qualities of Embodied Metaphors for Meditation

Our findings provide an overview of the embodied metaphors experienced during meditation, brought forward through two distinct mediums: an aural soundscape, and thermal patterns on the upper body. I now discuss the qualities of embodied metaphors and how these can support key aspects of meditation such as regulation of attention and attaining a non-judgemental stance. I also reflect on these qualities and their tensions in order to inform a design framework for meditation technologies.

Qualities Impacting on Metaphor Understanding

Participants' description of their experience of meditation with aural and thermal feedback emphasized that metaphors instantiated through the Muse's rainforest soundscape were easier to discover and understand than those provided by WarmMind. The mapped mindfulness and mind-wandering states as two opposite states on a continuum, one of which desirable, also indicates the polarity characteristic of the embodied schemata slow-fast, which has been suggested as important for embodied tangible interaction [169]. However, the continuous aural feedback goes beyond polarity, by providing also the mapping for all the changes between these two key states.

The change of state in Muse app maps transitions between the two polar states; albeit it does so in a rather symmetric manner, mapping in the same way any change of state. While easy to understand, hence discoverable, this symmetry is less supported by experiential accounts of expert meditators [67] according to whom the movement from mind-wandering to mindfulness is slow and gradual, but the reverse movement can be immediate. These insights suggest a more nuanced understanding of supporting discoverability, strongly advocated in tangible interaction research [169, 225]. First, discoverability works best for the two polar states, but less so for the change of state.

Our findings also indicate that one property of the sound stimuli that can vary consistently across the continuum between the polar states, is the one that drives the instantiation of image schemata (tempo for Muse), while the other sound properties can be leveraged to increase discoverability (timbre and pitch for Muse), and limit distraction (symmetric transition).

In contrast to the high discoverability of the embodied metaphors of the Muse app, the ones provided by the WarmMind prototype were less discoverable. Indeed, while all participants felt the warmth and most of them used it as a prompt to bring attention back to the body and breathing, the patterns were however not clearly associated with mindfulness and mind-wandering states. While challenging, ambiguity can also be a resource to design evocative systems intended to support more open interpretations [94, 227]. For instance, Sanches et al. argue for the use of ambiguity in the prototypes that rely on technologies that people have limited familiarity with, such as their prototype mapping skin conductance to arousal-based visualizations [227]. This resonates with our work, as I are targeting concepts that people are less familiar with such as thermal actuations, or are difficult to access and be aware of such as meditation states.

In the attempt to increase the rather limited expressiveness of the thermal patterns (for which I can only manipulate intensity and rhythm while our comparable, highly expressive Muse app manipulates four properties of sound), I decided to work with 4 actuators to more expressively communicate the random pattern for the mind-wandering state. On reflection, this was a less ideal choice, as it added more complexity than probably needed, thus challenging the understanding of this mapping. I can now see additional limitations with the movement metaphor, as I start asking ourselves what is the movement about? What is meant to be moved? To answer these questions, I reflected back on cognitive linguistic findings where the movement is described as one of a preoccupied mind, the movement of chaotic thoughts [138, 249]. For WarmMind, however, the warmth-based embodied movement would do better to reflect the body rather than an abstract movement of thoughts, as the random pattern does little to support bodily awareness during mind-wandering moments. In fact, it does the opposite, by bringing attention to something less structured, it can hinder the focus of attention when is most needed to be regained.

Qualities Impacting on Attention Regulation

Findings indicate that while Muse app supported better discoverability of the metaphorical mappings, it was also more distracting as participants tried to regulate their attention. In contrast, while less discoverable, WarmMind appears to be better suited to support the regulation of attention. Several qualities of embodied metaphors appear to have contributed to this outcome, the most important being interoceptive and subtleness of the WarmMind vs exteroceptive and richness of the Muse app.

Findings indicate that with its inwards focus on the body, the WarmMind prototype remained in the background. Due to its low-intensity actuation (warmth rather than hot or cold), sampled discretely based on changes of meditation states rather than continuously, and its lower expressiveness, conveyed through the fewer properties of thermal actuators compared to sound ones; WarmMind allowed for the main focus of attention to remain on the breathing, rather than being required to continuously attend to the interaction itself. These outcomes contribute to the HCI work on subtle interaction [208] and extend the previous emphasis on multimodality [120] in tangible interaction, towards interoceptive modality and particularly thermoception. They also highlight the challenge of continuous feedback, as regulating attention is a key skill that meditation practice aims to support, albeit not trivial to develop [277].

During meditation, it is easy to engage with distracting thoughts or external stimuli, hence novice meditators usually rely on support to help them bring attention back to the present moment e.g. audio instructions [69], prescribed movements [239], or interactive technologies [252, 263]. Whilst in traditional meditation such support is provided in a discrete manner e.g. the teacher says a generic statement every few minutes to foster bringing the attention back to the present moment [137], most interactive technologies provide a continuous stream of feedback adapting in real-time to the changes in meditation states (Figure 9.4). Our outcomes indicate that for FAM, a more discrete type of feedback may be more beneficial.

An interesting outcome is that, although not significant, MAAS questionnaire has shown a larger increase in mindfulness state after using the Muse app. This is surprising given participants' increased challenges for attention regulation experienced while using Muse app. It may be that our two interfaces supported mindfulness state through different mechanisms, and future work is needed to explore this. It is worth highlighting that Muse app's nature-based soundscape was characterized by white noise consisting of different sounds at multiple frequencies with limited changes in rhythm or pitch [292], similar to other sounds encountered in nature, created for instance by rivers, ocean waves, wind blowing through vegetation, rain or fire. White noise is frequently used in music therapy and consistent findings have shown its impact on increased positive emotions, and relaxation [71, 255]. Moreover, consistent findings have also shown the link between mindfulness and connectedness with nature, as well nature's restorative value for our attention capability [243], allowing for "relatively effortless attention and processing in an environment to which humans are evolutionarily adapted" ([101] p. 10).

Qualities Supporting Non-judgemental Stance

Findings indicate that unlike WarmMind prototype, Muse app has led most participants to take a judgemental stance regarding their meditation session. Several qualities facilitated this, such as high discoverability [169, 225], rich and continuous feedback allowing participants to know moment by moment how well or less well they were doing, and in particular polarity coupled with gamification principle [252]. According to this, birdsongs, mapped to mindfulness state, were particularly distinct (different timbre) and easy to perceive as reward, whereas heavy rain mapped to mind-wandering state was perceived as negative feedback. In turn, this led to a judgemental stance towards meditation states, as participants felt compelled to maintain the mindfulness state to keep hearing the songbirds and to transition out from mind-wandering to no longer hear the heavy rain. In other words, they started experiencing attachment towards the meditation's goal rather than being present within the meditation process. This contrasts a key tenant of meditation practice, namely the non-judgemental acceptance of all experiences that may arise during it [277].

9.3 Framework for Designing Embodied Metaphor Inspired Meditation Systems

To better support a metaphor-inspired approach to designing for meditation, I describe an initial framework capturing the main qualities of the embodied metaphors that our findings highlighted, and the relative tension between them. This is intended to summarise in a concise manner the richness of our data. I also describe its evaluation, as I have used it to populate it not only the two systems I have explored: Muse app and WarmMind prototype, but also with 7 additional meditation technologies I reviewed in the state-of-the-art which employed neurofeedback-based embodied metaphors on exteroceptive modalities such as visual, auditory interfaces and VR environment.

The framework is organised to reflect the tension highlighted by our findings between discoverability on the one hand, and attention regulation on the other hand. Then, this tension was further broken down into 3 of the key qualities supporting them both, albeit in opposing ways: sensory stimulation (rich or subtle), temporal aspects (continuous or discrete feedback), and ambiguity (familiar or ambiguous mapping). Given the importance of nature-inspired design in Muse app, I provided another layer to the framework by marking with the leaf the systems employing nature-inspired metaphors.

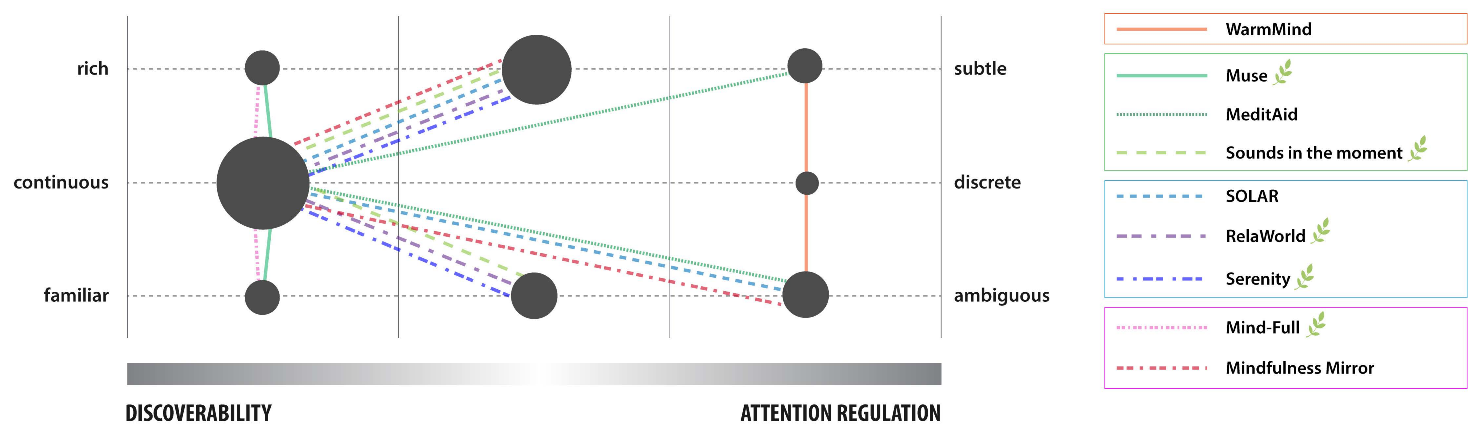


Figure 9.4: Framework populated with the 9 EEG-based interactive systems for meditation identified in the related work review in Chapter 2, including WarmMind and Muse, with each of these systems placed on its corresponding position across each of the three design tensions (on the left qualities mainly supporting discoverability, on the right qualities mainly supporting attention regulation): familiar - ambiguous metaphorical mapping, continuous - discrete feedback, rich - subtle sensory stimulation. The circles' size is proportional to the number of systems with that quality. On the right side, the legend lists the systems categorized by the type of technology: on-body haptics in orange (WarmMind), audio-based systems in green (Muse commercial app [186] and [59, 230]), immersive VR in blue ([55, 150, 210]), and screen-based in pink ([8, 127]).

Figure 9.4 shows the framework populated with all 9 systems, each one across each of the three horizontal qualities, with the size of the circle representing the number of systems in that space. Also, the qualities listed on the left side (i.e. rich, continuous, familiar) seem to better support discoverability, and the ones on the right (i.e. subtle, discrete, ambiguous) better support attention regulation, subject to how these design tensions are balanced out. For instance, Muse is rich in sensory stimulation (top left), provides continuous feedback (middle left), and has a familiar mapping (bottom left). As illustrated, most neurofeedback meditation systems in HCI provide a moderate level of sensory stimulation, continuous feedback, and moderate to ambiguous mappings. For example, in Relaworld the aesthetics of the virtual scene are intentionally minimal to modestly capture attention without eliciting mental fatigue and cognitive overload, i.e. only display the ocean and the sky in a range of gray-scale shades, yet supporting discoverability by being continuous and nature-based mapping [150].

Nevertheless, the exploration of the qualities of subtle and discrete feedback have been less explored in current interactive systems for meditation, yet our findings with WarmMind suggest their benefit to the practices of interoception and attention regulation during meditation. Also, whilst traditional guided meditation practices account for this by providing temporal-based discrete feedback, all the neurofeedback systems for meditation in HCI provide continuous feedback mapping all changes in meditation states in real-time. Although this highly supports discoverability, I found it may also overwhelm the meditator and challenge the regulation of attention. WarmMind provides event-based discrete feedback, i.e. tailored to the meditator's experience but requiring a lower engagement with the technology hence facilitating attention regulation, which is a space that has not been explored for meditation technologies and our findings support their potential benefits for meditation.

9.3.1 Implications for Design

We now report on the value of our findings for the design of meditation technologies highlighting the need for a deep understanding of the metaphors to design for, the tension of supporting both discoverability and attention regulation, and for sensitive design of the mapping for being mindful.

9.3.1.1 Understanding and Experiencing the Embodied Metaphors

Our findings indicate the importance of designers' deep understanding of the metaphor, its origin, and what it can be applied to, without altering aspects which would make it less effective, i.e. in our case the chaotic movement of thoughts to the random movement of warmth on the body.

We argue for the benefit of drawing from multiple sources to understand the metaphors [120] such as spiritual tradition, cognitive linguistics, and phenomenology of meditation, engaging in first-person somadesign exploration of the metaphors, and running user studies with contrasting prototypes to better understand how the metaphors work or not. I also call for HCI research to articulate the rationale of the chosen metaphors and of image schemata instantiating them, so can share and build resources for designing with metaphors in general such as tangible interaction, or technologies for affect regulation, and for attention regulation in particular.

9.3.1.2 Supporting Discoverability of Embodied Metaphors

Our findings indicate that many qualities of embodied metaphors support their understanding. The following list, illustrated with examples from Muse app and WarmMind, offers a valuable resource to consider when designing for discoverability: (i) type of interaction with exteroceptive being easier to understand than exteroceptive; (ii) increased stimulation and expressiveness as a higher number of modality properties being manipulated for the design of the metaphors: 4 vs 2, timbre, tempo, volume, and pitch vs rhythm and intensity, (iii) pace at which metaphors are presented: quick and continuous for representing major changes from one meditation state to another as well as minor ones vs slow and discrete triggered only by major changes from one meditation state to another; (iv) high polarity: two main states; (v) ambiguity: low vs high; (vi) gamification: reward for mindfulness vs punitive for mindlessness; (vi) nature-inspired content.

9.3.1.3 Supporting Attention Regulation and Non-judgemental Stance

Findings also indicate qualities that particularly support attention regulation and non-judgemental stance: (i) type of interaction: interoceptive rather than exteroceptive, (ii) limited stimulation and expressiveness as lower number of modalities and properties being manipulated, (iii) pace of metaphors' presentation: slow and discrete vs quick and continuous, (iv) moderate polarity: two states; (v) ambiguity: high vs low; (vi) no gamification.

9.3.1.4 Sensitive Mapping for Mindlessness State

Findings indicate the mindlessness with its lack of awareness of bodily states is not easy to design for. Moreover, any intense stimulation design to attract attention may be perceived as punitive. Thus, I argue for the value of sensitively mapping the problematic mindlessness state not so much by mirroring it, but to better support its attention regulation.

To a less extent, a similar approach has been seen in Muse app through its symmetric transition representing the movement between the two polar states. I will go even further to suggest metaphors for mind-wandering state that only do not attract attention, but which purposefully support its regulation (see below).

9.3.1.5 Thermal-based Metaphors for Meditation

For future thermal-based feedback for meditation technologies, I suggest building on the growing HCI interest in thermal interaction [232, 275] to explore the warmth metaphor as dominant (rather than movement metaphor), mapping the higher, radiant warmth to mindfulness state, and less warmth to mind-wandering state (rather than cold as I considered in our initial design exploration). The image schemata will be high-low, emphasizing both high-low warmth intensities, and high-low placement of thermal actuators on the body: chest for mindfulness, belly for mind-wandering. Thus, the metaphor of mind-wandering state will be warmth aimed not to emphasize awareness of mind wandering, but to help the meditator bring their attention to the breathing in the belly. I also suggest working with the low expressiveness of thermal properties without attempting to heighten it at the expense of discoverability, e.g. using no more than two actuators, enough to communicate the two main states.

9.4 Summary

This chapter provides a rich exploration of the practice of sitting meditation mediated by technology to mitigate one of the main challenges: supporting the regulation of attention towards an inward focus or internal bodily sensations and away from external stimuli or distractors. Most meditation technologies employ metaphorical mappings of meditative states to visual or soundscape representations to support awareness of mind wandering and attention regulation, although the rationale for such mappings is seldom articulated. Findings have revealed the experiences of my participants when meditating with soundscape and warmth-based representations of their mindfulness states: whilst the soundscape was perceived as an external and expressive feedback modality, thermal patterns were felt as subtle experiences coming from inside the body. Also, design tension are outline between the highly discoverable soundscape's metaphors which however hinder attention regulation, and the ambiguous thermal metaphors experienced as coming from the body and supported attention regulation. Finally, it provides a discussion of the challenges that HCI researchers face when designing technologies for sitting meditation (building on prior discussion in chapters 7 and 8), highlighting the qualities of embodied metaphors underpinning this tension and propose an initial framework to inform the design of metaphorical mappings for meditation technologies.

Chapter 10

Discussion & Conclusion

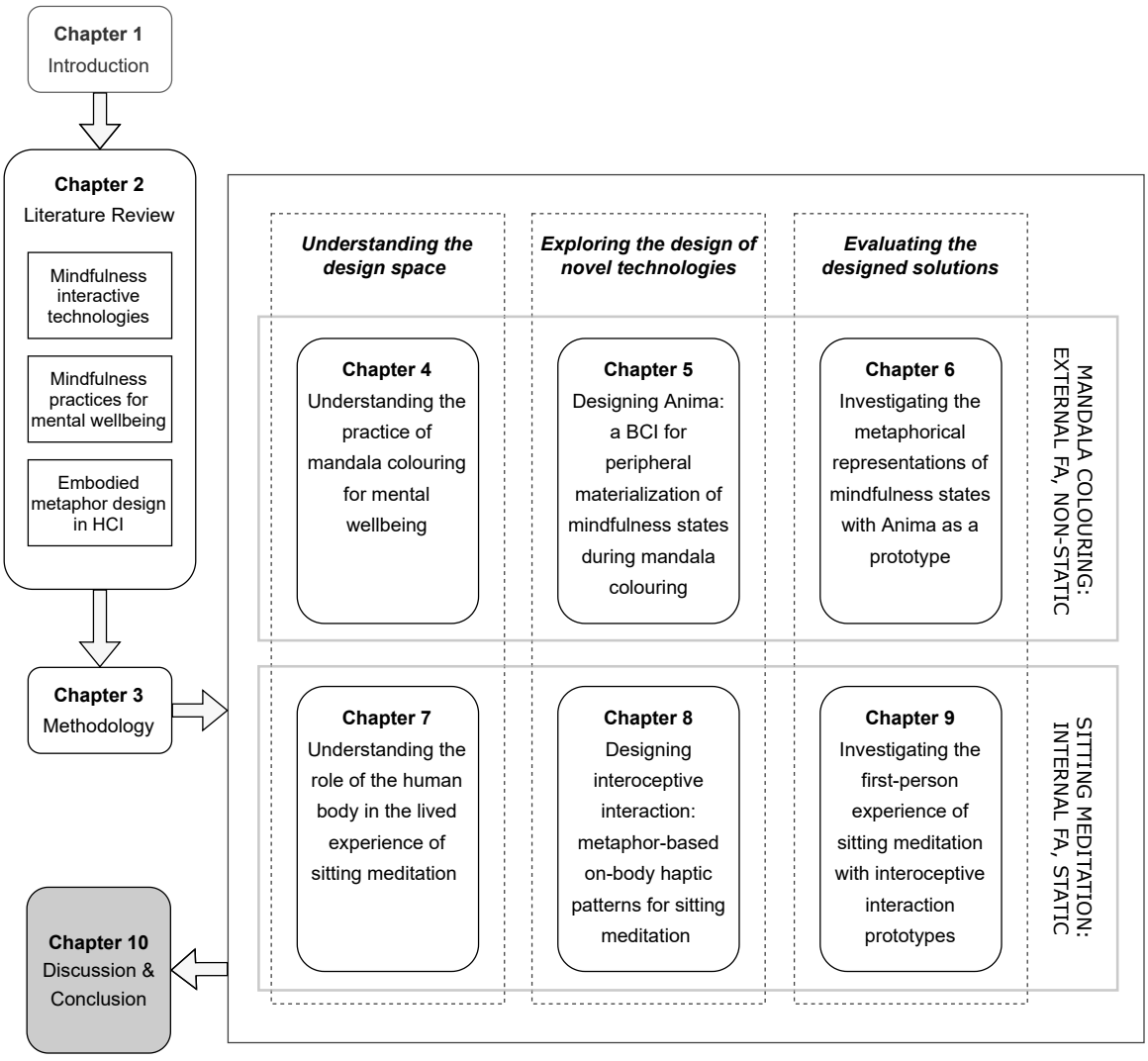


Figure 10.1: Chapter 9 of Thesis structure

10.1 Introduction

Over the past three years I have investigated the first-person experiences of two FAM practices for mental well-being -i.e. mandala colouring illustrating a non-static FAM with an external focus of attention, and sitting meditation illustrating a static FAM with an internal focus of attention-; and how I can design to enhance the main benefits and overcome the challenges of these practices. This Chapter concludes the thesis by revisiting the aims and objectives laid out in Chapter 1, and confirming the contributions of this work. Finally, it provides a review the discussion points from Chapters 2-9 in context of current and future practice.

10.2 Review of Research Aims and Contributions

Chapter 1 states three research aims for this thesis to: (i) understand the design space, (ii) explore the design of novel technologies to mitigate the challenges identified, and (iii) evaluate the designed solutions. This section provides a description of how the work contained within Chapters 2-9 has achieved these research aims and contributes to academic knowledge.

10.2.1 Research Aim 1

> ***To understand the motivations and challenges of practising FAM for mental well-being during mandala colouring and sitting meditation, as well as the qualities of the lived experience associated with such practices.***

There is growing interest in HCI to design and develop interactive technologies to facilitate FAM practices [263]. Despite the broad range of traditional FAM practices with shown benefits for mental and physical health [40, 239], as detailed in Chapter 2, the majority of work in HCI has focused in static FAM practices [263], some have started to look into full-body movement FAM practices [185, 51], and very little work has explored the middle space of involving fine movements [52].

Chapter 4 explores the motivations and challenges of regularly engaging with the practice of mandala colouring for mental well-being, which illustrates the potential of the design space of non-static FAM with external object of attention. I emphasise the opportunities for the HCI community to investigate the under-explored design space of FAM with an external object of attention that rely on fine skilled movement, as well as incorporating approaches for mental well-being from other disciplines such as art therapy [142, 144, 160].

From this, the specific contributions are as follows:

- An in-depth analysis of the practice of mandala colouring with people that have engaged with it regularly, identifying new insights including: the ritualistic aspect of the mandala colouring emphasising the context in which the practice unfolds; the practice of emotion awareness and regulation through the use of colours and self-expression; and the execution of slow and continuous movement to colour the intricate geometry of the mandala, as well as the importance of mistakes and imperfections for practising acceptance. This advances the state-of-the-art and the limited insights regarding the main qualities of the context and unfolding of the practice of mandala colouring for mental well-being.

- A critical overview of how the current technological approaches to augment mandala colouring, mainly in commercial apps for smartphones, fail to support the core components that make this practice a non-static FAM for mental well-being. I emphasise the need for HCI researchers to translate analogue practices into digital by focusing on the underlying processes rather than only on the final result -in this case, a beautiful image with no imperfections.

- A rich discussion of the identified novel opportunities for the HCI community to design interactive technologies to facilitate non-static FAM practices with an external focus of attention, such as mandala colouring. These include: designing for intricate confines to scaffold slow, continuous and structured fine movement; designing for expressiveness by making the intangible tangible such as supporting interacting with brain activity data; and designing for re-colouring mandalas as a tool to support re-appraisal by facilitating reframing past experiences.

Despite the increasing HCI work exploring the design of interactive technologies to facilitate the practice of sitting meditation, there has been limited work investigating the felt experience of this popular FAM [203]. This is, however, key in order to design support systems that facilitate guiding and sustaining the attention inwards; which is not trivial [168] but is one of the core processes benefiting mental well-being [81].

Therefore, Chapter 7 investigates the motivations and challenges as well as the first-person felt experience of sitting meditation; illustrating novel opportunities for designing technologies to facilitate static FAM practices with an internal object of attention. Specifically, the contributions are the following:

- A detailed analysis of the motivations and challenges of sitting meditation for mental well-being with experts, as well as through an auto-ethnographic exploration of meditation apps. Findings revealed that the current off-the-shelf technological solutions to facilitate the practice of sitting meditation overlook the person's body, despite the growing evidence of interoceptiveness and bodily awareness being core components of meditation. These novel insights contribute to the discussions in designing for mindfulness, by calling for incorporating new perspectives that are already well-established in HCI such as somaesthetic [112], tangible and embodied interaction design [124, 75].

- The use of a novel methodology, drawing from the areas of research through design and material speculation [286, 7], to facilitate the exploration, reflection and communication of abstract, non-familiar or tacit bodily sensations associated with different mental states. Importantly, findings show this methodology to be valuable also with participants without previous design expertise.

- Confirm and expand previous work exploring the experiential qualities of meditation [203] by identifying the main stages that occur during sitting meditation (i.e. grounding, becoming mindful, being mindful, and mind-wandering with distracting and dismissible thoughts), the bodily sensations associated with each of them (including body locations, physical sensations, and description of the embodied metaphors), and the way they are inter-connected uncovering that meditation is a non-linear journey. I highlight the opportunities for the HCI community to design from and for the human body to facilitate the training of FAM practices with an internal object of attention i.e. with tangible interfaces rather than audiovisual to support an intrinsic focus, and designing cyclic feedback patterns tailored to the meditation stages rather than providing continuous support.

10.2.2 Research Aim 2

To explore the design of novel interactive technologies to facilitate the practice of FAM, with either external or internal main objects of attention, in order to mitigate the identified challenges.

The insights gathered from previous chapters are consolidated to create design solutions to facilitate the successful practice of mandala colouring and sitting meditation for mental well-being, aiming to overcome the challenges of these practices and fostering the engagement with the key beneficial components.

One of the main challenges of FAM practices is the non-judgemental monitoring of the experience i.e. becoming aware of the present moment from mind-wandering moments to being mindful. Interactive technologies aim to mitigate this difficulty by mapping biodata onto creative outputs to facilitate the understanding of different mindfulness states, with most work in this space exploring metaphorical representations of respiration data onto audiovisual feedback [212, 200] e.g. slow respiration is mindful, agitated breathing represents mind-wandering. Although respiration can be an indicator of such mindfulness states, brain activity data has been shown to be the most appropriate physiological response to accurately monitor FAM practices [154, 80, 25]. Yet making sense of the mindfulness states captured by the EEG data is not trivial, and neither is capturing them through design.

In Chapter 5, the themes from the exploration of mandala colouring were developed into an interactive prototype that uses colour-based metaphors to materialise mindfulness states in a peripheral interface in real-time, named Anima. From this, the contributions are as follows:

- Building on the participants' experiences with mandala colouring outlined in Chapter 4, I express the need of incorporating into the design solutions the contextual aspects that make up their ritualistic practice, such as the qualities and location of the materials used (i.e. individual crayons that are placed in the periphery but within reach during the practice). This advances the state of the art by highlighting the benefits and issues of mediating a traditional practice with technology, and confirm the potential of using colour-based metaphors to facilitate the FAM practice of mandala colouring with an external object of attention.

- While I found instances of previous work digitally augmenting mandala colouring to support mindfulness training and mental well-being [68, 291, 269], findings that these designs have focused on the facilitating byproducts (e.g. creating a beautiful image) rather than on the process and context of its practice (e.g. preparation of the space and selection of colours, slow and focused process of colouring the mandala). A key contribution of this thesis is highlighting the importance of embracing traditional and innovative qualities in hybrid designs to provide meaningful technology-mediated experiences for mental well-being. With the Anima prototype I provide an illustration of augmenting a traditional practice with technology, i.e. mandala colouring, that maintain the core components identified to support mental well-being (e.g. main external object of attention supporting continuous fine movement). Yet mediating the interaction with technology through the digital materials to facilitate subtle and non-judgemental self-awareness of mindfulness states during the non-static FAM practice.

- Chapters 5 and 6 explore how to materialise brain activity data using colour-based metaphorical representations of mindfulness states, refined by the perceptions of experts in mandala colouring. These outputs provide new insights surrounding the design of colour-based metaphorical representations, including the colours' physical appearance: RGB value (e.g. saturation, brightness, hue), temporal appearance (e.g. how often and for how long should the data be represented), and spatial placement (e.g. how should the data be represented and arranged in the interface). This expands previous work exploring the metaphorical representations of mindfulness states from brain activity onto the main object of attention into sound [230] or visual [5] feedback; with a key novel contribution being the exploration of monitoring the mindfulness states on the periphery whilst fine movements are the main object of attention.

Chapter 8 builds on the bodily sensations and their association to meditation stages identified in Chapter 7, and explores the design of on-body haptic feedback to facilitate the practice of focused attention with an internal object of attention. The main contributions are:

- A rich analysis of metaphors used in meditation in other disciplines such as cognitive linguistics and spiritual Buddhist practices, and how their qualities could be transferred onto the design of FAM technologies. In particular, exploring how these qualities (i.e. rhythm, intensity, image schemata, and embodied metaphors) can be integrated onto different feedback modalities such as aural and thermal stimuli.

The themes that emerged in Chapter 7 uncovering the role of the human body in sitting meditation were developed into design knowledge to inform the design of metaphorical representations of the meditation stages to support an inwards focus of attention. These discussions bring new questions to the HCI community exploring the design of mindfulness technologies, such as how can felt experiences be metaphorically represented to facilitate static FAM practices? And how to design such experiences to scaffold the meditation trajectory without the technological input becoming too cognitive demanding that distracts from one's personal experience?

- A discussion on the methods to designing first-person experiences to foster turning the attention inwards during static, concentrative practices. This approach is illustrated by exploring on-body warmth-based feedback, and provides novel insights regarding the experiential qualities and design considerations of using heat directly on the skin in the upper body, thus expanding previous work in this space [132]. Furthermore, I argue for HCI researchers designing for an inwards focus of attention, contrary to related work in this space mediating the experience with cognitive demanding external objects, to place the body at the centre of the experience: focusing on the sense of interoception to direct the attention towards the body (e.g. bodily sensations), mediated by bodily processes (e.g. brain activity), using the body as the output interface (e.g. on-skin haptic feedback).

- The design of thermal-based patterns applied on the upper-body to foster interoceptive awareness during sitting meditation. That is, to facilitate focusing the attention on internal stimuli, despite mediating the experience with technology. I discuss the exploration metaphorical representations of mindfulness states through thermal stimuli, with novel design insights including: how to successfully represent mindfulness metaphors with heat (e.g. using warmth instead of cold due to the experiential qualities of heat), how to create sensations of movement on the body (i.e. exploring the location, size and duration of the actuations), and how these can inform the design of thermal patterns to depict and provide support during different meditation stages (i.e. grounding, becoming mindful, being mindful, and mind-wandering).

10.2.3 Research Aim 3

To investigate people's perceptions of the metaphorical representations of mindfulness states to successfully support FAM practices, with either external or internal main objects of attention, with the novel design solutions.

Finally, the design solutions proposed in Chapter 5 and Chapter 8 to facilitate the practice of FAM practices with an external and internal object of attention respectively, are evaluated in participatory studies exploring people's perceptions and understanding of the proposed metaphorical representations of mindfulness states.

To best of our knowledge, these are the first studies exploring the first-person experience and understanding of metaphorical representations of mindfulness states with users. In the broader body of work of biofeedback, recent work has started to look into how to represent physiological processes such as EDA or HRV to track arousal [276, 227], although with very limited user-centred research [2]. Therefore, the insights from the studies presented in Chapter 6 and Chapter 9 provide an initial set of guidelines to designing for the materialisation of brain activity data and, in particular, to support FAM practices for mental well-being.

Chapter 6 investigates the colour-based metaphorical representations of mindfulness states with Anima as a prototype to support and enhance the FAM practice of mandala colouring for mental well-being. The contributions are the following:

- Presentation and acknowledgement of the participants' perceptions and experiences with the use of Anima to practice mandala colouring, specifically with the use of colour-based metaphorical representations in the periphery to monitor the FAM practice. These notions also confirm and expand the outcomes from the design exploration detailed in Chapter 5. Overall, these provide novel insights that contribute to the HCI community uncovering opportunities and challenges for designing tangible interfaces to support mindfulness training.

- A discussion of the challenges of designing visualisations of abstract and unfamiliar data, i.e. brain activity, to support both awareness and reflection through metaphorical representations. Identifying two key concepts that can inform HCI researchers how to design for meaningful mappings of brain activity data, as well as other biodata: representational ambiguity and temporal ambiguity. These build on previous work exploring the representation of physiological data [227], and extents it by providing insights on the form of such representations when designing for peripheral interaction -and not for the data to be the main object of attention.

- A report of the processes of reflection on mindfulness states during a non-static FAM practice, using a peripheral interface with colour-based metaphorical representations of such states as part of the external object of attention. These followed categories surrounding: interactions between the main and the peripheral interface to facilitate focused attention, reflection in and on action of mindfulness states, and the opportunities and challenges of using a peripheral interface to scaffold the practice open monitoring mindfulness. There, these insights open a new design space in HCI research to develop experiences that scaffold FAM practices without fully appropriating attention, as most systems to date [263].

In Chapter 9, the first-person experience of sitting meditation mediated with different metaphorical representations of mindfulness states is investigated. With Muse using sound modality, and the WarmMind prototype providing on-body thermal patterns. From this, the contributions are as follows:

- Adding to the discussion of challenges of sitting meditation in Chapter 7, the findings from the study provide insights on how these may be mittigated with technology. Key novel insights include the concept of interoceptive interaction, which focuses on designing experiences that mediate the experience of focusing inwards, to bodily sensations, with technological solutions perceived as unobtrusive (i.e. part of the first-person experience). The WarmMind prototype shows that when designing with interoceptive interction, as in with the thermal patterns recreating mindfulness states, participants described how the feedback was perceived as coming from within the body and not from an external. This contributes to the growing body of work in HCI designing for sitting meditation with an internal object of attention [252, 263], by providing new design considerations in which the attention is kept concentrated on one's body and felt experience despite being mediated by technology.

- A highlight of the opportunities and challenges of designing metaphorical representations of meditation states with haptic feedback, in particular warmth, in comparison to more common modalities such as audiovisual feedback. Also providing specific design recommendations that aim to address these concerns in the form of a framework, which consists of three dimensions: familiar ambiguous metaphorical mapping, continuous discrete feedback, rich subtle. This framework aims to inform HCI research on FAM mindfulness practices to mitigate the challenge of supporting both awareness of mindfulness states and attention regulation in FAM with an internal object of attention, regardless of the modality of the feedback.

10.3 Methodological Reflection

The work presented in this thesis, can be divided in three research phases: (1) understanding the design space, (2) exploring the design of novel technologies, and (3) evaluating the designed solutions. In this section, I discuss the lessons learnt when applying different methodologies in each of these research phases, to investigate two different practices i.e. mandala colouring (non-static FAM with an external focus of attention) and sitting meditation (static FAM with an internal focus of attention).

10.3.1 Exploring First-Person Experiences with *Other People*

Employing semi-structured interviews to explore the practices of mandala colouring (Chapter 4) and sitting meditation (Chapter 7), allowed me to explore the lived experience and perceptions around specific aspects of mindfulness practices with participants. Nevertheless, one of the limitations of this method was tapping on the nuances of the first-person experience –which many times the person is not conscious of and / or struggles to communicate with words (e.g. How does your body feel when you achieve a mindfulness state? And when you get distracted? And in between these two states?). This issue has started to become of interest in HCI, with a growing number of researchers interested in developing methods to explore and communicate first-person experiences (e.g. micro-phenomenological interviews [203]. With this in mind, in Chapter 7 I used semi-structured interviews in combination with a version of the Making Magic Machines methodology [6] to understand the underlying processes and sensations of meditations. Using a material speculation approach allowed participants to explore these abstract concepts of internal bodily sensations during meditation more openly and creatively; and it gave them new vocabulary to express these ideas, by manipulating the materials and presenting them in a performative way. Therefore, the participatory design workshop facilitated opening up self-exploration of their lived experience of meditation; and the semi-structured interview that followed permitted exploring their meditation experience in-depth, including their initial ideas and those that came up during the workshops.

10.3.2 Exploring First-Person Experiences with *Oneself*

Another interesting aspect of the methodology employed in this thesis is the exploration of first-person experiences in oneself (i.e. the researcher). This was carefully considered and a key process to understand the design space, and to explore the design of novel technologies. I had previous experience in mandala colouring and sitting meditation, having practised both regularly for a few years. Nevertheless, following an autoethnographic approach to explore the state of the art technologies for mandala colouring (Chapter 4) and sitting meditation (Chapter 7), allowed me to gain a deeper understanding of how these traditional practices were translated into the digital world; including what worked, and what got lost in translation.

Thermal and movement-based metaphors were highlighted by experts when communicating their meditation experiences (Chapter 7), therefore, haptic feedback became a very interesting space to explore. Despite haptics being a well-established and growing field of research, there is little work in on-body warmth actuations. Then, the somaesthetics design approach to explore the design of the warmth-based patterns in WarmMind was also a core aspect of the research presented in this thesis. That is, exploring different actuations (including variations in size, intensity, body location) and different movement-based patterns to recreate metaphorical representations of mindfulness states (including variations in tempo and duration), in different bodies with members of the research team (including variations in age, gender, weight). Hence the explorative phase employing the somaesthetics methods became an important research step to understand this underexplored sensory modality prior to the design of the novel technology i.e. WarmMind.

10.4 Future Work

In this section, I utilise the findings, discussions and implications for design across the thesis to provide suggestions for future work. I envisage that the findings detailed in this thesis will enable researchers to address their work with more context and insight. However, below I outline opportunities beyond the scope and contribution of this PhD thesis for the HCI community to explore.

10.4.1 Making the Unconscious Conscious: Designing for Meaningful Metaphorical Representations of Brain Activity Data

In Chapter 2, I provide a detailed overview of the work to date exploring the materialisation of physiological processes onto different feedback modalities to support FAM practices. In this context, brain activity is the most appropriate physiological signal to use to support technology-mediated FAM practices, as it can successfully and unobtrusively monitor the nuances of mindfulness processes such as differentiating between just relaxation (also accessible with other biodata such as respiration or HRV) and a combination of deep focus and relaxation (i.e. a mindfulness state). Nevertheless, designing for materialising brain activity has received little attention due to its numerous challenges to design mappings that are easy to make sense and act upon -it is easier to understand and respond to feedback telling you to slow your breathing pace, than a system telling you to lower your alpha from your brain activity. To make this approach more solid and accessible, HCI researchers and designers from different research areas are likely going to need to work together and collaboratively to develop solutions such a set of design guidelines for materialising unconscious processes. I imagine that a workshop at an HCI conference such as CHI or DIS would be a reasonable next step to initiate this process.

In Chapter 5 and Chapter 8, I provided a detailed overview of mapping brain activity data onto visual and haptic metaphorical representations, respectively. These designs were informed by the understanding of the mental states associated with specific FAM practices, as detailed in Chapter 4 for mandala colouring and Chapter 7 for sitting meditation. Whilst the design recommendations can apply to FAM practices in general, I establish the importance that HCI researchers gather a complete picture of the practice being approached. Especially, when designing to support FAM practices with an internal object of attention since this can be difficult to mediate with technology, as a I reflect on the CHI 2018 paper [69], DIS 2020 paper [67] and CHI 2021 paper [70].

10.4.2 The Body as a Canvas: Mediating Interoceptive Experiences From, Through, and Onto the Human Body

Concurrent themes within this thesis revolve around embodied approaches to designing for meditation. In Chapters 4-6, the body is an active ingredient of the non-static FAM practice as the slow, controlled and fine movements being structured by the intricate geometry of the mandala become the main focus of attention. Whilst most work in HCI focused on facilitating mindfulness training has focused on static FAM practices such as meditation and there is a growing interest in exploring full-body mindfulness practices such as yoga or walking meditation, future work could explore the under-explored space of practices relying on fine movement skills. As I reflect on in the publication in CHI2019 [68] and in T&F (under submission), fine hand movements have different neurological underpinnings hence can tap on novel design solutions to support practices for mental well-being.

Even more importantly, the body becomes the core component of the experience in FAM practices with an internal object of attention such as in sitting meditation (as detailed in Chapters 7-9). Conversely, many interactive systems that aim to facilitate the FAM sitting meditation with an internal focus of attention, mediate the experience with an external interface that becomes the main object of attention (e.g. a visualisation or soundscape). Reflecting on the publications at CHI 2018 [69], DIS 2020 [67] and CHI 2021 [70], future work could further explore how to design interoceptive experiences that keep the loop of sensing to actuating within the body.

10.5 Thesis Conclusion

The aim of this body of work was to explore two illustrative FAM practices with benefits for mental well-being: mandala colouring (non-static FAM with an external focus of attention), and sitting meditation (static FAM with an internal focus of attention). The studies presented in this thesis were conducted in three different phases from focusing on problem identification and opportunities to mitigate them, design of the novel solutions to the problems, to the evaluation of the design solutions. I have shown the main motivations, challenges and qualities of these practices, which have informed the design of two novel prototypes: Anima, supporting the peripheral colour-based metaphorical representation of mindfulness states during mandala colouring, and WarmMind, facilitating focusing the attention inwards during sitting meditation through on-body thermal patterns representing mindfulness states. Not only have I shown the value of using metaphorical representations to support the practice of two main approaches to FAM training for mental well-being, but I have produced and published meaningful advances in the field of interactive technologies for (i) mindfulness, (ii) mental well-being, and (iii) designing with biodata.

Bibliography

[1] C Abras, D Maloney-Krichmar, and et al et. "User-Centered Design BT - Bainbridge". In: *Bainbridge* (2004).

[2] Miquel Alfaras et al. "From Biodata to Somadata". In: *Proceedings Computer in Human Factors CHI 2020. ACM.* 2020. ISBN: 9781450367080. DOI: 10.1145/3313831.XXXXXXX. URL: https://doi.org/10.1145/3313831.XXXXXXX.

[3] Abstract N Alissa Antle, Greg Corness, and Milena Droumeva. *Springboard: Exploring Embodiment, Balance and Social Justice*. ISBN: 9781605582474.

[4] Judith Amores, Xavier Benavides, and Pattie Maes. "PsychicVR". In: *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '16*. New York, New York, USA: ACM Press, 2016, pp. 2–2. ISBN: 9781450340823. DOI: 10.1145/2851581.2889442. URL: http://dl.acm.org/citation.cfm?doid=2851581.2889442.

[5] Judith Amores, Xavier Benavides, and Pattie Maes. "PsychicVR: Increasing mindfulness by using virtual reality and brain computer interfaces". In: *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '16*. New York, New York, USA: ACM Press, 2016, pp. 2–2. ISBN: 9781450340823. DOI: 10.1145/2851581.2889442. URL: http://dl.acm.org/citation.cfm?doid=2851581.2889442.

[6] Kristina Andersen. "Making Magic Machines". In: *Proceedings of Crafting the Future: 10th European Academy of Design Conference*. 2013.

[7] Kristina Andersen and Ron Wakkary. "The Magic Machine Workshops: Making Personal Design Knowledge". In: *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '19*. New York, New York, USA: ACM Press, 2019, pp. 1–13. ISBN: 9781450359702. DOI: 10.1145/3290605.3300342. URL: http://dl.acm.org/citation.cfm?doid=3290605.3300342.

[8] Alissa N. Antle, Leslie Chesick, and Elgin Skye McLaren. "Opening up the design space of neurofeedback brain-computer interfaces for children". In: *ACM Transactions on Computer-Human Interaction* 24.6 (Jan. 2018). ISSN: 15577325. DOI: 10.1145/3131607.

[9] Alissa N. Antle, Greg Corness, and Milena Droumeva. "What the body knows: Exploring the benefits of embodied metaphors in hybrid physical digital environments". In: *Interacting with Computers* 21.1-2 (Jan. 2009), pp. 66–75. ISSN: 09535438. DOI: 10.1016/j.intcom.2008.10.005. URL: https://academic.oup.com/iwc/article-lookup/doi/10.1016/j.intcom.2008.10.005.

[10] Alissa N. Antle, Milena Droumeva, and Greg Corness. "Playing with the sound maker: do embodied metaphors help children learn?" In: *Proceedings of the 7th International Conference on Interaction Design and Children, IDC 2008*. 2008. ISBN: 9781595939944. DOI: 10.1145/1463689.1463754.

[11] Alissa N. Antle et al. "Designing to support reasoned imagination through embodied metaphor". In: *C and C 2009 - Proceedings of the 2009 ACM SIGCHI Conference on Creativity and Cognition*. 2009. ISBN: 9781605584034. DOI: 10.1145/1640233.1640275.

[12] Alissa N. Antle et al. "Evaluating the impact of a mobile neurofeedback app for young children at school and home". In: *Conference on Human Factors in Computing Systems - Proceedings*. Association for Computing Machinery, May 2019. ISBN: 9781450359702. DOI: 10.1145/3290605.3300266.

[13] Anastasia Babouchkina and Steven J. Robbins. "No Title". In: *Art Therapy* 32.1 (Jan. 2015), pp. 34–39. DOI: 10.1080/07421656.2015.994428. URL: http://www.tandfonline.com/doi/full/10.1080/07421656.2015.994428.

[14] Anastasia Babouchkina and Steven J. Robbins. "Reducing negative mood through mandala creation: A randomized controlled trial". In: *Art Therapy* 32.1 (2015), pp. 34–39. ISSN: 07421656. DOI: 10.1080/07421656.2015.994428. URL: http://www.tandfonline.com/doi/full/10.1080/07421656.2015.994428.

[15] Ruth A. Baer. *Mindfulness Training as a Clinical Intervention: A Conceptual and Empirical Review*. 2003.

[16] Ruth A. Baer, Gregory T. Smith, and Kristin B. Allen. "Assessment of mindfulness by self-report: the Kentucky inventory of mindfulness skills." In: *Assessment* 11.3 (Sept. 2004), pp. 191–206. ISSN: 1073-1911. DOI: 10.1177/1073191104268029. URL: http://journals.sagepub.com/doi/10.1177/1073191104268029%20http://journals.sagepub.com/doi/pdf/10.1177/1073191104268029%20http://www.ncbi.nlm.nih.gov/pubmed/15358875.

[17] Ruth A. Baer et al. "Using Self-Report Assessment Methods to Explore Facets of Mindfulness". In: *Assessment* 13.1 (Mar. 2006), pp. 27–45. ISSN: 1073-1911. DOI: 10.1177/1073191105283504. URL: http://journals.sagepub.com/doi/10.1177/1073191105283504.

[18] Saskia Bakker, Alissa N. Antle, and Elise Van Den Hoven. "Embodied metaphors in tangible interaction design". In: *Personal and Ubiquitous Computing* 16.4 (Apr. 2012), pp. 433–449. ISSN: 16174909. DOI: 10.1007/s00779-011-0410-4.

[19] Saskia Bakker, Alissa N. Antle, and Elise Van Den Hoven. "Identifying embodied metaphors in children's sound-action mappings". In: *Proceedings of IDC 2009 - The 8th International Conference on Interaction Design and Children*. 2009. ISBN: 9781605583952. DOI: 10.1145/1551788.1551812.

[20] Mayienne Bakkers et al. *Temperature threshold testing: a systematic review*. 2013. DOI: 10.1111/jns5.12001.

[21] Liam Bannon. "Reimagining HCI: Toward a more human-centered perspective". In: *Interactions* (2011). ISSN: 10725520. DOI: 10.1145/1978822.1978833.

[22] Lyn Bartram, Abhisekh Patra, and Maureen Stone. "Affective Color in Visualization". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*. New York, New York, USA: ACM Press, 2017, pp. 1364–1374. ISBN: 9781450346559. DOI: 10.1145/3025453.3026041. URL: http://dl.acm.org/citation.cfm?doid=3025453.3026041.

[23] Denice Basnett. *LOOKING INWARDS, SPEAKING OUT: EXPLORING MEDITATION WITH NOVICE MEDITATORS TAKING PART IN A SHORT-TERM MEDITATION PROGRAM*. Tech. rep. 2016.

[24] Alessandra N. Bazzano et al. "Human-centred design in global health: A scoping review of applications and contexts". In: *PLoS ONE* (2017). ISSN: 19326203. DOI: 10.1371/journal.pone.0186744.

[25] Tal Dotan Ben-Soussan, Joseph Glicksohn, and Aviva Berkovich-Ohana. "Attentional Effort, Mindfulness, and Altered States of Consciousness Experiences Following Quadrato Motor Training". In: *Mindfulness* 8.1 (Feb. 2017), pp. 59–67. ISSN: 18688535. DOI: 10.1007/s12671-015-0469-5. URL: http://link.springer.com/10.1007/s12671-015-0469-5.

[26] Amanda E. Berman and Larry Stevens. "EEG manifestations of nondual experiences in meditators". In: *Consciousness and Cognition* 31 (2015), pp. 1–11. ISSN: 10902376. DOI: 10.1016/j.concog.2014.10.002.

[27] Hanaan Bing-Canar, Jacquelyne Pizzuto, and Rebecca J. Compton. "Mindfulness-of-breathing exercise modulates EEG alpha activity during cognitive performance". In: *Psychophysiology* 53.9 (2016), pp. 1366–1376. ISSN: 15405958. DOI: 10.1111/psyp.12678. URL: http://doi.wiley.com/10.1111/psyp.12678.

[28] Heidi Blackburn and Claire E Chamley. "Color me calm: Adult coloring and the university library". In: (2016).

[29] Alan F. Blackwell. *The reification of metaphor as a design tool*. 2006. DOI: 10.1145/1188816.1188820.

[30] Ann Blandford. "Semi-Structured Qualitative Studies". In: *The Encyclopedia of Human-Computer Intreraction* (2013). ISSN: 8792964001.

[31] Christina Blomdahl et al. "A realist review of art therapy for clients with depression". In: *Arts in Psychotherapy* 40.3 (July 2013), pp. 322–330. ISSN: 01974556. DOI: 10.1016/j.aip.2013.05.009. URL: https://www.sciencedirect.com/science/article/pii/S0197455613001123.

[32] Mark Blythe et al. "Imaginary Design Workbooks: Constructive Criticism and Practical Provocation". In: *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. New York, New York, USA: ACM Press, 2018, pp. 1–12. ISBN: 9781450356206. DOI: 10.1145/3173574.3173807. URL: http://dl.acm.org/citation.cfm?doid=3173574.3173807.

[33] Susanne Bødker. "When second wave HCI meets third wave challenges". In: *Proceedings of the 4th Nordic conference on Human-computer interaction changing roles - NordiCHI '06*. New York, New York, USA: ACM Press, 2006, pp. 1–8. ISBN: 1595933255. DOI: 10.1145/1182475.1182476. URL: http://portal.acm.org/citation.cfm?doid=1182475.1182476.

[34] Susanne Bødker and Morten Kyng. "Participatory design that matters—Facing the big issues". In: *ACM Transactions on Computer-Human Interaction* (2018). ISSN: 15577325. DOI: 10.1145/3152421.

[35] Kirsten Boehner et al. "How HCI interprets the probes". In: *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '07*. New York, New York, USA: ACM Press, 2007, p. 1077. ISBN: 9781595935939. DOI: 10.1145/1240624.1240789. URL: http://portal.acm.org/citation.cfm?doid=1240624.1240789.

[36] Matthias Böhmer et al. "Interrupted by a phone call: Exploring designs for lowering the impact of call notifications for smartphone users". In: *Conference on Human Factors in Computing Systems - Proceedings*. Association for Computing Machinery, 2014, pp. 3045–3054. ISBN: 9781450324731. DOI: 10.1145/2556288.2557066.

[37] Boris Bornemann et al. "Differential changes in self-reported aspects of interoceptive awareness through 3 months of contemplative training". In: *Frontiers in Psychology* 5 (Jan. 2015), p. 1504. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2014.01504. URL: http://journal.frontiersin.org/article/10.3389/fpsyg.2014.01504/abstract.

[38] Claire Braboszcz and Stéphanie Hahusseau. "Meditation and Neuroscience : From Basic Research to Clinical Practice Different Types of Meditation". In: *Psychiatry: Interpersonal and Biological Processes* (2010).

[39] Barry Brown et al. "Five provocations for ethical HCI research". In: *Conference on Human Factors in Computing Systems - Proceedings*. Association for Computing Machinery, May 2016, pp. 852–863. ISBN: 9781450333627. DOI: 10.1145/2858036.2858313.

[40] Kirk Warren Brown and Richard M. Ryan. "The benefits of being present: Mindfulness and its role in psychological well-being." In: *Journal of Personality and Social Psychology* 84.4 (2003), pp. 822–848. ISSN: 1939-1315. DOI: 10.1037/0022-3514.84.4.822. URL: http://doi.apa.org/getdoi.cfm?doi=10.1037/0022-3514.84.4.822.

[41] Antoinette Leanna Bumatay and Jinsil Hwaryoung Seo. "Investigating the Role of Haptic Stimulation in Mobile Meditation Tools". In: Springer, Cham, 2015, pp. 451–456. DOI: 10.1007/978-3-319-21383-5{_}75. URL: http://link.springer.com/10.1007/978-3-319-21383-5_75.

[42] Daniel Buschek, Mariam Hassib, and Florian Alt. "Personal mobile messaging in context: Chat augmentations for expressiveness and awareness". In: *ACM Transactions on Computer-Human Interaction* 25.4 (Aug. 2018), pp. 1–33. ISSN: 15577325. DOI: 10.1145/3201404. URL: https://dl.acm.org/doi/10.1145/3201404.

[43] Rafael A Calvo and Dorian Peters. *Positive computing: technology for wellbeing and human potential*. 2014. ISBN: 978-0-262-02815-8. DOI: 10.1021/acs.molpharmaceut.8b00354.

[44] C. Estelle Campenni and Ashley Hartman. "The Effects of Completing Mandalas on Mood, Anxiety, and State Mindfulness". In: *Art Therapy* 37.1 (Jan. 2020), pp. 25–33. ISSN: 0742-1656. DOI: 10.1080/07421656.2019.1669980. URL: https://www.tandfonline.com/doi/full/10.1080/07421656.2019.1669980.

[45] Yves Candau et al. "Cultivating kinaesthetic awareness through interaction". In: *Proceedings of the 4th International Symposium on Movement and Computing* (2017), pp. 35–40. DOI: 10.1145/3077981.3078042. URL: http://dl.acm.org/citation.cfm?doid=3077981.3078042.

[46] Claudia Carissoli, Daniela Villani, and Giuseppe Riva. "Does a Meditation Protocol Supported by a Mobile Application Help People Reduce Stress? Suggestions from a Controlled Pragmatic Trial". In: *Cyberpsychology, Behavior, and Social Networking* 18.1 (Jan. 2015), pp. 46–53. ISSN: 2152-2715. DOI: 10.

1089/cyber.2014.0062. URL: http://online.liebertpub.com/doi/abs/10.1089/cyber.2014.0062.

[47] James Carmody and Ruth A. Baer. "Relationships between mindfulness practice and levels of mindfulness, medical and psychological symptoms and well-being in a mindfulness-based stress reduction program". In: *Journal of Behavioral Medicine* 31.1 (2008), pp. 23–33. ISSN: 0160-7715. DOI: 10.1007/s10865-007-9130-7. URL: http://link.springer.com/10.1007/s10865-007-9130-7.

[48] John M. Carroll, Robert L. Mack, and Wendy A. Kellogg. "Interface Metaphors and User Interface Design". In: *Handbook of Human-Computer Interaction*. 1988. DOI: 10.1016/b978-0-444-70536-5.50008-7.

[49] Richard Chambers, Eleonora Gullone, and Nicholas B. Allen. "Mindful emotion regulation: An integrative review". In: *Clinical Psychology Review* 29.6 (Aug. 2009), pp. 560–572. ISSN: 02727358. DOI: 10.1016/j.cpr.2009.06.005. URL: http://www.sciencedirect.com/science/article/pii/S0272735809000865%20http://linkinghub.elsevier.com/retrieve/pii/S0272735809000865%20http://www.ncbi.nlm.nih.gov/pubmed/19632752.

[50] Runyuan (Jason) Chen et al. "An Empirical Exploration of Mindfulness Design Using Solo Travel Domain". In: *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. New York, New York, USA: ACM Press, 2018, pp. 1–12. ISBN: 9781450356206. DOI: 10.1145/3173574.3173671. URL: http://dl.acm.org/citation.cfm?doid=3173574.3173671.

[51] Weiqin Chen. "Multitouch Tabletop Technology for People with Autism Spectrum Disorder : A review of the Literature". In: *Procedia Computer Science* 14 (2012), pp. 198–207. DOI: 10.1016/j.procs.2012.10.023.

[52] Peng Cheng, Andrés Lucero, and Jacob Buur. "PAUSE: exploring mindful touch interaction on smartphones". In: *Proceedings of the 20th International Academic Mindtrek Conference on - AcademicMindtrek '16*. New York, New York, USA: ACM Press, 2016, pp. 184–191. ISBN: 9781450343671. DOI: 10.1145/2994310.2994342. URL: http://dl.acm.org/citation.cfm?doid=2994310.2994342.

[53] Sibela Chinareva et al. "Lotus: Mediating Mindful Breathing". In: *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 2020, pp. 1–7. URL: https://dl.acm.org/doi/abs/10.1145/3334480.3382938.

[54] Luca Chittaro and Andrea Vianello. "Evaluation of a mobile mindfulness app distributed through on-line stores: A 4-week study". In: *International Journal of Human Computer Studies* 86 (2016), pp. 63–80. ISSN: 10959300. DOI: 10.1016/j.ijhcs.2015.09.004.

[55] Amber Choo and Aaron May. "Virtual mindfulness meditation: Virtual reality and electroencephalography for health gamification". In: *Conference Proceedings - 2014 IEEE Games, Media, Entertainment Conference, IEEE GEM 2014*. Institute of Electrical and Electronics Engineers Inc., Feb. 2015. ISBN: 9781479975464. DOI: 10.1109/GEM.2014.7048076.

[56] Yen Chua. "Art therapy inspired by Buddhism". In: *Art Therapy in Asia*. Jessica Kingsley Publishers, 2012. Chap. 10, pp. 144–157. ISBN: 1849052107.

[57] Dav Clark, Frank Schumann, and Stewart H. Mostofsky. "Mindful movement and skilled attention". In: *Frontiers in Human Neuroscience* 9 (June 2015), p. 297. ISSN: 1662-5161. DOI: 10.3389/fnhum.2015.00297. URL: http://journal.frontiersin.org/Article/10.3389/fnhum.2015.00297/abstract.

[58] D. Claus et al. "Methods of measurement of thermal thresholds". In: *Acta Neurologica Scandinavica* (1987). ISSN: 16000404. DOI: 10.1111/j.1600-0404.1987.tb03583.x.

[59] Karen Anne Cochrane et al. "Sounds in the moment: Designing an Interactive EEG Nature Soundscape for Novice Mindfulness Meditators". In: *Proceedings of the 30th Australian Conference on Computer-Human Interaction - OzCHI '18*. 2018, pp. 298–302. ISBN: 9781450361880. DOI: 10.1145/3292147.3292215.

[60] Mark R. Costa et al. "Nature Inspired Scenes for Guided Mindfulness Training: Presence, Perceived Restorativeness and Meditation Depth". In: 2019, pp. 517–532. DOI: 10.1007/978-3-030-22419-6{_}37. URL: http://link.springer.com/10.1007/978-3-030-22419-6_37.

[61] Anna L. Cox et al. "Design Frictions for Mindful Interactions: The case for microboundaries". In: *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '16*. New York, New York, USA: ACM Press, 2016, pp. 1389–1397. ISBN: 9781450340823. DOI: 10.1145/2851581.2892410. URL: http://dl.acm.org/citation.cfm?doid=2851581.2892410.

[62] Mihaly Csikszentmihalyi. *Beyond Boredom and Anxiety*. 1975. ISBN: 0787951404. DOI: 10.2307/2065805.

[63] Sally Jo Cunningham and Matt Jones. "Autoethnography: A tool for practice and education". In: *ACM International Conference Proceeding Series*. 2005. ISBN: 1595930361. DOI: 10.1145/1073943.1073944.

[64] Nancy A. Curry and Tim Kasser. "Can coloring mandalas reduce anxiety?" In: *Art Therapy* 22.2 (2005), pp. 81–85. ISSN: 07421656. DOI: 10.1080/07421656.2005.10129441. URL: http://www.tandfonline.com/doi/abs/10.1080/07421656.2005.10129441.

[65] Dianne Cyr, Milena Head, and Hector Larios. "Colour appeal in website design within and across cultures: A multi-method evaluation". In: *International Journal of Human-Computer Studies* 68.1-2 (2010), pp. 1–21. ISSN: 1071-5819. DOI: 10.1016/J.IJHCS.2009.08.005.

[66] Claudia Dauden Roquet and Corina Sas. "A Scoping Review of Interactive Mindfulness Technologies for Mental Wellbeing: Considerations from HCI and Psychology". In: *25th annual international CyberPsychology, CyberTherapy & Social Networking Conference*. 2020.

[67] Claudia Daudén Roquet and Corina Sas. "Body Matters: Exploration of the Human Body as a Resource for the Design of Technologies for Meditation". In: *Proceedings of Designing Interactive Systems, DIS 2020, ACM* May (2020). DOI: 10.1145/3357236.3395499. URL: http://dx.doi.org/10.1145/3357236.3395499.

[68] Claudia Daudén Roquet and Corina Sas. "Digital Wellbeing: Evaluating Mandala Coloring Apps". In: *ACM CHI Conference on Human Factors in Computing Systems – Designing for Digital Wellbeing Workshop*. 2019. ISBN: 9781450359719.

[69] Claudia Daudén Roquet and Corina Sas. "Evaluating Mindfulness Meditation Apps". In: *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018, pp. 1–6.

[70] Claudia Daudén Roquet and Corina Sas. "Interoceptive Interaction: An Embodied Metaphor Inspired Approach to Designing for Meditation". In: *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. CHI '21. Yokohama, Japan: Association for Computing Machinery, 2021. ISBN: 9781450380966. DOI: 10.1145/3411764.3445137. URL: https://doi.org/10.1145/3411764.3445137.

[71] Alana G. DeLoach, Jeff P. Carter, and Jonas Braasch. "Tuning the cognitive environment: Sound masking with "natural" sounds in open-plan offices". In: *The Journal of the Acoustical Society of America* (2015). ISSN: 0001-4966. DOI: 10.1121/1.4920363.

[72] Kathleen DeMarrais. "Qualitative interview studies: Learning through experience". In: *Foundations for Research: Methods of Inquiry in Education and the Social Sciences*. 2003. ISBN: 1410609375. DOI: 10.4324/9781410609373.

[73] Audrey Desjardins and Aubree Ball. "Revealing Tensions in Autobiographical Design in HCI". In: *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18*. New York, New York, USA: ACM Press, 2018, pp. 753–764. ISBN: 9781450351980. DOI: 10.1145/3196709.3196781. URL: http://dl.acm.org/citation.cfm?doid=3196709.3196781.

[74] Gavin Doherty, David Coyle, and Mark Matthews. "Design and evaluation guidelines for mental health technologies". In: *Interacting with Computers* (2010). ISSN: 09535438. DOI: 10.1016/j.intcom.2010.02.006.

[75] Paul Dourish. *Where the Action is: The Foundations of Embodied Interaction*. 2004. URL: https://books.google.co.uk/books?hl=en&lr=&id=DCIy2zxrCqcC&oi=fnd&pg=PR7&dq=embodied+interaction+hci&ots=oF3094a7Yl&sig=JuIZrhA20fj-OIYNfD4wE_y-N-A&redir_esc=y#v=onepage&q=embodied%20interaction%20hci&f=false.

[76] Margot Duncan. "Autoethnography: Critical Appreciation of an Emerging Art". In: *International Journal of Qualitative Methods* (2004). ISSN: 1609-4069. DOI: 10.1177/160940690400300403.

[77] Abdallah El Ali et al. "ThermalWear: Exploring Wearable On-chest Thermal Displays to Augment Voice Messages with Affect". In: (). DOI: 10.1145/3313831.3376682. URL: https://doi.org/10.1145/3313831.3376682.

[78] Carolyn Ellis, Tony E Adams, and Arthur P Bochner. "History of Autoethnography". In: *Volume 12, No. 1, Art. 10 January 2011* (2011).

[79] Chris Elsden et al. "On Speculative Enactments". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*. New York, New York, USA: ACM Press, 2017, pp. 5386–5399. ISBN: 9781450346559. DOI: 10.1145/3025453.3025503. URL: http://dl.acm.org/citation.cfm?doid=3025453.3025503.

[80] Tobias Esch. "The Neurobiology of Meditation and Mindfulness". In: 2014. DOI: 10.1007/978-3-319-01634-4{_}9.

[81] Norman Farb et al. "Interoception, contemplative practice, and health". In: *Frontiers in Psychology* 6 (June 2015), p. 763. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2015.00763. URL: http://journal.frontiersin.org/Article/10.3389/fpsyg.2015.00763/abstract.

[82] Norman A S Farb et al. "Mindfulness Interventions and Emotion Regulation". In: *Handbook of Emotion Regulation*. 2014, pp. 548–567. ISBN: 9781462512560\r1462512569.

[83] Norman A. S. Farb, Zindel V. Segal, and Adam K. Anderson. "Mindfulness meditation training alters cortical representations of interoceptive attention". In: *Social Cognitive and Affective Neuroscience* 8.1 (Jan. 2013), pp. 15–26. ISSN: 1749-5024. DOI: 10.1093/scan/nss066. URL: https://academic.oup.com/scan/article/8/1/15/1696050.

[84] Greg Feldman, Jeff Greeson, and Joanna Senville. "Differential effects of mindful breathing, progressive muscle relaxation, and loving-kindness meditation on decentering and negative reactions to repetitive thoughts". In: *Behaviour Research and Therapy* 48.10 (Oct. 2010), pp. 1002–1011. ISSN: 00057967. DOI: 10.1016/j.brat.2010.06.006. URL: http://linkinghub.elsevier.com/retrieve/pii/S0005796710001324.

[85] Jennifer Fereday and Eimear Muir-Cochrane. "Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development". In: *International Journal of Qualitative Methods* 5.1 (Mar. 2006), pp. 80–92. ISSN: 1609-4069. DOI: 10.1177/160940690600500107. URL: http://journals.sagepub.com/doi/10.1177/160940690600500107.

[86] Y Fernaeus, J Tholander, and M Jonsson. *Beyond representations: towards an action-centric perspective on tangible interaction*. Tech. rep. 2008, pp. 249–267.

[87] Susanne F Fincher. *Coloring mandalas 1: For insight, healing, and self-expression*. Vol. 1. Shambhala Publications, 2000.

[88] Jayde A. M Flett et al. "Sharpen Your Pencils: Preliminary Evidence that Adult Coloring Reduces Depressive Symptoms and Anxiety". In: *Creativity Research Journal* 29.4 (Oct. 2017), pp. 409–416. ISSN: 1040-0419. DOI: 10.1080/10400419.2017.1376505. URL: https://www.tandfonline.com/doi/full/10.1080/10400419.2017.1376505.

[89] Esther Foo et al. "Soft Robotic Compression Garment to Assist Novice Meditators". In: *CHI EA '20: Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 2020, pp. 1–8. URL: https://dl.acm.org/doi/abs/10.1145/3334480.3382919.

[90] Kieran C. R. Fox et al. "Meditation Experience Predicts Introspective Accuracy". In: *PLoS ONE* 7.9 (Sept. 2012). Ed. by Luis M. Martinez, e45370. ISSN: 1932-6203. DOI: 10.1371/journal.pone.0045370. URL: http://dx.plos.org/10.1371/journal.pone.0045370.

[91] Jules Françoise et al. "Designing for Kinesthetic Awareness: Revealing User Experiences Through Second-Person Inquiry". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (2017), pp. 5171–5183. DOI: 10.1145/3025453.3025714. URL: http://dl.acm.org/citation.

cfm?doid=3025453.3025714%20http://doi.acm.org/10.1145/3025453.3025714%5Cnhttps://dl.acm.org/authorize?N38827.

[92] Christopher Frauenberger, Judith Good, and Wendy Keay-Bright. "Phenomenology, a framework for participatory design". In: *ACM International Conference Proceeding Series*. 2010. ISBN: 9781450301312. DOI: 10.1145/1900441.1900474.

[93] Anne Galletta and William E. Cross. *Mastering the semi-structured interview and beyond: From research design to analysis and publication*. 2013. ISBN: 9780814732953. DOI: 10.5860/choice.51-2430.

[94] William W. Gaver, Jacob Beaver, and Steve Benford. "Ambiguity as a resource for design". In: *Proceedings of the conference on Human factors in computing systems - CHI '03*. New York, New York, USA: ACM Press, 2003, p. 233. ISBN: 1581136307. DOI: 10.1145/642611.642653. URL: http://portal.acm.org/citation.cfm?doid=642611.642653.

[95] Elisa Giaccardi and Elvin Karana. "Foundations of Materials Experience". In: *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*. New York, New York, USA: ACM Press, 2015, pp. 2447–2456. ISBN: 9781450331456. DOI: 10.1145/2702123.2702337. URL: http://dl.acm.org/citation.cfm?doid=2702123.2702337.

[96] Joseph Giacomin. "What is human centred design?" In: *Design Journal* (2014). ISSN: 14606925. DOI: 10.2752/175630614X14056185480186.

[97] Jonathan Gibson. "Mindfulness, Interoception, and the Body: A Contemporary Perspective". In: *Frontiers in Psychology* (2019). ISSN: 16641078. DOI: 10.3389/fpsyg.2019.02012.

[98] Diane Gromala et al. "The Virtual Meditative Walk: Virtual Reality Therapy for Chronic Pain Management". In: *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*. New York, New York, USA: ACM Press, 2015, pp. 521–524. ISBN: 9781450331456. DOI: 10.1145/2702123.2702344. URL: http://dl.acm.org/citation.cfm?doid=2702123.2702344.

[99] Paul Grossman et al. "Mindfulness-based stress reduction and health benefits: A meta-analysis". In: *Journal of Psychosomatic Research* 57.1 (July 2004), pp. 35–43. DOI: 10.1016/S0022-3999(03)00573-7. URL: http://www.sciencedirect.com/science/article/pii/S0022399903005737.

[100] Arzu Guneysu Ozgur et al. "Iterative Design of an Upper Limb Rehabilitation Game with Tangible Robots". In: *ACM/IEEE International Conference on Human-Robot Interaction*. IEEE Computer Society, Feb. 2018, pp. 241–250. ISBN: 9781450349536. DOI: 10.1145/3171221.3171262.

[101] Gwyneth A Hamann and Itai Ivtzan. "Social Inquiry into Well-Being 30 Minutes in Nature a Day Can Increase Mood, Well-Being, Meaning in Life and Mindfulness: Effects of a Pilot Programme". In: *Social Inquiry into Well-Being* 2.2 (Oct. 2016), pp. 34–46. ISSN: 2351-6682. DOI: 10.13165/SIIW-16-2-2-04. URL: http://siiw.mruni..

[102] Ping-Hsuan Han et al. "My Tai-Chi coaches: an augmented learning tool for practicing Tai-Chi Chuan". In: *Proceedings of the 8th Augmented Human International Conference on - AH '17*. New York, New York, USA: ACM Press, 2017, pp. 1–4. ISBN: 9781450348355. DOI: 10.1145/3041164.3041194. URL: http://dl.acm.org/citation.cfm?doid=3041164.3041194.

[103] Adam W. Hanley, Wolf E. Mehling, and Eric L. Garland. "Holding the body in mind: Interoceptive awareness, dispositional mindfulness and psychological well-being". In: *Journal of Psychosomatic Research* 99 (Aug. 2017), pp. 13–20. ISSN: 0022-3999. DOI: 10.1016/J.JPSYCHORES.2017.05.014. URL: https://www.sciencedirect.com/science/article/pii/S0022399917301393.

[104] Wendy Hasenkamp and Lawrence W. Barsalou. "Effects of Meditation Experience on Functional Connectivity of Distributed Brain Networks". In: *Frontiers in Human Neuroscience* 6 (Mar. 2012), p. 38. ISSN: 1662-5161. DOI: 10.3389/fnhum.2012.00038. URL: http://journal.frontiersin.org/article/10.3389/fnhum.2012.00038/abstract.

[105] Steven C. Hayes et al. "Open, aware, and active: Contextual approaches as an emerging trend in the behavioral and cognitive therapies". In: *Annual Review of Clinical Psychology* (2011). ISSN: 15485943. DOI: 10.1146/annurev-clinpsy-032210-104449.

[106] Marti A. Hearst, Paul Laskowski, and Luis Silva. "Evaluating information visualization via the interplay of heuristic evaluation and question-based scoring". In: *Conference on Human Factors in Computing Systems - Proceedings*. New York, NY, USA: Association for Computing Machinery, May 2016, pp. 5028–5033. ISBN: 9781450333627. DOI: 10.1145/2858036.2858280. URL: https://dl.acm.org/doi/10.1145/2858036.2858280.

[107] Patti Henderson, David Rosen, and Nathan Mascaro. "Empirical study on the healing nature of mandalas." In: *Psychology of Aesthetics, Creativity, and the Arts* 1.3 (Aug. 2007), pp. 148–154. ISSN: 1931-390X. DOI: 10.1037/1931-3896.1.3.148. URL: http://people.tamu.edu/~David-Rosen/documents/Empirical%20Study%20on%20Healing%20Nature%20of%20Mandalas.pdf%20http://doi.apa.org/getdoi.cfm?doi=10.1037/1931-3896.1.3.148.

[108] Thilo Hinterberger and Thilo. "The Sensorium: A Multimodal Neurofeedback Environment". In: *Advances in Human-Computer Interaction* 2011 (2011), pp. 1–10. ISSN: 1687-5893. DOI: 10.1155/2011/724204. URL: http://www.hindawi.com/journals/ahci/2011/724204/.

[109] Russell Hodgson, Elinor Morgan Graham, and Amanda McGough. "Improving the well-being of staff through mindfulness at the Tees, Esk, and Wear Valleys NHS Foundation Trust". In: *Global Business and Organizational Excellence* (2018). ISSN: 19322062. DOI: 10.1002/joe.21874.

[110] Britta K. Hölzel et al. "How Does Mindfulness Meditation Work? Proposing Mechanisms of Action From a Conceptual and Neural Perspective". In: *Perspectives on Psychological Science* 6.6 (Nov. 2011), pp. 537–559. ISSN: 1745-6916. DOI: 10.1177/1745691611419671. URL: http://journals.sagepub.com/doi/10.1177/1745691611419671.

[111] Kristina Hoök and Jonas Lowgren. "Strong concepts: Intermediate-level knowledge in interaction Design research". In: *ACM Transactions on Computer-Human Interaction* (2012). ISSN: 10730516. DOI: 10.1145/2362364.2362371.

[112] Kristina Höök. *Designing with the Body: Somaesthetic Interaction Design*. 2018. URL: https://books.google.co.uk/books?hl=en&lr=&id=9oZ0DwAAQBAJ&oi=fnd&pg=PR7&dq=hook+somaesthetics&ots=V1vQ2Csb0b&sig=ZrXla3jRmz0T4i6YiZaE9L9VQSA&redir_esc=y#v=onepage&q=hook%20somaesthetics&f=false.

[113] Kristina Höök. "Transferring qualities from horseback riding to design". In: *Proceedings of the 6th Nordic Conference on Human-Computer Interaction Extending Boundaries - NordiCHI '10*. New York, New York, USA: ACM Press, 2010, p. 226. ISBN: 9781605589343. DOI: 10.1145/1868914.1868943. URL: http://portal.acm.org/citation.cfm?doid=1868914.1868943.

[114] Kristina Höök and Martin Jonsson. "Move to be Moved". In: *CHI Extended Abstracts on Human Factors in Computing Systems* (2016), pp. 3301–3308. DOI: 10.1145/2851581.2856470. URL: http://dl.acm.org/citation.cfm?doid=2851581.2856470.

[115] Kristina Höök et al. *Embracing first-person perspectives in soma-based design*. Feb. 2018. DOI: 10.3390/informatics5010008.

[116] Kristina Höök et al. "Interactional empowerment". In: *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*. New York, New York, USA: ACM Press, 2008, p. 647. ISBN: 9781605580111. DOI: 10.1145/1357054.1357157. URL: http://portal.acm.org/citation.cfm?doid=1357054.1357157.

[117] Kristina Höök et al. "Somaesthetic Appreciation Design". In: *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*. New York, New York, USA: ACM Press, 2016, pp. 3131–3142. ISBN: 9781450333627. DOI: 10.1145/2858036.2858583. URL: http://dl.acm.org/citation.cfm?doid=2858036.2858583.

[118] Eva Hornecker. "Beyond affordance: Tangibles' hybrid nature". In: *Proceedings of the 6th International Conference on Tangible, Embedded and Embodied Interaction, TEI 2012*. 2012. ISBN: 9781450311748. DOI: 10.1145/2148131.2148168.

[119] Annika Howells, Itai Ivtzan, and Francisco Jose Eiroa-Orosa. "Putting the 'app' in Happiness: A Randomised Controlled Trial of a Smartphone-Based Mindfulness Intervention to Enhance Wellbeing". In: *Journal of Happiness Studies* 17.1 (Feb. 2016), pp. 163–185. ISSN: 15737780. DOI: 10.1007/s10902-014-9589-1. URL: http://link.springer.com/10.1007/s10902-014-9589-1.

[120] Jörn Hurtienne. "How Cognitive Linguistics Inspires HCI: Image Schemas and Image-Schematic Metaphors". In: *International Journal of Human-Computer Interaction* (2017). ISSN: 15327590. DOI: 10.1080/10447318.2016.1232227.

[121] Hilary Hutchinson et al. "Technology probes: inspiring design for and with families". In: *Proceedings of the conference on Human factors in computing systems - CHI '03*. New York, New York, USA: ACM Press, 2003, pp. 17–24. ISBN: 1581136307. DOI: 10.1145/642611.642616. URL: http://portal.acm.org/citation.cfm?doid=642611.642616.

[122] Mona Irrmischer et al. "Controlling the Temporal Structure of Brain Oscillations by Focused Attention Meditation". In: *Human Brain Mapping* 39.4 (Apr. 2018), pp. 1825–1838. ISSN: 1065-9471. DOI: 10.1002/hbm.23971. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/hbm.23971.

[123] Ellen Isaacs et al. "Echoes from the past". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*. New York, New York, USA: ACM Press, 2013, p. 1071. ISBN: 9781450318990. DOI: 10.1145/2470654.2466137. URL: http://dl.acm.org/citation.cfm?doid=2470654.2466137.

[124] Katherine Isbister and Michael Karlesky. "Embodied Self-Regulation with Tangibles". In: (). URL: http://mentalhealth.media.mit.edu/wp-content/uploads/sites/46/2016/04/isbisterworkshoppaper.pdf.

[125] Takahiro Iwaanaguchi et al. "Cyber Tai Chi - CG-based Video Materials for Tai Chi Chuan Self-Study". In: *2015 International Conference on Cyberworlds (CW)*. IEEE, Oct. 2015, pp. 365–368. ISBN: 978-1-4673-9403-1. DOI: 10.1109/CW.2015.13. URL: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=7398443.

[126] Giulio Jacucci and Ina Wagner. "Performative roles of materiality for collective creativity". In: *Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition - C&C '07*. New York, New York, USA: ACM Press, 2007, p. 73. ISBN: 9781595937124. DOI: 10.1145/1254960.1254971. URL: http://portal.acm.org/citation.cfm?doid=1254960.1254971.

[127] C. James-Reynolds and Ed Currie. "Mindfulness Mirror". In: *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. Vol. 11927 LNAI. Springer, Dec. 2019, pp. 456–461. ISBN: 9783030348847. DOI: 10.1007/978-3-030-34885-4{_}36. URL: https://link.springer.com/chapter/10.1007/978-3-030-34885-4_36.

[128] Mark Johnson. "The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason". In: *The Journal of Aesthetics and Art Criticism* (1989). ISSN: 00218529. DOI: 10.2307/431155.

[129] Lee Jones et al. "Ambient Notifications with Shape Changing Circuits in Peripheral Locations". In: *Proceedings of the Interactive Surfaces and Spaces on ZZZ - ISS '17*. New York, New York, USA: ACM Press, 2017, pp. 405–408. ISBN: 9781450346917. DOI: 10.1145/3132272.3132291. URL: http://dl.acm.org/citation.cfm?doid=3132272.3132291.

[130] Lynette A. Jones and Michal Berris. "The psychophysics of temperature perception and thermal-interface design". In: *Proceedings - 10th Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, HAPTICS 2002*. 2002. ISBN: 0769514898. DOI: 10.1109/HAPTIC.2002.998951.

[131] Lynette A. Jones and Hsin Ni Ho. "Warm or cool, large or small? The challenge of thermal displays". In: *IEEE Transactions on Haptics* (2008). ISSN: 19391412. DOI: 10.1109/TOH.2008.2.

[132] Martin Jonsson et al. "The Aesthetics of Heat". In: *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '16*. New York, New York, USA: ACM Press, Feb. 2016, pp. 109–117. ISBN: 9781450335829. DOI: 10.1145/2839462.2839487. URL: http://dl.acm.org/citation.cfm?doid=2839462.2839487.

[133] Heekyoung Jung and Erik Stolterman. "Material probe". In: *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction - TEI '11*. New York, New York, USA: ACM Press, 2011, p. 153. ISBN: 9781450304788. DOI: 10.1145/1935701.1935731. URL: http://portal.acm.org/citation.cfm?doid=1935701.1935731.

[134] Jon Kabat-Zinn. "An outpatient program in behavioral medicine for chronic pain patients based on the practice of mindfulness meditation: Theoretical considerations and preliminary results". In: *General Hospital Psychiatry* 4.1 (1982), pp. 33–47. ISSN: 01638343. DOI: 10.1016/0163-8343(82)90026-3.

[135] Jon Kabat-Zinn. *Mindfulness-based interventions in context: Past, present, and future*. May 2003. DOI: 10.1093/clipsy/bpg016. URL: http://doi.wiley.com/10.1093/clipsy.bpg016.

[136] Jon Kabat-Zinn. "Some reflections on the origins of MBSR, skillful means, and the trouble with maps". In: *Contemporary Buddhism* 12.1 (May 2011), pp. 281–306. ISSN: 1463-9947. DOI: 10.1080/14639947.2011.564844. URL: http://www.tandfonline.com/doi/abs/10.1080/14639947.2011.564844.

[137] Jon Kabat-Zinn. *Wherever you go, there you are: mindfulness meditation in everyday life*. Hyperion e-book, 2009. ISBN: 1401394671.

[138] Byongchang Kang. "Unifying opposites through metaphor: A cognitive approach to the Buddhist metaphors for the mind in the Awakening of Faith discourse". In: *Religions* (2018). ISSN: 20771444. DOI: 10.3390/rel9110345.

[139] Stephen Kaplan. "The restorative benefits of nature: Toward an integrative framework". In: *Journal of Environmental Psychology* 15.3 (Sept. 1995), pp. 169–182. ISSN: 0272-4944. DOI: 10.1016/0272-4944(95)90001-2. URL: https://www.sciencedirect.com/science/article/pii/0272494495900012.

[140] Elvin Karana et al. "The tuning of materials: A designer's journey". In: *DIS 2016 - Proceedings of the 2016 ACM Conference on Designing Interactive Systems: Fuse*. Association for Computing Machinery, Inc, June 2016, pp. 619–631. ISBN: 9781450340311. DOI: 10.1145/2901790.2901909.

[141] Michael Karlesky and Katherine Isbister. "Understanding fidget widgets: Exploring the design space of embodied self-regulation". In: *ACM International Conference Proceeding Series*. Vol. 23-27-October-2016. Association for Computing Machinery, Oct. 2016. ISBN: 9781450347631. DOI: 10.1145/2971485.2971557.

[142] Jared D Kass et al. *Mindfulness and the arts therapies: Theory and practice*. Jessica Kingsley Publishers, 2013.

[143] Alan E. Kazdin and Sarah M. Rabbitt. "Novel models for delivering mental health services and reducing the burdens of mental illness". In: *Clinical Psychological Science* 1.2 (Apr. 2013), pp. 170–191. ISSN: 21677026. DOI: 10.1177/2167702612463566. URL: http://journals.sagepub.com/doi/10.1177/2167702612463566.

[144] Joan Kellogg et al. "The use of the mandala in psychological evaluation and treatment". In: *American Journal of Art Therapy* 16.July (1977), pp. 123–134. ISSN: 00074764.

[145] Catherine E. Kerr et al. "Mindfulness starts with the body: somatosensory attention and top-down modulation of cortical alpha rhythms in mindfulness meditation". In: *Frontiers in Human Neuroscience* 7 (2013), p. 12. ISSN: 1662-5161. DOI: 10.3389/fnhum.2013.00012.

[146] John Killick and Claire Craig. *Creativity and communication in persons with dementia*. Jessica Kingsley Publishers, 2011, p. 212. ISBN: 0857003011.

[147] Alexandra Kitson, Mirjana Prpa, and Bernhard E. Riecke. "Immersive Interactive Technologies for Positive Change: A Scoping Review and Design Considerations". In: *Frontiers in Psychology | www.frontiersin.org* 1 (2018), p. 1354. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2018.01354. URL: https://www.frontiersin.org/article/10.3389/fpsyg.2018.01354/full%20www.frontiersin.org.

[148] Jan J. Koenderink et al. "Ambiguity and the 'mental eye' in pictorial relief". In: *Perception* (2001). ISSN: 03010066. DOI: 10.1068/p3030.

[149] Bethany E. Kok and Tania Singer. "Phenomenological Fingerprints of Four Meditations: Differential State Changes in Affect, Mind-Wandering, Meta-Cognition, and Interoception Before and After Daily Practice Across 9 Months of Training". In: *Mindfulness* 8.1 (Feb. 2017), pp. 218–231. ISSN: 1868-8527. DOI: 10.1007/s12671-016-0594-9. URL: http://link.springer.com/10.1007/s12671-016-0594-9.

[150] Ilkka Kosunen et al. "RelaWorld: Neuroadaptive and Immersive Virtual Reality Meditation System". In: *Iui 2016* (2016), pp. 208–217. DOI: 10.1145/2856767.2856796. URL: http://dl.acm.org/citation.cfm?doid=2856767.2856796%20http://dl.acm.org/citation.cfm?id=2856796.

[151] Olave E. Krigolson et al. "Choosing MUSE: Validation of a low-cost, portable EEG system for ERP research". In: *Frontiers in Neuroscience* 11.MAR (2017), p. 109. ISSN: 1662453X. DOI: 10.3389/fnins.2017.00109. URL: http://journal.frontiersin.org/article/10.3389/fnins.2017.00109/full.

[152] Klaus Krippendorff. "Intrinsic motivation and human-centred design". In: *Theoretical Issues in Ergonomics Science* (2004). ISSN: 1464536X. DOI: 10.1080/1463922031000086717.

[153] Willem Kuyken et al. "Efficacy of Mindfulness-Based Cognitive Therapy in Prevention of Depressive Relapse". In: *JAMA Psychiatry* 73.6 (June 2016), p. 565. ISSN: 2168-622X. DOI: 10.1001/jamapsychiatry.2016.0076. URL: http://archpsyc.jamanetwork.com/article.aspx?doi=10.1001/jamapsychiatry.2016.0076.

[154] Jim Lagopoulos et al. "Increased theta and alpha EEG activity during nondirective meditation". In: *Journal of Alternative and Complementary Medicine* 15.11 (2009), pp. 1187–1192. ISSN: 10755535. DOI: 10.1089/acm.2009.0113. URL: http://www.liebertpub.com/doi/10.1089/acm.2009.0113.

[155] George Lakoff and Mark Johnson. *Metaphors We Live By*. 2013. DOI: 10.7208/chicago/9780226470993.001.0001.

[156] Ronald W. Langacker and George Lakoff. "Women, Fire, and Dangerous Things: What Categories Reveal about the Mind". In: *Language* (1988). ISSN: 00978507. DOI: 10.2307/415440.

[157] Ellen J. Langer and Mihnca Moldoveanu. "The construct of mindfulness". In: *Journal of Social Issues* 56.1 (2000), pp. 1–9. ISSN: 00224537. DOI: 10.1111/0022-4537.00148.

[158] William Langston. "Violating Orientational Metaphors Slows Reading". In: *Discourse Processes* (2002). ISSN: 0163-853X. DOI: 10.1207/s15326950dp3403{_}3.

[159] Linda Larkey et al. "Meditative movement as a category of exercise: implications for research." In: *Journal of physical activity & health* 6.2 (Mar. 2009), pp. 230–8. ISSN: 1543-3080. URL: http://www.ncbi.nlm.nih.gov/pubmed/19420401.

[160] Amanda Lazar et al. "Making as Expression: Informing Design with People with Complex Communication Needs through Art Therapy". In: *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. New York, New York, USA: ACM Press, 2018, pp. 1–16. ISBN: 9781450356206. DOI: 10.1145/3173574.3173925. URL: http://dl.acm.org/citation.cfm?doid=3173574.3173925.

[161] Marie Christine Lichtlé. "The effect of an advertisement's colour on emotions evoked by an ad and attitude towards the ad". In: *International Journal of Advertising* 26.1 (2007), pp. 37–62. ISSN: 02650487. DOI: 10.1080/02650487.2007.11072995. URL: https://www.tandfonline.com/doi/full/10.1080/02650487.2007.11072995.

[162] Youn-kyung Lim et al. "Emotional Experience and Interaction Design". In: *Affect and Emotion in Human-Computer Interaction*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2008, pp. 116–129. DOI: 10.1007/978-3-540-85099-1{_}10. URL: http://link.springer.com/10.1007/978-3-540-85099-1_10.

[163] Jared R. Lindahl et al. "The varieties of contemplative experience: A mixed-methods study of meditation-related challenges in Western Buddhists". In: *PLoS ONE* 12.5 (May 2017). Ed. by Kirk Warren Brown, e0176239. ISSN: 19326203. DOI: 10.1371/journal.pone.0176239. URL: http://dx.plos.org/10.1371/journal.pone.0176239.

[164] Kiel Long and John Vines. "Mind Pool: Encouraging Self-Reflection Through Ambiguous Bio-Feedback". In: *Conference on Human Factors in Computing Systems - Proceedings*. Vol. 2013-April. New York, New York, USA: ACM Press, 2013, pp. 2975–2978. ISBN: 9781450318990. DOI: 10.1145/2468356.2479588. URL: http://dl.acm.org/citation.cfm?doid=2468356.2479588%20http://dl.acm.org/citation.cfm?id=2479588%5Cnfile:///C:/Users/hsimoham/AppData/Local/Mendeley%20Ltd./Mendeley%20Desktop/Downloaded/Long,%20Vines%20-%202013%20-%20Mind%20pool%20encouraging%20self-reflection%20through%20ambiguous.

[165] K. Louise Barriball and Alison While. "Collecting data using a semi-structured interview: a discussion paper". In: *Journal of Advanced Nursing* (1994). ISSN: 13652648. DOI: 10.1111/j.1365-2648.1994.tb01088.x.

[166] Kai Lukoff et al. "From Ancient Contemplative Practice to the App Store: Designing a Digital Container for Mindfulness". In: (2020). DOI: 10.1145/3357236.3395444. URL: https://doi.org/10.1145/3357236.3395444.

[167] Vija B. Lusebrink. "Assessment and therapeutic application of the expressive therapies continuum: Implications for brain structures and functions". In: *Art Therapy* 27.4 (2010), pp. 168–177. ISSN: 07421656. DOI: 10.1080/07421656.2010.10129380. URL: http://www.tandfonline.com/doi/abs/10.1080/07421656.2010.10129380.

[168] Antoine Lutz et al. "Attention regulation and monitoring in meditation". In: *Trends in Cognitive Sciences* 12.4 (2008), pp. 163–169.

[169] Anna Macaranas, Alissa N. Antle, and Bernhard E. Riecke. "What is Intuitive Interaction? Balancing Users' Performance and Satisfaction with Natural User Interfaces". In: *Interacting with Computers* (2015). ISSN: 09535438. DOI: 10.1093/iwc/iwv003.

[170] Karon E. MacLean. "Designing with haptic feedback". In: *Proceedings - IEEE International Conference on Robotics and Automation*. Vol. 1. 2000, pp. 783–787. DOI: 10.1109/robot.2000.844146.

[171] Katherine A. MacLean et al. "Intensive Meditation Training Improves Perceptual Discrimination and Sustained Attention". In: *Psychological Science* 21.6 (June 2010), pp. 829–839. ISSN: 0956-7976. DOI: 10.1177/0956797610371339. URL: http://journals.sagepub.com/doi/10.1177/0956797610371339.

[172] Martin Maguire. "Methods to support human-centred design". In: *International Journal of Human Computer Studies* (2001). ISSN: 10715819. DOI: 10.1006/ijhc.2001.0503.

[173] Cathy Malchiodi. *Handbook of Art Therapy*. Ed. by Cathy A. Malchiodi. Guilford Press, 2011. ISBN: 9781609189754.

[174] Madhavan Mani et al. "Review and Evaluation of Mindfulness-Based iPhone Apps". In: *JMIR mHealth and uHealth* 3.3 (Aug. 2015), e82. ISSN: 2291-5222. DOI: 10.2196/mhealth.4328. URL: http://mhealth.jmir.org/2015/3/e82/.

[175] Josef Mattes. "Attentional focus in motor learning, the feldenkrais method, and mindful movement". In: *Perceptual and Motor Skills* 123.1 (2016), pp. 258–276. ISSN: 1558688X. DOI: 10.1177/0031512516661275. URL: https://journals.sagepub.com/doi/pdf/10.1177/0031512516661275.

[176] Tara Matthews, Tye Rattenbury, and Scott Carter. "Defining, designing and evaluating peripheral displays: An analysis using activity theory". In: *Human-Computer Interaction* (2007). ISSN: 07370024.

[177] Daniel McDuff et al. "AffectAura". In: *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*. New York, New York, USA: ACM Press, 2012, p. 849. ISBN: 9781450310154. DOI: 10.1145/2207676.2208525. URL: http://dl.acm.org/citation.cfm?doid=2207676.2208525.

[178] Wolf Mehling. *Differentiating attention styles and regulatory aspects of self-reported interoceptive sensibility*. 2016. DOI: 10.1098/rstb.2016.0013.

[179] Wolf E. Mehling et al. "The Multidimensional Assessment of Interoceptive Awareness (MAIA)". In: *PLoS ONE* (2012). ISSN: 19326203. DOI: 10.1371/journal.pone.0048230.

[180] Pardis Miri et al. "Evaluating a Personalizable, Inconspicuous Vibrotactile(PIV) Breathing Pacer for In-the-Moment Affect Regulation". In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 2020, pp. 1–12. URL: https://dl.acm.org/doi/abs/10.1145/3313831.3376757.

[181] Mahmoud Mohamed et al. "Understanding the Role of Human Senses in Interactive Meditation". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*. New York, New York, USA: ACM Press, 2017, pp. 4960–4965. ISBN: 9781450346559. DOI: 10.1145/3025453.3026000. URL: http://dl.acm.org/citation.cfm?doid=3025453.3026000.

[182] Daniel A. Monti and Caroline Peterson. "Mindfulness-Based Art Therapy (MBAT)". In: *INTEGRATIVE CANCER THERAPIES* 2.1 (2003), pp. 81–83. URL: http://journals.sagepub.com/doi/pdf/10.1177/1534735403002001010.

[183] Daniel A. Monti et al. "A randomized, controlled trial of mindfulness-based art therapy (MBAT) for women with cancer". In: *Psycho-Oncology* 15.5 (May 2006), pp. 363–373. ISSN: 10579249. DOI: 10.1002/pon.988. URL: http://doi.wiley.com/10.1002/pon.988.

[184] Catherine Hyland Moon. "Theorizing Materiality in Art Therapy: Negotiating Meanings". In: *Materials & Media in Art Therapy: Critical Understandings of Diverse Artistic Vocabularies*. Routledge, Jan. 2010, pp. 49–88. DOI: 10.4324/9780203858073-10. URL: https://www.taylorfrancis.com/books/e/9781135161637/chapters/10.4324%2F9780203858073-10.

[185] Joan Mora-guiard, Ciera Crowell, and Narcis Pares. "A Play Therapy based Full-body Interaction Intervention Tool for Children with Autism". In: ().

[186] *Muse™ - Meditation Made Easy with the Muse Headband*. URL: https://choosemuse.com/.

[187] Lennart Erik Nacke et al. "Biofeedback game design: using direct and indirect physiological control to enhance game interaction". In: *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*. New York, New York, USA: ACM Press, 2011, p. 103. ISBN: 9781450302289. DOI: 10.1145/1978942.1978958. URL: http://dl.acm.org/citation.cfm?doid=1978942.1978958.

[188] José Naranjo and Stefan Schmidt. "Is it me or not me? Modulation of perceptual-motor awareness and visuomotor performance by mindfulness meditation". In: *BMC Neuroscience* 13.1 (July 2012), p. 88. ISSN: 1471-2202. DOI: 10.1186/1471-2202-13-88. URL: http://bmcneurosci.biomedcentral.com/articles/10.1186/1471-2202-13-88.

[189] Jonathan D Nash and Andrew Newberg. "Toward a unifying taxonomy and definition for meditation." In: *Frontiers in psychology* 4 (2013), p. 806. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2013.00806. URL: http://www.ncbi.nlm.nih.gov/pubmed/24312060%20http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3834522.

[190] Carman Neustaedter and Phoebe Sengers. "Autobiographical design in HCI research: Designing and learning through use-it-yourself". In: *Proceedings of the Designing Interactive Systems Conference, DIS '12*. 2012. ISBN: 9781450312103. DOI: 10.1145/2317956.2318034.

[191] Carman Neustaedter et al. "Sharing domestic life through long-term video connections". In: *ACM Transactions on Computer-Human Interaction* 22.1 (Feb. 2015), p. 3. ISSN: 15577325. DOI: 10.1145/2696869. URL: https://dl.acm.org/doi/10.1145/2696869.

[192] Jakob Nielsen and Rolf Molich. "Heuristic evaluation of user interfaces". In: *Proceedings of the SIGCHI conference on Human factors in computing systems Empowering people - CHI '90*. New York, New York, USA: ACM Press, 1990, pp. 249–256. ISBN: 0201509326. DOI: 10.1145/97243.97281. URL: http://portal.acm.org/citation.cfm?doid=97243.97281.

[193] Nielsen BookScan. *Child's Play: Millennial Women Drive Sales of Adult Coloring Books*. 2016. URL: http://www.nielsen.com/us/en/insights/news/2016/childs-play-millennial-women-drive-sales-of-adult-coloring-books.html.

[194] Francisco Nunes et al. "Self-Care Technologies in HCI". In: *ACM Transactions on Computer-Human Interaction* 22.6 (Dec. 2015), pp. 1–45. ISSN: 10730516. DOI: 10.1145/2803173. URL: http://dl.acm.org/citation.cfm?doid=2830543.2803173.

[195] Claudia Núñez-Pacheco. "Expanding our perceptual world through technology: A subjective bodily perspective". In: *UbiComp and ISWC 2015 - Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and the Proceedings of the 2015 ACM International Symposium on Wearable Computers*. Association for Computing Machinery, Inc, Sept. 2015, pp. 951–956. ISBN: 9781450335751. DOI: 10.1145/2800835.2806206.

[196] Kenton O'Hara, Abigail Sellen, and Richard Harper. "Embodiment in brain-computer interaction". In: *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*. New York, New York, USA: ACM Press, 2011, p. 353. ISBN: 9781450302289. DOI: 10.1145/1978942.1978994. URL: http://dl.acm.org/citation.cfm?doid=1978942.1978994.

[197] Aisling Ann O'Kane, Yvonne Rogers, and Ann Blandford. "Gaining empathy for non-routine mobile device use hrough autoethnography". In: *Conference on Human Factors in Computing Systems - Proceedings*. 2014. ISBN: 9781450324731. DOI: 10.1145/2556288.2557179.

[198] Lawrence A. Palinkas et al. "Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research". In: *Administration and Policy in Mental Health and Mental Health Services Research* (2015). ISSN: 15733289. DOI: 10.1007/s10488-013-0528-y.

[199] Jin-Yung Park and Tek-Jin Nam. "Dynamic design elements for the peripheral interaction of ambient media". In: *Proceeding of the twenty-sixth annual CHI conference extended abstracts on Human factors in computing systems - CHI '08*. New York, New York, USA: ACM Press, 2008, p. 3717. ISBN: 978160558012X. DOI: 10.1145/1358628.1358919. URL: http://portal.acm.org/citation.cfm?doid=1358628.1358919.

[200] Rakesh Patibanda et al. "Life Tree". In: *Proceedings of the Annual Symposium on Computer-Human Interaction in Play - CHI PLAY '17*. New York, New York, USA: ACM Press, 2017, pp. 19–31. ISBN: 9781450348980. DOI: 10.1145/3116595.3116621. URL: http://dl.acm.org/citation.cfm?doid=3116595.3116621.

[201] James W. Pennebaker. "Theories, therapies, and taxpayers: On the complexities of the expressive writing paradigm". In: *Clinical Psychology: Science and Practice* (2004). ISSN: 09695893. DOI: 10.1093/clipsy/bph063.

[202] David M. Perlman et al. "Differential Effects on Pain Intensity and Unpleasantness of Two Meditation Practices". In: *Emotion* (2010). ISSN: 15283542. DOI: 10.1037/a0018440.

[203] Claire Petitmengin et al. *Studying the experience of meditation through Microphenomenology*. Aug. 2019. DOI: 10.1016/j.copsyc.2018.10.009.

[204] James Pierce. "Undesigning technology: Considering the negation of design by design". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2012, pp. 957–966. ISBN: 9781450310154. DOI: 10.1145/2208516.2208540.

[205] Jacob Piet and Esben Hougaard. *The effect of mindfulness-based cognitive therapy for prevention of relapse in recurrent major depressive disorder: A systematic review and meta-analysis*. Aug. 2011. DOI: 10.1016/j.cpr.2011.05.002. URL: https://www.sciencedirect.com/science/article/pii/S0272735811000973.

[206] Sebastiaan Pijnappel and Florian Floyd Mueller. "4 design themes for skateboarding". In: *Conference on Human Factors in Computing Systems - Proceedings*. 2013. ISBN: 9781450318990. DOI: 10.1145/2470654.2466165.

[207] Inmaculada Plaza et al. "Mindfulness-based mobile applications: literature review and analysis of current features." In: *JMIR mHealth and uHealth* 1.2 (Nov. 2013), e24. ISSN: 22915222. DOI: 10.2196/mhealth.2733. URL: http://www.ncbi.nlm.nih.gov/pubmed/25099314%20http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4114453%20http://www.ncbi.nlm.nih.gov/pubmed/25099314%5Cnhttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4114453.

[208] Henning Pohl, Andreea Muresan, and Kasper Hornbæk. "Charting subtle interaction in the HCI literature". In: *Conference on Human Factors in Computing Systems - Proceedings*. 2019. ISBN: 9781450359702. DOI: 10.1145/3290605.3300648.

[209] Otniel Portillo-Rodriguez et al. "Real-Time Gesture Recognition, Evaluation and Feed-Forward Correction of a Multimodal Tai-Chi Platform". In: *Haptic and Audio Interaction Design*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2008, pp. 30–39. DOI: 10.1007/978-3-540-87883-4{_}4. URL: http://link.springer.com/10.1007/978-3-540-87883-4_4.

[210] Mirjana Prpa, Karen Cochrane, and Bernhard E. Riecke. "Hacking Alternatives in 21st Century: Designing a Bio-Responsive Virtual Environment for Stress Reduction". In: Springer, Cham, 2016, pp. 34–39. DOI: 10.1007/978-3-319-32270-4{_}4. URL: http://link.springer.com/10.1007/978-3-319-32270-4_4.

[211] Mirjana Prpa et al. "Articulating Experience: Reflections from Experts Applying Micro-Phenomenology to Design Research in HCI". In: *Conference on Human Factors in Computing Systems - Proceedings*. 2020. ISBN: 9781450367080. DOI: 10.1145/3313831.3376664.

[212] Mirjana Prpa et al. "Attending to Breath: Exploring How the Cues in a Virtual Environment Guide the Attention to Breath and Shape the Quality of Experience to Support Mindfulness". In: *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18*. New York, New York, USA: ACM Press, 2018, pp. 71–84. ISBN: 9781450351980. DOI: 10.1145/3196709.3196765. URL: http://dl.acm.org/citation.cfm?doid=3196709.3196765.

[213] Chengcheng Qu et al. "Functionality of Top-Rated Mobile Apps for Depression: Systematic Search and Evaluation". In: *JMIR Ment Health* 7.2 (2020), p. 1. DOI: 10.2196/18042. URL: https://mental.jmir.org/2020/1/e15321/URL:

http://mental.jmir.org/2020/2/e18042/http://mental.jmir.org/2020/2/e18042/.

[214] Sandy Q. Qu and John Dumay. *The qualitative research interview*. 2011. DOI: 10.1108/11766091111162070.

[215] Naveendran Rajendran et al. "Randomized Controlled Trial of Adult Therapeutic Coloring for the Management of Significant Anxiety in the Emergency Department". In: *Academic Emergency Medicine* 27.2 (2020), pp. 92–99.

[216] Amon Rapp. "Autoethnography in Human-Computer Interaction: Theory and Practice". In: 2018. DOI: 10.1007/978-3-319-73374-6{_}3.

[217] Laury Rappaport. *Focusing-oriented art therapy: Accessing the body's wisdom and creative intelligence*. 2009. ISBN: 9781843107606. DOI: 10.1080/07421656.2011.622706. URL: https://books.google.co.uk/books?hl=ca&lr=&id=Rw3Jub4hnhgC&oi=fnd&pg=PP1&dq=mindfulness&ots=kiQ_o3w7f6&sig=YzF9QK3ECQm5J01p6QnwLoglbA0&redir_esc=y#v=onepage&q=mindfulness&f=false.

[218] Johan Redström. "Towards user design? on the shift from object to user as the subject of design". In: *Design Studies* (2006). ISSN: 0142694X. DOI: 10.1016/j.destud.2005.06.001.

[219] Robert Richer et al. "Real-time Mental State Recognition using a Wearable EEG". In: *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*. IEEE, July 2018, pp. 5495–5498. ISBN: 978-1-5386-3646-6. DOI: 10.1109/EMBC.2018.8513653. URL: https://ieeexplore.ieee.org/document/8513653/.

[220] J Brendan Ritchie and Peter Carruthers. "Oxford Handbooks Online The Bodily Senses 1 The Interoceptive Senses". In: November 2018 (July 2015), pp. 1–22. DOI: 10.1093/oxfordhb/9780199600472.013.026. URL: https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199600472.001.0001/oxfordhb-9780199600472-e-026.

[221] Yvonne Rogers et al. "Ambient influence: can twinkly lights lure and abstract representations trigger behavioral change?" In: *Proceedings of the 12th ACM international conference on Ubiquitous computing - Ubicomp '10*. New York, New York, USA: ACM Press, 2010, p. 261. ISBN: 9781605588438. DOI: 10.1145/1864349.1864372. URL: http://portal.acm.org/citation.cfm?doid=1864349.1864372.

[222] Serena M. Roney-Dougal and Jerry Solfvin. "Exploring the relationship between tibetan meditation attainment and precognition". In: *Journal of Scientific Exploration* (2011). ISSN: 08923310.

[223] Joan Sol Roo et al. "Inner Garden: Connecting Inner States to a Mixed Reality Sandbox for Mindfulness". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*. New York, New York, USA: ACM Press, 2017, pp. 1459–1470. ISBN: 9781450346559. DOI: 10.1145/3025453.3025743. URL: http://dl.acm.org/citation.cfm?doid=3025453.3025743.

[224] Daniela K. Rosner et al. "Designing with traces". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*. New York, New York, USA: ACM Press, 2013, pp. 1649–1658. ISBN: 9781450318990. DOI: 10.1145/2470654.2466218. URL: http://dl.acm.org/citation.cfm?doid=2470654.2466218.

[225] Da Saffer. "The Role of Metaphor in Interaction Design". In: *Citeseer* (2005). DOI: 10.1207/s15327868ms2003{_}1.

[226] Kavous Salehzadeh Niksirat et al. "A Framework for Interactive Mindfulness Meditation Using Attention-Regulation Process". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*. New York, New York, USA: ACM Press, 2017, pp. 2672–2684. ISBN: 9781450346559. DOI: 10.1145/3025453.3025914. URL: http://dl.acm.org/citation.cfm?doid=3025453.3025914.

[227] Pedro Sanches et al. "Ambiguity as a resource to inform proto-practices: The case of skin conductance". In: *ACM Transactions on Computer-Human Interaction (TOCHI)* 10.20 (2019).

[228] Pedro Sanches et al. "HCI and Affective Health Taking stock of a decade of studies and charting future research directions". In: *Conference on Human Factors in Computing Systems - Proceedings*. ACM, Dec. 2019. ISBN: 9781450359702. DOI: 10.1145/3290605.3300475.

[229] Corina Sas. "Being Present – Being Mindful Conceptual delimitations and comparative analysis". In: *Proceedings of Peach Summer School*. 2007. URL: https://s3.amazonaws.com/academia.edu.documents/44090323/Peach_Summer_School_2007_Extended_Abstra20160325-4478-1w7nfno.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1516032920&Signature=DdiTrHxEYx%2BYyAg09wpLay%2BHcCg%3D&response-content-disposition=inl.

[230] Corina Sas and Rohit Chopra. "MeditAid: a wearable adaptive neurofeedback-based system for training mindfulness state". In: *Personal and Ubiquitous Computing* 19.7 (Oct. 2015), pp. 1169–1182. ISSN: 1617-4909. DOI: 10.1007/s00779-015-0870-z. URL: http://link.springer.com/10.1007/s00779-015-0870-z.

[231] Corina Sas and Alina Coman. "Designing personal grief rituals: An analysis of symbolic objects and actions". In: *Death Studies* 40.9 (2016), pp. 558–569. ISSN: 10917683. DOI: 10.1080/07481187.2016.1188868.

[232] Corina Sas and Carman Neustaedter. "Exploring DIY practices of complex home technologies". In: *ACM Transactions on Computer-Human Interaction* (2017). ISSN: 15577325. DOI: 10.1145/3057863.

[233] Corina Sas, Karen Wisbach, and Alina Coman. "Craft-based exploration of sense of self". In: *Conference on Human Factors in Computing Systems - Proceedings*. Vol. Part F1276. 2017, pp. 2891–2899. ISBN: 9781450346566. DOI: 10.1145/3027063.3053270. URL: https://eprints.lancs.ac.uk/id/eprint/84715/1/Craft_based_Exploration_of_Sense_of_Self_accepted.pdf.

[234] Corina Sas et al. "Generating implications for design through design research". In: *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14* (2014), pp. 1971–1980. DOI: 10.1145/2556288.2557357. URL: http://dl.acm.org/citation.cfm?doid=2556288.2557357.

[235] Corina Sas et al. "Self-Defining Memory Cues: Creative Expression and Emotional Meaning". In: *Extended Abstracts of the ACM CHI'15 Conference on Human Factors in Computing Systems* 2 (2015), pp. 2013–2018. DOI: 10.1145/2702613.2732842. URL: http://dl.acm.org/citation.cfm?doid=2702613.2732842%20http://dx.doi.org/10.1145/2702613.2732842.

[236] Corina Sas et al. "Supporting Stimulation Needs in Dementia Care through Wall-Sized Displays". In: *Conference on Human Factors in Computing Systems - Proceedings*. 2020. ISBN: 9781450367080. DOI: 10.1145/3313831.3376361.

[237] Bee Scherer and Jeff Waistell. "METAPHORS OF MINDFULNESS". In: *Contemporary Buddhism* (2018). ISSN: 14767953. DOI: 10.1080/14639947.2018.1479557.

[238] Thecla Schiphorst. "Soft(n): Toward a somaesthetics of touch". In: *Conference on Human Factors in Computing Systems - Proceedings*. 2009, pp. 2427–2438. ISBN: 9781605582474. DOI: 10.1145/1520340.1520345.

[239] Laura Schmalzl, Mardi A Crane-Godreau, and Peter Payne. "Movement-based embodied contemplative practices: definitions and paradigms". In: *Frontiers in Human Neuroscience* 8 (2014), p. 205. ISSN: 1662-5161. DOI: 10.3389/fnhum.2014.00205. URL: http://www.ncbi.nlm.nih.gov/pubmed/24782738%20http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3995074%20http://journal.frontiersin.org/article/10.3389/fnhum.2014.00205/abstract.

[240] Donald A. Schön. *The Reflective Practitioner*. Routledge, Mar. 2017. ISBN: 9781315237473. DOI: 10.4324/9781315237473. URL: https://www.taylorfrancis.com/books/9781315237473.

[241] Crystal Schrade, Loel Tronsky, and Donna H. Kaiser. "Physiological effects of mandala making in adults with intellectual disability". In: *Arts in Psychotherapy* 38.2 (Apr. 2011), pp. 109–113. ISSN: 01974556. DOI: 10.1016/j.aip.2011.01.002. URL: http://www.sciencedirect.com/science/article/pii/S0197455611000037.

[242] Douglas Schuler and Aki Namioka. *Participatory design: Principles and practices*. 2017. ISBN: 9781351425780. DOI: 10.1201/9780203744338.

[243] Nicola S. Schutte and John M. Malouff. "Mindfulness and connectedness to nature: A meta-analytic investigation". In: *Personality and Individual Differences* (2018). ISSN: 01918869. DOI: 10.1016/j.paid.2018.01.034.

[244] Katie Seaborn et al. "Accessible play in everyday spaces: Mixed reality gaming for adult powered chair users". In: *ACM Transactions on Computer-Human Interaction* 23.2 (May 2016), pp. 1–28. ISSN: 15577325. DOI: 10.1145/2893182. URL: https://dl.acm.org/doi/10.1145/2893182.

[245] Sensor Tower Store Intelligence. *Consumer Obsession With Adult Coloring Books Is Creating a Revenue Boom on the App Store*. 2017. URL: https://sensortower.com/blog/adult-coloring-book-apps.

[246] Shauna L. Shapiro and Linda E. Carlson. *The art and science of mindfulness: Integrating mindfulness into psychology and the helping professions.* Washington: American Psychological Association, 2017. ISBN: 1-4338-2698-4. DOI: 10.1037/0000022-000. URL: http://content.apa.org/books/15990-000.

[247] Chris D Shaw, Diane Gromala, and A Fleming Seay. "The Meditation Chamber: Enacting Autonomic Senses". In: *Proc. of ENACTIVE/07*. 2007, pp. 405–408.

[248] Richard Shusterman. *Body Consciousness: A Philosophy of Mindfulness and Somaesthetics*. 2008.

[249] Antonio José Silvestre-López and Ignasi Navarro i Ferrando. "Metaphors in the conceptualisation of meditative practices". In: *Metaphor and the Social World* (2017). ISSN: 2210-4070. DOI: 10.1075/msw.7.1.03sil.

[250] Aneesha Singh et al. "Are HIV Smartphone Apps and Online Interventions Fit for Purpose?" In: *Proceedings of the 2017 International Conference on Digital Health - DH '17*. New York, New York, USA: ACM Press, 2017, pp. 6–15. ISBN: 9781450352499. DOI: 10.1145/3079452.3079469. URL: http://dl.acm.org/citation.cfm?doid=3079452.3079469.

[251] Maralynn Hagood Slegelis. "A study of Jung's Mandala and its relationship to art psychotherapy". In: *The Arts in Psychotherapy* 14.4 (1987), pp. 301–311. ISSN: 01974556. DOI: 10.1016/0197-4556(87)90018-9.

[252] Jacek Sliwinski, Mary Katsikitis, and Christian Martyn Jones. *A Review of Interactive Technologies as Support Tools for the Cultivation of Mindfulness*. Oct. 2017. DOI: 10.1007/s12671-017-0698-x. URL: x.

[253] Yesim Canan Sokmen and Alan Watters. "Emotion Regulation with Mindful Arts Activities Using a Personalized Self-Soothing Kit". In: *Occupational Therapy in Mental Health* 32.4 (Oct. 2016), pp. 345–369. ISSN: 0164-212X. DOI: 10.1080/0164212X.2016.1165642. URL: https://www.tandfonline.com/doi/full/10.1080/0164212X.2016.1165642.

[254] Anna Ståhl et al. "Experiencing the affective diary". In: *Personal and Ubiquitous Computing* 13.5 (2009), pp. 365–378. ISSN: 16174909. DOI: 10.1007/s00779-008-0202-7.

[255] Michael L. Stanchina et al. "The influence of white noise on sleep in subjects exposed to ICU noise". In: *Sleep Medicine* (2005). ISSN: 13899457. DOI: 10.1016/j.sleep.2004.12.004.

[256] Stoyan R Stoyanov et al. "Mobile App Rating Scale: A New Tool for Assessing the Quality of Health Mobile Apps". In: *JMIR mHealth and uHealth* 3.1 (Mar. 2015), e27. ISSN: 2291-5222. DOI: 10.2196/mhealth.3422. URL: http://mhealth.jmir.org/2015/1/e27/%20http://www.ncbi.nlm.nih.gov/pubmed/25760773%20http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4376132.

[257] Colin Strang. "XIV—The Perception of Heat". In: *Proceedings of the Aristotelian Society* (1961). ISSN: 0066-7374. DOI: 10.1093/aristotelian/61.1.239.

[258] Cally Strobel et al. "The Lived Experience of Adults Using a Meditation App: A Phenomenological Study". In: *Master of Arts in Holistic Health Studies Research Papers* (May 2017). URL: http://sophia.stkate.edu/ma_hhs/15.

[259] Petra Sundström et al. "Experiential artifacts as a design method for somaesthetic service development". In: *RDURP'11 - Proceedings of the 2011 ACM Symposium on the Role of Design in UbiComp Research and Practice*. 2011, pp. 33–36. ISBN: 9781450309318. DOI: 10.1145/2030031.2030041.

[260] Shunryu Suzuki. *Zen mind, beginner's mind: Informal talks on Zen meditation and practice.* 2010. DOI: 10.5860/choice.26-5404.

[261] Yi-Yuan Tang, Britta K. Hölzel, and Michael I. Posner. "The neuroscience of mindfulness meditation". In: *Nature Reviews Neuroscience* 16.4 (Apr. 2015), pp. 213–225. ISSN: 1471-003X. DOI: 10.1038/nrn3916. URL: http://www.nature.com/articles/nrn3916.

[262] John D. Teasdale et al. "Prevention of relapse/recurrence in major depression by mindfulness-based cognitive therapy." In: *Journal of Consulting and Clinical Psychology* 68.4 (2000), pp. 615–623. ISSN: 1939-2117. DOI: 10.1037/0022-006X.68.4.615. URL: http://doi.apa.org/getdoi.cfm?doi=10.1037/0022-006X.68.4.615.

[263] Nađa Terzimehić et al. "A review & Analysis of mindfulness research in HCI framing current lines of research and future opportunities". In: *Conference on Human Factors in Computing Systems - Proceedings*. New York: ACM Press, 2019, pp. 1–13. ISBN: 9781450359702. DOI: 10.1145/3290605.3300687.

[264] Jordan Tewell, Jon Bird, and George R. Buchanan. "The Heat is On". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. Vol. 2017-May. New York, NY, USA: ACM, May 2017, pp. 1756–1767. ISBN: 9781450346559. DOI: 10.1145/3025453.3025844. URL: https://dl.acm.org/doi/10.1145/3025453.3025844.

[265] Pariwat Thaisetthawatkul. "Quantitative sensory testing". In: *Neuromuscular Disorders in Clinical Practice*. 2014. ISBN: 9781461465676. DOI: 10.1007/978-1-4614-6567-6{_}11.

[266] *The Mindful Attention Awareness Scale (MAAS) - State*. URL: https://ggsc.berkeley.edu/images/uploads/The_Mindful_Attention_Awareness_Scale_-_State.pdf.

[267] Anja Thieme et al. "Design to promote mindfulness practice and sense of self for vulnerable women in secure hospital services". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*. New York, New York, USA: ACM Press, 2013, p. 2647. ISBN: 9781450318990. DOI: 10.1145/2470654.2481366. URL: http://dl.acm.org/citation.cfm?doid=2470654.2481366.

[268] Anja Thieme et al. "Designing for mental wellbeing: towards a more holistic approach in the treatment and prevention of mental illness". In: *Proceedings of the 2015 British HCI Conference on - British HCI '15*. 2015, pp. 1–10. ISBN: 9781450336437. DOI: 10.1145/2783446.2783586. URL: https://designandwellbeing.com/papers/britishHCI2015.pdf%20http://dl.acm.org/citation.cfm?doid=2783446.2783586.

[269] Tomohiro Tokunaga and Michael J Lyons. "Enactive Mandala : Audio-visualizing Brain Waves". In: *Proceedings of the International Conference on New Interfaces for Musical Expression*. 2013, pp. 8–9. URL: http://nime.org/proceedings/2013/nime2013_16.pdf.

[270] Barbara Tomasino, Alberto Chiesa, and Franco Fabbro. "Disentangling the neural mechanisms involved in Hinduism- and Buddhism-related meditations". In: *Brain and Cognition* 90 (2014), pp. 32–40. ISSN: 10902147. DOI: 10.1016/j.bandc.2014.03.013.

[271] Isaac N. Treves et al. "The relationship between mindfulness and objective measures of body awareness: A meta-analysis". In: *Scientific Reports* (2019). ISSN: 20452322. DOI: 10.1038/s41598-019-53978-6.

[272] Vasiliki Tsaknaki and Ylva Fernaeus. "Expanding on Wabi-Sabi as a Design Resource in HCI". In: *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*. New York, New York, USA: ACM Press, 2016, pp. 5970–5983. ISBN: 9781450333627. DOI: 10.1145/2858036.2858459. URL: http://dl.acm.org/citation.cfm?doid=2858036.2858459.

[273] Giuseppe Tucci. *The Theory and Practice of the Mandala: With special reference to the modern psychology of the subconscious*. Courier Corporation, 2001, p. 145. ISBN: 0877280746 9780877280743.

[274] Muhammad Umair, Muhammad Hamza Latif, and Corina Sas. "Dynamic Displays at Wrist for Real Time Visualization of Affective Data". In: *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility - DIS '18*. New York, New York, USA: ACM Press, 2018, pp. 201–205. ISBN: 9781450356312. DOI: 10.1145/3197391.3205436. URL: http://dl.acm.org/citation.cfm?doid=3197391.3205436.

[275] Muhammad Umair, Corina Sas, and Miquel Alfaras. "ThermoPixels: Toolkit for Personalizing Arousal-based Interfaces through Hybrid Crafting". In: *Proceedings of Designing Interactive Systems, DIS 2020, ACM*. ACM, Apr. 2020.

[276] Muhammad Umair, Corina Sas, and Muhammad Hamza Latif. "Towards affective chronometry: Exploring smart materials and actuators for real-time representation of changes in arousal". In: *Proceedings of the 2019 on Designing Interactive Systems Conference*. 2019, pp. 1479–1494.

[277] David R. Vago and David A. Silbersweig. "Self-awareness, self-regulation, and self-transcendence (S-ART): a framework for understanding the neurobiological mechanisms of mindfulness". In: *Frontiers in Human Neuroscience* 6 (Oct. 2012), p. 296. ISSN: 1662-5161. DOI: 10.3389/fnhum.2012.00296. URL: http:

//journal.frontiersin.org/article/10.3389/fnhum.2012.00296/abstract.

[278] Patricia Valdez and Albert Mehrabian. "Effects of color on emotions." In: *Journal of Experimental Psychology: General* 123.4 (1994), pp. 394–409. ISSN: 1939-2222. DOI: 10.1037/0096-3445.123.4.394. URL: http://doi.apa.org/getdoi.cfm?doi=10.1037/0096-3445.123.4.394.

[279] Nicholas T. Van Dam et al. "Mind the Hype: A Critical Evaluation and Prescriptive Agenda for Research on Mindfulness and Meditation". In: *Perspectives on Psychological Science* 1 (Oct. 2017), p. 174569161770958. ISSN: 1745-6916. DOI: 10.1177/1745691617709589. URL: http://journals.sagepub.com/doi/10.1177/1745691617709589%20www.psychologicalscience.org/PPS.

[280] Peter-Paul Verbeek. "Postphenomenology". In: *What things do. Philosophical reflections on technology, agency and design*. 2005.

[281] David J. Vernon. *Can neurofeedback training enhance performance? An evaluation of the evidence with implications for future research*. 2005. DOI: 10.1007/s10484-005-8421-4.

[282] Andrea Vianello, Luca Chittaro, and Assunta Matassa. "TANGAEON: tangible interaction to support people in a mindfulness practice". In: *International Journal of Human–Computer Interaction* 35.12 (2019), pp. 1086–1101.

[283] Michael de Vibe et al. *Mindfulness-Based Stress Reduction (MBSR) for improving health, quality of life and social functioning in adults*. Tech. rep. Nov. 2017. DOI: 10.4073/csr.2017.11. URL: https://www.campbellcollaboration.org/library/mindfulness-stress-reduction-for-adults.html.

[284] Jay Vidyarthi, Bernhard E. Riecke, and Diane Gromala. "Sonic Cradle". In: *Proceedings of the Designing Interactive Systems Conference*. New York, New York, USA: ACM Press, 2012, p. 408. ISBN: 9781450312103. DOI: 10.1145/2317956.2318017. URL: http://dl.acm.org/citation.cfm?doid=2317956.2318017.

[285] Helané Wahbeh et al. "A Systematic Review of Transcendent States Across Meditation and Contemplative Traditions". In: *EXPLORE* 14.1 (2018), pp. 19–35. ISSN: 1550-8307. DOI: 10.1016/J.EXPLORE.2017.07.007.

[286] Ron Wakkary et al. "Material Speculation: Actual Artifacts for Critical Inquiry". In: *Aarhus Series on Human Centered Computing*. Vol. 1. 1. Aarhus University Press, Oct. 2015, p. 12. DOI: 10.7146/aahcc.v1i1.21299. URL: https://tidsskrift.dk/ashcc/article/view/21299.

[287] Yufan (Wei) Wang. "Channel of Mindfulness". PhD thesis. Copenhagen Institute of Interaction Design, 2011.

[288] Graham Wilson, Gavin Davidson, and Stephen A. Brewster. "In the Heat of the Moment". In: *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*. Vol. 2015-April. New York, New York, USA: ACM Press, Apr. 2015, pp. 2063–2072. ISBN: 9781450331456. DOI: 10.1145/2702123.2702219. URL: http://dl.acm.org/citation.cfm?doid=2702123.2702219.

[289] Richard Winter. "Buddhism and action research: towards an appropriate model of inquiry for the caring professions". In: *Educational Action Research* 11.1 (Mar. 2003), pp. 141–160. ISSN: 0965-0792. DOI: 10.1080/09650790300200208. URL: http://www.tandfonline.com/doi/abs/10.1080/09650790300200208.

[290] Richmond Y. Wong and Deirdre K. Mulligan. "Bringing design to the privacy table broadening "design" in "Privacy by design" through the lens of HCI". In: *Conference on Human Factors in Computing Systems - Proceedings*. Association for Computing Machinery, May 2019. ISBN: 9781450359702. DOI: 10.1145/3290605.3300492.

[291] Joonsung Yoon, Kwanho Song, and Insub Kim. "Digital Mandala: The post-virtual as meditation of impermanence or a new reality". In: *Leonardo* 46.5 (2013), pp. 496–497.

[292] Bin Yu et al. "Unwind: a musical biofeedback for relaxation assistance". In: *Behaviour and Information Technology* (2018). ISSN: 13623001. DOI: 10.1080/0144929X.2018.1484515.

[293] Fabio Zambetta et al. "Reducing perceived waiting time in theme park queues via an augmented reality game". In: *ACM Transactions on Computer-Human Interaction* 27.1 (Jan. 2020), pp. 1–30. ISSN: 15577325. DOI: 10.1145/3361524. URL: https://dl.acm.org/doi/10.1145/3361524.

[294] Fadel Zeidan et al. "The Effects of Brief Mindfulness Meditation Training on Experimentally Induced Pain". In: *The Journal of Pain* 11.3 (Mar. 2010), pp. 199–209. ISSN: 1526-5900. DOI: 10.1016/J.JPAIN.2009.07.015. URL: https://www.sciencedirect.com/science/article/pii/S1526590009006919.

[295] Xianglong Zeng, Tian P.S. Oei, and Xiangping Liu. "Monitoring Emotion Through Body Sensation: A Review of Awareness in Goenka's Vipassana". In: *Journal of Religion and Health* 53.6 (Dec. 2014), pp. 1693–1705. ISSN: 00224197. DOI: 10.1007/s10943-013-9754-6.

[296] Bin Zhu, Anders Hedman, and Haibo Li. "Designing Digital Mindfulness: Presence-In and Presence-With versus Presence-Through". In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*. New York, New York, USA: ACM Press, 2017, pp. 2685–2695. ISBN: 9781450346559. DOI: 10.1145/3025453.3025590. URL: http://dl.acm.org/citation.cfm?doid=3025453.3025590.

[297] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. "Research through design as a method for interaction design research in HCI". In: *Conference on Human Factors in Computing Systems - Proceedings*. 2007, pp. 493–502. ISBN: 1595935932. DOI: 10.1145/1240624.1240704.