Sonic Cradle: Designing for an Immersive Experience of Meditation by Connecting Respiration to Music

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ABSTRACT
Sonic Cradle is a chamber of complete darkness where users shape a peaceful soundscape using only their respiration. This interactive system was designed to foster a meditative experience by facilitating users' sense of immersion while following a specific attentional pattern characteristic of *mindfulness*. The goal of *Sonic Cradle* is twofold: first, to trigger the proven effects of mindfulness on stress, and second, to help teach and demystify the concept of meditation for users' long-term benefit. This paper presents the design phase of the project, starting by theoretically grounding the initial concept. We then discuss 15 co-design sessions which provided informal conceptual validation and led to several concrete design iterations aimed at balancing users' perceived sense of control. The presented approach to designing an interactive stress management system can be considered *research through design*, as it also resulted in a novel theoretical framework for the psychology of media *immersion* which has implications for a wide range of research areas.

Author Keywords
Design, biofeedback, immersion, mindfulness, sound, music, persuasion, self-regulation, stress, psychology, research through design.

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interface: user-centered design, auditory feedback.

General Terms
Design, Human Factors, Theory

INTRODUCTION
As clinicians embrace pro-active and preventative approaches, patients' ability to promote and manage their own health is becoming critical. Researchers are actively pursuing an applicable model to equip clinicians and patients with the insight needed to improve behavioural *self-regulation* in the context of maintaining health [2]. A new crop of technologies are also being designed to support the self-regulation of exercise, eating habits, work breaks, cigarette smoking and more [4, 5, 21]. While these tools join a large family of medical technologies designed primarily to prevent and treat physiological problems, there are relatively fewer systems specifically designed to provide psychological support.

Biological and physiological sensors have been used to externally manifest one's internal states in biofeedback: a technology which has been shown to have therapeutic benefits [17, 18]. At DIS 2010, Sanches et. al. [36] presented an attempt to create a mobile biofeedback system for ongoing stress management called *Affective Health*. Through their design exploration, these authors showed *"that it is currently very challenging to diagnose stress from bio[feedback]-sensors that can be worn comfortably and continuously in everyday situations."* After confronting this obstacle, the authors claimed that, until we develop more robust biofeedback sensors, future directions for stress management technology are limited to systems which allow for interpretive self-reflection on bodily states in short-term sessions as opposed to real-time, continuous use. In this manuscript, we propose an interactive medium designed to motivate and teach non-technological practices known to help manage stress, sidestepping the documented ineffectiveness of systems which rely on continuous engagement with physiological sensors in daily life.

Contemporary evidence points to *mindfulness meditation* as an effective therapeutic tool for psychological self-regulation which requires no technology at all. This rapidly spreading eastern spiritual practice has been described as an intentional and non-judgmental focusing of attention to the present [1]. The advent of *calming technologies*, that *"induce cognitive, physiological, or affective states"* of *"restful alertness"* [30], demonstrates that interaction designers are already beginning to incorporate meditative principles in stress management applications. While other therapeutic technologies distract users from negative experiences [20, 28, 44], these systems are often designed using concepts from meditation to support the self-regulation of stress through heightened awareness of internal processes [29, 39, 37, 45].

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In this paper, we report on an attempt to design a new form of stress management system which intentionally promotes the specific pattern of awareness and attention characteristic of mindfulness practice. The goal is to design an interactive system which helps users achieve a holistically meditative user experience. If successful, the system will have the potential to not only reduce stress and arousal in the short-term, but also to demystify the process, experientially educating people about mindfulness and its benefits. The present writing starts by clarifying the concept of meditation as it applies to interactive system design and stress management. We then proceed to describe a detailed psychological framework for the concept of *immersion* which was instrumental in our design process for *Sonic Cradle*. Finally, we present the interactive system itself and a series of co-design sessions which helped iteratively improve its interface.

THEORETICAL UNDERPINNINGS

Interactively Mediating Mindfulness

In order to design an interactive system to promote meditation, we must recognize the existence of diverse forms of this practice. In surveying common themes of a wide range of meditative practices, Lutz et. al. [26] created a paradigmatic framework which depicts the core of this family of practice as a balance between *"one-pointed concentration on a specific object"* and insight into one's own *"habits and assumptions about identity and emotions"*. The authors proceed to discuss a growing contemporary movement known as *Vipassana* as *"especially emblematic"* of this balance because it represents a *"simplified and regularized set of meditation instructions available to a wide population"*. This practice has also been a focus in medical and psychological literature under the name of *mindfulness meditation*. The key element of mindfulness is the cultivation of a focused attention; whenever attention wanders, one is to gently guide attention back to some focus point without being discouraged or punitive towards the self. The focus is commonly interoceptive: directed at breathing or other internal, bodily sensations.

Ongoing research depicts mindfulness as a promising non-pharmacological tool to improve the psychological state of those suffering from chronic clinical problems, including anxiety (**figure 1**), chronic pain, panic disorders, and depression [reviews: 1, 3, 14, 23]. One of the most ubiquitous elements of this research is the mention of direct effects on stress: a major factor in all the aforementioned conditions. Stress is known to trigger a complex cascade between the hypothalamus, pituitary gland and adrenal gland (the HPA axis), which can affect gene expression, generating severe negative effects on the human brain at all stages of life, from prenatal babies to the elderly [27]. The neurally distinct experiential focus promoted by mindfulness practice [13] seems to have an inhibitory effect on the stress response. In fact so much so that Jon Kabat-Zinn, the major proponent of mindfulness meditation in therapy, sees this effect as central enough to refer to it directly in the title of his treatment intervention: *Mindfulness-Based Stress Reduction* or *MBSR* [23]. This intervention and its ongoing validation suggest that interactive systems which can help generate, encourage, motivate or teach the practice of mindfulness meditation are promising directions for stress management technology.

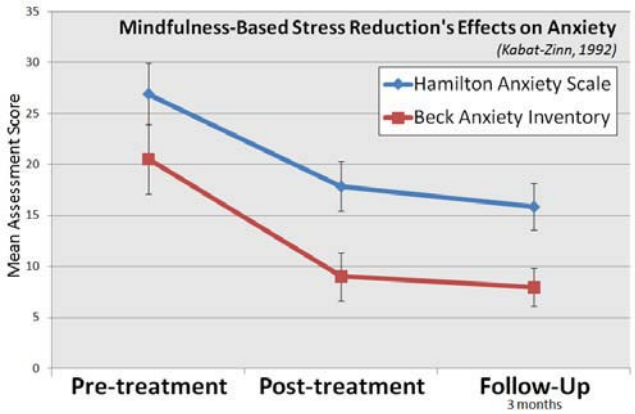

Figure 1. A simplified re-plot of data from Kabat-Zinn's 1992 study of *Mindfulness-Based Stress Reduction* created to clearly portray its persistent effects on anxiety; an addendum states that effects persisted in a 3-year follow-up as well [22].

An instrumental element of Kabat-Zinn's approach to optimizing the delivery of therapeutic mindfulness is its attempt to somehow translate the eastern practice for a western audience: *"the intervention needed to be free of the cultural, religious, and ideological factors associated with the Buddhist origins of mindfulness"* [23]. In the present work, we aim to build upon this approach by designing an interactive system focused on promoting a meditative experience which not only minimizes spiritual dogma as MBSR does, but also minimizes meditation's learning curve by reinforcing the attention patterns of mindfulness practice through interaction design. This system – *Sonic Cradle* – aims to afford the basic characteristics of mindfulness with the goal of providing non-meditators with intimate knowledge of the experience and benefits of meditation. Not only does technology have the potential to reduce the need for an expert trainer, but more importantly, an interactive approach may be able to guide one toward critical experiential knowledge of mindfulness without complex instruction or initial feelings of failure.

Mindfulness and Stress Management

In managing stress, overarching organizational principles of our skeletal muscle system, autonomic nervous system, and neuroendocrine system suggest *"the individual's reaction to stress … as consisting of two major phases: an active coping phase and a rest phase"* [43]. While meditation can certainly benefit everyone, it is of particular interest to chronic disease sufferers who tend to have a hard time

transitioning from the active coping mode to a relaxed state. In the case of anxiety and panic disorder, the inability to make this transition is a defining characteristic of the condition itself. Other conditions like chronic pain and depression generate perpetual stressors which consistently interrupt transitions to the rest phase. Mindfulness seems to support exactly such transitions by *"bridging the gap between rest and coping"* [43].

Contrary to popular assumptions about meditation, the goal of mindfulness is not simply to relax; the practice essentially aims to catalyze state change by applying the behavioural tendencies of the overdriven coping mode (focused attention, mental effort, etc.) directly to properties of the relaxed mode (tranquility, an absence of striving, etc.). In other words, mindfulness involves using the subtle tranquility of internal sensations as the focus of active coping mechanisms. When stressful distractions inevitably disrupt the process of establishing an active tranquility, a knowledgeable practitioner knows to calmly regain an internal focus, and the cycle repeats. We aim to design an interaction paradigm which generates this same cycle of attention between a focused internal attention, an external awareness, inevitable distractions and a calm return to internal focus (without a feeling of failure). A positive outcome of such a system would be consistent transitions from active, coping phases to more passive, restful mental states in diverse non-meditators without extensive time spent on instruction, preparation, training or usage.

We are not blind to the apparent redundancy of introducing a new technology to combat stress: a phenomenon often associated with technology itself. However, note that the majority of technologies in the past century have been created with goals of productivity, efficiency, and organization. We feel it is not necessarily some fundamental property of computer technology which acts as a stressor; systems designed with different goals, such as relaxation, focus, awareness, a sense of calm, and self-exploration, may have completely different effects on the human mind. Further, as concluded by Sanches et. al. after exploring *Affective Health* [36], psychologically-relevant systems do not necessarily require continued use to have a lasting effect if they lead to interpretive self-reflection. Technology can serve as a trigger for behaviour change in the long-term [15]. If our interactive system were truly able to generate an experience of mindfulness, participants would not only see proximal stress reduction, but potentially a demystification of meditation which may encourage them to establish their own self-regulatory practice afterward. In some ways, such a system could be described as an educational tool for mindfulness. Before validating such bold claims, we must first establish how to go about designing a meditative human-computer interface.

RESEARCH THROUGH DESIGN

In pursuing this work, the fruits of our investigation led us beyond simply designing and validating a system. Our approach can be considered *research through design* for two reasons: first, it produced a design artifact which explores *"what a potential future might be"*, and second, it *"[led] to theory development even though [that] might not have been the original intention"* [46]. The interactive artifact produced – *Sonic Cradle* – stands as an ongoing investigation into a *"potential future"* for mediated stress management. Conceptualizing *Sonic Cradle* also led to *"theory development"*, motivating the pursuit of a psychological understanding of *immersion* which applies to any medium: book, video game, virtual reality, art, and unconventional interactive systems. This is a case of design process leading to theoretical implications beyond the proximal artifact (the essence of *research through design)*. Before we discuss *Sonic Cradle* itself in the next section, we will first outline its theoretical origin: a framework for the psychological nature of media immersion.

Immersion into Subtle Sensations

A trained practitioner engaging in mindfulness meditation has learned to engage an extreme level of focus and attention inward. Without extensive training, non-meditators will be easily distracted when trying to interoceptively engage themselves to any comparable degree. Here we find the major design challenge of an interactive system which promotes an experience of mindfulness: generating complete engagement without simultaneously providing new sources of distraction. This challenge drew us to explore the concept of *immersion*: a term which seems to capture the media-driven, focused, enveloped state we hope to instill in our participants. We came across a series of theorists characterizing this term in different ways depending on the medium and field of study [6, 12, 32, 34, 35, 42]. This was a major difficulty in our attempt to theoretically ground our design process.

Video games, virtual reality, and literature certainly promote immersion into compelling subjective worlds; however, trying to use such media to support the subtle, internal focus characteristic of mindfulness is problematic. Bright screens, 3D environments and narrative story-worlds may capture intense attention and focus away from physical reality, but they shift one's perceptual context toward a multi-faceted virtual reality which continues to inspire a continuously shifting focus. This contrasts with our aim to engage such a process of media immersion toward a one-pointed, internal sensation. By synthesizing diverse theories of immersion into a framework, we were able to conceptualize a non-traditional system designed to promote immersive engagement with an endogenous meditative experience without using distractive virtual environments, contemplative story-worlds, or invasive technologies.

A Psychological Framework of Immersion

Diverse media-focused theories of immersion seem to share a concern for balancing *top-down* and *bottom-up* factors. Top-down processing refers to cognitive influence on one's

perceptual world from high-level declarative knowledge, while bottom-up processing refers to information in the outside environment being sensed and processed more directly [7]. For instance, consider the optical illusion in **figure 2**: there appears to be a finite arrangement of ink on the page stimulating our visual sense (bottom-up), yet our cognition can also influence how the illustration is perceived (top-down). The concept of immersion into various media is often discussed with a similar dichotomy. Research in the context of video games separates a "sensory" form of immersion from an "imaginative" form [12]. Mel Slater, a leading virtual reality theorist, uses the term immersion as a descriptor of inanimate technological systems; he also makes a distinction between sensory and cognitive elements of engagement with virtual reality through his nuanced discussion of *presence* [42]. Lombard & Ditton [25] again present this same dichotomy between a "perceptual" and a "psychological" component. In literature, immersion is described as the mind's active reduction of subjective distance to non-actual worlds depicted in the physical world as text [33, 35].

It seems that, whether engaging with fictional worlds in text or on screen, *"we do not merely suspend a critical faculty; we also exercise a creative faculty ... because of our desire to experience immersion, we focus our attention on the enveloping world and we use our intelligence to reinforce rather than to question the reality of the experience"* [31]. However, the aforementioned attempts to divide top-down and bottom-up forms of immersion seem misguided in light of research on consciousness which suggests all perception as the cognitive binding of multimodal stimuli into the experience of a coherent, subjective world [11]. A VR system may provide sensory saturation relative to a compelling novel, but both immersive experiences result from a combination of bottom-up and top-down processes in different proportion.

Are psychological forms of immersion actually different from perceptual forms? Assuming human engagement with diverse media varies mostly in the proportion of bottom-up and top-down factors involved, perhaps all media share a fundamental process of engagement. Could immersion into media which rely predominately on bottom-up factors (i.e. video games, VR) engage the same psychological process as those which rely more on top-down factors (i.e. books)? Contemporary research in perceptual psychology and cognitive neuroscience implies just such a dimensional quality. Mirror neurons [16], optical illusions [19], neuroplasticity [38], inattentional blindness [41], and the psychology of fiction [33] suggest that the human mind is not only capable, but constantly in an active state of applying prior knowledge to construct a cohesive perception of our sensed reality. Systematically tying the presented literature together, we established a framework implying that immersion should be defined as this process of cognitively integrating relatively crude stimuli into cohesive subjective realities (**figure 3**). The same process

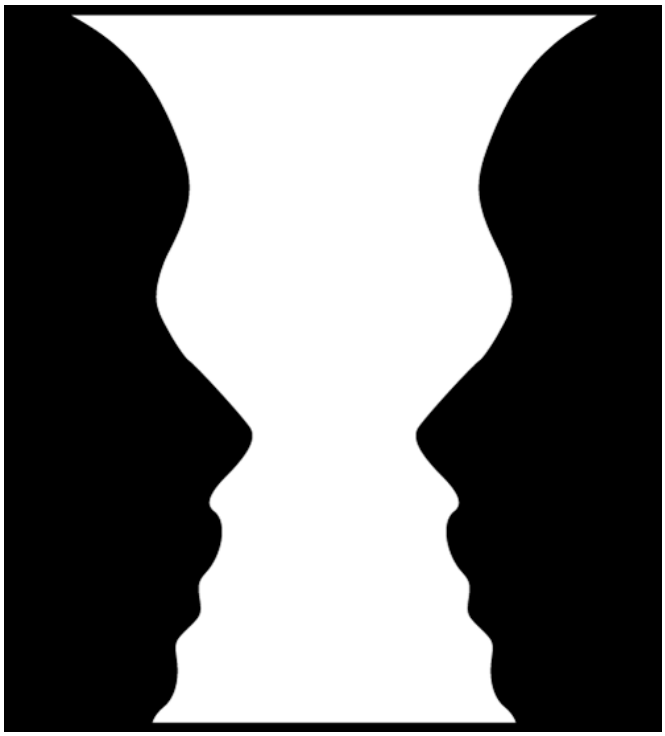

Figure 2. The "Rubin's Vase" Illusion. One can cognitively influence perception of this sensory stimulus to interpret it as either two dark facial silhouettes or a white vase.

which generates our cohesive experience of day-to-day reality seems to be hijacked and exploited by certain media which we consider *immersive*, using the physical metaphor of a liquid within which we can be submerged. Certain affordances somehow inspire our minds to meet them halfway, actively creating the experience of a second, mediated world using our prior knowledge. An account of this framework was discussed in detail in a panel session at the *Society of Literature, Science and Art* and a final iteration is forthcoming. This theoretical output defines the Sonic Cradle project as *research through design* [46].

According to our framework for immersion, creating a system which occludes sensory access to physical reality should maximize the proportion of sensory input occupied by even the most subtle of media, encouraging disengagement with the physical world. While traditional media use this approach to lubricate immersion into mediated, external worlds (i.e. watching movies in the dark), this disengagement with the physical world should help maximize interoceptive engagement as well (explaining why it helps to close one's eyes during meditation). Using this framework for design inspiration, we hypothesize that a creative interaction paradigm will prime users to cognitively construct the experience of a mediated world by placing them in a naturally authorial role, encouraging them to shape their own experience. The next section describes *Sonic Cradle*: a system which occludes the visual world, removes interoceptive sources of

distraction, and encourages a subtle creativity based on a one-pointed internal sensation: respiration. The system is designed to consistently foster meditative experiences.

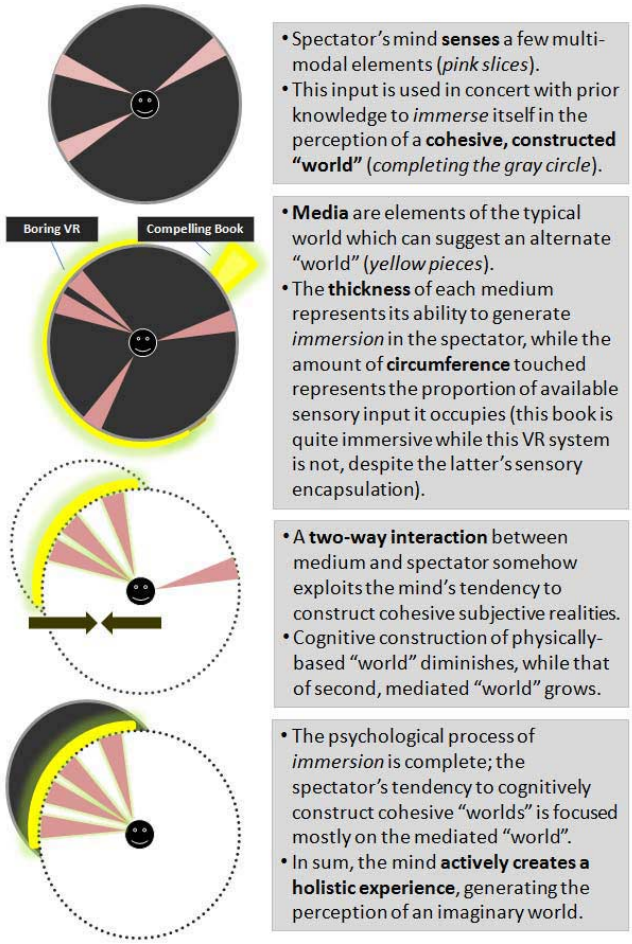

Figure 3. A visual explanation of the framework of *immersion* which conceptually underlies *Sonic Cradle*. "Spectator" = users, audiences, readers, etc. "World" = cohesive, subjective reality.

DESIGN CONCEPT: *SONIC CRADLE*

Integrating the presented research on mindfulness, stress management and immersion, we developed an initial design concept aimed at mimicking meditation in order to promote psychological self-regulation. *Sonic Cradle* provides a non-traditional, non-visual immersive experience where a participant is suspended in darkness, controlling sound through the exploration of their own respiration. The system suspends one's body in a dark chamber where two respiratory biofeedback sensors (*Thought Technology*'s *SA9311M* which measures respiration through chest expansion) connect to a 4.1 speaker system through custom software written in *Max/MSP*. Instead of passively listening to specific sounds touted as having healing properties, *Sonic Cradle* aims to foster a creative experience. It is not some specific property of the sound itself that is to help ease stress, but instead the patterns of attention stimulated by immersion into the system's creative interaction paradigm. We chose to use the aural modality because of sound's natural potential to envelop the listener without demanding clear, directed attentional focus.

In general, participants interact with the system by exploring different breathing patterns which actively shape a soundscape. Participants hold their breath to summon a new sound, and then shape that sound in real-time by breathing in different ways. Attributes of participants' respiration (rate, depth, thoracic/abdominal ratio) control audio parameters of that recently-added sound (respectively: reverberation effects, equalization filters, volume). If participants hold their breath a second time, the first sound continues to play with its attributes locked, and another sound is added to the environment and shaped in the same way. When ready to move on, participants can lock the second sound and summon a third sound to the mix in the same way, and the process continues. Essentially, participants use their breath to progressively shape and mix pre-recorded sounds together in unique ways. Based on our framework of immersion, we expect this subtly creative interaction paradigm to bolster the mind's natural attempts to holistically experience the system as a cohesive subjective reality, maximizing their focus and attention as they actively construct an experience for themselves.

Sonic Cradle enables participants to construct a sound environment through respiratory biofeedback. Not only has biofeedback been generally successful in therapeutic contexts [17, 18], but connecting respiration and sound/music to generate relaxation and positive health effects has shown its potential in studies which use simpler implementations [37, 45]. Further, previous evidence suggests that sensory deprivation can be independently therapeutic [40]. *Sonic Cradle*'s complete lack of visual input prevents visual distractions from stealing attention away from the breath-based interaction paradigm. Not only does darkness and isolation prevent external distractions, but suspension in a comfortable hammock greatly reduces the potential for interoceptive distractions (orientation, discomfort, pain, etc). In this regard, *Sonic Cradle* is theoretically similar to sensory deprivation tanks which shut out all light and suspend participants in saltwater (see studies on *Flotation REST* [24]). These elements of *Sonic Cradle* were inspired by our psychological framework's prediction that the occlusion of sensory access to physical reality will lubricate immersion. The relationship between individual elements of *Sonic Cradle* and mechanisms underlying mindfulness meditation remains unclear, but the potential certainly exists for an informed combination of sensory deprivation, biofeedback, respiratory interactivity, and sound to generate positive psychological effects. A less obvious question is whether this interactive system will lead to subjective reports which align with the practice of mindfulness meditation.

More cohesive design concepts related directly to *Sonic Cradle* also exist. Shaw et. al.'s *Meditation Chamber* [39] is similar in its high-level objectives and combination of biofeedback and interactivity, but it differs in its use of galvanic skin response as its main bio-sensor, precluding the attentional draw of a more direct control paradigm. *Sonic Cradle* holds much more similarity to an art installation created by Char Davies called *Osmose* [8]. As a multi-layered experience involving suggestive virtual environments and complex soundscapes, *Osmose* allows users to freely explore abstract worlds using their breathing and physical balance. This installation not only shares *Sonic Cradle*'s breath-based interactivity, but it also implicitly relies on the user to piece together a cohesive experience based on abstract sensory input. Further, participant responses to *Osmose* seem to align with *Sonic Cradle*'s meditative goals: *"The experience of seeing and floating through things, along with the work's reliance on breath and balance as well as on solitary immersion, causes many participants to relinquish desire for active 'doing' in favor of contemplative 'being'"* [9]. *Sonic Cradle* builds upon this previous work with a rigorous, systematic design approach based on the psychological sciences in pursuit of a clearer goal: an immersive, subjective experience of mindfulness.

In essence, *Sonic Cradle* participants can either focus on exploring the respiratory control paradigm or be in a state of internal distraction. Even when distracted, participants have no choice but to breathe and influence their sound environment; their only choice is whether to do so intentionally or not. This is because healthy human respiration proceeds autonomously and automatically unless we re-orient our attention and assume control. As they explore the system, participants will achieve a calm focus on their breathing and a general awareness of their sound environment. Just as in mindfulness practice, participants will eventually be distracted by other thoughts. When in a distracted state, the sound environment continues to respond to the participant's autonomous breathing. Changes in the sound environment will trigger a curious re-orientation of attention toward breathing. Astute readers will notice a critical difference from typical meditative instruction: as participants are not initially instructed to willfully focus or orient their attention in any way, they will loop through this process without any expectations, negativity or punitive thoughts. Whereas typical attempts to learn meditation inevitably lead to a feeling of failure upon realization that one has been distracted, distractions hold no negative valence in *Sonic Cradle* as participants are not instructed to focus. This enables the calm refocusing of attention characteristic of experienced mindfulness practitioners to proceed unencumbered as a natural response to the interaction paradigm.

CO-DESIGN SESSIONS

Balancing Perceived Control

In order to tweak and refine *Sonic Cradle*'s interaction paradigm, we engaged in 15 co-design sessions [10] with naïve participants. The participants were simply recruited as they passed by our lab facilities. As our institution is focused on human-computer interaction research and interactive art, the sessions included not only laypeople, but also graduate students, post-doctoral students and faculty who share a deep interest in technology and design. It is moot that this population does not represent a purposive sample of our target demographic or a random sample of an experimental population, as these informal co-design sessions were used to discuss the system openly, gathering ideas and inspiration for reflective design of the human-computer interface (a more controlled and contextually interesting investigation of a purposive sample has now been conducted and will be published in the upcoming year). After 20 minutes in *Sonic Cradle* (**figure 4**), participants were asked to express their subjective experience freely. Follow-up questions probed temporal elements of the system, ratios of focus/distraction, ratios of relaxation/excitement, interpretations of the system, feelings of control, and general user experience. These sessions led us to make several changes which all surrounded what we now understand to be a critical dimension for the interaction design of meditative technologies: participants' perceived sense of control.

Much of the discussion in these co-design sessions surrounded the topic of perceived control. The first few participants reported a decreased sense of control when using the system after several sounds had been summoned; they felt like their respiration was no longer having strong effects on the sound (i.e. "*After the third sound, I felt I had absolutely no control.*", "*I wish I could isolate the sound a bit more and control it.*"). While adding a first, second or even third sound led to a profound change which captured participants' attention, adding sounds beyond three seemed to have progressively less effect as the soundscape became much more crowded. This was critical, not only because the experience became less engaging over time, but also because stress is often associated with a perceived loss of control [43]. However, there were also comments suggesting that the lack of obvious, explicit controls helped participants focus in what seemed to be a meditative way (i.e. "*the sounds are ambiguous enough that there's no direct correlation, which helped you lose the desire to control it so much, stopping your thought.*", "*It wasn't as dramatic as I had expected, I expected to really be able to tell when new sounds came in but it was more subtle, I had to listen*"). After a few sessions, it became clear that systems focused on generating heightened focus on a subtle stimulus need to deliver a consistent sense of control to maximize engagement, without rendering participants' perception of the mechanism too obvious. A certain level of ambiguity seems to help motivate prolonged engagement

through a feeling of discovery, perhaps even engaging the process of immersion by increasing the requirement to actively construct one's own experience. Throughout the ensuing sessions, iterative design exploration eventually led to the following improvements to the system which all relate to optimizing participants' perceived sense of control:

Figure 4. A participant suspended in the *Sonic Cradle*. A light is turned on and the image is artificially brightened; normally the participant would be in complete darkness. Watch a video demonstration which better explains the system and includes some participant comments at **http://www.jayvidyarthi.com/cradle** .

Spatializing Sounds

In order to help achieve a consistent sense of control no matter how many sounds are playing, we added a spatial dimension to the system: instead of playing all sounds from all speakers, the idea involved having new sounds come from new directions. Even if a few sounds were already mixing in a participant's environment, a new sound will be easier to notice and focus on individually if it comes from a new spatial direction. Further, when several sounds are playing together, they will not all come from the same speakers, adding clarity and distinction to the sound quality.

Crowd-sourcing Sounds

We felt the quality of the individual sounds we used in the first *Sonic Cradle* prototype also contributed to participants' decreasing sense of control. As we created all the sounds for our initial prototype ourselves, they were very similar in rhythm, pitch and timbre: once participants summoned several sounds, they all seemed to blend together, making new sounds less noticeable. In response to this, we implemented a website which presented the basic concept of the system and enabled the crowd-sourcing of audio samples. The website included a form which allowed contributors to directly upload their own interpretations of peaceful sound. As of this writing, we have collected over 30 sounds from a range of musicians and sound artists of different styles which ensure that stimuli remain diverse. Participants are now able to progressively summon and shape field recordings, acoustic instruments, digital sound generators, abstract mash-ups, spoken word poetry and more.

Enabling Sound Elimination

Most of the negative comments which were made during the co-design sessions were related to specific sounds. This should come as no surprise, as people typically hold quite diverse tastes in music (i.e. "*the very first sound, which was like a percussion instrument where you have break in between and harsh-onsets, kind of counteracted my attempts to relax*"). While there did not appear to be a pattern as to which specific sounds were annoying, we solved this problem by implementing a control parameter which enables participants to work backwards, progressively removing sounds from their environment through a series of short, rapid breaths. This not only gives participants the option to eliminate unpleasant sounds, but also enables them to manage their own perceived control in a way: they can simplify their sound environment if they feel lost and overcrowded.

Adding Feedback for Summoning Sounds

As another intervention to help foster a consistent sense of control, we implemented an audio feedback mechanism. As mentioned in the previous section, the system requires participants to hold their breath for a prolonged period of time in order to summon new sounds. However, our first co-design sessions revealed that participants were often not able to remain perfectly still when holding their breath. In other words, a participant may think they are holding their breath and expect to summon a new sound, but their respiratory data reveals fluctuations and subtle exhalations taking place. Since the participant is not aware of these fluctuations, the system simply seems unresponsive. We managed to correct this problem by adding feedback: when respiration is held completely still, a low rumble begins to sound, increasing in volume until the threshold for adding a new sound has been reached. When the rumble abruptly stops due to fluctuating breath, participants seemed aware that something had gone wrong in their attempt to summon a sound. A quiet meditative chime was also added to signify the exact moment when a new sound has been successfully summoned to the soundscape. The chime serves to provide feedback and also to prime a participant's attention, as it preempts the newly added sound from a new spatial direction.

Tweaking Participant Instructions

Since *Sonic Cradle* employs a novel interaction paradigm which will be unfamiliar to participants, the way it is introduced will have a large effect on their perception and experience. Throughout our co-design sessions, we iteratively experimented with various verbal introductions to the system. We took the opportunity to explore what level of specific instruction would optimize the experience toward the goal of the project. Participants were briefed

with varying levels of detail, spanning the range from no instruction at all to a complete explanation of the interaction paradigm. As might be expected, a lack of instruction led to confusion and even clear expression of a desire for more explicit instructions (i.e. "*when you attach sensors, that's telling me there is an interaction happening to some extent, and that there is some level of control ... [that] could have been something that was brought more to the forefront initially*").

When instructions were too specific, participants tended to think very semantically about the experience, and in some cases it even generated a goal orientation in usage of the system (i.e. "*I was trying to win ... I was trying to quickly initiate the sounds so I could see what it was like ... instead of trying to enjoy what was happening*", "*I would imagine you'd want to say less; explain the basic mechanism and that's it*"). The compromise turned out to be a few vague instructions surrounding the summoning and elimination of sounds. In the current protocol, participants are simply instructed that they can stop breathing to explore new sounds, and to breathe quickly when they feel lost and want to simplify their sound environment; the specifics of the interactive control paradigm are not divulged, again, to balance a vague sense of control with variations so subtle that attempts to logically decipher them quickly seem futile.

Informal Concept Validation

In the previous section we discussed the main improvements and tweaks which resulted from our 15 informal co-design sessions. Throughout these sessions there were also a lot of comments which, unbeknownst to our participants, aligned directly with our theoretical directions. As this was not a scientifically sound participant sample, we urge the reader not to over-interpret these trends as concrete findings until we report on our formal study with a purposive sample. In the meantime, we thought it appropriate to dedicate a short, final section of this paper to discuss a few promising trends which seem to connect *Sonic Cradle* directly to its theoretical underpinnings:

11 out of 15 co-design participants described the experience as 'relaxing' (i.e. "*I'm giving you lots of minutiae feedback, but the whole thing was overwhelmingly calming and relaxing*", "*It was pretty cool, I'd like to have one in my home, just to relax*").

When asked about the temporal aspect of their experience, 9 out of 15 participants clearly alluded to a single point of transition from an active, thinking mode to a more restful alertness: (i.e. "*At first I was playing around with the controls ... but then after a while I just kind of realized that I had stopped doing that and was just breathing... in a way that I don't normally breathe*", "*At first ... I was thinking about it pretty hard and experimenting with it a lot, by the end I realized the best way to go through it was to not think about it so hard and just listen ... I kind of turned my brain off*"). It is important to note that many participants worked in technology and therefore may have been more likely to start by toying with the control paradigm.

10 out of 15 participants alluded to some perceptual experience akin to actively constructing an alternate world which aligns with our framework of immersion. Subtle stimuli and a creative interaction paradigm seemed to inspire visualizations, disengagement with the physical world, and more (i.e. "*I was visualizing the ocean, the waves at dusk… it's a water-like experience … not from any specific sound, but the experience and low rumbles felt like a deep body of water*", "W*hen I was starting to get really into it, I stopped noticing the speakers and ... it just became sort of this reality that there was nothing beyond my breath and this noise... and eventually I wasn't even thinking about my breath anymore ... and that was where I got that floating in sound immersion feeling when I felt like I was pretty much one with the noise that I was making, I felt like it was all one thing*").

Although most participants understood that the system had something to do with meditation in advance, it is interesting to note that 5 participants directly articulated why they thought the experience was meditative (i.e. "*It's an exploration using your breath, but you also start to explore the way your mind reacts to these things, and that's pretty meditative*", "*I've tried meditation briefly, but that felt like the ... best attempt ... there was this moment where I thought 'that's what meditation is all about' ... this 10 or 20 second window where my entire body was just numb and I thought 'whoa, what's happening here?'*"

8 participants were asked what percentage of the time they felt they were entirely focused on the sound and their own breathing (as opposed to distracted in thought), and the average of participants' estimates was approximately 78% which translates to an average of 15 minutes and 36 seconds out of each 20 minute session.

CONCLUSION AND NEXT STEPS

After synthesizing relevant research surrounding mindfulness meditation, stress management and media *immersion*, we conceptualized a novel interactive medium designed to promote meditative experiences: *Sonic Cradle*. The process can be considered *research through design*, as it resulted not only in an exemplary design artifact which explores a new approach to mediated stress management, but also in a psychological framework for immersion which is relevant and applicable beyond the design and analysis of *Sonic Cradle*. After prototyping the system, it was iteratively improved with 15 participants in co-design sessions which led us to conclude that the level of perceived control is a critical dimension for systems which aim to generate meditative experiences. Further, these sessions informally validated our concept and *research through design* approach, setting the stage for a formal study to confirm findings and articulate directions forward. This next step will involve analyzing qualitative data for

evidence of an immersive, meditative experience while simultaneously measuring non-invasive physiological indicators for significant decreases of arousal.

Positive results in the next step could lead to targeted experimentation exploring the mechanisms behind the effects of *Sonic Cradle* and the artful pairing of sound with breath. A more detailed exploration of different sound dimensions on participant experience would certainly be of interest to optimize the system's effectiveness (i.e. real-world vs. synthesized, harmonic vs. dissonant, etc.). It would also be productive to compare specific elements of the interaction paradigm with each other; effects could be compared with control conditions involving non-interactive music in the darkened chamber or interactive music in a well-lit room. If such studies yield clearer hypothesized mechanisms for technologically-mediated meditative experiences, our design concept could be optimized not only for new, more effective, versions of *Sonic Cradle*, but these mechanisms could be exploited for new interactive system designs aimed at psychological benefit. Prototypes of such devices could be subjected to rigorous mixed methods studies over a longer term to determine whether the technological induction of meditative experience can have widespread positive impact in our lives outside the laboratory.

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