Mediated Meditation: Cultivating Mindfulness with *Sonic Cradle*

Jay Vidyarthi
Simon Fraser University
Vancouver, Canada
kvidyart@sfu.ca

Bernhard E. Riecke
Simon Fraser University
Vancouver, Canada
ber1@sfu.ca

Abstract
Sonic Cradle enables users to shape sound using their breathing while suspended in a completely dark chamber. The system attempts to provide an initial experience of mindfulness meditation. To validate this subjective design goal, we conducted a qualitative investigation with 39 purposefully-selected participants. Systematic analysis using 3 independent data coders produced 11 specific findings which richly describe the *Sonic Cradle* experience. Several findings clearly compare to mindfulness meditation (e.g. clarity of mind, loss of intention). This paper introduces evidence suggesting that interactive 'training wheels' could have a positive impact on long-term psychological health by experientially introducing established self-regulatory practices to non-practitioners.

Author Keywords
Biofeedback, mindfulness, meditation, sound, music, stress, deprivation, persuasion, qualitative, purposive.

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interfaces: user-centered design, auditory feedback, evaluation/methodology.

General Terms
Human Factors; Design; Measurement; Experimentation.

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Introduction
Most of us no longer confront threatening circumstances on the regular basis for which our stress response has evolved. While stress – a "cognitive perception of uncontrollability and/or unpredictability that is expressed in a physiological and behavioural response" [17] – can be positive or negative, too much stress has a negative impact on the immune system [10], brain [18], and behaviour (i.e. loss of sleep, unhealthy eating, drug use, etc.) [21]. Proponents of self-regulation in healthcare would agree that

encouraging people to learn how to curb unnecessary stress is essential for a healthy body and mind [2].

Human-computer interfaces can help self-regulate exercise, nutrition, and more [5, 11]. However, there are fewer systems specifically designed to provide psychological support for problems like stress. Such technologies would be critical to help those suffering from mental disorders (prevalence is 30% in USA, with other countries not far behind [3, 15]), and also help regulate the psychology of non-clinical populations.

Biofeedback can be therapeutic [9], but inadequate mobile biofeedback sensing limits stress management technology to short-term-use systems for physiological self-evaluation and reflection [24]. However, persuasive technologies can have a lasting effect by triggering long-term changes in behaviour and routine [7]. To this end, we designed a musical biofeedback chamber called *Sonic Cradle* to experientially introduce mindfulness meditation to non-practitioners [29]. This paper presents a qualitative study of subjective experiences in this system: a prerequisite for future work in this new and ambitious application area.

Mindfulness, Stress and Technology

Mindfulness meditation has been described as an intentional and non-judgmental experience of the present [1, 13]. The practice revolves around the cultivation of focused attention on breathing or other internal, bodily sensations [19]. When one's mind inevitably wanders, attention is gently and pleasantly guided back to the initial focus point. In the words of Jon Kabat-Zinn (a proponent of the practice in the medical field) "mindfulness can be thought of as moment-to-moment, non-judgmental awareness, cultivated by paying attention in a specific way, that is, in the present moment, and as non-reactively, as non-judgmentally, and as openheartedly as possible" [13]. Jon Kabat-Zinn refers directly to stress in the title of his clinical intervention rooted in meditation: Mindfulness-Based Stress Reduction or MBSR [12]. Ongoing research depicts MBSR as a promising non-pharmacological tool to inhibit stress and improve the psychological state of those suffering from chronic clinical problems including anxiety, chronic pain, panic disorders, and depression [1, 4, 6, 12]. An interactive system which demystifies and introduces non-practitioners to mindfulness meditation could help broader audiences experience its vital benefits.

Sonic Cradle is a "calming technology" [23] which aims to catalyze transitions to a restful clarity. While existing therapeutic technologies distract users [20, 30] or provide feedback on internal processes [23, 25, 26, 31], *Sonic Cradle* aims to introduce non-practitioners to an intimate and effortless experience of mindfulness meditation. This would contrast with the difficulties encountered by new students (e.g. unintentional distractions, mindless boredom, and feelings of failure [13]). The training wheels of a children's bicycle serve as an apt metaphor for our approach; if an interactive medium were to help non-practitioners experience mindfulness meditation for the first time, might it also have the potential to persuade them to independently learn and benefit from this self-regulatory practice?

What is *Sonic Cradle*?

Sonic Cradle comfortably suspends users in complete darkness, enabling them to shape a peaceful soundscape using only their breathing (**figure 1**). The system was designed to covertly mimic mindfulness

meditation, cycling attention between awareness of breath, mental distractions, and a calm return to focus.

A previous paper includes: theoretical situation of the *Sonic Cradle* concept; related work; a cross-disciplinary framework for media *immersion* which underlies *Sonic Cradle*'s physical manifestation (bodily suspension, darkness, etc); detailed explanation of the *Sonic Cradle* paradigm and how it fosters mindful attention patterns; and documentation of several iterations to the system based on 15 co-design sessions [29].

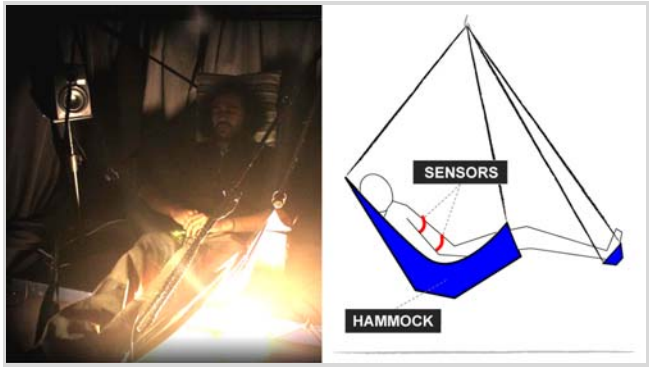

Figure 1. *Sonic Cradle* photograph (lit for clarity) and diagram. User is surrounded by a 4.1 speaker system.

The prototype involves a hammock-chair from *Island Chairs* suspended in a completely dark and quiet room. Four *Mackie MR5mk2* speakers surround the chair and a large subwoofer is installed below it. Two breathing sensors are attached to participants' abdomen and thorax to measure chest expansion (*Thought Technology*'s *SA9311M* and *ProComp2* encoder: 32 Hz). *Sonic Cradle*'s software (implemented in *Max/MSP*) manipulates sound using breathing data collected in real-time. Essentially, *Sonic Cradle* users experience a heightened and compelling breath awareness which enables them to add, remove, and shape (reverberation effects, notch equalization between 50Hz and 1950Hz, and volume) crowd-sourced sounds which come from different spatial directions. Audio recordings are available at *soniccradle.bandcamp.com*.

Methods and Research Goals

Acute stress effects could be measured in *Sonic Cradle* using questionnaires and physiological measures. However, *Sonic Cradle* was not designed to provide short-term stress relief; the paradigm aims to provide an experience of mindfulness meditation to enourage long-term psychological health promotion. Evidence of acute stress reduction would not necessarily suggest that *Sonic Cradle* is achieving that goal.

A more valid investigation would explore how subjective experiences in the system influence users' attitudes towards meditation longitudinally. However, this would require commitment from diverse specialists and funding for meticulous control conditions on a timescale of years. Justifying such intensive longitudinal research on our prototype would be difficult without a preliminary investigation in the short-term.

The present study aims to motivate and guide future research by first answering the following question: **can users' experiences in a carefully designed human-computer interaction paradigm be subjectively similar to the intimate, contemplative practice of mindfulness meditation?** As this research question targets subjective experience, we used a non-traditional approach for human-computer interaction: a basic interpretive qualitative methodology [22]. While psychological questionnaires might also be feasible,

Interview Questions:

1. How did you find the experience?
2. How would you describe your thoughts and behaviour throughout the experience?
3. If we divide the experience into a beginning, middle and end, how would you say your thoughts and experiences changed over time?
4. If you went halfway around the world and were hanging out with someone who has never heard of this thing, and probably will never get to try it, how would you describe the experience to them in your own words?
5. What percentage of time would you say your attention was focused on distractive, completely unrelated, everyday thoughts?
6. Would you compare this experience to any other experiences you've had?
7. Can you describe any prior experiences you've had related to meditation?
8. Is there anything else you personally experienced in here that you want to share before we end the interview?

they tend to be suggestive, asking participants to agree or disagree with leading statements (e.g. [8]).

The rest of this paper summarizes a systematic, inductive analysis of interview data involving strict, numeric criteria and multiple independent coders to maximize validity. The goal is to open a new field of research on persuasive catalysts for psychological self-regulation and interactive teaching tools for meditation.

Purposive Participant Sampling in HCI

Qualitative research is typically most effective with a *purposive* participant sample [22]. While random samples are externally valid, *purposive* sampling specifically selects participants likely to provide articulate, valid and useful insight. The present work introduces how *purposive* sampling can be used in human-computer interaction: participants uniquely suited to respond to a forward-thinking artifact can guide innovation and justify involved methodologies by providing an early glimpse into future possibilities.

We recruited at *TEDActive 2012*, an exclusive and expensive conference which clearly does not represent those in serious need (e.g. clinical populations). However, the conference proved to be a good source for people likely to engage with *Sonic Cradle* for two reasons. First, the conference's progressive focus suggested participants would be optimistic and primed for novelty. Second, an essay-based screening process ensured attendees would be proactive leaders in their communities (likely with busy schedules). We purposefully recruited participants who might value *Sonic Cradle* enough to provide deep insight; the depth of our findings confirm that this strategy was successful. Unlike quantitative studies, this type of research does not try to make generalizable claims about external populations. Findings simply reveal that – at least in one population – the ambitious goal of mediating mindfulness meditation is actually possible.

Sessions took place with 24 males and 15 females. We removed 5 participants due to evident biases (alcohol, prior knowledge, system malfunction). Participants were classified into two groups based on whether they claimed to have previously had informal experiences related to meditation (e.g. yoga, individual sessions; n=20) or no relevant experiences (n=14).

Procedure

Individual Sessions at the Conference

Participants were fitted with sensors, seated in the hammock, and briefed. The briefing included a vague description of the control paradigm: "…if you want to add more sound to your environment and increase its complexity, you simply have to stop breathing … if you feel like you've lost control of the system or are overwhelmed, you can simplify your sound environment by breathing as quickly as possible." Participants were then left alone for 15 minutes before being subjected to a semi-structured interview (see sidebar for questions).

Qualitative Data Analysis

Interview transcripts were broken down into granular bullet points and clustered into meaningful codes. To address our own biases, two external data coders were hired to maximize the reliability and internal validity of the analysis. The first author was considered data coder A; we provided instructions and data to two external data coders (B and C) who worked in parallel.

After receiving all data codes, we were left with six datasheets: coders A, B and C each provided data codes for those with *no meditation experience* and those with *some meditation experience*. All codes were put through three criteria: **(1)** any codes which did not include at least 3 individual participants were removed; **(2)** any codes which did not satisfy that first criterion in all 3 independent analyses (provided by coders A, B and C) were removed; and **(3)** findings which did not meet the first and second criteria in both groups (no / some mediation experience) were removed. Finally, we made every attempt to maintain an objective stance in a process of aggregation and interpretation.

Qualitative Findings

The three columns on the left side of **figure 2** present the number of participants included in each finding by each data coder (our first and second criteria guarantee no number below 3). The bar graph on the right side of **figure 2** presents the average number of participants included in each finding (our third criterion guarantees no number below 6). The abundance of consensus across participants, data coders, and groups suggests a level of validity. We are limited in space here, but the next page summarizes 4 key findings and aims to provide a glimpse into our massive collection of participant quotes describing *Sonic Cradle*. The reader is encouraged to contact the authors for the complete

Qualitative Findings (Subjective experiences in Sonic Cradle)	**No Meditation Experience Group** (n = 14)	**Some Meditation Experience Group** (n = 20)	**Average # of Individual Participants Included**
1 A Relaxing, Refreshing Experience	(A9-B11-C9)	(A15-B9-C14)	22.33
2 A Feeling of Floating	(A7-B6-C6)	(A11-B4-C9)	14.33
3 An Initial Tendency to Explore the Control Paradigm	(A13-B10-C10)	(A12-B14-C14)	24.33
4 An Eventual Transition to Less Intentional Control	(A13-B4-C8)	(A15-B12-C8)	20.00
5 Imagery and Visual Experiences	(A4-B3-C3)	(A5-B5-C5)	8.33
6 An Expressed Desire for More	(A5-B3-C3)	(A8-B5-C3)	9.00
7 Bodily Sensations	(A6-B5-C6)	(A6-B4-C7)	11.33
8 Clarity of Mind, Reduced Thinking, and Emptiness	(A9-B4-C9)	(A9-B7-C8)	15.33
9 A Distorted Sense of Time	(A4-B5-C4)	(A7-B4-C8)	10.66
10 Positive and Emotional Responses	(A11-B10-C5)	(A13-B11-C12)	20.66
11 A Semi-Conscious, Sleep-like State	(A9-B4-C3)	(A4-B3-C8)	10.33

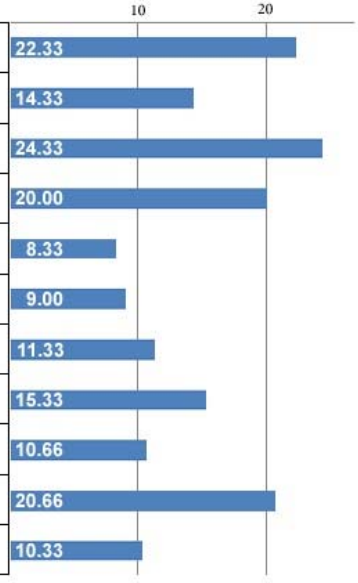

Figure 2. Qualitative findings and the number of individual participants included by each independent data coder.

presentation of all 11 rich, descriptive findings.

An Eventual Transition to Less Intentional Control

The majority of participants reported that they eventually stopped trying to intentionally control the system (P24: “I just sort of surrendered to it … first figuring out the mechanics of it, then ultimately disappearing into a place where I wasn’t fully conscious.” / P32: “Right at the end … I got to an equilibrium place where I wasn't thinking about controlling it, I wasn't thinking about how complex or uncomplex [the sound] should be” / P34: “At the beginning I was … trying to assess how it was working … the middle I'd say was more kind of going with whatever was going on.”) Many responses clearly expressed two phases of the experience (P4: “I found myself at the beginning wanting to use it, but at the middle and end I was just going along for the ride." / P38: “[I] can't really distinguish the middle from end.”).

Imagery and Visual Experiences

Some participants reported visual experiences (P5: "It's not like you're actually seeing but it's the feeling of seeing something." / P15: “I kept seeing a blue stencil through grey, imagery of grey almost mist. Closer to the end I was able to see more of this very subtle green pattern that was almost like a stenciling … [but] every time … I wanted to move the grey out of the way, the green went away.”).

Clarity of Mind, Reduced Thinking, and Emptiness

Participants tended to describe their experience with reference to a reduction of thought (P5: “My thoughts were blank … I felt myself thinking less and less as the whole thing progressed.” / P9: “[the system] lends a positive hand to making the mind chatter quiet … sometimes I don't succeed, you know, and the mind wins, the chatter wins. I think this almost overpowers the chatter at points, and the mind just gives up.” / P13: “I'd say that it essentially let me empty my mind … what I felt was almost a state of emptiness. I wasn't perceiving or thinking about anything, not even about how relaxed I was … it would just be this state of being like an empty vessel almost, that's probably how I'd describe it.” / P14: “I spent a lot of time with a clear mind … I guess the sounds that were going on kept other thoughts from entering my mind … you got to take a break from the everyday noise in your head.” / P18: “I had no sense of time or space and I was in harmony with breathing … It relates to you in a way that helps you remove thinking, focusing your own thoughts.” / P20: " I think it [was] generally about getting to a point where you turn off the internal narrative, which is kind of amazing because I have this constant internal narrative going on. I felt like the experience was really about transcending that.”).

Positive and Emotional Responses

Many comments communicated an intense enjoyment of the experience (P27: “First word would be amazing, second word would be surprising. It was just really unbelievable. It was hard to describe.”). A few participants communicated a deep, emotional response to the system (P4: “[The system] brought me to a place in my childhood out of nowhere, and I felt like it was good. I felt like I was going to an extreme comfort zone where I wanted to hear more, and I was enjoying it.” / P24: “When you said to [be careful] because this [is] the only prototype, I was overwhelmed thinking I was responsible for the only prototype of something, a thing so important to our world.”).

Limitations and Potential Sources of Bias

Any basic interpretive qualitative study which relies on interview data inherently comes with potential biases (moderator demographics / tone, pre-determined interview content, subjective aggregation / reporting, inaccurate participant self-reports). Although atypical for qualitative methods, a lack of control could also be a source of bias in this case. We did not control for time of day, and the simple fact that participants sat alone for 15 minutes during a busy conference program may have contributed to findings in some way. Finally, participants vaguely understood that *Sonic Cradle* was somehow related to meditation in advance; this may have influenced their responses.

Discussion

Previous work has shown that respiratory biofeedback can reduce arousal in the context of music [31], respiratory control of music can reduce blood pressure [25], sensory deprived floatation tanks can have psychological benefits [16], and visual deprivation can improve self-reported pain scores in back-pain sufferers [27]. Considering *Sonic Cradle*'s direct relationship to all of these apparatuses, it is no surprise that participants reported relaxation [*finding 1*]. However, semi-conscious, sleep-like states [*finding 11*] suggest that *Sonic Cradle* may have been too relaxing: "[If] relaxation techniques are overused, they are likely to propel the practitioner into dullness and hence hinder the meditation." [19]

The clarity of mind reported by participants [*finding 8*] suggests that the relaxation felt in *Sonic Cradle* more likely reflects a mindful balance than any kind of dullness. Reduced thinking is directly related to descriptions of mindfulness as "non-judgmental" [13]. In the words of Kang & Whittingham [14], who contextualize the psychology of mindfulness with its Buddhist origins: mindfulness "is often described as nonjudgmental, or not making value judgments on experienced content." These authors go on to claim that the "simple awareness" which characterizes mindfulness "is non-elaborative and relatively unencumbered by language or conception, giving it a directness of access to experiential content." *Sonic Cradle* was successful in generating this clear-minded experiential focus which seems to directly characterize mindfulness. Taken in context with participants' positive responses to the system [*finding 10*], it seems interactive media do have the potential to portray central qualities of mindfulness as desirable, potentially encouraging further practice.

Previous work used a questionnaire targeting hypnosis, meditation, and imaging to measure experiential differences between mindfulness practitioners engaged in a 2-day retreat, a 2-week retreat, and a 3-month retreat [8]. The questionnaire was leading, but differences between groups remain valid. Subjects in progressively longer retreats were more able to maintain attentional focus with less semantic thinking and planning. This aligns directly with *Sonic Cradle* participant reports of a heightened clarity of mind [*finding 8*]. Subjects in the 2-week retreat were also likely to share other experiences with *Sonic Cradle* participants: visual imagery [*finding 5*], perceived changes in bodily state [*finding 7*], and distortions of time (though in the opposite direction;[*finding 9*]). This suggests that *Sonic Cradle* might indeed be able to provide novices with an experience of mindfulness most comparable to those with a bit more experience.

Stoyva & Carlson [28] describe mindfulness meditation as facilitating stress management transitions by applying behavioural tendencies of an active coping mode (e.g. focused attention) toward a resting state. Such a transition was reflected directly in *Sonic Cradle* participants' switching from an initial tendency to explore the control paradigm [*finding 3*] to less intentional control [*finding 4*]. This is important, as stress management transitions are critical for managing clinical problems; we are already planning an investigation of *Sonic Cradle* with chronic pain patients.

Before drawing conclusions, note that our findings are based on 15-minute sessions which seemed too short; participants stated a desire for more and longer sessions [*finding 6*]. This is important because it suggests that extended use could impact our conclusions. Future work in this area should involve longer sessions and repeated exposure to investigate the longitudinal depth and consistency of interventions.

Conclusion

The main contribution of this paper is evidence that **using technology to induce experiences of mindfulness meditation is a realistic goal for stress management technology.** A secondary contribution is a case where basic interpretive qualitative methods and *purposive* participant sampling were used to reveal the possibility and potential of a new application area for human-computer interaction.

Sonic Cradle is a design artifact where subjective user experience is not some secondary attribute to a main task, but instead it is the primary goal. The system was designed to foster an experiential introduction to mindfulness meditation in non-practitioners. The present study used basic interpretive qualitative methods and *purposive* sampling to explore the feasibility of this ambitious, subjective design goal with 39 participants at *TEDActive 2012*. Strict analytic criteria ensure that the findings discussed here are each based on a robust consensus across participants (as independently judged by 3 data coders).

This study suggests that interactively mediating experiences of mindfulness meditation is possible. Systematic analysis of interviews conducted after the *Sonic Cradle* experience revealed clear subjective elements of mindfulness meditation as described in relevant literature [8, 13, 14, 19, 28]. Participants consistently reported starting their session by exploring the control paradigm before transitioning to a loss of intention and clarity of mind. Participants also reported imagery, bodily sensations, and time distortions, paralleling mindfulness meditators on a 2-week retreat. *Sonic Cradle* was described as relaxing and desirable, suggesting that it may have the potential to significantly promote psychological health by persuading users to engage with mindfulness. Those who enjoyed participating in the present study could read this paper and learn that *Sonic Cradle* was systematically observed to be comparable to a practice called mindfulness meditation. This may motivate some of those participants to independently pursue similar experiences by learning and benefitting from this known therapeutic practice.

The sheer quantity of findings which exhibited enough consensus to satisfy our analytic criteria suggests a certain level of validity. However, the present study was not without its limitations. We invite the research community to help us clarify, reproduce, iterate, and

expand on this new type of stress intervention which does not rely on self-evaluation and technological dependency; instead, human-computer interaction paradigms can deliver experiences which educate people about self-regulatory capabilities intrinsic to their own body and mind. Diverse specialists and community resources are needed to help us confirm whether this 'training wheels' approach can promote continued psychological health through long-term engagement with known, beneficial practices.

Cultivating Mindfulness

We did not follow-up with participants, but *Sonic Cradle*'s longitudinal potential was best exemplified by a spontaneous e-mail from P13 after the study: "Your research project has certainly made trying meditation a priority as I seek to find calm in the midst of the storms in which I live … it was a real eye-opener for me … Based on my very positive experience in the *Sonic Cradle*, I've been actively looking into mindfulness meditation … and am committed to [my first attempt] tomorrow morning."

If interactive media can consistently elicit such a response, the human-computer interaction community could help curb the proliferation of stress and stress-related clinical problems. The present study demonstrates how technology can subjectively introduce people to self-regulatory practices which do not actually depend on that technology for long-term engagement. *Sonic Cradle* may seem like a paradox in this regard, but it is actually a contextually-appropriate interaction design born from deep contemplation about the *immersive* quality of our media-saturated environments.

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