Assisting Mindfulness Practice To Promote Emotional Resilience

A thesis submitted to the School of Design, Carnegie Mellon University, for the degree of Master of Design in Design for Interactions

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Abstract

Emotion plays a key role in human experience by affecting how we perceive, memorize and make decisions. Therefore, being able to recognize and regulate our own emotions is an essential skill for psychological well-being. However, screen-based technologies are providing constant stimuli to attract our attention to the screens and away from ourselves. Among the most frequent users of screen-based technologies are young adults. As they grow occupied by and habituated to responding to external stimuli in autopilot mode, their cognitive capacity to attend to their own emotional experiences is negatively affected. The inability to recognize and cope with difficult emotions is associated with many prevalent mental health issues found in young adults including anxiety, depression, and eating disorders. To help address the problem, this project aimed to study how we might promote emotional resilience in young adults by assisting them in being mindful of emotions.

Based on research on what having emotions means for both humans and computer systems as well as empirical research on mindfulness practices, this project proposed a design intervention that creates an ambient display from one's emotional states using affective technology. By closing the biofeedback loop and providing suggestive feedback, the intervention helped to increase emotional awareness and facilitate self-regulation of stress. A prototype of the intervention was developed and tested with 5 participants. Results from the evaluative research showed that the intervention allowed the participants to be aware of the dynamic nature of emotions and evoked self-reflection on one's experience. The feedback provided by the prototype also motivated the participants to engage in self-regulation of stress, although the effectiveness and impact of different feedback mechanisms need further study. Overall, this project contributed to the studies on how affective technologies can be used to enhance our people's own affective abilities.

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Acknowledgments

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Chapter 1 Introduction

1.1 Personal Motivations

This thesis project partially stemmed from a desire to better understand my own emotions. Although I consider myself an overall optimistic person who always tries to and is fairly good at seeing the positive side of things, there were times when I would find myself engaging in compulsive behaviors that resulted from ruminative thoughts. It was as if the negative emotions that I had tried to oppress and ignore previously never went away, and during those times not only did they come out, but they came out strong to take control of my mind and behavior. That observation came with two realizations. First, even though I believed myself to be a rational thinker with a previous background in physical science, sometimes emotions still exercised great influence on how I made decisions. Second, emotions were not always caught by the subjective voice in my head and could not be easily talked away by it either. It occurred to me that choosing to focus solely on positive emotions might not be the best way to handle those difficult ones. And in fact, that strategy hindered my ability to recognize those difficult emotions and how they were exercising power in my unconscious mind. As a result of those realizations, I wanted to find ways to help surface my emotions and allow me to better understand how I really feel.

On the other hand, I was intrigued by the explorations of affective AI systems in popular culture and academia. In the Interaction Design Studio during our first year of the MDes program, we watched clips from the movie Her, a sci-fi movie in which an AI agent was programmed to recognize and respond to human emotions in an empathetic way. In the movie, emotional intelligence created a new relationship between humans and AI as the main character gradually fell in love with his AI assistant through their daily conversations. As skeptical as I was about the idea of creating AI systems that can develop deep emotional bonding such as love with humans, I found that having affect-sensitive and responsive systems as additional sources of mental support could be beneficial for people who were not usually expressive about their feelings. I then discovered that building emotional intelligence into machines was not only a concept from sci-fi fantasies but had also been explored by scientists in the field of affective computing since the late 90s. More details about the field will be discussed in Chapter 2. In short, with the advancement in technology that can recognize emotion-induced responses, there is a growing interest in building machines that can adapt their behaviors based on human affect. Those encounters with machines that could detect and respond to emotions inspired me to explore how they could be designed to help increase our understanding of ourselves.

1.2 Objectives

This project aims to explore the potential of affective technologies to enhance human skills in the context of mental health. The main research question of the project is:

> *How might we create ambient displays with affective technology to help young adults cultivate mindfulness of emotions?*

To help answer the question, there are also three secondary focuses:

1. Explore the ways that ambient displays can simulate emotional experiences from detected emotion signals to help increase awareness of those emotions.
2. Explore design opportunities for affective technology to support mindfulness practices, especially for beginners.
3. Investigate, design, and evaluate interactions with ambient displays for facilitating self-regulation of emotions.

1.3 Outcomes

In this project, a physical computing prototype that can visualize real-time emotion metrics detected from brain wave activities through light was created. As part of the visualization, mapping logics between emotion metrics and the characteristics of the light output were proposed to simulate emotional experiences. Interactive components were also designed and implemented to guide users through a breathing exercise for self-regulation of stress. Results from five informal evaluative testing sessions showed that the ambient display led to an awareness of changes in emotional states and prompted self-reflection on the emotional experiences. It was also learned that seeing their high-stress level visualized could generally motivate self-regulation, although some participants might find being immersed in the red/orange colors representing high-stress states made it more difficult for them to try to stay focused and calm. The learnings from this project provided implications for future studies on how affective technologies can create ambient displays to give people agency to recognize and regulate their emotions at the home setting.

1.4 Organization of Content

The remainder of the work is organized as follows: Chapter 2 will introduce the theoretical frameworks that provided the building blocks for the project including the theories of emotions, self-consciousness, affective computing, and biofeedback. Chapter 3 reviews a few artifacts that had been inspiring to the project including commercial devices that provide biofeedback, tools to cultivate emotional intelligence, and an art installation that turned emotions into an audiovisual medium. Chapter 4 covers the expert interview that was done to better understand mindfulness by learning from people who had been practicing mindfulness for years, and the diary study conducted with college students to discover opportunities to assist young adults in observing their emotional experiences. Chapter 5 will present the design prototype as well as the learning results from evaluative research. Chapter 6 concludes by summarizing the overall learnings from the project and listing opportunities for future research.

Chapter 2 Theoretical Background

2.1 Theories of Emotion

2.1.1 Definition: Discrete Model vs. Dimensional Model

Defining emotions has been a challenge for social and behavioral scientists (Mauss & Robinson, 2009; Scherer, 2005), but it is generally agreed upon that emotions are psychological states of episodic nature, triggered by some events, and lead to behavioral and physiological responses. Several theories have been proposed to define and distinguish different emotions. The discrete emotion theory believes that humans have a finite number of basic emotions and that each basic emotion triggers the same responses in different people. Another theory that has gained prominence in recent years is the appraisal theory. The appraisal theory proposes that emotions result from the appraisal of stimuli (i.e. images, sounds, events, etc.), a process in which an individual evaluates stimuli based on a set of dimensions such as valence, intensity, and predictability (Moors, 2017). In contrast to using discrete categories, the appraisal theory uses a dimensional model to define and differentiate emotions by plotting emotions along several descriptive axes or dimensions (Figure 1). The biggest difference between the discrete and dimensional emotion models is that the discrete model use a finite number of basic emotions as the building block of emotional experience, while the dimensions used in dimensional model are not emotions. This study uses the appraisal theory and the dimensional model of emotions as the theoretical framework as it as it provides a smoother variation between emotions and is therefore better at representing their dynamic nature and helping people recognize subtle emotion differences.

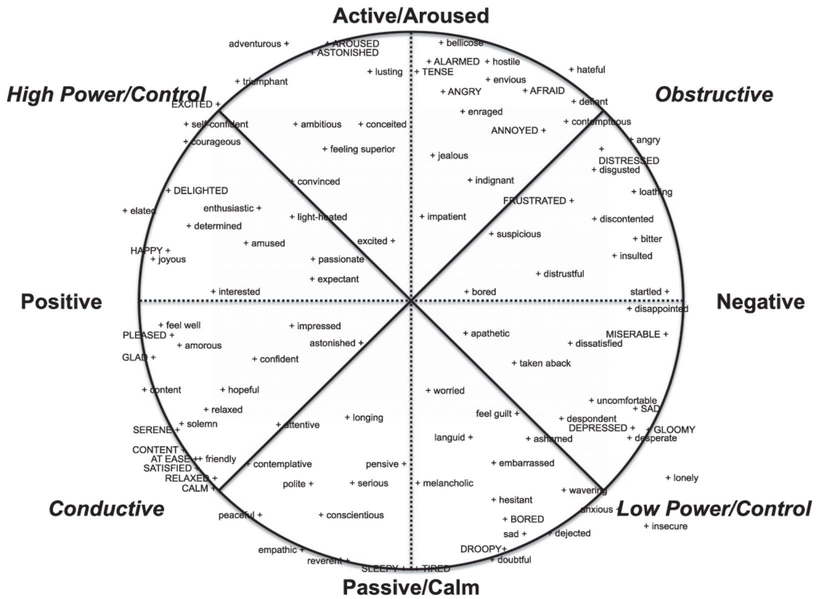


Figure 1. Alternative dimensional structures of the semantic space for emotions (Scherer, 2005).

2.1.2 Emotion vs. Mood

To set the scope for the project, it is necessary to distinguish emotion from mood, another affective phenomenon that is often confused with emotion. According to Scherer (2005), mood is a “diffuse” and low-intensity affective state that may not have any apparent cause and can last a long time with little impact on behavior. In contrast, emotion is appraisal-driven and therefore is always associated with a cause (Scherer, 2005). And although the duration of emotion is usually short, emotion has a larger impact on human behavior.

2.2 The Construction of the Self and Its Implications for Mental Health

Emotion is a subjective experience that is closely related to how one becomes conscious of oneself. Studies have shown that many mental health problems related to the dysregulation of emotions are characterized by excessive and negative self-referential thoughts (Hadash et al., 2016; Jennifer K et al., 2021; Lin et al., 2018). Therefore, understanding how the self is constructed and perceived has important implications for emotional functioning such as awareness and regulation (Jennifer K et al., 2021). According to the psychological theory of *self-reference*, we become conscious of the self through two integrated but neurally distinctive modes, the narrative self and the experiential self (Farb et al., 2007).

The narrative self is the self as experienced across time. It occurs when the mind wanders and we start to contemplate on our past or future experiences. In this process, we weave together a narrative that helps to construct a permanence beneath various experiences, and this permanence constitutes the self (Farb et al., 2007). When in the narrative mode, we undergo elaborate mental events and focus on processing information with our own interpretations. Forms of the narrative self include mental time travel, rumination, and self-criticism (Lin et al., 2018).

In contrast, the experiential self is about the immediate, momentary consciousness. Instead of selective attention to mental events, the experiential self calls for a broad observation of sensory objects, physical sensations, and feelings at the present moment without goal or purpose (Farb et al., 2007). By inhibiting excessive thoughts concerning the past and future, consciousness through the experiential mode helps to avoid rumination and allows a better understanding of reality in real-time.

Farb et al.(2007) suggested that although the experiential mode is related to the evolutionary older part of the brain, we have a tendency to default to narrative processing as its neural mechanism is similar to brain activities during a resting state. In addition, the narrative mode is “an overlearned mode of information processing that has become automatic through practice” (Farb et al., 2007). This implies that the overloading of information in modern times has increased our ability to contemplate the past and future. However, as we devote more time to temporarily extended events, our capacity to attend to the momentary experience through bodily sensory processes is negatively affected.

The ability to control which mode one is on and engage in more experiential self-awareness is important for maintaining mental health. Research has shown that people who regularly practice mindfulness techniques such as meditation are better at knowing which mode they are on at any time and could switch between them more easily. Whereas people who have not practiced tend to default to the narrative path (Farb et al., 2007).

“...the capacity to disengage temporally extended narrative and engage more momentary self-awareness has important implications for mood and anxiety disorders...” (Farb et al., 2007)

2.3 Affective Computing

The concept of emotion does not only live in social sciences, but has also gained growing interest among computer scientists and engineers. Affective computing is a multidisciplinary field that studies “computing that relates to, arises from, or deliberately influences emotions”(Picard, 1997). The research area was initiated by MIT Media Lab researcher and engineer Rosalind Picard in the late 90s after she realized the key role emotions play in human perception and rational thinking. In establishing the building blocks for affective computing in her 1997 book of the same name, Picard used neurological evidence that sensory inputs first pass through the emotional limbic brain before being sent to the cerebral cortex for analysis to demonstrate that emotions are not only external factors that impact rational thinking, but are an integral process of how people perceive and behave in an intelligent way. Recognizing emotion as an essential part of intelligence, Picard (1997) argued that the efforts to build “genuinely intelligent” machines need to give machines the ability to sense and adapt to human emotions in order for them to interact with people naturally and intelligently.

2.3.1 Designing Affective Computers

Affective computing endows computers with affective abilities through “adapting human emotions for computers” (Picard, 1997). Based on what is known about human emotional intelligence, Picard proposed design criteria for how a computer system can integrate three core affective abilities including the ability to recognize, express, and have emotions respectively. The design criteria are summarized below.

<u>Criteria for emotion recognition</u>

- Receiving input signals of emotions (i.e. facial expression, posture, and physiological responses, etc.).
- Performing classification and feature extraction to distinguish between emotions.
- Reasoning about underlying emotions based on contextual information (i.e. personal goals and preferences, social display rules, etc.).
- Learning about the factors that are most important for one’s emotions so as to get better at recognizing them.
- Biasing the recognition of ambiguous emotions if the computer has emotions.

- Naming and describing the recognized emotions.

Criteria for emotion expression

- Receiving instructions on what emotions to express.
- Being activated by either intentional decisions or spontaneously generated emotions by systems that have emotion. This deals with the fact that computers do not have to have emotions to express them and can display a different state than their internal affective state.
- Providing feedback to the affective state.
- Having “bias-exclusion”, meaning that expressing the current emotion makes expressing some other emotions more difficult.
- Abiding by social display rules when expressing emotions.
- Modulating visual or audio cues in both apparent and subtle ways.

Criteria for having emotions

- Displaying behavior that appear to arise from emotions, such as showing a smiley face on the screen when users turn on the laptop.
- Having fast primary emotions, emotions that trigger certain immediate responses without knowing the full picture.
- Generating emotions based on cognitive reasoning.
- Experiencing emotions through cognitive awareness, physiological awareness, and subjective feelings so as to better understand the present emotional state.
- Imitating human body-mind interactions and modulating system behaviors based on the system’s emotional state.

2.3.2 Challenges

With increasing interest and attention given to affective computing, there have also been several challenges and criticisms (Picard, 2003). The challenges that are most pertinent and important to consider for this project include emotion recognition, ethics, and giving computers affective abilities.

Emotion Recognition: Aside from the fact that scientists are still yet to fully understand the mechanism of human emotions, the broad range of modalities it can be expressed and current development in emotion modeling make it difficult to recognize emotions with accurate labels. Picard (2003) addressed this challenge by comparing emotion recognition to weather forecasting as both are subjected to unknown factors and therefore are yet to produce perfect predictions. Similar to how current methods can only recognize signs of a few extreme weather events, there are only a few emotional states that can be recognized relatively accurately (Picard, 2003). However, partial solutions such as letting people prepare for a potential thunderstorm can still offer value. Likewise, allowing people to observe the limited affective states that can be detected and learn about how they shift over time can still help people gain a better understanding of themselves.

Ethics: As emotion is a very personal experience, it is not unexpected that having computers to detect and potentially alter emotions has caused fear of a breach of ethics. Picard (2003) countered this criticism by suggesting that humans constantly recognize, respond to and manipulate emotions in ways that would be considered ethical. For example, a person seeing a friend looking distressed might choose to speak more gently to the friend and offer to play some music to cheer him or her up. To ensure that affective systems are not taken advantage of for nefarious purposes, it is important for the systems to use the data for the users' own benefit while being transparent about what data is collected, how the data is processed, and who has access to the data.

Making Computers Affective: There is also doubt about whether computer systems should not aspire to emulate every human ability, especially the ones that can be problematic such as emotions (Picard, 2003). To address this point, Picard stressed that the main purpose of endowing computers with affective abilities is not to create human-like systems, but to make them work better for human needs. As she stated in her book (1997), "the greatest need for affective computing may not be so much to improve the intelligence of the computer, as to validate, and thereby facilitate the natural abilities of the user." This project also strives to put the focus on giving people agency to practice mindfulness skills rather than building systems that are emotionally intelligent.

2.4 Biofeedback

The mechanism through which many existing applications use affective computing to support mental wellness falls under a concept called biofeedback. The term refers to a technique that uses electronic systems to monitor and convert physiological activities into comprehensible information such as visual and audio cues, and then feed the information back to the users. In turn, users gain more awareness of their bodily processes and learn to regulate them (Figure 2). The term was coined in 1969 based on the feedback concept from cybernetics, which refers to the process in which the outcomes of a system are taken as inputs for the system's self-regulatory process (Frank et al., 2010; GREEN et al., 1970; Satar & Valdiya, 1999). An important premise for biofeedback is that people are able to control their internal responses such as heart rate and body temperature. It came as a surprising discovery in psychology during the twentieth century as those responses had long been thought to be involuntary and out of conscious control (Satar & Valdiya, 1999). Since then, many studies have proven that people can indeed learn to voluntarily alter their physiological responses through techniques such as biofeedback.

To explain how the biofeedback loop functions, scientists had compared it to using a mirror (Frank et al., 2010). When we see ourselves in the mirror, we may become aware of the tense look on our faces or the poor posture of our bodies. The awareness of those non-ideal behaviors often motivates us to correct them promptly. Similarly, biofeedback allows us to see inside our bodies. With appropriate information and guidance, we can learn what our bodies tell us and how we can direct our bodily responses in a healthy direction.

Biofeedback's potential in facilitating self-regulation of internal states has great significance for psychological therapy and treatments. It has been adopted in the clinical setting to complement cognitive-behavioral therapy for treating anxiety and depression (Peper et al., 2015). Recent years have also seen a rise in commercial wellness products that support activities including meditation and brain games with biofeedback. A few examples will be discussed in the artifact review section. The biggest advantage of those commercial products is their ability to democratize biofeedback data and allow more people to take advantage of it in their daily lives. This project also aims to design a system that can be used in the home setting and give people agency to benefit from their own data.

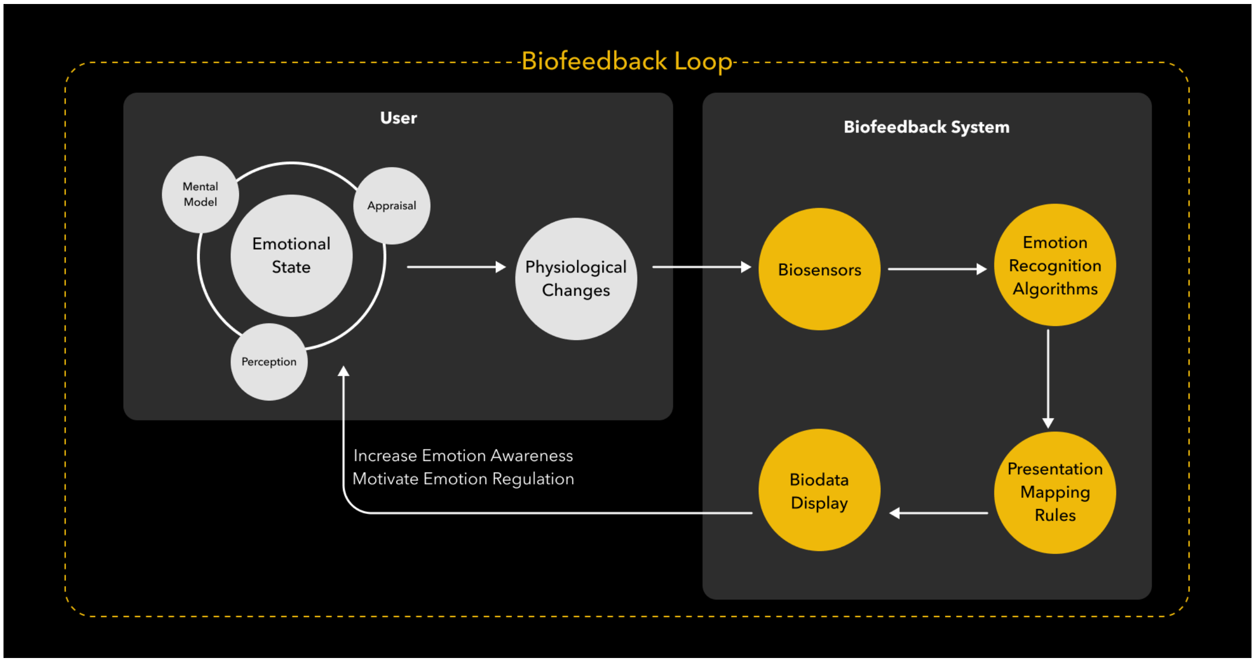
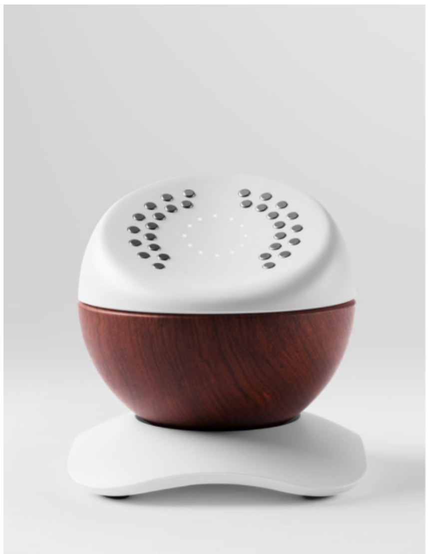


Figure 2. Mechanism of biofeedback.

Chapter 3 Artifact Review

3.1 Meditation Tools Using Biofeedback

3.1.1 Core Meditation Trainer



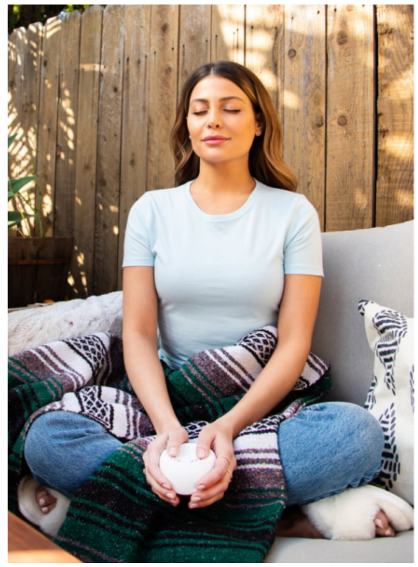


Figure 3. Core meditation trainer. Reprinted from *Products* by Hyperice. n.d. Retrieved from https://hyperice.com/products/core-essential/. Copyright 2022 by Hyperice.

Core Meditation Trainer (Figure 3) assists meditation practice through a handheld device and a mobile app. The device is designed to be held with two thumbs on the dots on the top surface. Those dots are Electrocardiogram (ECG) sensors that monitor users' heart rate variability (HRV), an indicator for activity in the nervous system. While the body of the device vibrates to guide users' breathing patterns, HRV is recorded to provide feedback on how much time is spent in a deeply calm state during the mediation. The mobile app provides guided meditation recordings and allows users to track their progress over time.

This product demonstrates how a physical device can create a more immersive meditation experience through multimodal interaction. The physical device is successful for its scientific premise and human-centered design. It is known that meditation activates the parasympathetic nervous system and thus has measurable physiological effects. Therefore, haptic feedback serves as a nice additional channel for the body to engage in meditation. The form of the device is designed with ergonomics in mind. It allows users to comfortably hold the device with both hands while resting their thumbs on the ECG sensors naturally. Moreover, interacting with the device fits well into the meditation practice as it's similar to holding a singbowl, a popular meditation tool, and the act of holding something with both hands creates a nice sense of ritual. The accompanying app is also a good design example of how to help users make sense of physiological data and how tracking those data is valuable in encouraging practice and improvement. Overall, Core Meditation Trainer sheds light on several helpful characteristics that my designed object can aim for: allows seamless integration into the mindfulness practice, provides clear explanations of physiological data in relation to mental health, and helps to track progress over time to show the effect of the practice.

3.1.2 Muse

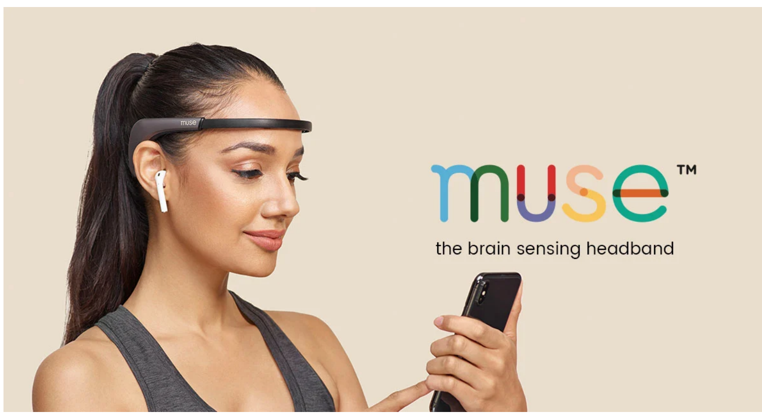


Figure 4. Muse 2 headband. Reprinted from *Introducing Muse 2* by Muse. n.d. Retrieved from https://choosemuse.com/muse-2/. Copyright 2021 by Muse.

Similar to the Core Meditation Trainer, Muse 2 is a product that supports meditation practice through biofeedback. The differences lie in the physiological data that is used for biofeedback and the kind of feedback provided by the system. Instead of using ECG and haptic feedback, Muse 2 headband measures electroencephalogram (EEG) signals related to one's focus levels and turns the signals into guiding sound for meditation. The headband is used with a mobile app with different preset environments for meditation. In different environments, the EEG signals are translated into different kinds of sounds in nature such as the rain in the rainforest, or the wind and waves on the beach. Users' level of focus is negatively correlated with the volume of the sound. As a user gets more distracted during a meditation session, the background sound will increase in volume as a reminder to bring back focus.

Muse 2 is an example of how real-time feedback on one’s state of mind can assist mindfulness practice. In contrast to the asynchronous recordings of mental state that Core Meditation Trainer provides, Muse 2 allows the users to sense their focus level synchronously through the audio channel during meditation, motivating them to intentionally adjust their focus so as to better engage in the meditation practice. Muse 2 also provoked an interesting question about the potential impact that might be caused by biofeedback. When trying to meditate with the headband, I found that although the increase in sound volume allowed me to notice when my focus level is low, the exaggerated sound also made it more difficult for me to concentrate as I preferred to be in a quiet environment for focused work. Therefore, it would be interesting to test different biofeedback with participants and evaluate in what scenarios would providing real-time feedback be helpful and in what scenarios it might cause adverse effects.

3.2 Affective Labeling Apps

3.2.1 Mood Meter

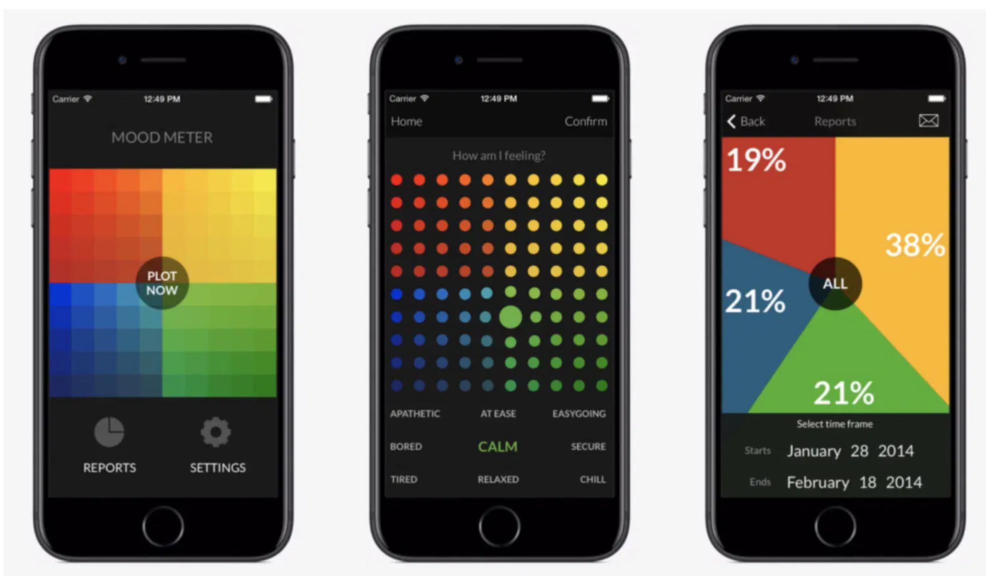


Figure 5. Mood Meter app. Reprinted from *Products* by HopeLab. n.d. Retrieved from https://hopelab.org/product/mood-meter/. Copyright 2022 by HopeLab.

The Mood Meter app helps users build emotional intelligence through labeling and recording their emotions. The app has a collection of 100 words for emotions mapped on two dimensions – arousal (low vs. high energy) and valence (pleasant vs. unpleasant). To record an emotion, users would first evaluate the two dimensions of the emotion using a 2x2 matrix. Then, users are directed to a page where the chosen quadrant is further divided into a 5x5 matrix with each representing a specific emotion. After labeling the emotion, the app invites users to reflect on potential causes of the emotion. Lastly, users can choose whether they want to keep or shift the identified emotion. If the answer is yes, the app will provide some small tips such as “stretching your body”. The answers are stored in the app to help users get greater insights into their emotional patterns.

This app is an example of supporting affective labeling using the dimensional emotion model. In this case, the two dimensions help users narrow down their choices of emotion label from 100 to 25. And by displaying the specific emotions along the dimensions, users can compare and contrast the similarities and differences among different emotions, allowing them to enhance their emotional vocabulary in the labeling process. Therefore, two key takeaways from the Mood Meter include:

- rating the dimensions of emotion before labeling can aid decision on the appropriate label
- placing labels in locations corresponding to their characteristics, and only showing a few labels at a time can inspire exploration and enhance vocabulary building.

3.2.2 Stop, Breathe & Think

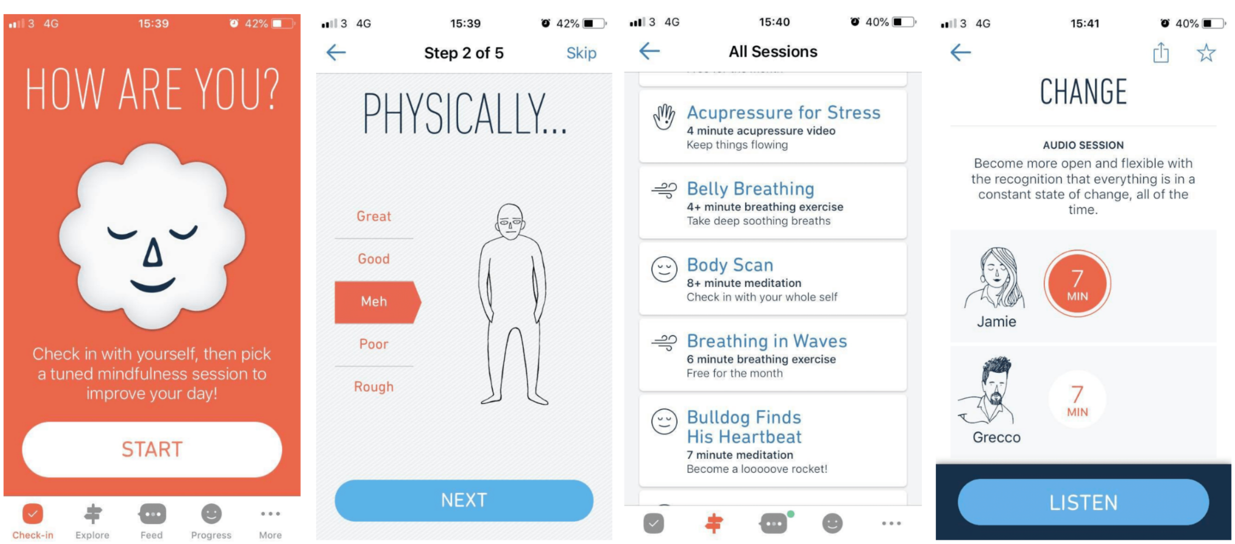


Figure 6. Stop, Breath and Think app. Reprinted from *Discover the Power of Meditation With These 5 Free Apps* by Surf & Unwind. n.d. Retrieved from https://www.surfandunwind.com/top-5-apps-to-jumpstart-your-meditation-practice/. Copyright 2022 by surfandunwind.com.

Stop, Breathe & Think is a meditation app that provides customized suggestions for meditation based on a user's reported physical, mental, and emotional states. Before users choose how they feel, they are first asked to take a 10-second breath. For physical and mental states, users can choose from one of the five states, and the selected state determines the appearance of the character. Labeling the emotional state is slightly different. Instead of choosing the text label, users first select an illustrated facial expression representing the emotion. Once an expression is selected, related emotion labels will be displayed and users can choose at most 5 labels to describe their experience.

A unique feature of the app is its division of an experience into physical, mental, and emotional components as users are guided to choose a state for each when logging an experience. This approach could be misleading and make people view the body, mind, and emotion as separate entities. Therefore, although this app offered a friendly and personable experience through intuitive graphic design, I found this app to be not very effective in cultivating an understanding of emotional experiences which arise from the interconnected mind and body.

3.3 Visualization of Emotions in Art

During 2017's Dutch Design Week, artist Nick Verstand created an immersive audiovisual installation named Aura that translated visitors' emotions into light pulses. As visitors entered the space, music was played to evoke emotional responses. Physiological signals including EEG, heart-rate, and galvanic skin response were then recorded by the various biosensors visitors wore and later used to generate light beams with different forms, colors and intensities surrounding the visitors like curtains. The transformation of emotions into light is based on a scientific system developed in collaboration with the Netherlands Organisation for Applied Scientific Research.

Figure 7. Aura, an audiovisual installation that materialized emotions into light. From “Aura” by H. Wetzers and N. Knulst, 2017, https://www.dezeen.com/2017/11/25/aura-installation-translates-emotions-into-beams-of-light-studio-nick-verstand-dutch-design-week/. Copyright 2022 by Dezeen.

3.4 Insights

A summary of insights from the artifact review is next provided:

- Being in an immersive environment can benefit meditation practice and a physical device providing haptic feedback can create an immersive experience.
- Assistive tools can be integrated into the mindfulness practice seamlessly by resembling a familiar object such as the singbowl for meditation.
- Evaluating an emotion along different dimensions can help in identifying the affective label for the emotion.
- Separating the body, mind, and emotion in self-reflection prevents a holistic understanding of emotional experiences.
- Immersive audiovisual displays can provide a poetic environment suitable for mindfulness practice.

Chapter 4 Primary Research

4.1 Expert Interview: A Peek Into Mindfulness by Learning From Meditators

4.1.1 Research Process

To better understand mindfulness and how it can be incorporated into everyday life from real-life experiences, I conducted expert interviews with four meditation practitioners who have done meditation regularly. The interviewees have 5 to over 20 years of meditation experience and two of them work as meditation instructors professionally. Three interviewees mentioned that their meditation practices were largely inspired by the teachings of the Zen master Thích Nhất Hạnh, and one interviewee followed an ancient Indian meditation technique called Vipassana. Although their meditation practices include various activities such as walking and singing, sitting meditation is the most popular technique and all participants practice it several times a week.

Each participant was invited to a 45-minute semi-structured interview conducted over Zoom. The conversations were structured to achieve four main goals:

- Understand what mindfulness means for each participant
- Learn about how they practice mindfulness through meditation including the setup of the environment, the tools they might use, the things they would focus on, etc.
- Understand what the experience is like during a sitting meditation session
- Gather the experts' suggestions for beginners to learn meditation

4.1.2 Insights

The interview notes were synthesized through affinity mapping and key insights emerged around three themes:

Theme 1: What Mindfulness Is

<u>Embracing what is</u>

One of the learnings I found most surprising was that quieting the mind is not the goal of meditation, embracing what comes to the mind is. Because having a quiet and still mind is what many people think mindfulness looks like and what poses a big challenge to beginners as they find it easy to be distracted. However, as one interviewee who had been teaching meditation for years mentioned, having that mental image of mindfulness "sets people up for a false expectation". When asked about how they kept focused without distractions, several interviewees emphasized that their minds were not fully clear of thoughts during meditation. They would allow thoughts, feelings, and sensations to come through the mind while being aware of the internal experiences at the present moment.

"Meditation isn't really about quieting the mind, it's just allowing the mind to do what it would like to do."

Anchored in the breath

A common practice that all interviewed meditators use during meditation is focused breathing. Anchoring in the breath is not only about paying close attention to the breath, but also about gradually expanding attention from the breath to the whole bodily experiences. As one interviewee commented, "anchoring on the breath, on one point, helps the mind to be sharp".

"It's about anchoring in the breath to help hold and open awareness to a larger experience than that."

Feeling connected to the immediate environment

With mindfulness of internal and external experiences, meditators are able to enter a deep meditative state where they feel deeply connected to their immediate surroundings. One interviewee referred to this feeling of connection as a "higher state of self-consciousness", a state in which one feels like being part of a whole.

"...it just feels like I'm connected to the energy around me. There's no separation of self and other."

Theme 2: How Mindfulness Can Help

Creates more resilient mindset

When asked about the benefits of practicing mindfulness, all interviewees mentioned an improved ability to maneuver through different situations in life. They were able to stay calm even when facing things that used to be challenging for them. One interviewee referred to this change as being able to "take a lot of things in stride", while another interviewee considered herself "less reactive" to letting her emotions influence her thoughts. Their meditation practices seemed to have helped them to develop a more resilient mindset in three steps:

(1) Creating a space between stimulus and one's response.
As they develop the ability to observe themselves, the interviewees became better at identifying their own feelings, thoughts, and behaviors as well as the things that incurred those reactions. This understanding helped them to "create space between stimulus and response", which allowed them to pause and contemplate the associations between the two.

(2) Helping to recognize mental patterns.
By closely examining themselves over time, the interviewees started to recognize patterns in their behaviors and develop a better understanding of themselves. For example, one interviewee realized that the reason that he often felt the need to defend himself was associated with his "self-esteem", "anxiety", and "fear". Understanding where things came up from was "clarifying" for him and helped him be more accepting of himself.

(3) Helping to set and move toward one's personal guiding principles.
Having a clearer picture of their existing mental models also helped the meditators to know what changes they would like to see in themselves and how they could make those changes happen. The participant mentioned above shared that he hoped to be less defensive and therefore incorporated gratitude practice into his meditation. By taking time to appreciate where he was in life at the present moment, he was able to overcome the feeling of needing to prove himself valid and choose not to defend himself in front of others.

Theme 3: Where Can Beginners Start

Creating a ritual is key

When asked about any advice they would have for beginners to start mindfulness practices, three interviewees brought up the importance of creating rituals for themselves. A ritual can be any repeated sequence of actions that are taken with intentions. Compared to habits and routines, another two kinds of repeated activities, rituals require a higher level of awareness and intentionality. Therefore, the interviewees suggested that rituals could serve as effective cues for the mind to direct attention to the present moment and develop a sense of purpose. A common strategy they used to create rituals for their meditation practice is having a regular place and time. One interviewee created a dedicated space for meditation in her home with a sitting cushion and objects that helped to create a peaceful atmosphere. Another interviewee preferred to simply meditate in bed because it allowed her to start a day feeling grounded and purposeful.

Figure 8. Comparison between rituals and other repeated activities. Adapted from “Habits, routines, rituals” by A.L. Cunff, Ness Labs. Retrieved April 30, 2022, from https://nesslabs.com/habits-routines-rituals. Copyright 2022 by Ness Labs.

4.2 Diary Study: Exploring the Emotional Experiences of Young Adults

4.2.1 Research Process

The expert interviews allowed me to take a peek into what mindfulness practices entail and how one might incorporate them into daily life. To understand how young adults who were not familiar with those practices might encounter mindfulness in their everyday experiences and discover opportunities to assist them in being more mindful of their emotions, I continued primary research by conducting a diary study. The diary study was done wth 7 young adults aging between 23 and 27 including one working professional and six graduate students in design, engineering, and law. Each participant was given 7 days to submit 5-7 diary entries using a Google survey.

Diary study was chosen because emotion is dynamic and heavily influenced by one’s surrounding environment. Therefore, it is preferable to study emotion in a familiar setting. Keeping a diary in the participants’ own time and space allows them to observe emotions in their natural contexts. In addition, it provides the benefit of learning about participants' experiences over time.

The design of the diary was inspired by the practice of affective labeling, an implicit approach to help people understand and regulate their emotions by putting emotions into words (Burklund et al., 2014; Torre & Lieberman, 2018). The participants were instructed to name an emotion they experienced either at the time of the diary entry or earlier in the day. To help prepare participants for labeling their emotions, an animated gif that guided viewers to take deep breaths was included at the beginning of the diary and 2 groups of affective labels were also attached . And to assist participants in observing their emotions in more detail, the diary asked participants to describe the context of their chosen emotional experience and rate it in six dimensions on a 1-5 unit scale through a series of questions . The six dimensions were chosen from the dimensional emotion model and included:

Table 1. Summary of six dimensions of emotion used in the diary study.

Dimension & Scale	Description
Valence *Negative (1) - Positive (5)*	The extent to which an emotion is positive or negative. The higher the valence, the more pleasant the experience is.
Arousal *Passive/Calm (1) - Active/Aroused (5)*	A subjective state of feeling activated or deactivated. Arousal measures the intensity or strength of an associated emotional state. High intensity is usually associated with high levels of physiological arousal.
Dominance *Low Power/Control (1) - High Power/Control (5)*	An individual's sense of having an ability to affect the environment, or being dominant and controlling versus submissive and controlled. For instance, the difference between anger and fear is that a person feeling angry has a high sense of control, while a fearful person feels more controlled and submissive. Therefore, anger is higher in dominance.
Conduciveness *Obstructive (1) - Conducive (5)*	The impact of emotion on achieving a goal. If the emotion makes it more difficult for you to achieve a goal, it is less conducive and more obtrusive.
Temporal Orientation *Past-Directed (1) - Future-Directed (5)*	Whether the emotion is induced by past or future events. For example, sadness is usually past-directed, whereas fear is usually future-directed.

Tendency of Action *Avoidance (1) - Approach (5)*	Whether an individual is motivated to approach (i.e. facilitated by excitement) or avoid (i.e. facilitated by anxiety) the emotional stimuli.

After the 7-day diary entry, participants were invited to a 20-minute semi-structured interview to share their experiences and thoughts. Prior to each interview, the participant's diaries were organized in tables and charts which were provided to the participant during the interview as a reference. The emotions were also visualized on a quadrant chart using circles with valence on the x-axis and arousal on the y-axis. The size of the circles corresponded to the level of dominance. At the end of the interview, participants were asked to choose a color for each circle that would best represent the emotional experience [Fiture 9]. The responses from all participants were combined on one chart in order to identify any patterns in mapping emotions to colors.

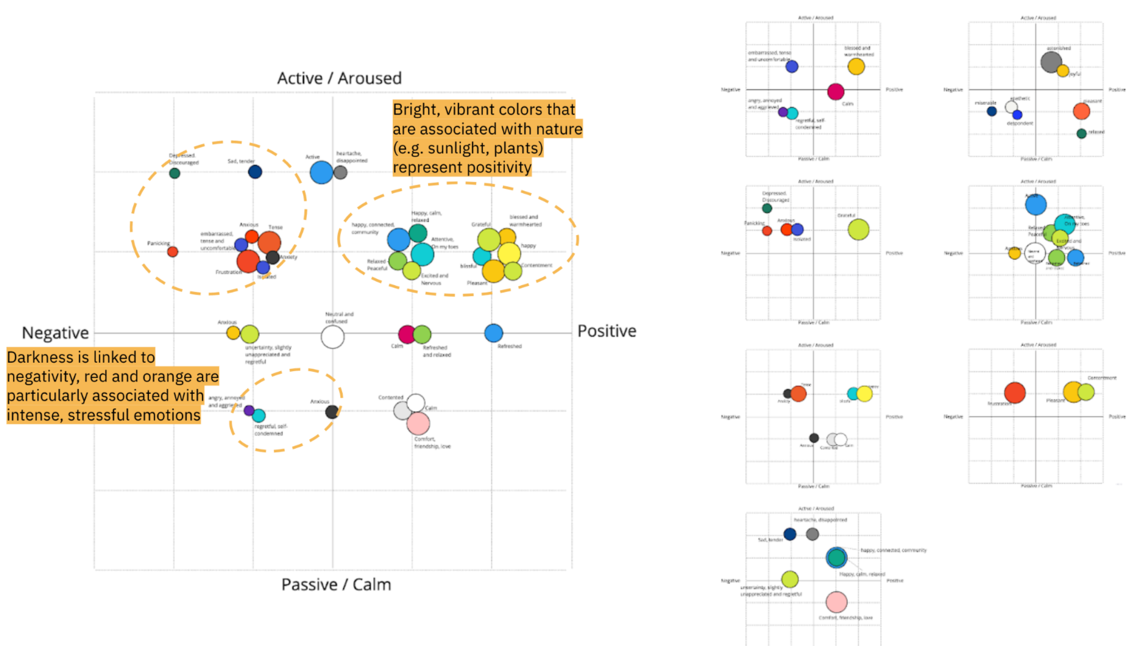


Figure 9. The diary study participants' choice of colors that best represent their emotional experiences (left: combined diagram, right: individual diagram).

4.2.2 Insights

All participants reported that they enjoyed doing the diary and appreciated the opportunity to practice introspection. They found it fairly easy to evaluate their emotions against the six dimensions and there were only a few instances where the rating was ambivalent. The key insights from the diary study included:

<u>People experience more emotions than they thought.</u>
One participant found it surprising how many different emotions she would experience within a day. On other days, she would try to “stay in a happy and comfortable state of emotion” rather than attempt to understand her real experience. And during the week of the diary study, she started to pay more attention to her own experiences and realized that her emotions could change more quickly than she previously thought. This realization indicated that reflection helped the participant to see emotion as dynamic and ever-changing in nature.

<u>Structured self-observation led to a non-judgemental attitude towards oneself.</u>
While it was expected to learn that participants were able to get a deeper understanding of their emotions by deconstructing and evaluating their experiences, one interesting theme that emerged was how intentionally examining their experiences from different dimensions led to the development of a “third-person” perspective on themselves. And this non-judgemental perspective allowed them to be more accepting and understanding of how they might feel in certain ways. This learning showed that using the dimensional emotion model to facilitate reflections on one’s emotional experiences can help cultivate self-compassion.

<u>Seeing a record of emotions motivated reflection on the causal relationship between stimuli and one’s responses.</u>
During the post diary study interview, participants were provided with a miro board with all their recorded responses. The original goal of providing the miro board was to help them remember what they wrote if needed to answer the interview questions. But several participants showed great appreciation for and interest in being able to see how their emotions varied during the week. The historic records prompted them to recollect the events that had contributed to their emotions, which then led them to reflect on the patterns in how they would respond to the different stimuli.

Chapter 5 Design Prototype

5.1 Exploring Light

5.1.1 Why Light

The choice of light as the medium to communicate emotions was based on my personal experience. I found light to be an affective medium as it could influence my emotional experiences effectively. For example, being bathed in the colorful artificial light at a James Turrell show would make me feel aroused and curious, and walking under the violet and orangish sky during sunset allowed me to feel calm and serene. Therefore, I wanted to take advantage of the power of light in the design.

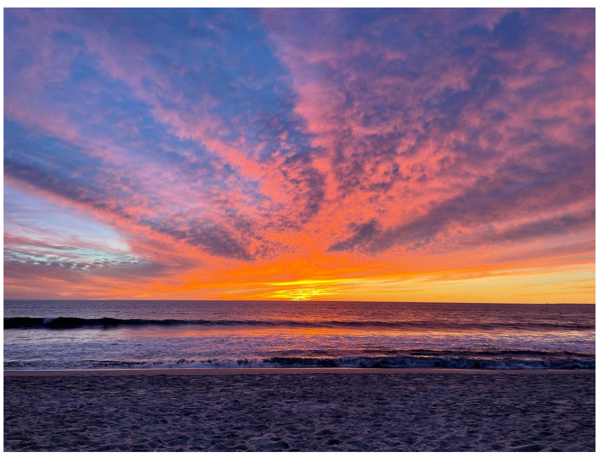


Figure 10. The violet and orangish sky during sunset would make me feel calm.

5.1.2 Creating Ambient Displays With Light

In exploring how light can create ambient displays to simulate emotional experiences, three quick prototypes were created and I tried to practice meditation with each display. In the first prototype, a 2D projection of Perlin noise fields was projected onto the wall behind a sitting area using a pico projector. Realizing that the 2D display would be hard to notice and had little impact on how I experienced the original environment, I created the second prototype using a floor lamp shade and a programmable LED strip. The LED strip was programmed to show a smooth transition of color from red to blue, simulating a changing level of stress. Being able to be immersed in the light immediately improved my perception of the light's changing colors and dynamics. In the last iteration, I added a light source to represent the valence of emotion. The second light source not only created a more dynamic effect by creating a color gradient but also added an additional layer of information. This additional information about the experience's valence was helpful to cultivate a more thoughtful evaluation of stress and allow one to see that having stress does not always lead to negative experiences.

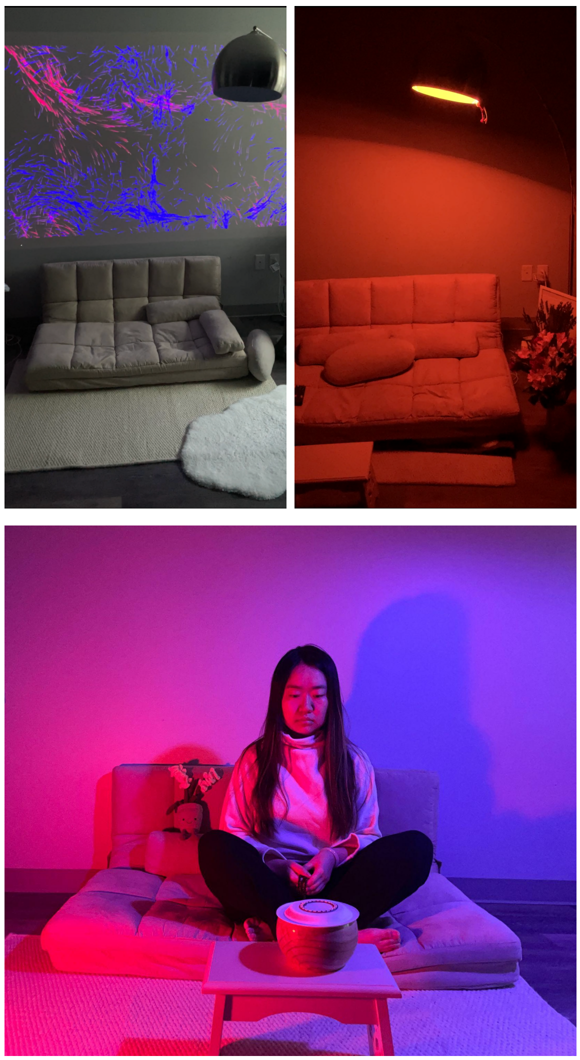


Figure 11. Explorations of using different forms of light to create ambient displays

5.2 System Overview

Based on previous research and explorations, I created a prototype that communicates a user's level of stress and the valence of the present experience through dynamic light output. The prototype was designed to assist mindfulness practices in a home setting and aimed to create ambient displays based on personal emotion data to increase awareness of the emotions and promote self-regulation of stress.

An overview of the components in the system is provided in Figure 12. On the left side of the diagram are the two sources of data input, one from the EEG headset and the other from the capacitive touch sensors built into the control device. The EEG data containing the emotion metrics are streamed to a python script which is used to publish events containing the target data (level of valence and stress) to the Particle Device Cloud. Depicted in the center is Particle Argon, the microcontroller used to subscribe to the data streams and apply logic to translate the two emotion metrics into two light outputs respectively. The gesture input detected by the capacitive touch sensor is used by the microcontroller to control the behavior of the LED ring on the control device.

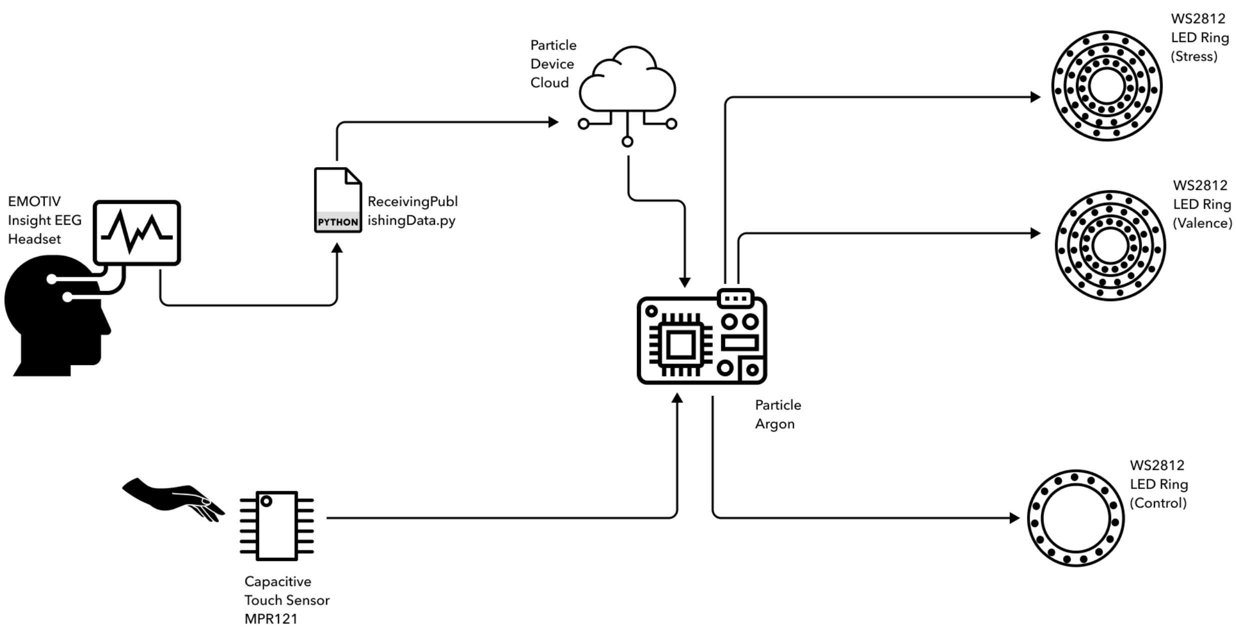


Figure 12. System diagram showing all the components in the prototype.

Figure 13 below shows how the prototype can be set up in a home environment including two light sources that create an ambient display in the background, and one control device placed in front of where users would sit so it can be easily reached to control the system.

Figure 13. Setup of the prototype in a home environment.

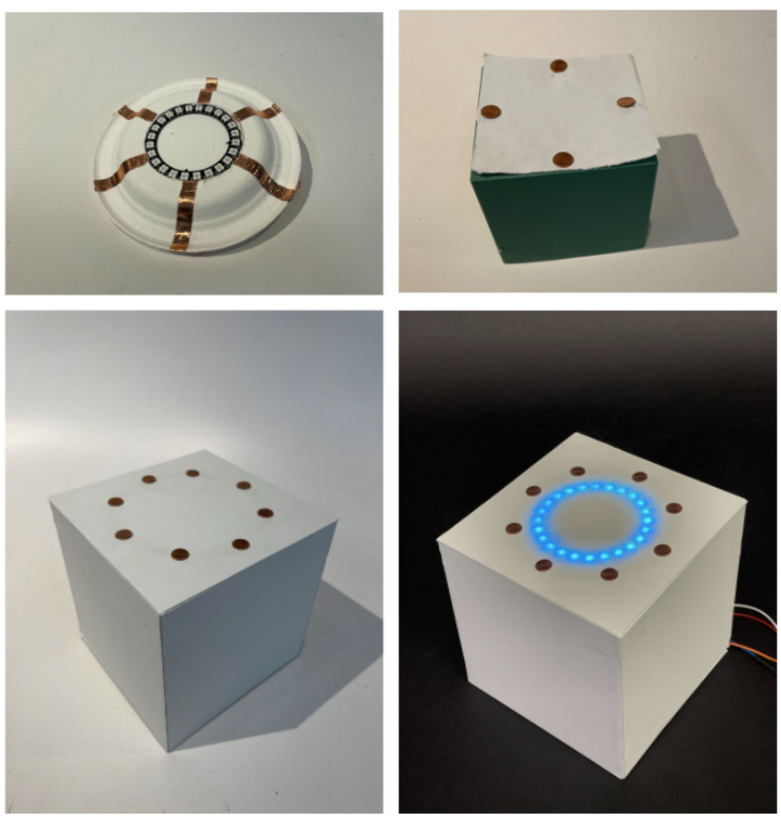


Figure 14. Iterations of the control device. The button row shows the final prototype.

5.3 User Journey

A journey map (Figure 15) was created to illustrate how users may interact with the proposed system during the five main phases to transition from a high-stress state to a calm state.

1. *Set Up*

User prepares and wears the EEG headset. Emotion data start to be collected. The lights are turned on to provide real-time biofeedback.

2. *Observation*

User identifies the emotional state being indicated by the lights and observes how it changes over time. The system detects that the user's stress level is high and provides alerts to the user through the control device by showing the LED ring in orange with a cyclone effect. Following the moving pixels on the LED ring, the user uses a circular gesture on the top surface of the control device to activate the regulation mode.

3. *Regulation*

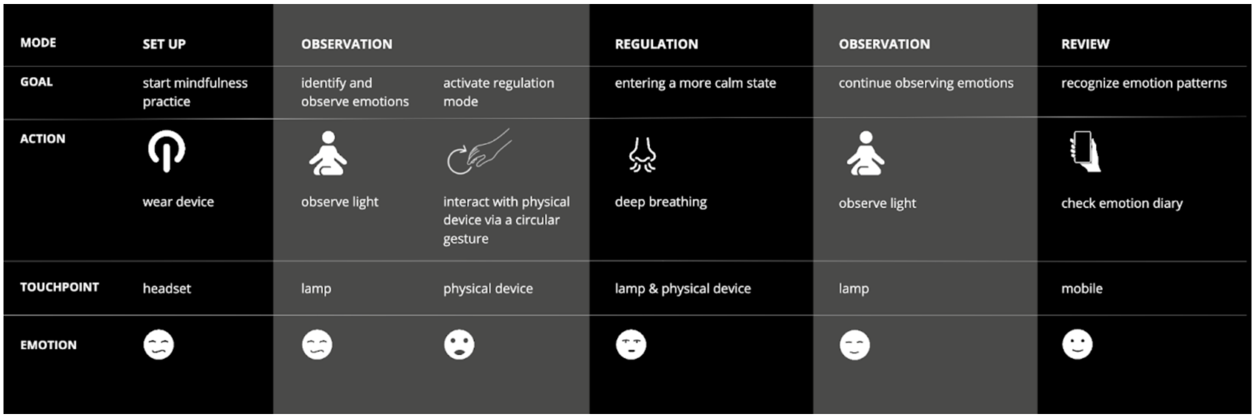
After the regulation mode is activated, the LED ring on the control device starts to breathe in blue. User follows the breathing light pattern to practice deep breathing while seeing the color of the light changing towards lower-stress states.

4. *Observation*

After the user enters a calm state, the system goes back to the observation mode and the breathing pattern on the control device stops. User continues to observe emotions through the lights.

5. *Review*

After using the device for a long term, the user can use a mobile app to check the recorded emotions during previous sessions. Due to time constraints, this feature is not demonstrated in the prototype.



MODE	SET UP	OBSERVATION		REGULATION	OBSERVATION	REVIEW
GOAL	start mindfulness practice	identify and observe emotions	activate regulation mode	entering a more calm state	continue observing emotions	recognize emotion patterns
ACTION	wear device	observe light	interact with physical device via a circular gesture	deep breathing	observe light	check emotion diary
TOUCHPOINT	headset	lamp	physical device	lamp & physical device	lamp	mobile
EMOTION						

Figure 15. User journey during the five main phases.

5.4 Emotion Presentation Mapping

For the prototype, two color mappings were explored for representing the emotion states. Both of the stress and valence data extracted from the EMOTIVPro software ranged from 0 to 1. In Figure16, the level of stress and valence were mapped to the hue of red and purple respectively. In Figure 17, a red-yellow-green color spectrum using the HSL color space was used to represent levels of stress, while a blue-cyan-green color spectrum was used for valence.

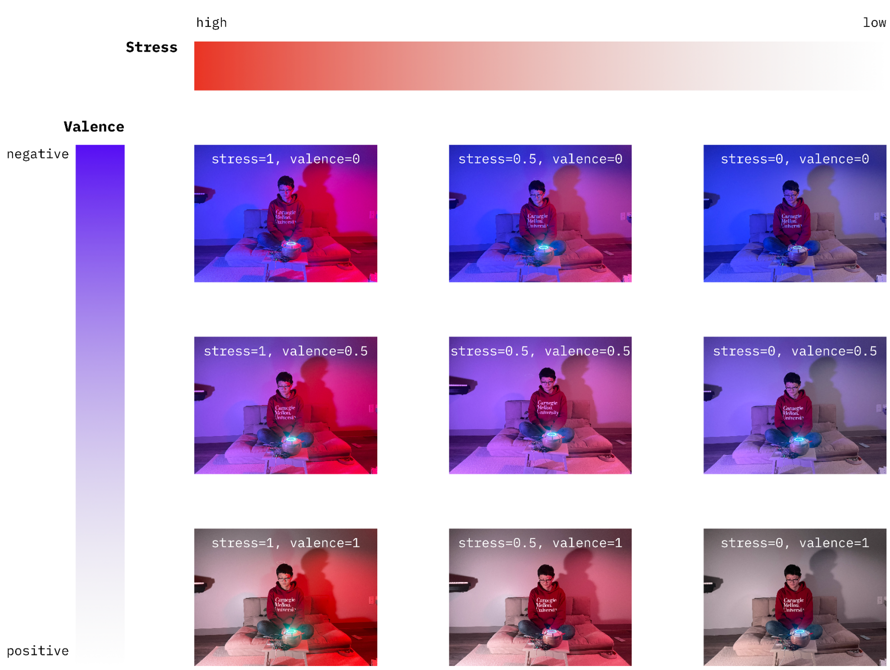


Figure 16. Emotion presentation mapping first iteration.

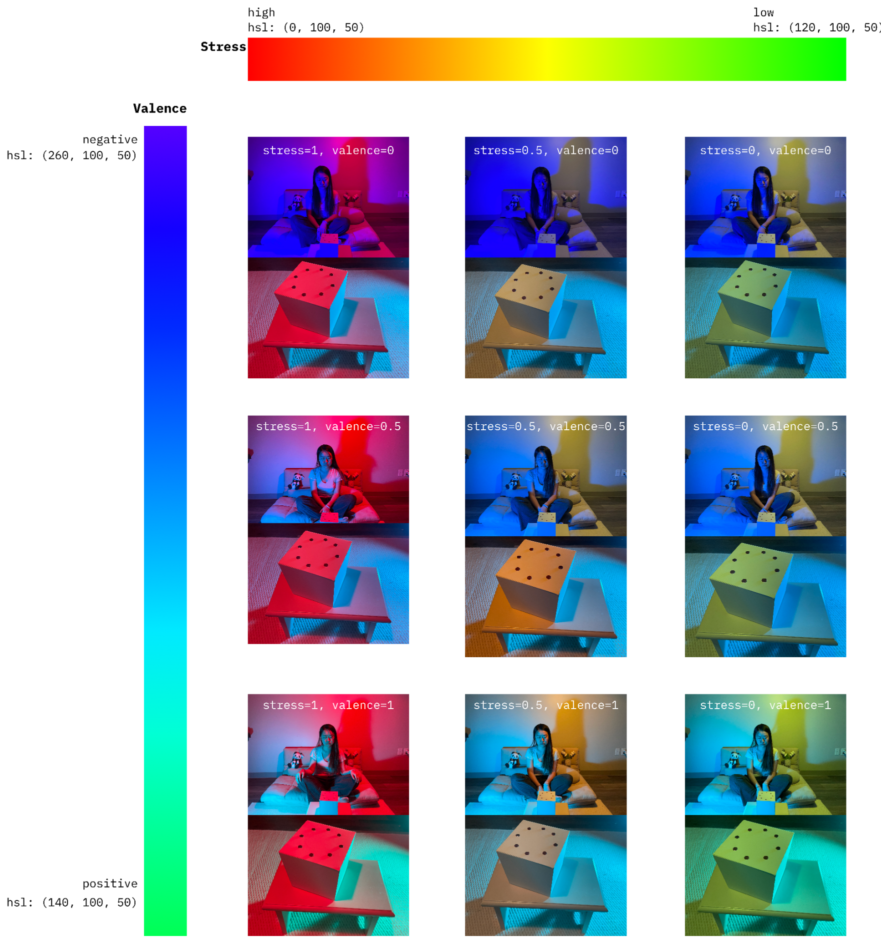


Figure 17. Emotion presentation mapping second iteration.

5.5 Evaluative Research

To get feedback on the design from potential users, I set up the prototype in the shooting studio in Margaret Morrison Carnegie Hall and invited five graduate students for evaluative research activities. The evaluative research focused on three main goals:

1. Investigate how seeing visual cues of emotional states affect emotional awareness.
2. Explore personalization opportunities to improve how the system represents individual emotions.
3. Compare the effectiveness of different feedback in motivating self-regulation.

5.4.1 Experiment Setup and Procedures

Two pairs of lights were set up in the shooting studio (Figure 18). One pair included the two WS2812 LED rings that were programmed to visualize EEG data from the EMOTIV Insight headset for real-time biofeedback. The LED rings were placed in round-shaped paper lanterns that were hung on two photography light stands on the left and right sides of a cushion where participants sit. The other pair was housed in translucent white lampshades and were placed in a similar position using two light stands. The difference was that the second pair consisted of two GE Cync smart bulbs whose colors could be controlled from a mobile app. The smart bulbs were used to quickly simulate different scenarios for testing purposes. The shooting studio was chosen for the evaluative research because it provided a completely dark environment. Due to the limited brightness of the LED rings used in the study, the effect of the light could be hard to perceive if there was too much natural light. The shooting studio allowed the light colors to be easily detectable as the prototype was the only light source in the room.

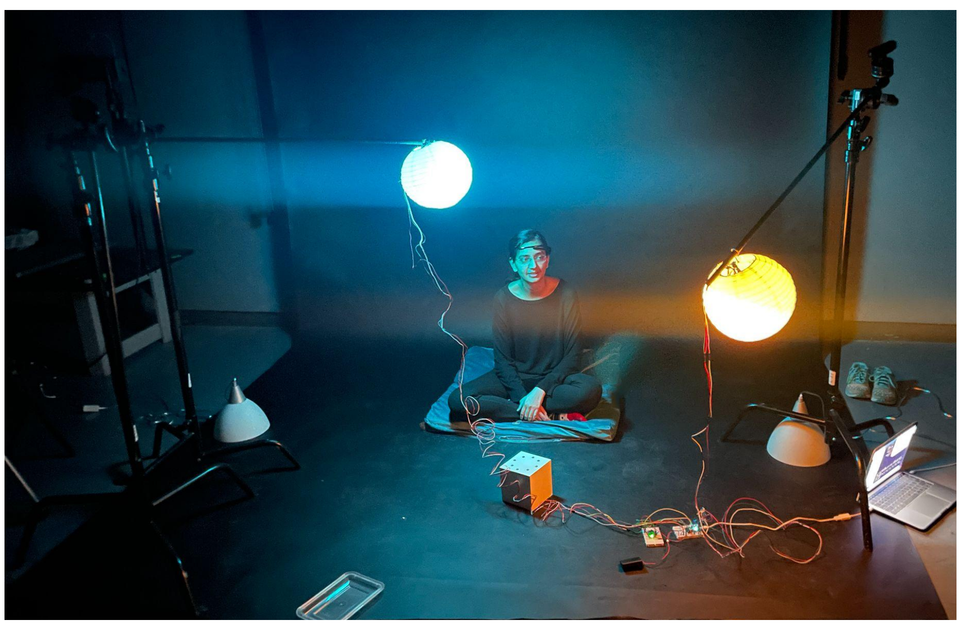


Figure 18. Set up of the evaluative research in the shooting studio.

Based on the three research goals, each research session consisted of three main activities as listed below. At the beginning of the session, each participant was shown the full spectrum of colors defined for the two lights to familiarize them with how emotional states were represented in the system.

1. The first activity was done in the observation mode. The participants were asked to observe the light visualizations of their real-time emotion data while thinking out loud and sharing what they notice.
2. Then, the participants used the smart bulbs and the accompanying mobile app to choose their own colors for high/low stress and negative/positive valence. They were also asked to share where they might place the light sources.
3. Lastly, the participants were instructed to pretend to be in a high-stress state and want to use regulation mode to help calm themselves down. After activating the regulation mode using the control device, the participants went through two deep breathing exercises under two different displays:
    a. The system visualized the high-stress state assumed by the participants;
    b. Instead of showing "real-time" emotion data, both lights were changed to a color that the participants found calming. In addition, peaceful piano music was played in the background.

5.4.2 Research Findings

Emotional Awareness

The first activity showed that it was easier for participants to recognize their level of stress than valence from the lights. This could be attributed to two reasons. First, the red-yellow-green color spectrum was easily associated with high-medium-low stress as red and orange represented intense negative emotions for most people. In contrast, the blue-cyan-green color spectrum for valence was more ambiguous for most people as they were not sure which end of the spectrum represented negative and which represented positive. Having a clear middle state color also appeared to help make inferences about emotions. When detecting stress levels, all participants would use shades of yellow to infer their stress level (orangish-yellow for higher stress, bright yellow for lower stress). Whereas in the valence light, there was no distinguishable middle state color to use as a reference. The second reason could be due to unfamiliarity with the valence dimension of emotions. Two participants asked for clarifications on the word during the tests, suggesting that the term "valence" might not be commonly used when thinking about emotions.

It was also observed that participants tended to rely more on the relative changes in the light color to infer their emotional state than directly reading from the light. For example, one participant commented that "it looks more yellow now, I think I'm less stressed". The color changes also prompted them to make associations between their emotions and what was happening around them. An example was when one participant's stress light turned to red from orange drastically, the participant then commented that she believed it was due to the dropped laptop that made her stress level go up. Another participant made the association between the orangish color in the stress light with her experiences in the previous days as she had a few presentations and deadlines, although she was somewhat surprised that her stress level might still be high even after the deadlines had passed. Overall, seeing the light display was effective in encouraging self-reflection on one's emotional experiences.

Color Mapping

One of the feedback received during the March presentation was that feelings around color were very personal, therefore the system could be improved by giving users the freedom to define their own color mapping. The evaluative research tested the methodology to support personalized color mapping by letting participants choose the colors for the two ends of both dimensions (i.e. high/low stress and negative/positive valence). Figure 19 shows the eight pairs of colors chosen by four participants. Then the participants-selected colors were used to interpolate color spectrums using HSL colorspace to represent the full range of emotional states. The interpolated spectrums for the eight pairs are shown in Figure 20. As discussed above, a color spectrum with a distinguishable middle state color can help with recognizing emotions from light. However, none of the spectrums in Figure 20 met the criteria with several having more than three hues. Therefore, the personalized color mapping generated from the chosen colors for extreme emotional states might cause confusion in use. This result indicated that either letting users choose their own colors for extreme states was not the most effective methodology to support personalized color mapping, or interpolation in the HSL colorspace was not the best way to generate a color spectrum for emotion representation.

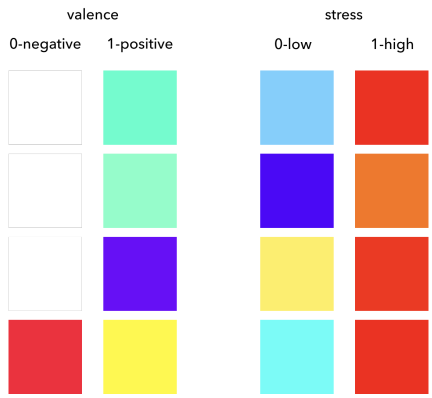


Figure 19. Colors chosen by the participants to represent the extreme emotional states.

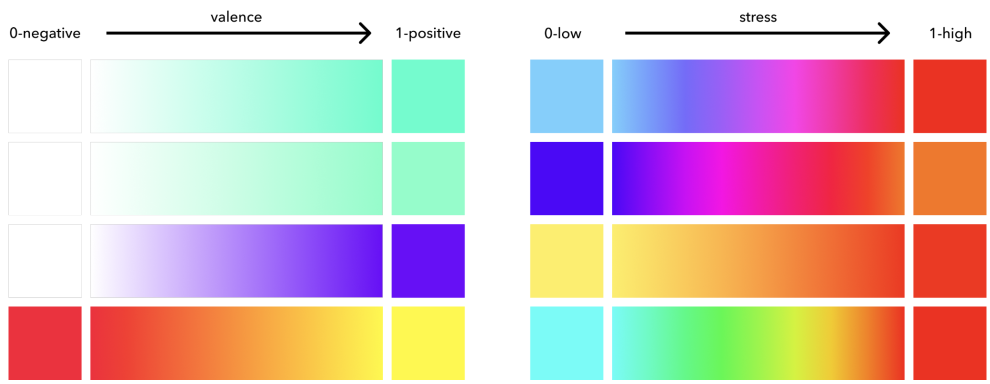


Figure 20. Interpolated color spectrums based on colors selected by participants.

Light Placement

Another personalization option explored was the placement of lights. Common feedback received was that the participants preferred not to see the light sources placed in front of them. Four alternative placement options (Figure 21) were suggested including:

1. Placing the two lights on both sides of the sitter and having the light appear to be emitting from the sitter.
2. Placing the two lights on the ground on both sides of the sitter and directing the light to the floor.
3. Hanging the two lights above the sitter so the sitter can be submerged in light.
4. Placing the two lights behind the sitter to allow light to emerge from behind.

Those four options were preferred as they were less distracting and allowed the sitter to feel more like “being part of the light” compared to the original study setup.

Figure 21. Light placement in the original study set up(left), and four alternative options proposed by the participants (right).

Providing Feedback for Assisted Self-Regulation

Figure 22 shows the two types of feedback that was evaluated with participants. The participants expressed different opinions over whether monitoring their real-time emotions or being put into a calming environment when their stress level was high could be more effective in facilitating self-regulation of emotions. All participants agreed that the red color representing high-stress levels was attention-grabbing and effectively signaled the need to change. However, some found the red light too distracting and disturbing for them to calm down while others appreciate seeing real-time emotion to monitor progress during self-regulation. One participant compared the effect of seeing the stress light turning red with encountering a challenge in a game. Being a competitive person, she immediately wanted to act upon the challenge and tried to turn the light to green by calming herself down. Her comments offered an interesting insight into how biofeedback could have different effects on people with different personalities. They also suggested the potential of combining biofeedback with gaming mechanisms to further incentivize self-regulation. Across all participants, the preference over the type of feedback one receives to facilitate self-regulation appeared to be affected by how the system was used. If the participants set the intention to actively engage with the system to practice mindfulness, they were more likely to expect to see real-time biofeedback and monitor their progress. If the participants were using the system in the background while working on other things when their stress levels became high, the participants' priority would be the task at focus and therefore prefer a calming display to help them regulate emotions in more subtle ways.

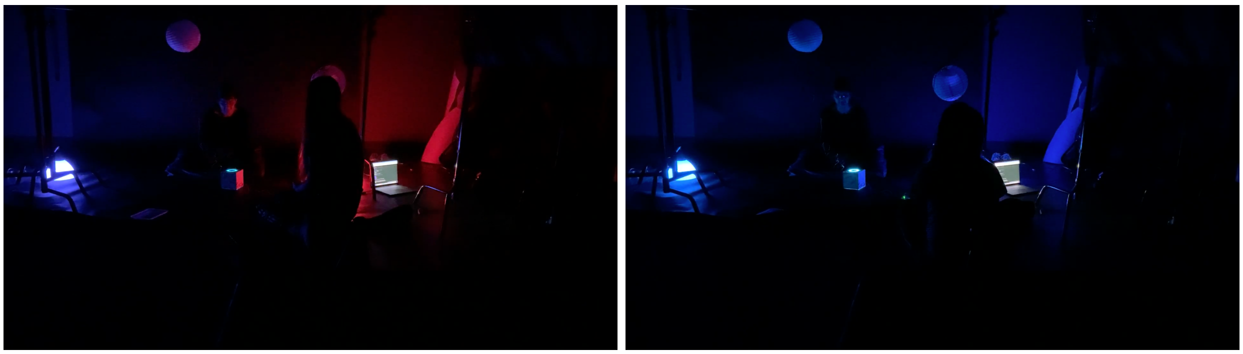


Figure 22. Different types of feedback to facilitate self-regulation: visualizing real-time emotion (left) vs. creating a calming environment (right).

Chapter 6 Conclusion & Reflection

6.1 Summary of Learnings

This project has explored and designed a system that uses affective technology to help cultivate mindfulness of emotions and facilitate self-regulation of stress. The presented design prototype measures a user's emotional state in real-time through an EEG headset and communicates the data via an ambient display consisting of two light sources and a control device. Findings from evaluative research showed that the ambient display allowed participants to recognize their emotional states from the relative changes in light color and was effective in motivating self-reflection. Some color mappings of the emotional states were proven to be more effective than others in assisting emotion recognition. For example, the red-yellow-green color spectrum made it easier to recognize stress levels as compared to valence levels. This is because the color spectrum aligned with people's association of red/orange color with intense emotions and had a discernible color (yellow) for intermediate emotion as a reference to infer other emotional states. In addition to assisting emotion recognition, different types of system feedback were evaluated for their effectiveness in facilitating self-regulation of stress. The findings show whether people prefer to see real-time emotion data or to be in a calming environment during regulation activities was dependent on their personality and if interacting with the system was the main focus of the user.

6.2 Limitations

Along with the findings and insights, this project also identified a few limitations in the proposed system.

6.2.1 Data

The two sets of emotion metrics data including level of stress and valence were directly obtained from EMOTIV's developer software. The software uses machine learning algorithms to calculate those emotion metrics from the raw EEG data detected by the headset. However, all the calculation is done on the backend and the company does not disclose details about the algorithms involved. The limited transparency on how the data is derived may pose challenges to establishing trust between the user and the system.

6.2.2 Technical Limits

The EEG headset used in the prototype required special care to provide good data quality. Users first need to go through a set up process to make sure all five sensors on the headset are in contact with the scalp. The process was found to be a challenge for people with long hair. Moreovere, the EEG sensors are sensitive to any body movement or facial expressions such as the blinking of an eye. As such, users need to be in a static position with minimal movement. This technical limitation could affect user experience and reduce the scenarios in which the system can be used.

6.2.3 Environment

The ambient display requires a relatively dark or dimly lit environment to provide the best experience. Having natural light or other light sources may interfere with the detection of the color changes in the two lights and therefore negatively affect a user's ability to recognize some communicated emotional states.

6.3 Future Research

6.3.1 Light Dynamics

Findings from this project have shown that having accurate color mapping for emotional states for every user can be a challenging task. To better assist users in identifying emotions from light, future research can investigate how dynamic lighting effects (e.g. pulsating, flickering, breathing, etc.) can be associated with perception of emotions and study how such effects might potentially enhance emotion expression in the ambient display.

6.3.2 Audio Feedback

When creating a calming environment for participants to practice emotion regulation, the peaceful Gymnopédie No.1 by Erik Satie was played. Most participants appreciated the added calming effect created by the audio feedback. The exploration of sound in biofeedback was beyond the scope of this thesis research. However, there are many opportunities to explore here. Further development on the system could explore how to incorporate audio feedback to assist emotion regulation and expression.

6.3.3 Interpersonal Emotion Communication

During the evaluative research, one participant commented that the system made it easy for others to sense their emotions and therefore they would consider using it for emotion communication. Therefore, in addition to letting people experience their own emotions, future research can explore how to design ambient displays to experience and relay other people’s emotions.

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