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Master's Thesis
Academic Year 2025

AuraStone: Designing a Multisensory Tactile Interface for Evoking Natural Emotional Resonance through Symbolic Stone Metaphor

Keio University
Graduate School of Media Design

Yuqiao Ruan

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

Yuqiao Ruan

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Abstract of Master's Thesis of Academic Year 2025

AuraStone: Designing a Multisensory Tactile Interface for Evoking Natural Emotional Resonance through Symbolic Stone Metaphor

Category: Design

Summary

In everyday digital environments, people often lack gentle, non-intrusive ways to regulate their emotions and reconnect with sensory cues. This study investigates how different input modalities affect emotional responses to identical nature-based audiovisual content. By comparing a symbolic, tactile stone interface with a standard keyboard, the research reveals how embodied, multisensory interaction can foster stronger affective engagement. Grounded in nature-inspired design and emotional interaction principles, the system offers a low-effort way to support mood regulation and sensory reconnection in everyday environments.

Keywords:

emotional interaction, tactile interface, multisensory design, nature metaphor

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Chapter 1
Introduction

1.1. Background

1.1.1 The Psychological Cost of Urban Living

Urban environments are increasingly associated with elevated levels of psychological stress. Studies have shown that densely populated cities—often characterized by sensory overload, social compression, and a lack of restorative environmental stimuli—contribute to cognitive fatigue, emotional depletion, and rising rates of anxiety-related symptoms [1]. In many everyday indoor contexts—such as offices, libraries, or shared lounges—these effects accumulate quietly, exacerbated by an absence of accessible, non-intrusive avenues for emotional self-regulation [2, 3].

1.1.2 The Rise of Nature-Themed Digital Content

As urban lifestyles limit direct contact with nature, digital content platforms such as YouTube have seen a notable rise in nature-related media consumption.[1] Reports indicate a substantial increase in the viewing of ambient nature videos, including forest walks, hiking vlogs, and nature sound compilations, particularly during and after the COVID-19 pandemic [4]. These trends reflect a growing collective desire to compensate for the absence of real nature through mediated sensory experiences [5].

However, passively consuming screen-based content may not always satisfy the deeper human need for embodied interaction and multisensory immersion. While mobile apps and online videos are accessible, they typically require visual focus,

1 `https://www.youtube.com/trends/articles/nature-sounds-views-increase/`

active selection, and cognitive engagement—factors that are not always feasible in low-energy or transitional moments [6].

1.1.3 Toward Tangible, Nature-Inspired Interfaces

While the psychological benefits of visual and auditory exposure to nature are well-documented [7, 8], tactile engagement with natural materials remains under-explored. This gap is particularly significant given that touch is one of the most immediate and emotionally resonant senses [9]. Among natural materials, stone offers unique physical and symbolic properties. Its surface irregularity, density, and perceptual weight evoke groundedness, stability, and timelessness—qualities that contrast with the overstimulation and impermanence of modern digital life [10].

Aesthetic movements such as Mono-ha (the Japanese "School of Things") have long emphasized the expressive potential of raw materials, including stone, in fostering reflective, embodied perception. When embedded into interactive systems, such materials can serve not only as physical substrates but also as conceptual mediums for emotional resonance.

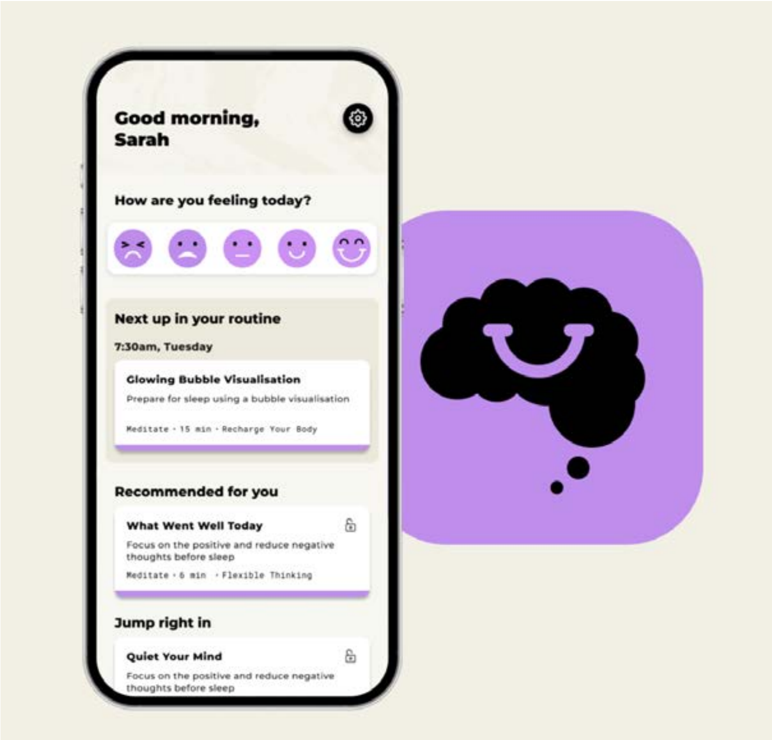
Building on these principles, this research explores a nature-inspired tactile interaction system designed to support subtle emotional self-regulation in everyday indoor spaces, such as home desks or office corners. The system integrates three components—touch-sensitive surfaces, natural sound playback, and ambient visual rendering—to evoke the emotional affordances of nature through short, casual interactions. By minimizing overt feedback and emphasizing material familiarity, the design aims to blend seamlessly into users' daily environments while offering quiet moments of emotional grounding.

1.1.4 Emotional Well-being and Current Coping Tools

To counter the rising emotional fatigue in digitally saturated lifestyles, a wide range of well-being tools has emerged over the past decade. Mobile meditation apps such as Headspace and Smiling Mind offer guided sessions focused on breath awareness, mindfulness tracking, and cognitive reframing. Headspace, for instance, presents a structured user flow of short animated videos and calming voiceovers, aiming to train attention and reduce stress through daily repetition.

Smiling Mind follows a similar approach, often targeting younger users and integrating mindfulness exercises into school and family routines (Figure 1.1).

Alongside app-based solutions, physical objects like the Fidget Cube offer haptic micro-interventions that involve clicking, spinning, or rubbing tactile elements to redirect nervous energy and improve focus (Figure 1.2). These tools provide immediate tactile feedback, but are typically limited to mechanical repetition and lack emotional or symbolic nuance. Other interventions, such as aromatherapy diffusers, noise-masking devices, or light therapy lamps, rely heavily on ambient sensory manipulation without user input.



(Source: Smiling Mind, https://www.smilingmind.com.au/)

Figure 1.1 Smiling Mind App

While each of these tools offers valid pathways for stress relief, they share several limitations in casual, multitasking contexts. Most require deliberate engagement—such as launching an app, following instructions, or allocating private space and time. In socially shared environments or transitional moments—like working

(Source: FIDGET CUBE, https://www.kickstarter.com/projects/antsylabs/fidget-cube-a-vinyl-desk-toy)

Figure 1.2 FIDGET CUBE

at a desk or preparing for sleep—users may not have the cognitive bandwidth or willingness to initiate structured emotional exercises. Moreover, the overt therapeutic framing of many tools can feel intrusive or stigmatizing in casual settings [11].

These challenges highlight a need for emotionally supportive systems that are ambient, intuitive, and symbolically grounded. Rather than offering structured training or direct self-regulation techniques, this study explores a nature-inspired tactile interaction model that integrates seamlessly into everyday environments. By drawing from the sensory qualities and cultural meanings of stone, the proposed system aims to enable low-effort, emotionally resonant interaction without explicit cognitive demand.

1.1.5 Why Stones? Symbolic and Sensory Justification

Among natural materials, stone holds a unique place both symbolically and sensorily [12]. Across cultures, stones are often associated with timelessness, grounding, stability, and a quiet kind of strength. In East Asian aesthetics, for instance, stones are prominently featured in Zen gardens and tea ceremonies as metaphors for natural stillness and permanence [10]. These associations make stone a powerful symbolic medium for fostering emotional calm and introspection.

On the sensory level, stones are dense, textured, and cool to the touch. These physical qualities stand in contrast to the smooth, uniform surfaces of most technological devices, offering a more embodied and reflective tactile experience. The irregularity and perceived weight of stones invite subconscious handling—being held, stroked, or pressed—without requiring instruction or cognitive load [9].

In the context of interaction design, stone-shaped tangible objects have also been explored for their emotional and communicative potential. Alsmeyer et al. (2008) developed a tactile device in the form of a "subtle stone," allowing users to self-report emotional states through squeezing and color changes [13]. Their findings emphasized the value of familiar, emotionally neutral objects in promoting private, low-effort emotional reflection. Similarly, Gooch et al. (2022) designed tangible devices for older adults to log emotional states in daily contexts, highlighting the accessibility and calming nature of graspable physical interfaces [14]. These examples support the idea that tangible interaction—especially when embedded in familiar material metaphors—can serve as a meaningful platform for emotional engagement.

In this study, a stone-shaped object is reimagined as an emotionally responsive interface, leveraging both the physical properties and cultural associations of stone to support ambient emotional interaction. The goal is not to simulate nature literally, but to evoke its calming qualities through material metaphors and subtle multisensory feedback.

1.2. Motivation and Purpose

In an age dominated by screens, multitasking, and sensory overstimulation, emotional fatigue has become increasingly common. While conventional affective technologies—such as meditation apps, mood-tracking software, or ambient displays—offer some relief, they often impose cognitive load and require intentional engagement [15]. These characteristics make them less effective in contexts where users are mentally exhausted, momentarily distracted, or engaged in light tasks.

This research is motivated by a desire to explore alternative affective interaction paradigms—ones that are intuitive, non-verbal, and materially grounded [16, 17]. By combining tactile interaction with nature-inspired audio-visual feedback, the project seeks to create a calming micro-intervention for everyday indoor settings such as home desks, workspaces, or personal corners. The interaction is designed to be passive, ambient, and low-effort—supporting brief emotional regulation without requiring conscious decision-making or verbal input [18].

Rather than aiming for therapeutic or clinical outcomes, this work focuses on subtle, self-paced emotional grounding through casual, multisensory interaction. The system offers an unobtrusive moment of calm that blends into the background of daily life, enhancing well-being through the symbolic presence of nature.

1.3. Research Contributions

This research makes the following contributions to the field of affective interaction and nature-inspired interface design:

- **Material-Centered Interaction:** The study proposes a tactile interaction system that foregrounds the material symbolism and sensory qualities of stone—an approach less explored in existing affective technologies.
- **Daily Usability in Casual Settings:** Unlike many affective systems designed for therapy or immersive installations, this system is embedded in casual, everyday environments such as home desks or shared workspaces. It emphasizes unobtrusive presence and effortless engagement.
- **Multisensory Feedback for Micro-Intervention:** By combining touch-triggered natural audio and ambient visual feedback, the system offers a form of micro-intervention that supports emotional grounding without demanding attention.
- **Comparative Evaluation with Conventional Interfaces:** The study introduces a user experiment comparing the emotional responses elicited by the stone-shaped interface versus a conventional control device, highlighting the value of symbolic natural metaphors in emotional regulation.

Together, these contributions point toward a new direction in emotionally aware design—one that is not only technologically minimal but also emotionally meaningful through its material expression.

1.4. Research Questions

This study is guided by the following research questions:

- **RQ1:** Can tactile interaction with stone-like materials reduce psychological stress and promote calm in everyday settings?
- **RQ2:** How do users' emotional responses differ when triggering natural audio-visual feedback via a stone-shaped tactile interface versus a conventional input method, and what design insights can be drawn from these differences?

1.5. Thesis Organization

This thesis is structured into eight chapters, each addressing a distinct phase of the research process—from conceptual development to system implementation, experimental evaluation, and critical reflection.

Chapter 1

This chapter introduces the research background, including the psychological stress of urban life and the limitations of current well-being tools. It explains the symbolic significance of stone in interaction design, presents the research motivation and questions, and outlines the originality and intended contributions of the study.

Chapter 2

This literature review examines prior work across four domains: tactile interaction for emotional regulation, biophilic and nature-inspired design, affective computing and experiential installations, and symbolic affordances of materials. These foundations support the multisensory interaction strategy of the proposed system.

Chapter 3

This chapter presents the early-stage concept development, including initial user research and visual ideation. It introduces the AuraStone prototype and explains the rationale for using natural metaphors and tactile form in combination with ambient audiovisual feedback.

Chapter 4

This chapter details the hardware and software implementation of AuraStone. It covers the stone's physical fabrication, sensor integration, audiovisual output system, and real-time interaction design using TouchDesigner and Arduino. The device responds to touch by playing calming natural sounds and displaying nature imagery on a screen.

Chapter 5

This chapter outlines the experimental methodology. It introduces a within-subject comparative study involving two conditions (AuraStone and keyboard), describes observational and questionnaire tools, and explains how emotional responses were measured using the PAD model along with statistical analysis.

Chapter 6

This chapter presents and interprets the experimental results. It includes PAD data visualization through scatter plots and heatmaps, statistical comparisons between conditions, and interpretation of affective patterns and engagement behaviors.

Chapter 7

This chapter offers a critical discussion of the findings. It addresses multisensory interaction, emotional symbolism, PAD-based emotional modulation, and theoretical implications. It also responds to the research questions and discusses limitations and ethical considerations.

Chapter 8

The final chapter concludes the thesis by summarizing its key contributions and outlining future directions. It reflects on the practical and theoretical significance of nature-inspired tactile systems for emotional interaction in everyday environments.

Chapter 2
Literature Review

2.1. Tactile Interaction and Emotional Soothing

2.1.1 Embodied Interaction Theories

Witten et al. (2023) suggest that touch-based interaction can provide a subtle yet powerful means of emotional communication, particularly in environments where verbal expression may be constrained [19]. By leveraging tactile modalities, individuals can engage with emotional content in a way that feels more personal and instinctive, thereby reducing cognitive load and enhancing the overall emotional experience. This approach is especially pertinent for emotionally responsive interfaces in public spaces, where privacy and social boundaries must be respected.

Similarly, Wilson et al. (2017) argue that individuals with a high capacity for vivid positive mental imagery are more likely to respond positively to external emotional stimuli, such as soothing images, which engage emotional processing systems in a similar manner [20]. This finding underscores the significance of enhancing emotional engagement through non-verbal and sensory interactions, aligning with the principles of using tactile feedback to foster emotional well-being in shared spaces.

Further supporting the importance of sensory stimuli, Ryynanen et al. (2023) highlight the mood-enhancing effects of nature-based sounds and soothing images in adolescents [21]. Their study found that exposure to these stimuli led to a significant reduction in negative mood states, such as anxiety and depression, while increasing feelings of serenity. This aligns with Witten et al.'s (2023) exploration of how external, nature-based sensory stimuli can help improve emotional regulation. The integration of visual and auditory nature-based elements not only improves emotional well-being but can also be leveraged in embodied interaction designs to provide a holistic and calming sensory experience, particularly for individuals with heightened emotional dysregulation. These findings reinforce the potential of sensory experiences in shaping emotional responses and support the notion that integrating such stimuli into interactive systems could further enhance emotional engagement and psychological health.

2.1.2 Affective Computing and Non-Verbal Feedback

Affective computing explores how systems can recognize, interpret, and respond to human emotions. Traditional models have heavily relied on facial recognition, speech analysis, or active input [22]. However, emerging research supports the use of passive, sensor-based modalities — particularly tactile and acoustic feedback — to support emotional awareness and regulation.

In particular, ambient feedback through soft light, sound, or vibration has been shown to reduce anxiety and support emotional grounding in clinical and everyday settings [23]. These systems benefit from their non-intrusive design, enabling users to engage with emotional support tools in the background of daily life. This research adopts a similar logic, embedding non-verbal feedback within a tactile, stone-like form that supports subtle, momentary regulation.

2.2. Natural Relaxation and Therapeutic Effects

Nature-based interventions (NBIs) have shown considerable promise in enhancing emotional well-being and promoting psychological relaxation, particularly through exposure to natural environments such as forests [24]. Studies on Shinrin-yoku (forest bathing) have consistently demonstrated its therapeutic effects. For example, Morita et al. (2006) found that forest environments significantly reduced hostility, depression, and anxiety, while improving feelings of liveliness and overall well-being, especially for individuals under chronic stress. The psychological effects of shinrin-yoku are particularly noteworthy in that they are effective not only in reducing negative emotions but also in promoting a sense of relaxation and restorative mental states [25].

Building on these findings, a study by Muro et al. (2021) explored the psychological benefits of forest bathing in a Mediterranean context, noting significant reductions in anxiety and depressive moods, alongside increases in positive emotions such as vigour and mindfulness. These effects were robust, even amidst the stresses generated by the COVID-19 pandemic, suggesting that exposure to natural environments provides a reliable method for improving mental health outcomes, particularly for those in urban or highly stressful conditions [26].

The concept of restorative environments is central to understanding these effects. As articulated by Laumann et al. (2001), environments rich in natural stimuli allow individuals to experience a sense of "being away" from daily stressors, which is crucial for emotional recovery [27]. They also noted that environments fostering fascination—in which attention is naturally drawn to the environment—are particularly effective in reducing mental fatigue and promoting relaxation. These elements are also present in nature-based interventions, where individuals are encouraged to engage with the natural world in a manner that requires minimal cognitive effort but allows for significant emotional recovery.

Further supporting these ideas, research by Wilkie and Davinson (2021) in their scoping review on NBIs highlights that green spaces and forests consistently outperform urban environments in improving mood and reducing stress. This systematic review confirmed that nature-based interventions, particularly those incorporating outdoor settings, are highly effective in reducing psychological distress and enhancing emotional well-being [28]. In addition, studies on nature-based guided imagery have shown that even virtual exposure to nature or the use of nature-themed content can evoke similar therapeutic effects, enhancing relaxation and reducing anxiety, further extending the potential applications of nature-inspired interventions [29] [30].

These findings are consistent with the growing body of evidence supporting biophilic design principles, which aim to integrate nature-inspired elements into built environments to improve emotional health. The research suggests that interactive design systems, such as the stone-like system explored in this study, can provide similar restorative effects by incorporating symbolic representations of nature. By engaging the user's senses and facilitating moments of reflection, these systems can serve as effective tools for emotional relaxation and stress reduction, making them valuable additions to therapeutic and exhibition spaces.

2.3. Nature-Inspired Design and Biophilic Interfaces

2.3.1 Symbolic Use of Form and Materiality

Rather than employing actual natural materials, many interaction systems adopt symbolic natural forms to evoke emotional resonance. In this study, the stone is fabricated via 3D printing but retains the visual and tactile qualities of real stone — solidity, groundedness, and irregular texture — without emphasizing material authenticity. This approach aligns with the expressive logic of movements such as Mono-ha [12], which explores the perceptual power of natural forms in context.

From an HCI perspective, such symbolic representation can stimulate reflective attention and emotional anchoring without mimicking nature literally [31]. Xuanyi Wang et al. identify specific emotional outcomes linked to nature contact — such as calmness, awe, and satisfaction — and highlight the regulatory role of embodied engagement [10]. Thus, symbolic natural forms can function as emotional cues, especially when activated through multimodal feedback.

2.3.2 Emotional Effects of Material Qualities

Materiality mediates emotional states not just through physical sensation, but also through associative meaning. Natural textures and forms can redirect attention, lower arousal levels, and invite moments of reflection, as found in studies highlighting the restorative effects of nature in built environments. According to Gifford (1987), exposure to natural elements in design can reduce stress and promote psychological restoration, improving both emotional well-being and cognitive function [32]. Similarly, Beukeboom et al. (2012) emphasize that natural elements like indoor plants in hospital environments have significant stress-reducing effects, even when mediated through artificial representations such as posters, demonstrating that the perception of nature itself contributes substantially to well-being [33]. In environments like healthcare settings, where stress levels are elevated, adding elements of nature—whether real or artificial—can foster a sense of calm and improve patient satisfaction, as patients exposed to plants report lower stress levels and higher perceptions of environmental attractiveness.

Additionally, Hartmann et al. (2013) discuss how nature imagery in advertising can enhance cognitive processing and memory, supporting the broader impact of nature exposure on mental functioning. Their studies demonstrate that visual representations of nature in advertisements evoke emotional responses akin to those experienced in real natural environments, which in turn improve memory recall and recognition of advertising messages. These findings underscore the broader emotional and cognitive benefits of nature, aligning with the idea that interaction with natural elements—whether physical or through imagery—can bolster cognitive resources and emotional well-being [34].

In this research, the use of a stone-like object is not simply aesthetic but designed to offer affective neutrality and embodied emotional access. Its tactile presence is accompanied by responsive visual and auditory cues, which, as Beukeboom et al. (2012) note, are essential for enhancing the emotional engagement of users. The interplay between physical texture and multi-sensory feedback reinforces its function as an emotional anchor, promoting a grounding and reflective experience. Drawing from Gifford (1987), Hartmann et al. (2013), and Beukeboom et al. (2012), the presence of such tactile objects in daily life can be particularly impactful in offering both affective neutrality and a space for emotional recovery. These materials do not just provide a sensory experience but act as conduits for emotional regulation, supporting a dynamic of calmness amidst the pressures of daily life. Thus, the design of such objects in interactive spaces can effectively serve as a tool for emotional resilience, further emphasizing the power of materiality to influence psychological states.

2.4. Natural Stimuli in Emotional Regulation

2.4.1 Sound-Based Nature Exposure

Natural soundscapes — including birdsong, rain, and water — consistently demonstrate positive psychological effects such as reduced stress, increased attention, [35]and elevated mood. These effects are tied to activation of the parasympathetic nervous system and suppression of stress markers such as cortisol [36].

Michels et al. found that natural sounds can accelerate stress recovery after anxiety-inducing tasks [37]. Van Renterghem et al. further showed that birdsong can mask urban noise and enhance the subjective experience of city walking [38]. These results support the inclusion of ambient nature sounds in affective interaction systems, particularly those aiming to reduce background tension without requiring active user engagement.

2.4.2 Multisensory and Passive Interaction Benefits

While much research focuses on visual exposure to nature, recent studies emphasize that multisensory inputs—especially passive ones—can produce stronger or more sustained emotional effects. Witten et al. found that natural sounds and images each improved emotional well-being, but their combined use did not always produce additive effects, suggesting sensory thresholds or cognitive overload [19].

This indicates that in low-energy or overstimulated contexts, passive and single-modal sensory inputs—such as soft touch or ambient sound—may be more effective. Ulrich's foundational work on stress recovery confirms that even brief exposure to natural stimuli can significantly influence mood and cognitive clarity [39]. These findings collectively validate the system's emphasis on minimal-effort, tactile-anchored interaction layered with symbolic auditory and visual feedback.

In a study by Kohler et al. (2011), it was revealed that multisensory experiences—incorporating touch, sound, and visual stimuli—enhanced participants' emotional engagement in virtual environments [40]. They found that immersive environments that stimulate multiple senses can generate a greater sense of presence and enjoyment, increasing users' connection to the virtual space and making interactions feel more authentic and engaging. This is particularly relevant when designing environments where the goal is to promote relaxation and creative expression, as seen in virtual co-creation systems where the interaction is enriched through sensory feedback.

2.5. Nature-Inspired Interfaces and Experiential Installations

A number of interactive installations in recent years have explored the integration of natural symbolism, sensor-based feedback, and multi-sensory interaction. These works demonstrate how environmentally themed interfaces can evoke reflection and emotional response without relying on verbal or screen-based modalities.

Marco Barotti: *MOSS*

Marco Barotti's *MOSS* is a kinetic sound installation that visualizes real-time air quality data from cities including Seoul, Berlin, and Beijing. The system uses 10 species of living moss mounted on actuated structures. These forms contract and expand rhythmically in a manner analogous to breathing. Their motion and accompanying soundscape are directly controlled by local environmental data streams, allowing the audience to experience air pollution levels as embodied, sensory phenomena.

(Source: MOSS, https://www.marcobarotti.com/MOSS-1, Made by Marco Barotti)

Figure 2.1 Marco Barotti — MOSS(1)

(Source: MOSS, https://www.marcobarotti.com/MOSS-1, Made by Marco Barotti)

Figure 2.2 Marco Barotti — MOSS(2)

Marco Barotti: *Fungi*

In another work, *Fungi*, Barotti combines mycorrhizal fungal data with 3D-printed ceramic forms and sound-based data sonification. The installation draws from the concept of the "Wood Wide Web," representing underground fungal networks as an ambient, digital-physical sculpture. Through abstract organic forms and ambient audio, the work creates a metaphorical interface with microbial ecosystems.

Marco Barotti: *Clams*

Barotti's installation *Clams* presents shell-like robotic sculptures that react to water quality changes. The shells open and close in response to environmental sensors, accompanied by synchronized sound. The work emphasizes rhythm, sound, and mechanical response as a way to materialize hidden aquatic conditions.

(Source: Fungi, https://www.marcobarotti.com/Fungi, Made by Marco Barotti)

Figure 2.3 Marco Barotti — Fungi(1)

(Source: Fungi, https://www.marcobarotti.com/Fungi, Made by Marco Barotti)

Figure 2.4 Marco Barotti — Fungi(2)

(Source: Clams, https://www.marcobarotti.com/Clams, Made by Marco Barotti)

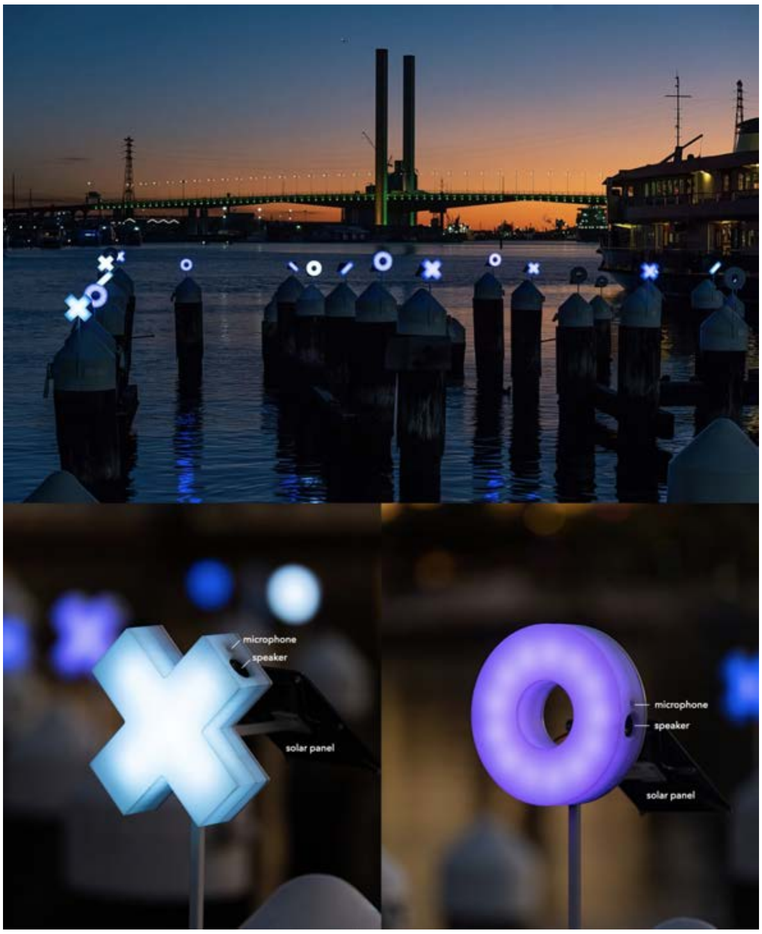
Figure 2.5 Marco Barotti — Clams(1)

(Source: Clams, https://www.marcobarotti.com/Clams, Made by Marco Barotti)

Figure 2.6 Marco Barotti — Clams(2)

Jon McCormack and Elliott Wilson: *Holon*

Holon is a sound installation by Jon McCormack and Elliott Wilson, located along Melbourne's Docklands. Multiple sound modules respond to real-time harbor data—such as tides, salinity, and temperature—by generating ambient, algorithmically composed soundscapes. The work transforms fluctuating marine conditions into a decentralized sonic experience, allowing the public to perceive environmental rhythms through sound rather than visual displays.



(Source: Holon, https://jonmccormack.info/project/holon, Made by Jon McCormack and Elliott Wilson)

Figure 2.7 Jon McCormack — Holon

Machine Hallucinations: Nature Dreams

Machine Hallucinations: Nature Dreams is an interactive art installation by Turkish-American artist Refik Anadol. The work explores the intersection of nature, machine learning, and human perception by using AI algorithms, such as DCGAN, PGAN, and StyleGAN, to generate surreal visual experiences. By training these algorithms on a large dataset of natural landscapes, Anadol creates dreamlike sequences that challenge the boundaries between human sensory experiences and machine-generated realities. Nature Dreams offers a digital reimagining of natural environments, inviting audiences to engage with AI's interpretation of nature in a visually immersive way.

(Source: Machine Hallucinations: Nature Dreams, https://refikanadol.com/works/machine-hallucinations-nature-dreams/, Made by Refik Anadol)

Figure 2.8 Refik Anadol — Machine Hallucinations: Nature Dreams

Sound Sculpture

Sound Sculpture is an interactive art installation by Masary Studios, located in various public spaces. This installation features a collection of dynamic sculptures that respond to human presence and movement by generating sound. The sculptures are equipped with sensors that detect nearby movement, triggering unique sound compositions based on the user's interactions. The work merges visual and auditory experiences, offering visitors an opportunity to engage with both the physical form of the sculptures and the auditory environment they create. By integrating motion-sensing technology and sound, Sound Sculpture invites the audience to explore the relationship between space, sound, and human interaction in a multisensory manner.

(Source: Unnatural Nature, https://www.masarystudios.com/sound-sculpture, Made by Masary Studios)

Figure 2.9 Masary Studios — Sound Sculpture(1)

(Source: Unnatural Nature, https://www.masarystudios.com/sound-sculpture, Made by Masary Studios)

Figure 2.10 Masary Studios — Sound Sculpture(2)

Shared Characteristics

These installations commonly integrate the following characteristics:

- **Symbolic Use of Natural Form:** Moss, fungi, shells, stones, and other organic metaphors are used to represent natural systems without replicating them literally. In this study, a 3D-printed stone form is adopted to convey similar symbolic qualities of groundedness and calm.
- **Ambient, Multisensory Feedback:** Most of the systems rely on non-verbal cues such as sound, motion, light, and tactile presence. The present system mirrors this approach by providing natural sound playback, emoji-based visual feedback, and ambient visual particle rendering.
- **Data-Driven or Sensor-Based Activation:** Several works respond to environmental data, while others rely on user proximity or touch. The proposed system utilizes capacitive touch sensing as a primary interaction mode.
- **Contextual Application in Experiential Settings:** These installations are typically situated in museums, art festivals, or public exhibitions. The current research proposes similar contexts of use, targeting emotional reflection and sensory engagement over functional utility.

This chapter synthesizes scholarship across HCI, affective computing, and environmental psychology. It provides a theoretical foundation for integrating tactile, symbolic, and sensory design elements into emotionally responsive systems for experiential contexts. The following chapter will introduce the concept design phase, focusing on the creation of a system that combines these elements to foster emotional engagement and well-being. Drawing from the insights discussed, the concept design will prioritize the use of multisensory interactions, including tactile feedback, auditory cues, and symbolic visual stimuli, to create an immersive and emotionally resonant experience. Building upon these design principles, the prototype development will focus on refining these concepts into a tangible, interactive system, capable of eliciting emotional responses in a variety of contexts, such as exhibition spaces. This prototype will serve as both a proof of concept and a tool for evaluating the efficacy of multisensory, low-effort interactions in promoting emotional regulation and cognitive clarity.

Chapter 3
Concept Design

This section will primarily focus on the first stage of the design process, which involves the development of the initial prototype. The first phase of prototyping includes material testing, form exploration, user research, and the integration of key sensory elements.

3.1. Preliminary User Research (Questionnaire and Interview-Based)

To inform the early stages of the concept design, a user research combining both questionnaire and interview methods was conducted to better understand participants' emotional stress profiles, sensory preferences, and expectations for nature-inspired interaction. The survey targeted individuals living in urban environments.

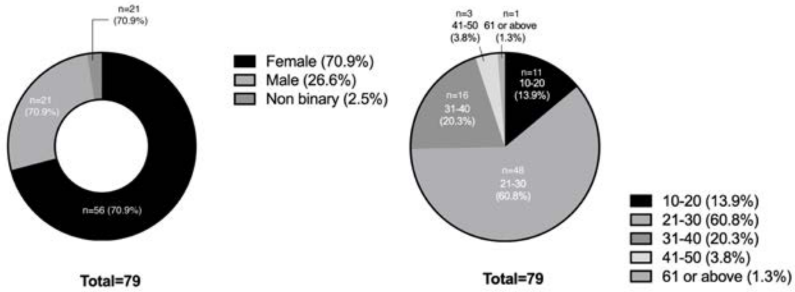


Figure 3.1 Demographic Distribution of Participants by Age and Gender

Preliminary User Research

Preliminary User Research

A total of 79 valid questionnaire and interview responses were gathered, and the data were subsequently integrated and analyzed for a comprehensive examination.

The majority of participants were aged between 21 and 30 (48 people), followed by those aged 31–40 (16 people). In terms of gender distribution, 56 participants identified as female. This demographic profile reflects a relatively young and gender-skewed user base, which may inform the target population for interaction design interventions.

Participants were asked to self-assess the frequency of stress they experience in daily life. A total of 45 participants reported feeling stressed either "very often" or "often," indicating a consistent presence of psychological pressure in their routines. This finding supports the relevance of developing unobtrusive, emotionally responsive tools for stress alleviation in everyday contexts.

Regarding personal strategies for stress relief, the most frequently selected activities were listening to music (55 participants), watching movies or entertainment (46), and walking in nature, such as parks, seaside, or forests (44). These preferences reveal a dominant tendency toward passive, sensory-based, and often solitary coping behaviors. Such patterns support the conceptual direction of the proposed system, which prioritizes low-effort, multisensory interaction inspired by natural elements to align with users' preferred stress relief habits.

To evaluate the role of tactile perception in daily life, participants were asked about their awareness of touch-related experiences. A combined total of 61 participants indicated they were either "very aware" or "somewhat aware" of tactile sensations, suggesting a widespread attentiveness to haptic stimuli. This supports the appropriateness of integrating touch as a primary interaction modality in emotionally oriented interface design.

Participants rated their level of enjoyment of activities such as hiking, forest walks, and listening to nature sounds. A total of 35 participants reported that they strongly enjoy nature-related experiences, and 24 indicated they enjoy these activities. This suggests a strong positive association with nature among the majority of participants, as most people are inclined to engage with nature when given the opportunity. These findings reinforce the idea that incorporating natural elements into design can have a profound impact on user well-being, particularly in environments like public spaces or workplaces. Given that many participants already appreciate nature experiences, it is likely that introducing nature-inspired elements (such as sounds or visuals) into user interfaces would resonate well with them and promote emotional well-being.

Auditory preferences for natural sounds were also surveyed in a multiple-choice question format, where participants could select up to three preferred sounds. The most frequently selected were birdsong (45 selections), rain (44), and wind (41), followed by insect sounds and garden ambiance. These results served as the basis for selecting the auditory cues implemented in the prototype, each linked to a corresponding touch-sensitive region.

Participants described the emotional associations they attached to tactile material qualities. Stone was frequently associated with the concept of "stability and grounding," while "softness" and "roughness" also appeared as recurring tactile descriptors. This aligns with prior findings that link natural textures to emotional regulation and further supports the selection of a stone-inspired form as the device's material metaphor.

With respect to visual form preferences, participants were asked to choose between abstract and naturalistic shapes. The majority favored organic forms such as stones, fruits, or branches. Among these, stone emerged as the most neutral and familiar, reinforcing its suitability for semi-public contexts where subtlety and discretion are necessary design considerations.

To assess perception of color-based visual feedback, participants were asked what impressions were evoked by the presence of soft green lighting. The responses predominantly included "plant growth," "energy flow," and "natural aura," indicating that the chosen visual aesthetic successfully conveyed biophilic qualities consistent with the project's design objectives.

Participants also rated their general liking for nature-related interaction. A total of 75 participants responded with a score of 3 or higher on a 5-point Likert scale, indicating an overall favorable disposition toward interactive systems grounded in natural metaphors.

When asked whether they had previous experience using digital tools specifically intended for emotional relaxation, 59 participants responded negatively. This suggests that nature-based, tactile systems remain undsponses. Auditory feedback, such as nature sounds like rain and birdsong, was selected by 62 participants, while tactile feedback was chosen by 61 participants. Visual feedback, including lighting and animations, was selected by fewer participants. This preference pattern indicates that a combination of auditory and tactile responses is likely to be the most effective approach for creating an emotionally supportive interaction design.

Finally, participants were asked about their professional or academic background. A total of 49 participants indicated that they were not engaged in fields related to media, technology, or design. This distribution implies that the sample was composed largely of general users, rather than individuals with specialized knowledge in interactive systems, thus increasing the generalizability of the findings.

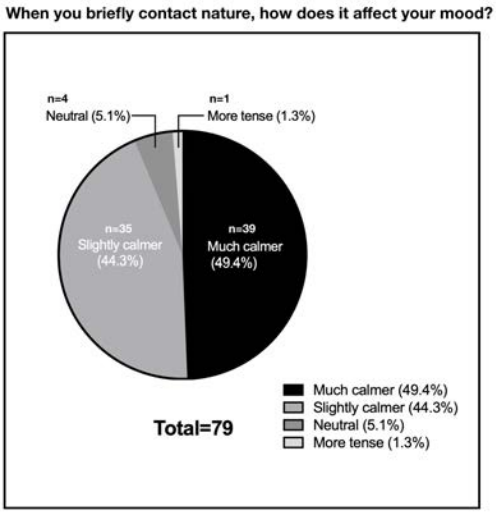


Figure 3.2 (a) Stress Frequency

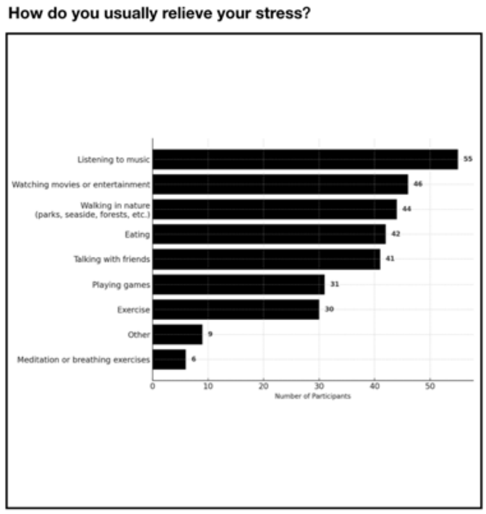


Figure 3.3 (b) Stress Relief Strategies

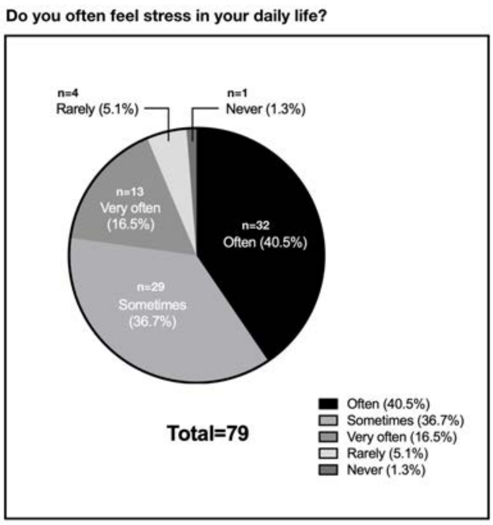


Figure 3.4 (c) Emotional Impact of Nature

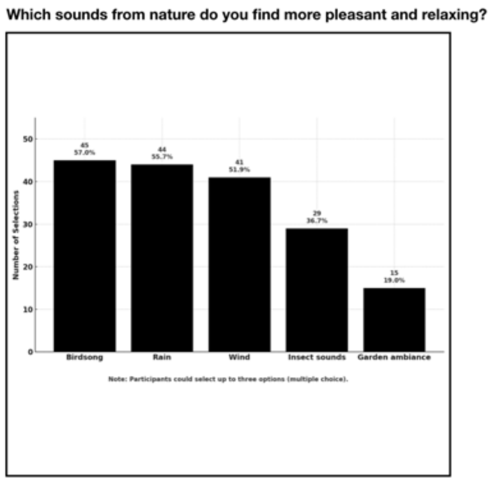


Figure 3.5 (d) Preferred Natural Sounds

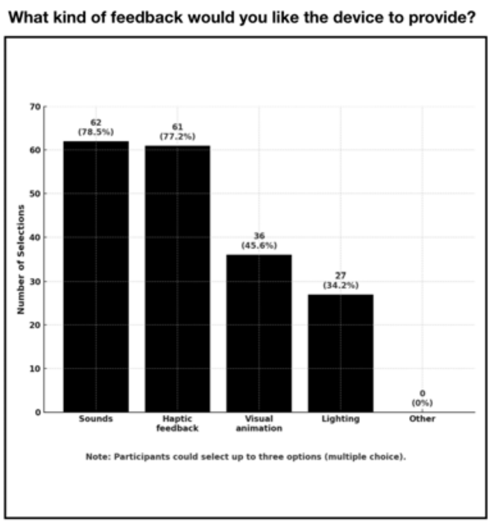


Figure 3.6 (e) Preferred Feedback Types

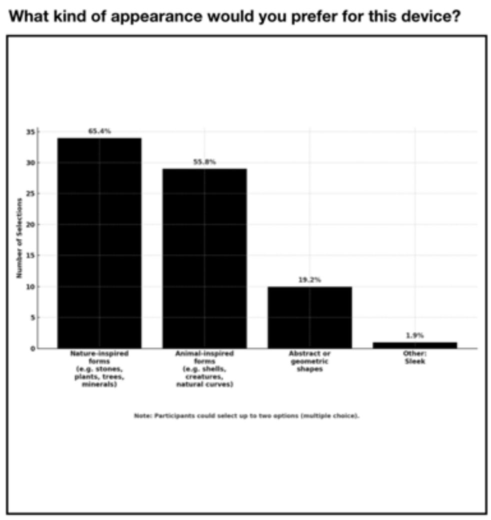


Figure 3.7 (f) Preferred Visual Form

In summary, the preliminary survey provided foundational insights into the emotional needs, sensory preferences, and interaction expectations of urban users. The results emphasized a clear demand for stress-relief experiences that are non-intrusive, sensory-rich, and symbolically grounded in nature. Strong associations with tactile awareness, natural sounds, and organic forms - particularly stone - validate the direction of designing a touch-based interaction system that is based on nature synergistic interactions. These findings directly informed the integration of stone-like textures, ambient natural audio, and minimal visual cues in the proposed prototype. Furthermore, the limited prior exposure to similar systems suggests an opportunity to introduce novel, embodied modalities for emotional regulation within semi-public or transitional settings such as lounges, open offices, or immersive environments like museums, interactive experience centers, and theme parks such as Disney.

3.2. Design Approach

3.2.1 Phase 1 Prototype: Real-Stone Touch Interface

The initial design exploration of the Phase 1 prototype focused on integrating interactive technology into a real stone.

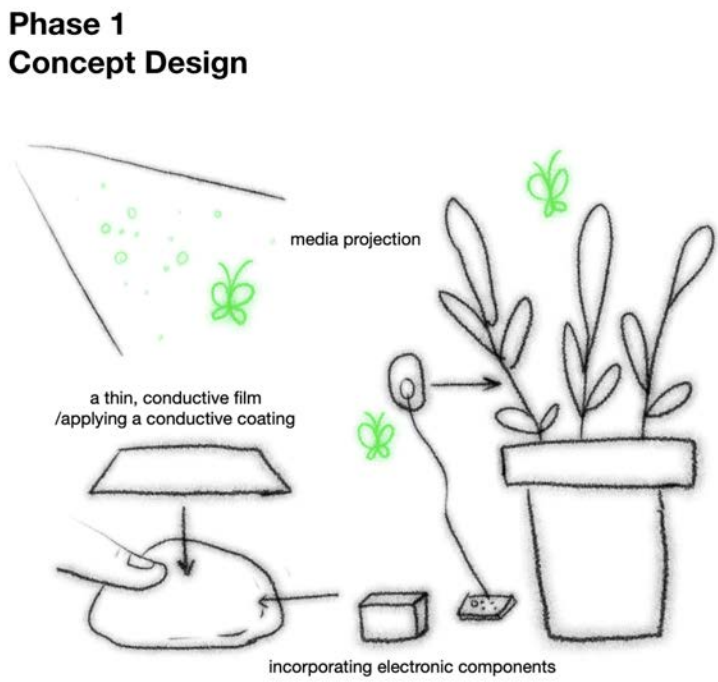


Figure 3.8 Concept Design of the Phase 1 Prototype

This approach aimed to investigate the feasibility of creating an emotionally resonant, materially authentic interface using natural elements. A hollowed-out stone was prepared by manually carving its interior to house a light strip, Arduino-based touch sensor circuit, and connecting wires. Capacitive sensing was enabled using copper foil affixed to the inner surface of the stone, while aluminum foil was applied beneath the stone's external surface to function as the touch-conductive layer. When touched, the stone would illuminate, and a connected computer would simultaneously play corresponding audio feedback.

Figure 3.9 Early Prototype in Maker Faire Tokyo 2024(1)

Figure 3.10 Early Prototype in Maker Faire Tokyo 2024(2)

This prototype was exhibited at the Maker Faire Tokyo(September 21, 2024) and received feedback from a diverse audience. Several technical limitations were observed:

- The physical thickness of the stone surface required careful balancing; if polished too thin, the stone became fragile.
- The copper foil exhibited poor adhesion on the irregular interior surfaces and often detached during repeated use.
- The uneven underside of the stone resulted in instability under pressure, occasionally dislodging internal components. This was temporarily resolved using paper stuffing to anchor elements.
- Users had difficulty locating the touch-sensitive zones. Suggestions included increasing the active touch area or embedding visual indicators at the touch points.
- A noticeable delay in the sound response, compounded by low volume output from the computer, negatively impacted the interaction quality. Incorporating onboard audio output via internal speakers was proposed.

From a design perspective, further enhancements were considered, including the replacement of copper foil with formal capacitive touch sensors, the introduction of programmable sound or visual feedback, and possibly integrating all systems into a Raspberry Pi to enable self-contained operation. Feedback also generated key behavioral insights. Participants were particularly drawn to the stone's natural materiality and often inquired about its geological origin. The system's interactive surprise moment evoked initial delight but offered limited replay value due to its simplicity. Notably, several users attempted to touch multiple stones simultaneously or requested broader interaction areas, prompting consideration of multi-zone composite designs.

Based on this experience, these limitations motivated a transition to 3D-printed synthetic forms. This shift enabled greater control over internal structure, surface texture, and sensor positioning while preserving the symbolic and visual qualities of stone. The following sections describe the resulting system's refinement through iterative prototyping and multimodal feedback design.

Chapter 4
AuraStone

4.1. Introduction of Phase 2 Prototype: AuraStone

AuraStone is a tactile, stone-shaped interactive object designed to support stress relief and emotional grounding in everyday environments. Inspired by the quiet strength and stability of natural stones, the device invites calm, contemplative interaction through simple physical contact. When touched, it responds with multisensory feedback—natural soundscapes, ambient lighting, and brief nature imagery displayed on a nearby screen.

The solid form, cool texture, and grounded appearance of the object allow it to integrate seamlessly into personal spaces such as desks or shelves. In its idle state, AuraStone remains quietly present, resembling an ordinary stone—unobtrusive yet reassuring. Upon engagement, it offers a momentary sensory pause, helping users reconnect with a sense of natural rhythm and inner calm without demanding attention or interpretation.

This design explores how a symbolic, nature-inspired object can facilitate emotional regulation through intuitive, low-effort interaction. By combining tactile input with synchronized audio-visual output, AuraStone serves as both a material anchor and a point of comparison for evaluating how embodied interfaces differ from conventional input devices in their emotional impact.

4.2. Concept and Visual Ideation

The 3D-printed version of the interactive tactile stone was conceived to overcome the physical and structural constraints of natural stone while maintaining its sym-

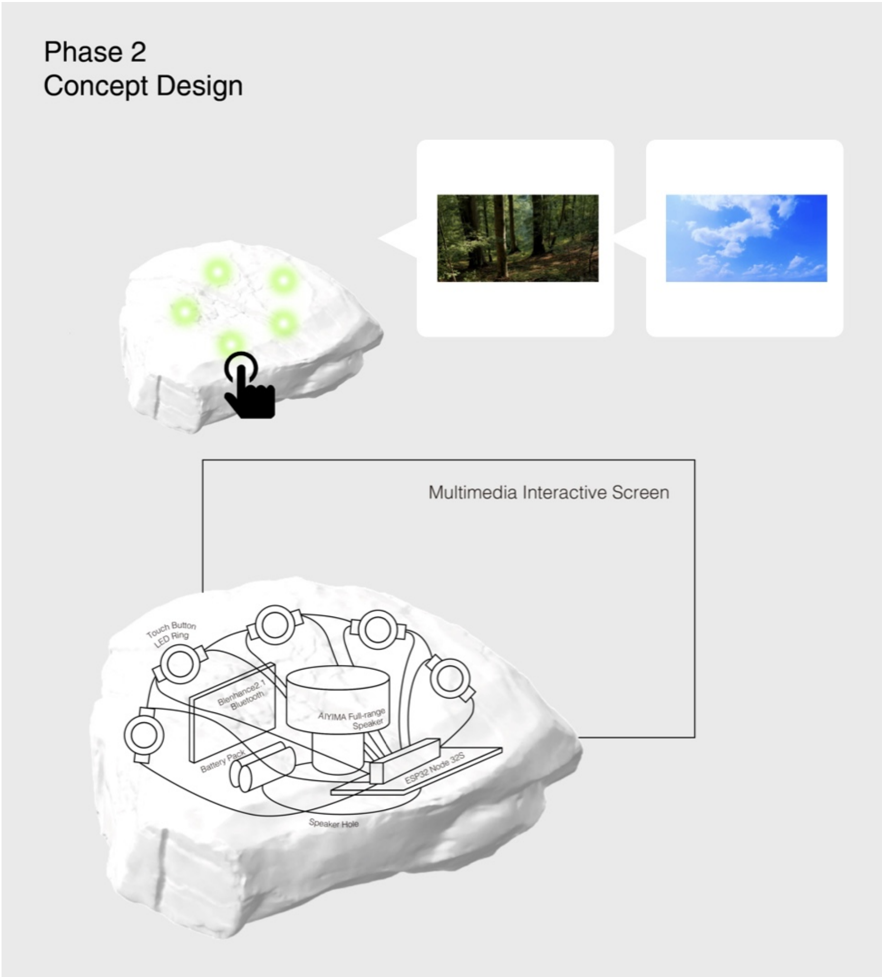


Figure 4.1 Concept Design of AuraStone System

bolic grounding. Initial concept sketches explored various naturalistic silhouettes (e.g., pebbles, river rocks) and abstract organic forms, seeking an ergonomic balance between familiarity and subtlety. The final design featured a oval shape with soft curvature, intended for stationary placement on shared surfaces.

To convey its ambient character and ensure universal appeal, the device avoids overt display or screen-based interfaces. Instead, all interactions are mediated through tactile engagement, synchronized sound, light, and symbolic visual output. The printed shell includes five subtle convex buttons that integrate seamlessly into the stone's texture and layout.

4.3. Hardware System

The hardware system was developed to support a tactile, low-cognitive-load interaction experience grounded in natural metaphors. Based on feedback from early user testing and the practical challenges encountered in the real-stone prototype, a 3D-printed shell was adopted to enable precise sensor placement and component integration. The final hardware configuration consists of capacitive touch inputs, ambient LED feedback, embedded sound playback, and Bluetooth-based emoji transmission, all powered through a stable 12V DC system. Figure 4.3 illustrates the key modules.

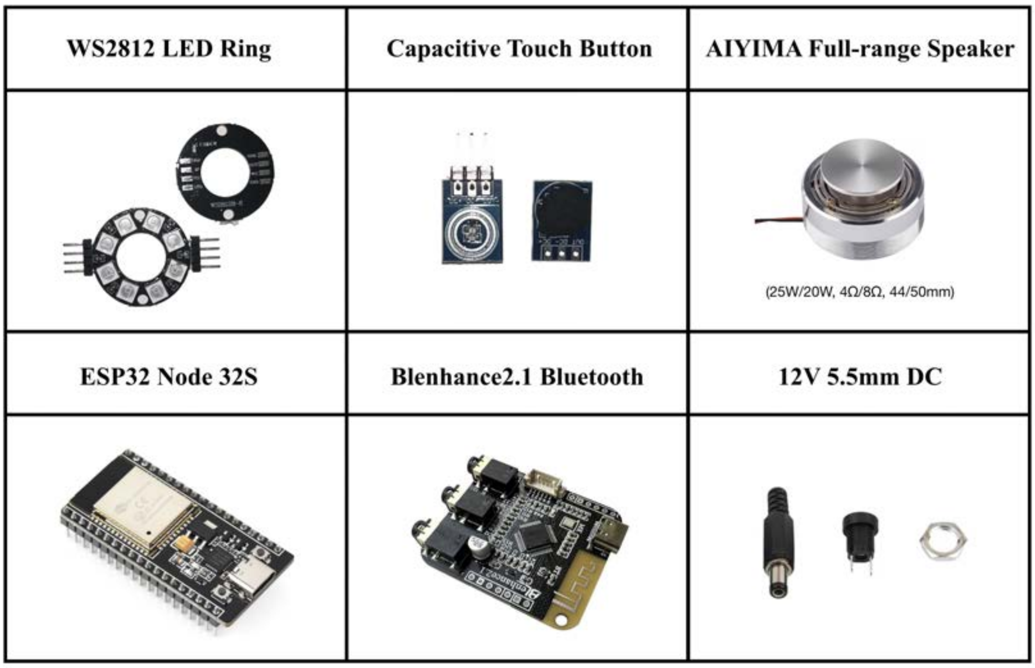


Figure 4.2 Key Modules

Sensor Integration and Interaction Mapping

The system utilizes five capacitive touch sensors embedded beneath the 3D-printed shell. Each sensor defines a discrete interaction zone and is calibrated to detect light touch through the surface. The ESP32 Node 32S microcontroller is responsible for signal processing and mapping input to feedback modules. Internal supports and insulation layers maintain the structural stability of sensor placement.

Lighting and Actuation

Each touch zone is surrounded by a WS2812 RGB LED ring programmed to emit a green, breathing-like glow. When touched, the corresponding ring gently pulses brighter, providing a calming, life-like signal that reinforces tactile interaction. The use of flowing green light reflects user preference data gathered during preliminary studies.

Audio Output and Embedded Speaker

An AIYIMA full-range speaker is enclosed within the body to produce high-fidelity natural sounds. Each touch zone triggers a unique ambient sound loop, such as birdsong, wind, or rain. This embedded audio element enhances the multisensory feedback without relying on external hardware.

Wireless Control and Connectivity

A blenhance2.1 Bluetooth module enables dual-mode operation: it transmits sound to nearby devices and functions as a Bluetooth keyboard. When a user touches the interface, a randomly selected emoji from a pre-defined group is sent to a connected display via simulated keypress. This symbolic output adds narrative playfulness while preserving discretion.

Microphone Input and Future Expansion

The system includes an onboard microphone that is currently inactive but reserved for future development. Potential extensions include environmental sound responsiveness or breathing rhythm detection, allowing for expanded interaction modes.

Power Supply Integration

To provide consistent power across components, a 12V 5.5mm DC socket is installed at the base. This standard interface supports reliable desktop or exhibition deployment without requiring battery management, and allows the device to operate continuously in long-duration public installations.

4.3.1 3D-Printed Shell Fabrication

The physical shell of the interactive stone was produced using 3D printing to allow for customizable internal structure, consistent surface finish, and reliable sensor embedding. Two versions were fabricated for comparative evaluation:

- **Version A**: Printed with a 0.3 mm layer height (coarser surface)
- **Version B**: Printed with a 0.12 mm layer height (smoother surface)

Figure 4.3 Two Versions of 3D-Printed Shell

User survey results from the preliminary questionnaire indicated a strong preference for smoother textures when interacting with touch-based interfaces. Based on this feedback, Version B (0.12 mm) was selected for final use, as its refined surface more closely resembles polished stone and enhances the tactile experience.

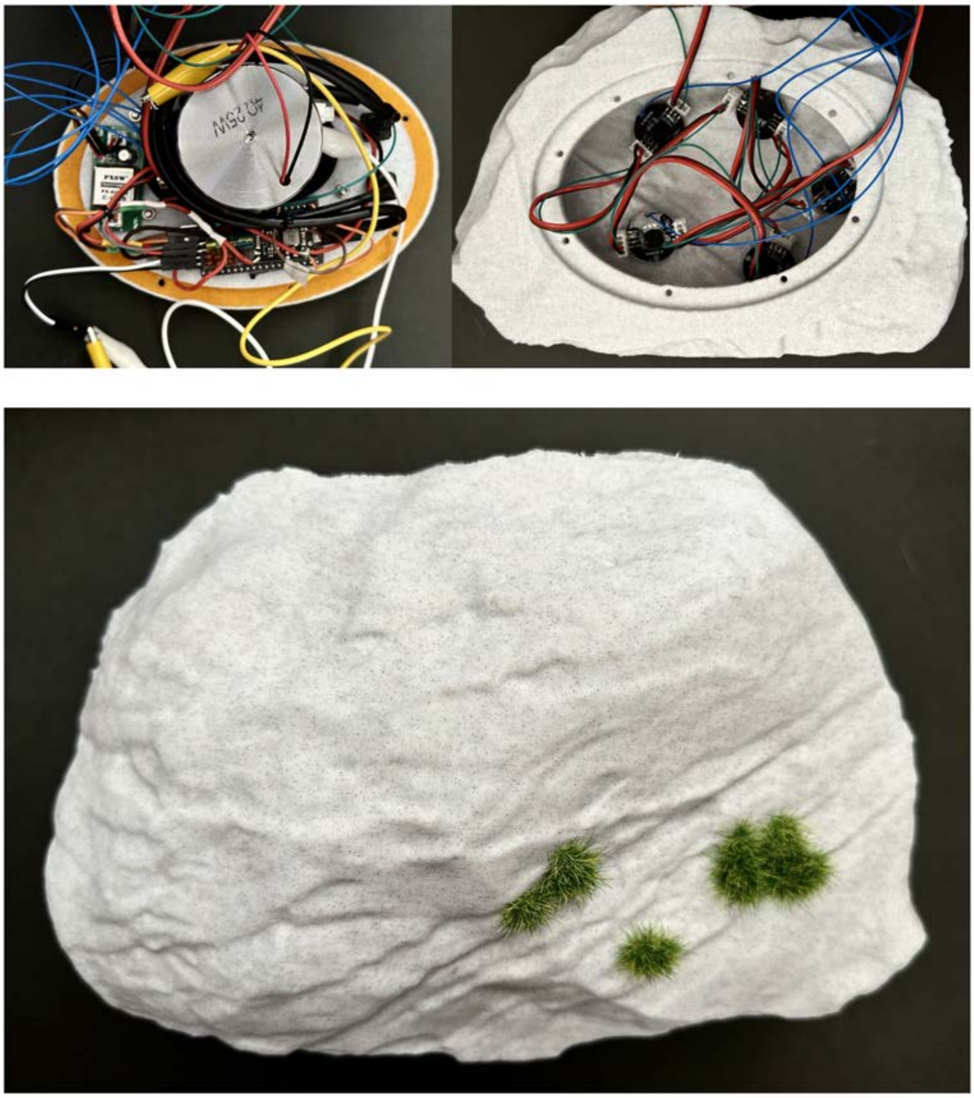


Figure 4.4 Internal Structure and External Presentation of the Device

4.4. Software Design

This chapter describes the software system that enables multisensory interaction through tactile input, nature sound playback, and visual feedback. The design focuses on offering ambient, non-verbal, and emotionally restorative experiences that align with the goals of calming presence and low-effort interaction in daily settings.

4.4.1 System Architecture

The AuraStone system architecture integrates tactile sensing, auditory-visual output, microcontroller coordination, and ambient visualization into a seamless emotional feedback experience. Figure 4.5 illustrates the key hardware and software components of the system and their interconnections.

- **Touch Input Layer:** The device features five capacitive touch zones embedded beneath the stone surface, each connected to a dedicated GPIO pin on the ESP32 Node 32S microcontroller. These sensors detect finger presses or sustained contact and initiate feedback routines.
- **Microcontroller and Control Logic:** The ESP32 Node 32S acts as the system's central controller. It continuously monitors input signals and triggers a combination of audio, video, and LED outputs in response to tactile activation. It also handles serial communication to an external computer.
- **Audio Output:** A compact AIYIMA speaker is embedded within the base of the device. Upon touch, one of five curated natural soundscapes (e.g., forest, sky, meadow, water, flower) is played back to reinforce the emotional theme.
- **Visual Output (Video):** Touch input also triggers one of five corresponding short nature video clips displayed on a connected screen. These video files are preloaded and rendered using a Processing script running on the paired laptop.
- **LED Feedback:** WS2812 addressable LED rings are embedded around each touch zone. They remain off in standby mode and gently pulse green

when a touch is detected, creating a calm and immediate visual response without distracting ambient glow when inactive.

- **Ambient Visualization (Optional):** An external webcam, linked to TouchDesigner, detects motion and creates generative particle-based mist or wave animations. This visual aura reacts subtly to user movement during interaction, complementing the calm experience.

This modular structure allows for flexible adjustments in hardware or media output, supporting future expansion such as adaptive soundscapes or physiological sensing. By limiting default activity and requiring touch activation, the system aligns with the project's goal of encouraging calm, intentional interaction within ordinary environments.

4.4.2 Rationale for Audio-Visual Feedback Selection

To support the emotional grounding of the tactile interaction system, a set of nature-inspired visual materials—such as forest, sky, and water scenes—was selected to accompany the sensory output of the device. These visuals serve to reinforce the calming effect of natural sounds and enhance the immersive quality of the interaction, as discussed in detail in Section 2.2.

Rather than abstract or symbolic imagery, this study emphasizes the use of realistic, photographic representations of natural elements—including forests, open fields, grassy meadows, water surfaces, skies, flowers, and animals—as these have been shown to offer consistent and measurable psychological benefits [34] [33].

Selected scenes include:

- Blooming Flower
- Green Forest
- Sunflower Meadow
- Clouded Sky
- Water Ripples

Figure 4.5 System Architecture of AuraStone

The selection of these image categories is grounded in empirical findings from two key studies. Brown et al. (2013) demonstrated that viewing natural scenes composed of trees, grass, and open landscapes can significantly enhance parasympathetic nervous system activity (HRV) after stress exposure, suggesting their potential to aid in physiological recovery. In their controlled laboratory setup, such natural scenes outperformed urban images in fostering self-regulation and emotional calmness even when viewed passively prior to stress onset [41].

Complementing this, Witten et al. (2023) evaluated a broader range of nature-related visuals using a large sample and found that images featuring water, forests, flowers, trees, and animals** all contributed to reduced negative affect and depressive mood, alongside increased serenity and feelings of being soothed. Their study used stimuli from Project Soothe's validated database, reinforcing the therapeutic potential of these specific categories. Interestingly, participants with higher baseline anxiety or depression showed greater emotional improvement from these nature-based stimuli, indicating a possible accessibility advantage for users in heightened emotional states [19].

These findings align directly with the aims of this research, which seeks to offer a non-verbal, sensory-based interface for momentary emotional regulation in everyday spaces. By incorporating nature imagery that has been proven to activate the "soothing system" (Gilbert, 2009), the interface aims to create a restorative micro-environment—one that quietly resonates with the user's emotional needs without requiring verbal expression or cognitive effort. The selection of these image types is not only aesthetic but functionally grounded in empirical evidence of their stress-buffering and emotional restorative capacities [42].

4.4.3 Media Attribution and Copyright Information

Figure 4.6 Nature Video Sources

Table 4.1 Nature Video Sources and Copyright Information

Video Scene	**File Name**	**Source URL**	**Copyright Holder**
Blooming Flower	flower.mp4	`https://youtu.be/aS-LUW5Jim0?si=ad5akgsjQ8dB2s50`	Cat Trumpet, 2019
Green Forest	forest.mp4	`https://youtu.be/FxAgAyZYXJ8?si=eZ5oKE7yUcql9yIA`	Petar Paunchev, 2021
Sunflower Meadow	meadow.mp4	`https://youtu.be/ipf7ifVSeDU?si=szH7Wy4--hQSz853`	Calmed by Nature, 2020
Clouded Sky	sky.mp4	`https://youtu.be/0_jNjpVxUt0?si=QHGEo5EGcCpTg50S`	Jakobsmeyer Visual Media, 2011
Water Ripples	water.mp4	`https://youtu.be/IvjMgVS6kng?si=-x0vBucIrEthl8T2`	Petar Paunchev, 2014

4.4.4 System Usage Flow

The following steps describe how users interact with the device in a typical everyday setting:

Step 1: Ambient Inactivity
When idle, the device resembles a natural stone—solid, stable, and lightless. It rests quietly on a desk or shelf, blending into the environment and contributing to visual calm without requesting attention. There is no light, sound, or movement.

Step 2: Tactile Activation
When a user touches any of the five tactile zones, the device lights up and initiates a sound and video pairing. A natural ambient audio clip plays through the speaker, while a short matching video is shown on a nearby screen. The corresponding LED zone glows softly during activation.

Step 3: Self-Fading Feedback
After a brief duration (approx. 15–30 seconds), the sound and video fade out, and the LED returns to an inactive state. The system automatically resets, requiring no user input to continue or exit.

This interaction model prioritizes low effort, subtle stimulation, and symbolic grounding through material and audiovisual metaphors. It allows the device to function as both a calming environmental object and a minimal affective support tool.

Chapter 5
Experimental Design

5.1. Experiment Setup and Tools

The aim of this experiment was to investigate the emotional resonance and symbolic perception elicited by a multisensory stone interface, in comparison with a conventional keyboard-based input. Specifically, this study was designed to address the following research questions:

- **RQ1:** How does the tactile stone interface influence users' emotional states compared to conventional interaction methods?
- **RQ2:** Can the stone interface support symbolic and affective interpretation beyond its functional role?

To answer these questions, a controlled user study was conducted involving 14 participants. The study employed a combination of post-interaction questionnaires, observational protocols, and behavioral reflection sheets. The purpose was to assess participants' emotional responses, perceived symbolic meanings, and the overall affective impact of the stone interface, with a direct comparison to a standard keyboard-based input system.

5.1.1 System Components

Two interactive systems were placed on a desk side-by-side: a standard computer keyboard and a custom-designed 3D-printed stone device. The keyboard was configured so that keys 1–5 each triggered a pre-assigned natural video with audio. The same five videos were also mapped to the five capacitive touch zones embedded in the stone device. Both systems were synchronized to deliver identical audiovisual feedback upon input.

The stone device featured a matte-surfaced organic form with embedded capacitive sensors connected to an Arduino board. Touch activation triggered the corresponding nature video and sound on screen, accompanied by subtle green ambient lighting around the button area. The stone remained visually quiet and unlit when idle, reinforcing its presence as a non-intrusive, grounding element.

5.1.2 Observation Tools and Reflection Sheets

During each session, facilitators observed and recorded participants' interactions using a structured checklist. Behavioral indicators included hesitation, hand position shifts, interaction duration, and spontaneous verbal expressions. In addition, facilitators completed reflection sheets after each session to note emotional cues, signs of engagement, or moments of confusion. These qualitative tools provided deeper context to complement quantitative data from the post-interaction questionnaire.

5.2. Procedure

5.2.1 Interaction Task Flow

Participants (aged 20–25) were invited individually into a quiet office or meeting room. After reviewing and signing the consent form, they were introduced to both the keyboard and the stone system placed on a desk. No information about the research purpose was revealed in advance to avoid bias.

Each participant was asked to conduct two rounds of interaction:

1. **Round 1:** Use the keyboard keys 1–5 to play five different nature scenes, as described in Section 4.4.3.

2. **Round 2:** Use the corresponding five touch zones on the stone device to play the exact same scenes.

Both rounds were completed in silence without guidance, allowing for natural interaction. After completing both interactions, participants filled out a detailed questionnaire assessing usability, emotional response, and symbolic impressions of

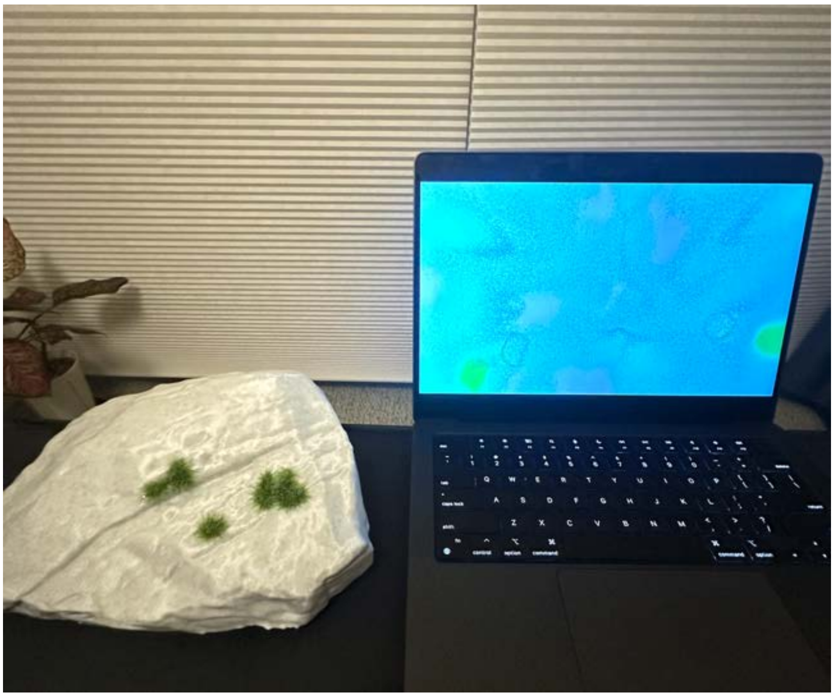


Figure 5.1 Experiment Setup

each device. The session concluded with a short post-test interview and reflection by the facilitator.

This structured procedure enabled a direct emotional and symbolic comparison between traditional and tactile multisensory interfaces in a controlled, ecologically relevant context.

5.2.2 Participants

A total of 14 participants (12 female, 2 male), aged between 22 and 34, took part in this study. All participants reported normal or corrected-to-normal vision and no known tactile or auditory impairments. Recruitment was conducted through university bulletin boards and online platforms, targeting individuals accustomed to daily use of digital interfaces such as keyboards and smartphones. Participants were not informed of the study's specific hypotheses to minimize priming effects.

Each participant completed a comparative interaction task involving two interfaces: a standard keyboard and a custom-designed tactile stone device. The

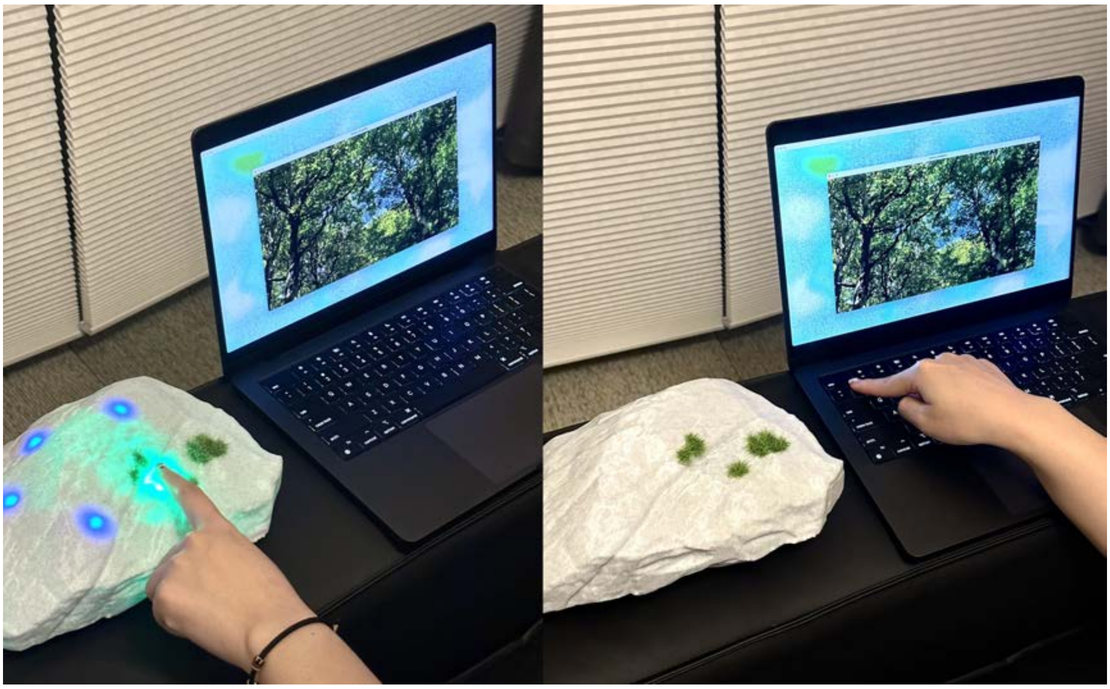


Figure 5.2 photo from the user study showing the participant interacting with the AuraStone and the keyboard(1)

task involved triggering nature-themed audiovisual content using each interface, followed by a structured feedback session. Participants rated their emotional responses, symbolic interpretations, and perceived practicality of both interfaces through a mixed-format questionnaire including multiple-choice, linear scale, and environment-preference items.

This multi-angle approach enabled a layered understanding of emotional resonance, usability expectations, and symbolic framing, particularly in relation to the contrast between conventional digital devices and nature-inspired tactile artifacts. Results from this session are presented in the following section.

Figure 5.3 photo from the user study showing the participant interacting with the AuraStone and the keyboard(2)

5.2.3 Post-Interaction User Evaluation

To further evaluate the emotional resonance and perceived meaning of the two interfaces, participants ($n = 14$) were asked to rate their affective impressions and symbolic associations after interaction.

Emotional Effect of Tactile Quality

When prompted to reflect on the emotional effect of the tactile quality of the stone, a majority of participants ($n = 8$, 57.1%) described the experience as "grounding," while $n = 4$ (28.6%) reported a "calming" effect, and $n = 2$ (14.3%) noted it was "slightly calming." No participants selected "no emotional effect" or "strongly grounding," suggesting that the tactile material evoked consistent, moderately positive emotional responses without overwhelming intensity. This pattern indicates the stone's tactile design effectively conveyed a sense of emotional stability and physical grounding.

Symbolic Categorization of Interfaces

Symbolic perception of the device diverged notably between the two interfaces. When describing the **keyboard**, $n = 10$ participants (71.4%) categorized it as a "digital tool," and $n = 4$ (28.6%) viewed it as a "neutral object." None identified it as an "emotional interface," confirming its conventional and emotionally disengaged role in comparison.

In contrast, the **stone device** was perceived with more affective and symbolic depth. A majority ($n = 8$, 57.1%) perceived it as a "relaxing interface," while $n = 5$ (35.7%) described it as a "symbolic item." Only $n = 1$ participant (7.1%) viewed it as a "digital tool," and none selected "decorative object." These results suggest that the stone successfully transcended mere functionality, being received instead as both a calming interface and a metaphor-laden object, aligned with its natural form factor and multisensory feedback.

Emotional Resonance Comparison

When asked which interaction felt more **emotionally resonant** on a 5-point linear scale (1 = Keyboard, 5 = Stone), the distribution strongly favored the stone: $n = 10$ (71.4%) selected 4, and $n = 3$ (21.4%) chose 5. Only one participant ($n = 1$, 7.1%) chose 2, and no participant selected 1 or 3. This trend indicates a high degree of affective alignment with the stone-based interaction.

Perceived Support for Emotional Regulation

In terms of **emotional self-regulation**, the difference was even more pronounced. When directly asked which interface better supported emotional regulation, $n = 12$ (85.7%) chose the stone, while only $n = 2$ (14.3%) selected the keyboard. This reinforces the stone device's potential as a tool for momentary emotional adjustment.

Suitability for Daily Use

Regarding **daily use potential**, responses showed a modest tilt toward the stone interface. On the same 5-point scale (1 = Keyboard, 5 = Stone), $n = 6$ (42.9%) selected 4, $n = 4$ (28.6%) chose 2, and $n = 2$ (14.3%) picked 1 and 3 respectively. No participants rated the stone as a strong "5" for daily suitability, suggesting that while the stone is emotionally resonant, its long-term practicality may benefit from further ergonomic or contextual refinement.

Preferred Usage Context

Participants were also asked about their **preferred usage context** for the stone device. Responses were evenly distributed between "Home" and "Office" ($n = 5$ each, 35.7%), followed by "Break area" ($n = 3$, 21.4%) and "Public exhibition" ($n = 1$, 7.1%). These preferences indicate the stone is well-suited for semi-private or transitional spaces where subtle emotional support is desirable.

Summary

Overall, these findings confirm the symbolic and emotional value of the stone interface. While the keyboard was perceived as a conventional, emotionally neutral tool, the stone emerged as a meaningful, calming object with strong emotional resonance. This divergence underscores the relevance of material, form, and metaphor in designing emotionally responsive systems.

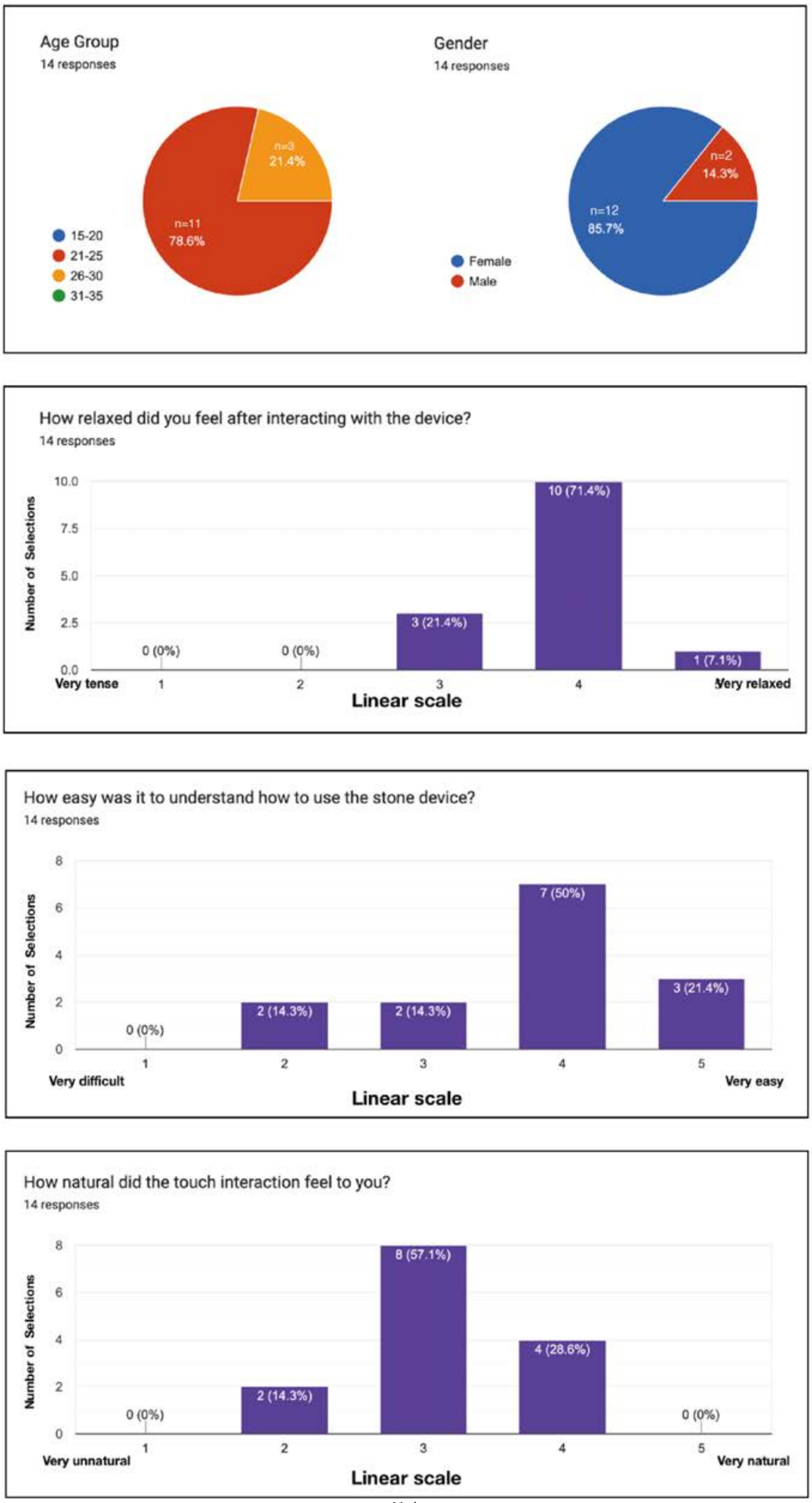


Figure 5.4 Post-Interaction User Evaluation

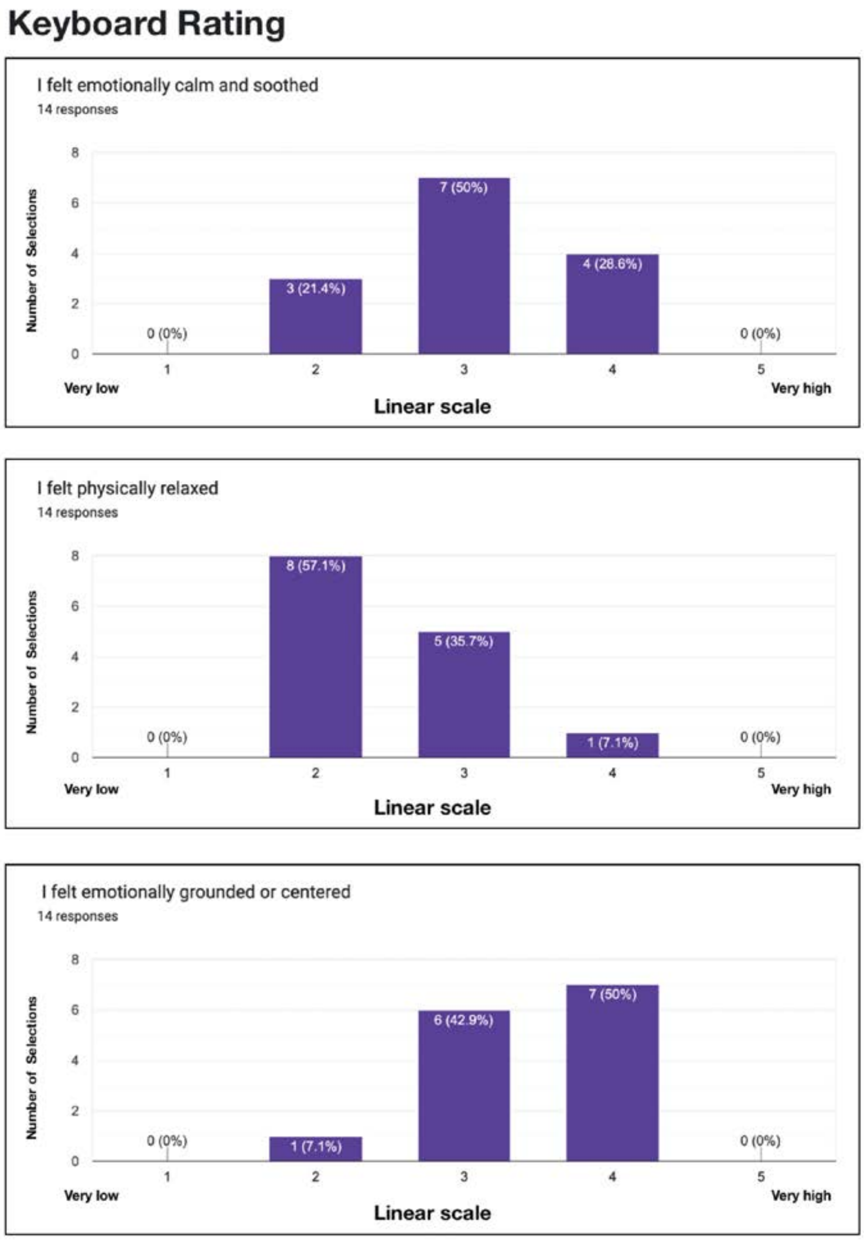


Figure 5.5 Post-Interaction User Evaluation-Keyboard Rating (1)

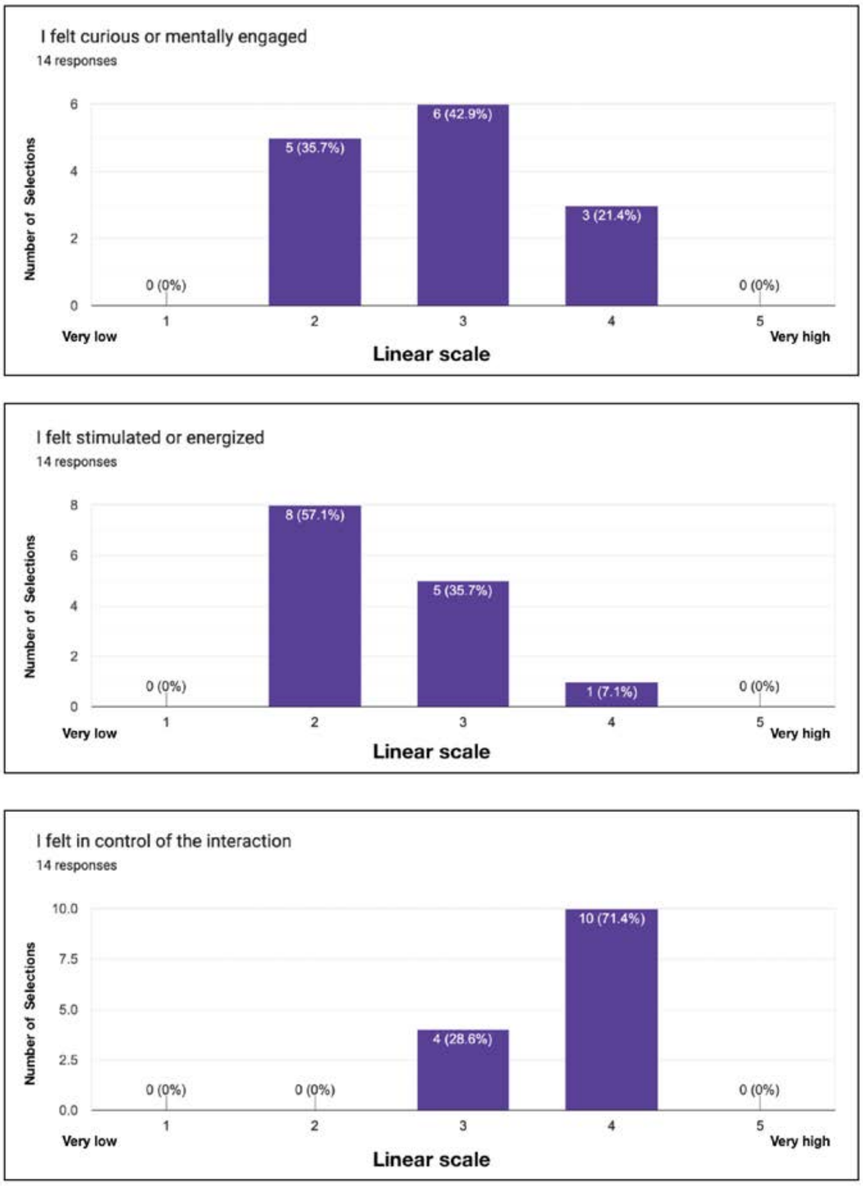


Figure 5.6 Post-Interaction User Evaluation-Keyboard Rating (2)

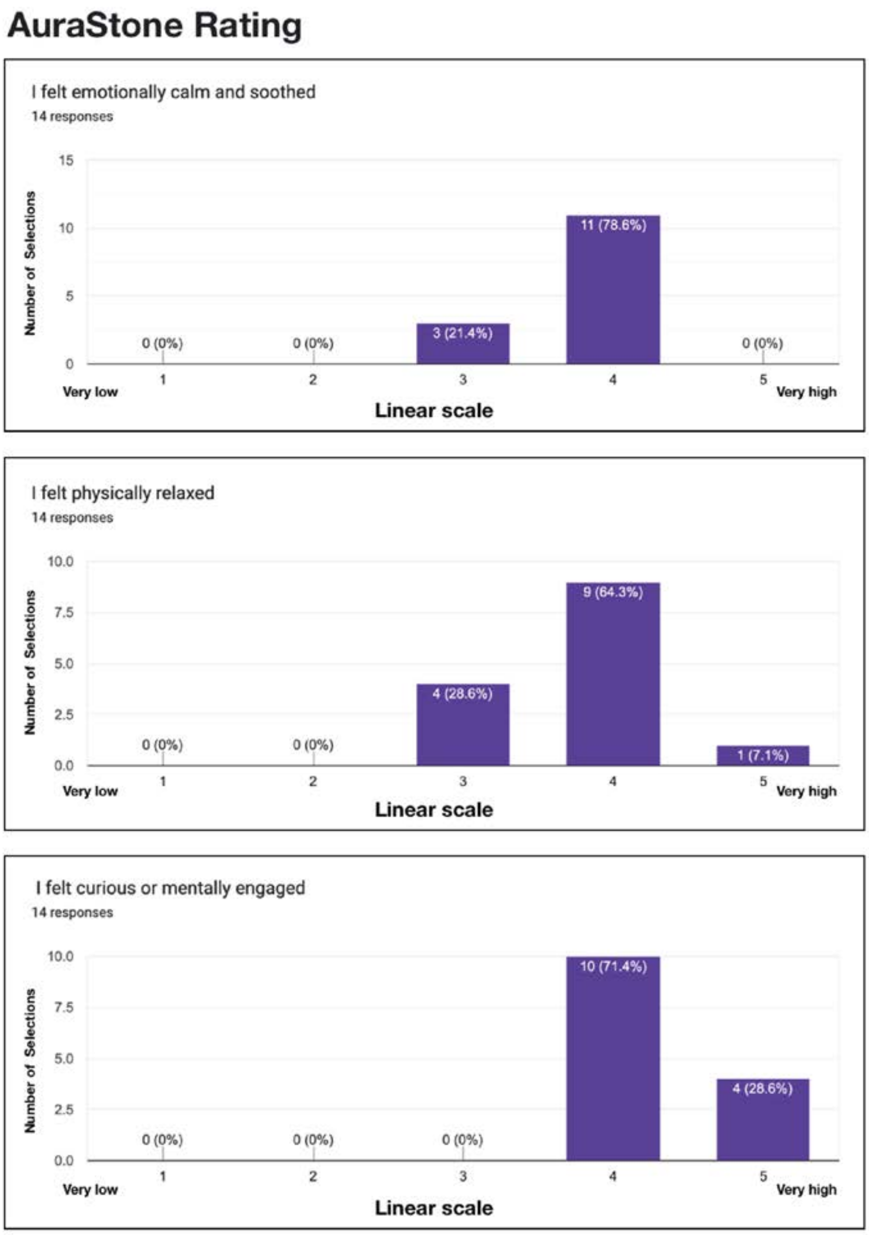


Figure 5.7 Post-Interaction User Evaluation-AuraStone Rating (1)

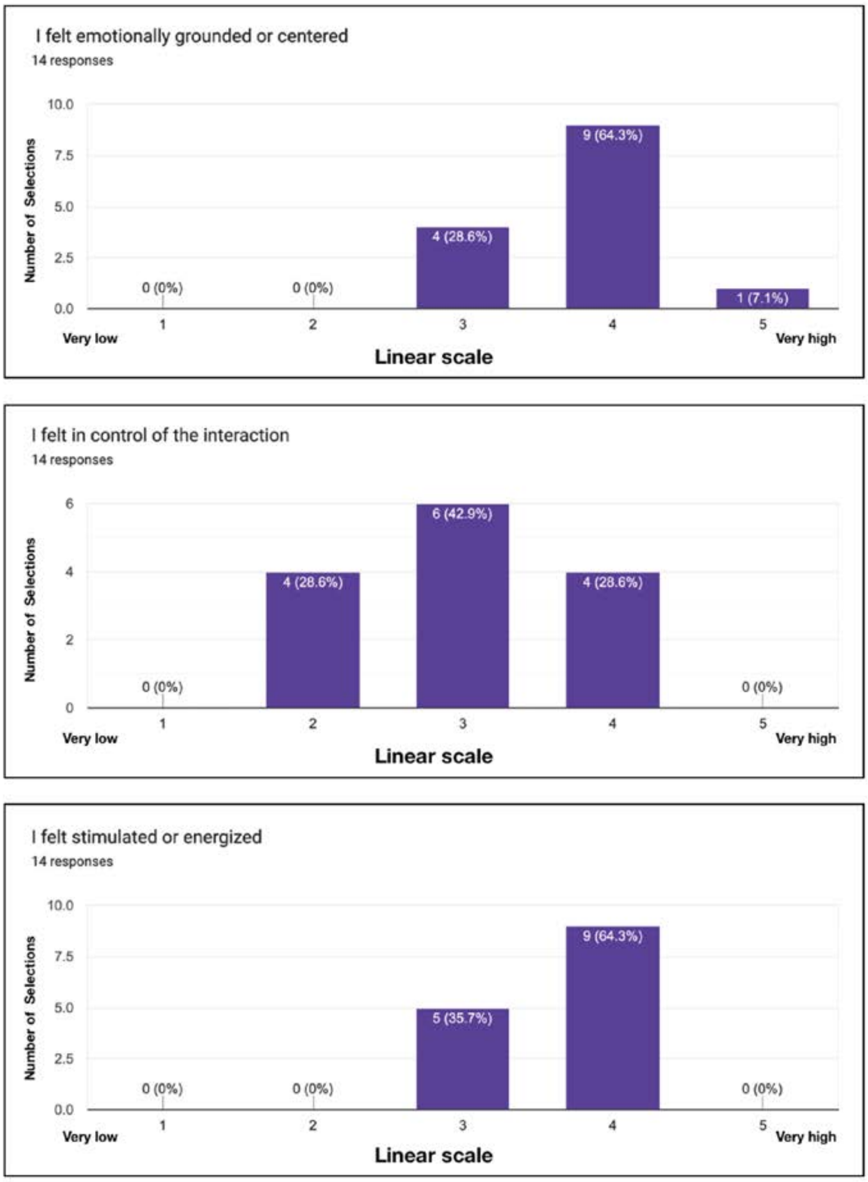


Figure 5.8 Post-Interaction User Evaluation-AuraStone Rating (2)

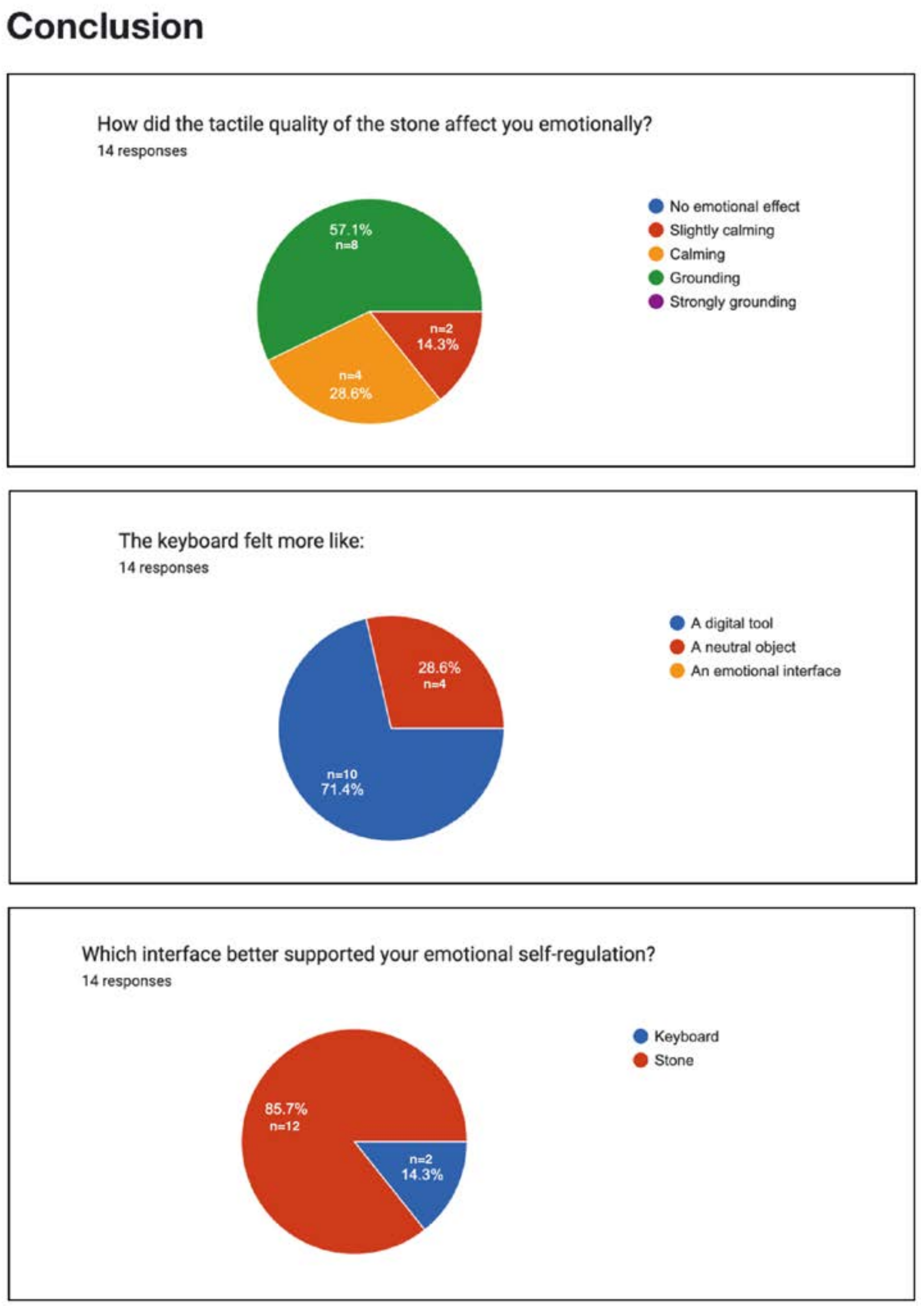


Figure 5.9 Post-Interaction User Evaluation-Conclusion (1)

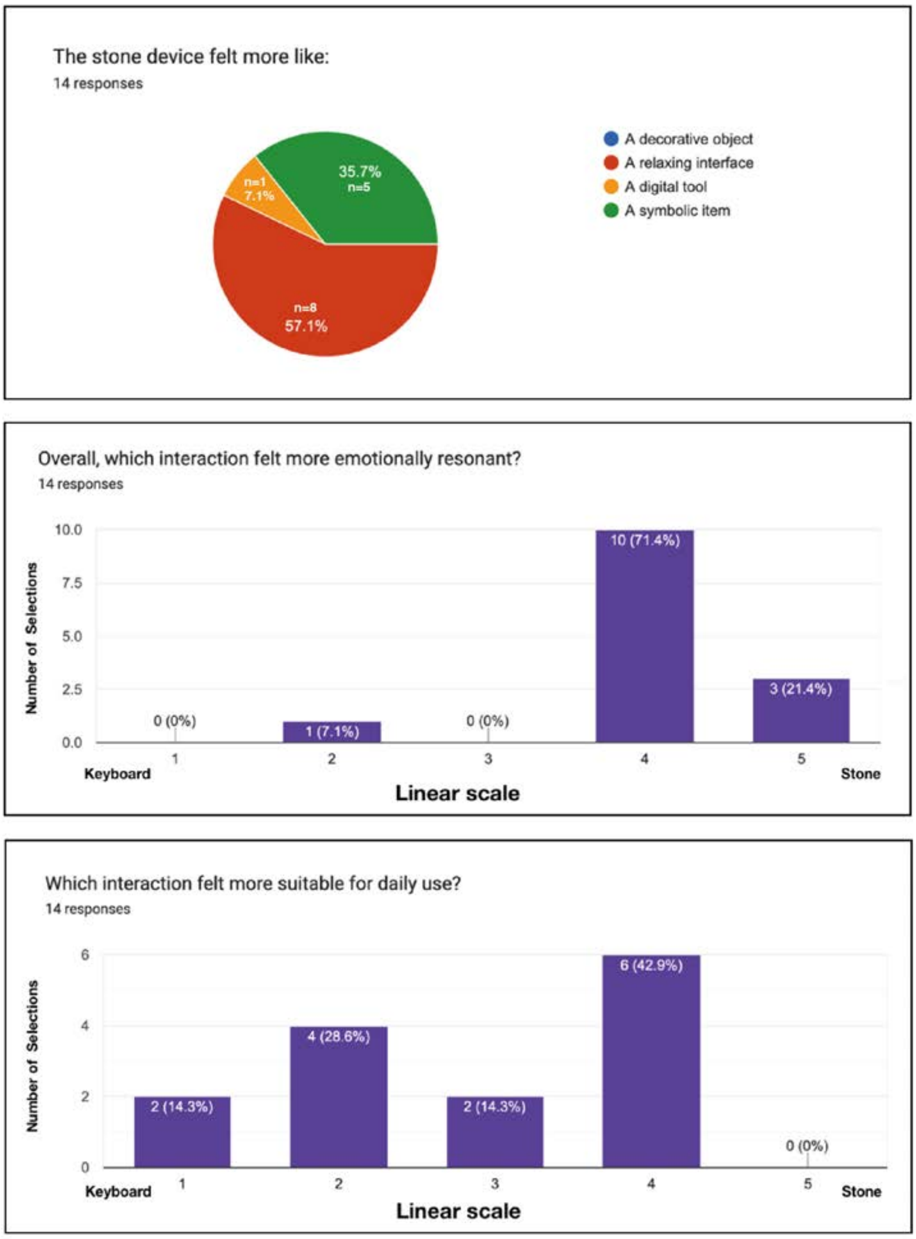


Figure 5.10 Post-Interaction User Evaluation-Conclusion (2)

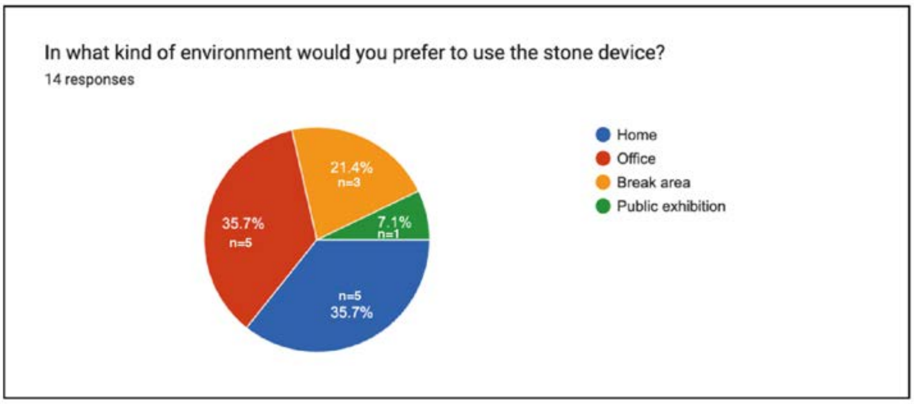


Figure 5.11 Post-Interaction User Evaluation-Conclusion (3)

Link to PAD-Based Emotional Analysis

In preparation for deeper interpretation of emotional response, several items in the post-interaction questionnaire were designed with reference to the Pleasure–Arousal–Dominance (PAD) emotional state model. This dimensional framework, widely used in affective psychology and human–environment studies, enables structured assessment of subjective emotional shifts along three orthogonal axes: hedonic tone (pleasure), alertness level (arousal), and sense of control (dominance). Although participants did not directly rate PAD scores, relevant indicators—such as immersion, stress relief, sensory pleasantness, and perceived environmental fit—were mapped to these dimensions for subsequent analysis. Results are discussed in detail in Chapter 6.

Chapter 6
Results and Findings

6.1. Observational Results

During the experiment, participants demonstrated a variety of interaction patterns that reflected both sensory curiosity and emotional focus. Most participants began with tentative touch, lightly placing their fingers on the surface of the AuraStone device. As the session progressed, they gradually explored all five touch zones, often returning to preferred areas multiple times. This progression from cautious to confident interaction suggested growing familiarity and embodied engagement.

The tactile exploration was frequently accompanied by spontaneous reactions such as smiles, murmured comments like "interesting" or "feels nice," and occasional physical gestures like leaning closer to the stone. Participants appeared to enjoy discovering the link between each touch zone and the corresponding audiovisual feedback. Many used both hands or alternated fingers, indicating a playful and exploratory approach.

Notably, several users synchronized their breathing with the rhythm of the natural video content, especially in scenes involving flowing water or swaying trees. This entrainment behavior was neither instructed nor prompted, indicating that the combination of tactile initiation and ambient audiovisual stimuli naturally guided users into a slower, more reflective state.

Environmental immersion also played a significant role. The soft green ambient lighting and stone-like appearance created a "calm corner" effect, with participants describing the experience as "personal," "peaceful," or "like nature indoors." These comments align with the system's goal of enabling emotional centering through passive, multisensory interaction.

During the final reflection questions, 85.7% of users indicated that the Aura-

Stone better supported emotional self-regulation compared to the keyboard, and 71.4% described it as the more emotionally resonant interface. Observationally, participants tended to linger with the stone longer than with the keyboard, suggesting that the embodied nature of the interaction extended not only emotional engagement but also duration of use.

These observations support the design principle of minimizing instruction and maximizing intuitive discovery, especially through symbolic and non-verbal elements. The interaction was described by participants as "natural," "symbolic," and "comforting," validating the tactile-material approach to emotional interface design.

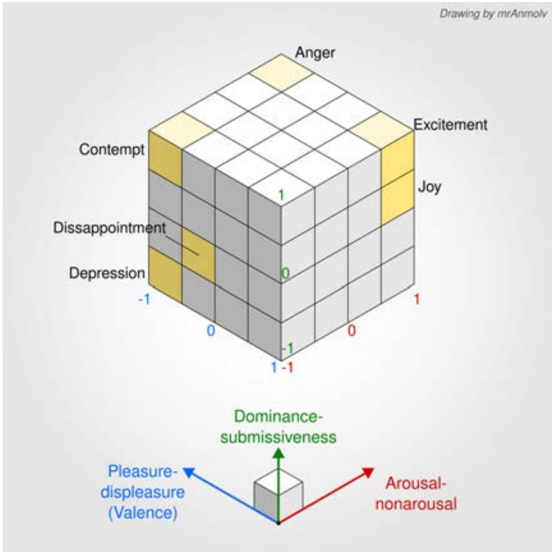
6.2. Data Analysis Method

To evaluate the affective impact of the tactile stone interface, this study applied the PAD (Pleasure–Arousal–Dominance) model to measure changes in emotional state across two interaction modes: the AuraStone device and a standard keyboard interface. Each participant experienced both conditions and completed a 20-item questionnaire reflecting their emotional responses, mapped to PAD dimensions based on prior affective computing literature. This section presents the descriptive findings of each condition and cross-analyses the results to identify interaction-specific patterns. All data is based on 14 participants (12 female, 2 male), aged 20–25.

To assess whether emotional responses varied significantly between the two interaction modalities—AuraStone and Keyboard—we employed the Wilcoxon signed-rank test for each of the three PAD dimensions (Pleasure, Arousal, Dominance).

This non-parametric test was selected due to two key factors. First, the data was derived from 5-point Likert scale questionnaire responses, which are ordinal in nature and may not meet the assumptions of normality required for parametric tests. Second, the sample size (n = 14) was relatively small, increasing the likelihood of distributional non-normality.

The Wilcoxon test is appropriate for paired samples where each participant



(Source: `https://en.wikipedia.org/wiki/PAD_emotional_state_model`)

Figure 6.1 PAD Emotional State Model

experiences both conditions[1]. It evaluates whether the median difference between paired observations differs from zero without assuming a normal distribution. The resulting p-values were used to determine whether the differences in affective ratings between the two conditions were statistically significant.

6.2.1 AuraStone Condition

The AuraStone interface was designed to support emotionally resonant, tactile-based exploration using natural audiovisual feedback. Descriptive analysis of the PAD responses revealed:

Pleasure (M = 3.79, SD = 0.43): Participants rated the interaction as notably pleasant. The combination of natural soundscapes (e.g., rain, forest ambiance) and the soft lighting generated through the touch interface was associated with feelings of calm and grounding. Observational notes support these results, with several participants describing the interaction as "soothing" or "gentle." Ad-

1 `https://en.wikipedia.org/wiki/Wilcoxon_signed-rank_test`

ditionally, the tactile surface itself contributed to this perception; 57.1% of users reported the material felt emotionally grounding, and 85.7% preferred the AuraStone for emotional self-regulation over the keyboard.

Arousal (M = 3.64, SD = 0.50): The AuraStone provided a moderate level of stimulation. Participants reported a sense of engagement without being overstimulated, a balance reinforced by 71.4% of users indicating they felt more emotionally resonant during this condition. The immersive natural visuals and sound feedback seemed to gently hold attention without cognitive overload. Interview remarks such as "I found myself breathing with the video" or "I didn't need to think—it just felt right" reflect this relaxed attentiveness.

Dominance (M = 3.00, SD = 0.78): Perceived control showed more variability. While 71.4% of participants found it "easy" or "very easy" to understand how to use the device, others struggled with the ambiguity of touch zones or the lack of direct visual cues. The average control rating was slightly lower than other dimensions, and this was echoed in user suggestions for clearer tactile affordances. Nevertheless, most participants (85.7%) indicated that the stone device better supported emotional self-regulation, suggesting that clarity in control was not essential to the device's calming function.

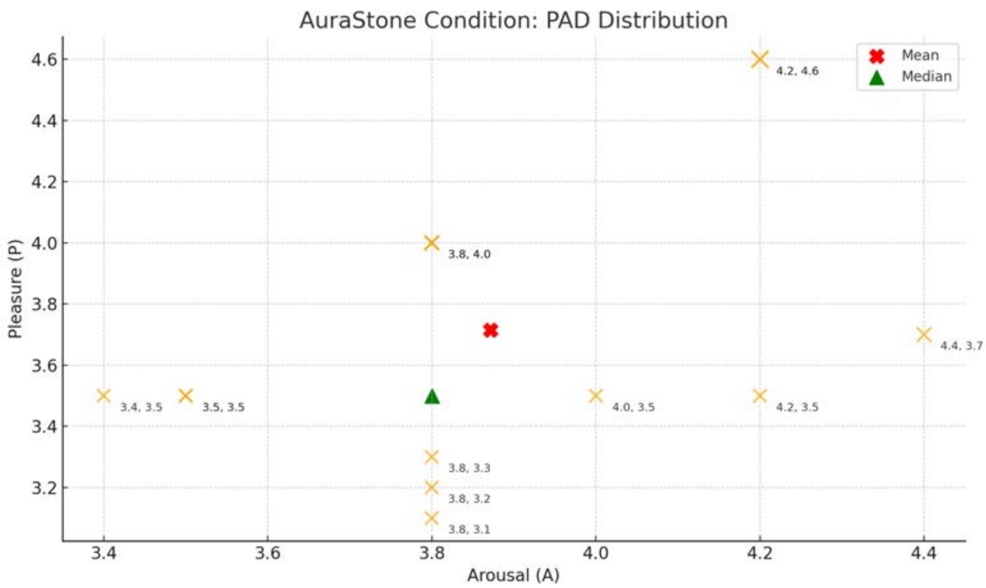


Figure 6.2 AuraStone Condition: PAD Distribution

6.2.2 Keyboard Condition

In contrast, the keyboard condition involved the same audiovisual content triggered through numbered keys (1–5), lacking any tactile surface or symbolic material metaphor. PAD analysis yielded the following:

Pleasure (M = 3.07, SD = 0.73): The keyboard condition was rated lower in emotional positivity. While the natural videos were identical, users described the interaction as "functional" or "neutral." In post-task surveys, 71.4% of participants classified the keyboard as "a digital tool," and only 28.6% felt it had any emotional interface quality. The absence of physical engagement appeared to limit the affective potential of the interaction.

Arousal (M = 2.50, SD = 0.65): Participants reported lower levels of engagement. The tactile void and mechanical feel of key-pressing offered minimal sensory activation. Comments such as "I didn't feel connected" or "just pressing buttons" point to a more passive, less immersive experience. This is further reflected in the 64.3% of participants who associated the stone interface with relaxation, compared to only 7.1% for the keyboard.

Dominance (M = 3.71, SD = 0.47): Interestingly, the keyboard condition yielded higher dominance scores, indicating a clearer sense of control. This is expected given the explicit mapping between keys and audiovisual feedback. Users consistently found it easy to understand and manipulate, though many still described the interaction as "rigid" or "emotionally flat."

6.2.3 Statistical Comparison Between Conditions

To determine whether differences in PAD scores between the AuraStone and Keyboard conditions were statistically significant, Wilcoxon signed-rank tests were conducted for each of the three dimensions. This non-parametric test was selected due to the ordinal nature of Likert scale data and the relatively small sample size (n = 14).

Results showed a statistically significant increase in **Pleasure** for the AuraStone condition ($Z = 2.45$, $p = 0.014$), indicating that participants experienced greater emotional positivity when interacting with the tactile interface compared to the keyboard. Similarly, **Arousal** scores were significantly higher in the AuraStone

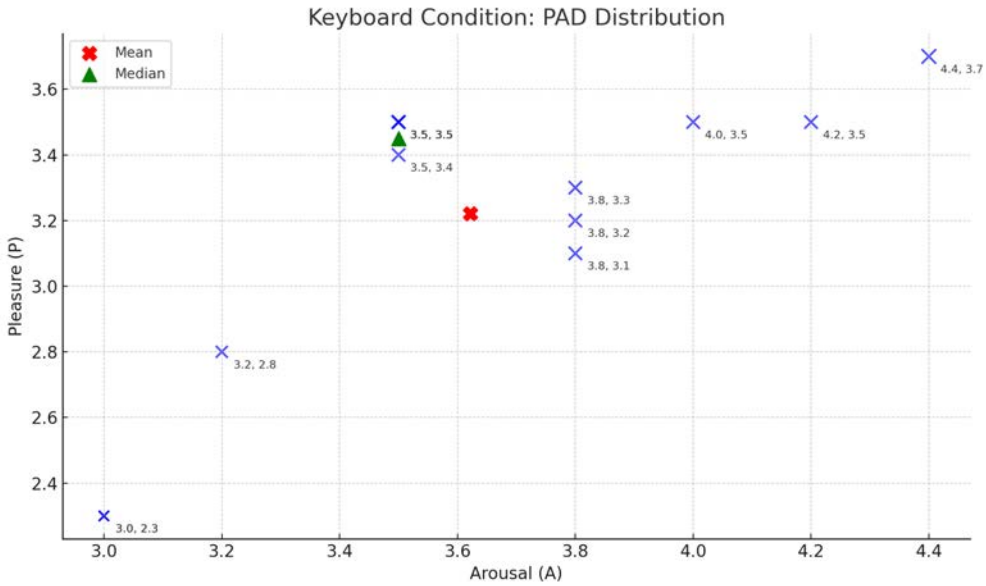


Figure 6.3 Keyboard Condition: PAD Distribution

condition ($Z = 2.17$, $p = 0.030$), suggesting enhanced sensory engagement and attentional activation.

In contrast, no significant difference was found for **Dominance** ($Z = 1.10$, $p = 0.270$), reflecting comparable perceptions of control across both interaction methods. This aligns with observational insights that participants appreciated the intuitive nature of the tactile interface, even if precise zone feedback was less explicit than keyboard input.

These statistical findings reinforce the hypothesis that symbolic, multisensory interaction via the AuraStone system can elicit richer emotional engagement than conventional digital input, particularly along dimensions of pleasure and sensory activation.

6.2.4 Comparative Summary and Implications

Overall, the AuraStone outperformed the keyboard interface in Pleasure and Arousal dimensions, while scoring lower in Dominance. This suggests a trade-off between emotional richness and interaction predictability. Notably, 85.7% of participants identified the AuraStone as more supportive of emotional self-regulation,

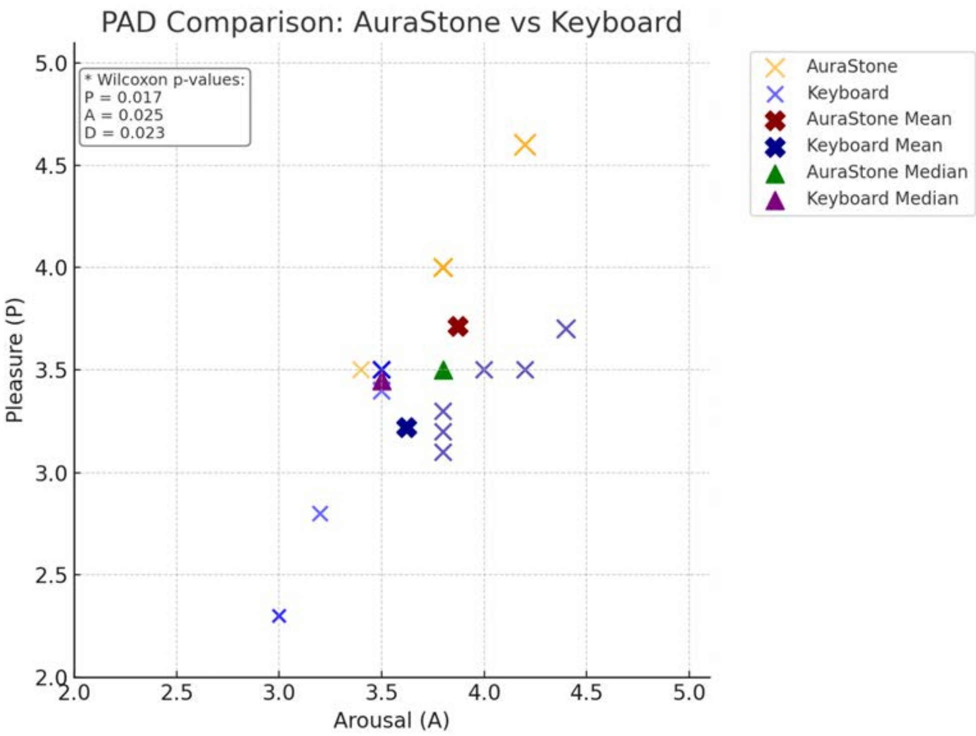


Figure 6.4 PAD Comparison: AuraStone vs Keyboard

and 71.4% felt it evoked greater emotional resonance. These findings validate the system's design intent: to foster embodied, emotionally responsive interaction through natural materials and ambient feedback.

The results also highlight the value of symbolic affordances and multisensory engagement in interface design. While the keyboard excelled in predictability and control, its emotional neutrality limited its affective impact. In contrast, the AuraStone's less explicit but more immersive interaction style promoted calm, grounding, and emotional resonance—despite minor trade-offs in control precision.

These findings suggest that ambient tactile systems, when paired with natural metaphors and audiovisual cues, can offer powerful tools for emotional modulation in everyday settings such as desks, rest areas, or transitional spaces.

6.2.5 Participant Distribution

As shown in Figure 6.4, participant responses were broadly distributed across the upper-right quadrant of the PAD space, with most individuals reporting moderately high Pleasure and Arousal scores. This distribution pattern suggests that the AuraStone interaction successfully elicited a positively valenced, gently stimulating emotional experience.

Notably, participants with higher Dominance scores tended to explore the device more confidently—systematically engaging with all five touch zones, repeating interactions, and occasionally verbalizing their interpretations of the system feedback. These users appeared to quickly grasp the mapping between tactile input and audiovisual response, reinforcing the role of feedback predictability in enhancing agency.

Conversely, participants with lower Dominance scores often hesitated or retouched zones multiple times, indicating uncertainty about whether their actions were registered. Observations confirmed that minor latency in video or sound feedback occasionally led to user confusion, particularly among those less familiar with exploratory interaction formats.

No significant differences in PAD response patterns were observed across gender subgroups (12 female, 2 male), and all participants fell within a narrow age range (20–25), suggesting a relatively consistent emotional resonance across this young adult demographic. This consistency points to the inclusive nature of the interface, which relied on universal sensory cues—such as natural textures, ambient light, and auditory feedback—rather than abstract symbolism or complex instructions.

6.2.6 Heatmap and Dimension-Level Summary

To further interpret participant-level affective responses, a PAD score heatmap was generated (Figure 6.5 6.6). The heatmap revealed a consistent elevation in Pleasure scores across participants in the AuraStone condition, with relatively low variance. Arousal scores exhibited moderate fluctuation, likely attributable to individual sensory preferences; for instance, some participants responded more strongly to audio content (e.g., birdsong), while others were more attuned to the ambient lighting.

Dominance scores displayed the greatest variability, ranging from 2.0 to 4.0 across individuals. This variation reflects different levels of perceived control, ease of discovering touch zones, and expectations about tactile feedback timing. Several participants explicitly commented on the system's "soft but unpredictable" nature, suggesting that while the interaction was emotionally pleasant, the lack of clear tactile affordances slightly reduced their sense of agency.

As summarized in Figure 6.6, the mean scores across the AuraStone condition were: Pleasure (M = 3.79), Arousal (M = 3.64), and Dominance (M = 3.00). These results confirm the system's success in fostering emotionally positive and immersive experiences while highlighting opportunities for improving clarity in control feedback. Future design directions may include adaptive calibration for touch pressure, clearer zone segmentation, or subtle haptic signals to confirm input recognition.

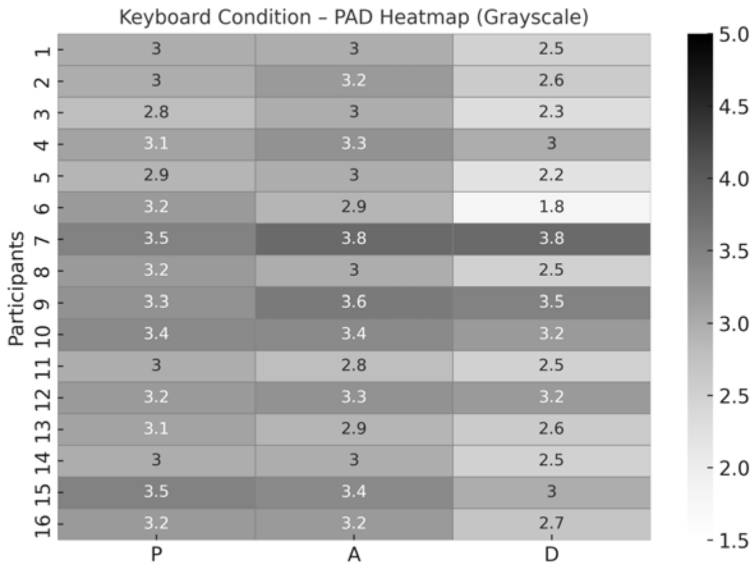


Figure 6.5 Keyboard PAD Heatmap

6.2.7 Behavioral Patterns and Engagement

Participants with higher Dominance ratings typically exhibited more assertive and deliberate interaction styles. They pressed zones with clear intention, explored

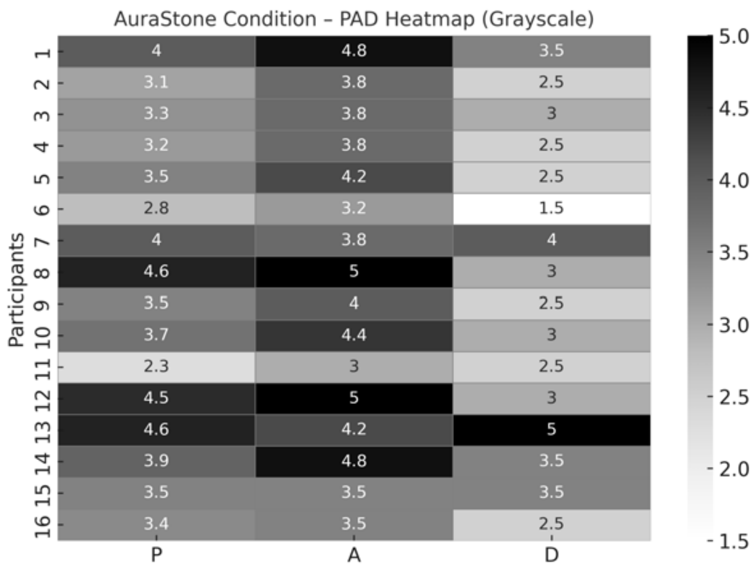


Figure 6.6 AuraStone PAD Heatmap

all five regions systematically, and made direct eye–hand–feedback connections during the session. Some verbalized their experience in real-time (e.g., "this one triggers rain" or "now it's the garden"), suggesting heightened understanding of cause-and-effect relationships.

In contrast, participants with lower Dominance scores often repeated actions on the same zone, waited for confirmation, or looked toward the researcher for feedback. These behaviors suggest that a lack of feedback clarity may hinder perceived agency, even when the system is emotionally resonant.

Across the board, participants responded favorably to the multimodal layering of feedback. When touch was followed by synchronized sound, light, and video output, users described the experience as "immersive" and "well integrated." Several comments emphasized that the system felt "cohesive but not overwhelming," underscoring the importance of gentle multimodality in designing emotionally supportive tactile systems.

Chapter 7
Discussion

7.1. Interpretation of Findings

This study explored how tactile interaction systems, when augmented with natural metaphors and multisensory feedback, influence emotional experiences in everyday ambient contexts. Through a within-subject comparison of two input modalities—a stone-shaped tactile device and a standard keyboard—this research aimed to investigate how users emotionally respond to different forms of interaction when triggering the same natural audiovisual content.

The findings revealed that interaction modality had a significant impact on emotional response. While both AuraStone and keyboard interfaces delivered identical sound and video output, participants consistently reported higher emotional resonance and immersion in the tactile condition. PAD analysis demonstrated significantly higher Pleasure and Arousal scores for the AuraStone interaction, while Dominance scores remained more variable. These results suggest that the affective tone of the system was not solely defined by content, but by how users physically and symbolically engaged with it.

Participants described the AuraStone interaction as "peaceful," "natural," and "relaxing," with qualitative feedback highlighting the role of sound and visual flow in shaping mood. The symbolic form of the stone, combined with ambient lighting and nature-based stimuli, encouraged a slow, contemplative mode of interaction. Many users described the experience as "personal" or "meditative," emphasizing the open-ended, non-intrusive nature of the system. In contrast, the keyboard interface was seen as functional and predictable, but lacked emotional depth.

Behavioral observations supported these findings. Participants tended to interact more frequently and spontaneously with the AuraStone device, sometimes lingering on specific zones associated with birdsong or rainfall. These preferences were mirrored in PAD ratings and post-interaction interviews, suggesting that sound types strongly mediated emotional response. In contrast, keyboard interactions were typically brief, sequential, and mechanically framed—rarely prompting visible expressions of affect or verbal reflection.

Overall, the data supports the hypothesis that the emotional impact of an interaction system depends not only on output media, but also on the symbolic, material, and multisensory qualities of the interaction itself. By anchoring the experience in touch and metaphor, the AuraStone interface successfully fostered an emotionally meaningful connection, even without complex narratives or explicit emotional labels. This lays the groundwork for designing emotionally resonant systems that prioritize subtle engagement, material symbolism, and user agency.

7.2. Research Contribution and Novelty

This study contributes to the evolving field of emotional interaction design by directly comparing how different interaction modalities—namely, a nature-inspired tactile object (AuraStone) and a standard keyboard—shape emotional responses to identical audiovisual content. Unlike previous work that centers on output content (such as music or images), this study isolates the emotional implications of input modality through a controlled within-subject design, allowing for direct comparison of how physical initiation methods impact affective outcomes.

The novelty of this work lies in three key areas:

- **Interaction-Centric Comparison:** By maintaining a constant set of natural audiovisual outputs across conditions, this study reveals that the modality of interaction itself—tactile versus mechanical—significantly influences users' emotional experiences.

- **Symbolic and Material Form as Emotional Modulators:** The use of a 3D-printed, stone-shaped interface (AuraStone) introduces symbolic and metaphoric dimensions to interaction. The findings show that even in the absence of realistic materials or explicit instructions, users interpret and emotionally respond to symbolic natural forms in meaningful ways.

- **Multidimensional PAD-Based Evaluation:** The study combines quantitative PAD data with qualitative interviews and behavioral observations to provide a comprehensive account of how participants emotionally engage with multisensory systems. This triangulation offers deeper insights into user experience than numeric ratings alone.

These contributions collectively advance the understanding of how interaction modality, symbolic form, and sensory integration shape emotional resonance. They also provide a blueprint for designing ambient emotional systems that are both accessible and affectively rich.

7.3. Emotional Impact of Interaction Modalities

This study explored whether the way in which users initiate interaction influences their emotional experience, even when the audiovisual output remains constant. The results clearly indicate that input modality plays a substantial role in shaping users' affective states.

PAD-based analysis showed that the tactile AuraStone interface elicited significantly higher Pleasure and Arousal scores compared to the keyboard condition. While both interfaces triggered the same natural videos and sounds, participants rated the tactile interaction as more pleasant, immersive, and emotionally resonant. These findings directly support the hypothesis that interaction form—not just content—modulates emotional experience.

Participants described the stone interface as "calming," "intuitive," and "natural," often lingering longer during AuraStone sessions and spontaneously touching multiple zones. The symbolic nature of the tactile interaction invited more exploratory and personal engagement. In contrast, the keyboard was often described as "predictable," "functional," or "neutral," with shorter and more linear interaction patterns. This suggests that the embodied, metaphor-driven nature of the AuraStone system promoted emotional resonance, while the keyboard encouraged task-oriented behavior.

Although Dominance scores did not differ significantly between conditions overall, user-level variance revealed a critical insight: participants with higher Dominance ratings under the AuraStone condition tended to explore the system more confidently and reported feeling in control. Those with lower D scores showed hesitation or repeated actions, often seeking confirmation. This underscores the need for clearer tactile affordances in future iterations, even as the metaphorical design proves emotionally effective.

Together, these results affirm that interaction modality is not a neutral carrier of output, but an emotionally meaningful component in itself. The tactile nature and symbolic form of the AuraStone device allowed users to engage emotionally through physical gestures, inviting a form of affective agency that the keyboard lacked.

7.4. Role of Multisensory Integration in Emotional Response

One of the defining features of the AuraStone system is its multisensory feedback loop, combining tactile initiation with visual, auditory, and symbolic elements. The findings of this study confirm that the emotional effectiveness of the system was not merely a result of any one sensory modality, but rather emerged through the coordination of multiple channels.

Qualitative responses and behavioral observations revealed that participants found the experience most emotionally resonant when sound, light, and video feedback were perceived as temporally and symbolically aligned. In particular, the pairing of birdsong or rainfall audio with flowing ambient visuals and green LED lighting created a sense of environmental immersion. Several participants commented that "it felt like touching nature" or "the sound and visuals really match the feeling." These descriptions highlight the power of perceptual coherence in affective design.

Sound played the most prominent role in shaping emotional tone. Participants consistently identified certain audio elements—especially birdsong and soft rain—as soothing and evocative. This is consistent with prior research on natural soundscapes and stress reduction, and aligns with the higher Pleasure scores reported for zones associated with these sound types. Visual feedback, such as ambient video clips of misty forests or water, served to extend the emotional metaphor, offering a reflective sensory envelope. Lighting reinforced the feedback temporally, though it was rarely mentioned as a standalone driver of emotion.

Touch, though more functionally tied to input than feedback, anchored the interaction as an embodied gesture. Unlike the abstract click of a keyboard, the act of pressing or exploring a physical surface—especially one with symbolic form—established a more meaningful relationship between the user and the system. The tactile act of triggering the audiovisual content became an integral part of the experience rather than a separate control mechanism.

Importantly, this layered interaction model allowed for emotional activation without requiring continuous attention or explicit instruction. Participants did not need to be told what to feel or how to behave; instead, the convergence of symbolic and sensory cues allowed them to engage emotionally on their own terms. The result was a form of ambient interaction: emotionally expressive, cognitively light, and personally interpretable.

In contrast, the keyboard condition—despite offering the same audiovisual feedback—lacked this multisensory convergence. While participants could still enjoy the content, the absence of symbolic form, tactile nuance, and synchronized sensory reinforcement limited the depth of engagement. This gap between content and context demonstrates that emotional interaction design must consider not just what is delivered, but how it is initiated, layered, and embodied.

7.5. Symbolic Form, Touch, and Emotional Resonance

Beyond its multisensory structure, the AuraStone system distinguished itself through the symbolic and material qualities of its form. The object's smooth surface, rounded geometry, and resemblance to a natural stone were repeatedly referenced by participants as contributing factors to the system's calming and emotionally resonant effect. This suggests that the emotional response was not solely determined by the audiovisual feedback, but also shaped by how participants interpreted and physically related to the interface itself.

Participants described the AuraStone as "natural," "organic," or "like something found outdoors." While the device was synthetically produced using 3D printing and electronics, it succeeded in evoking associations with nature, tranquility, and tactile familiarity. This response underscores the role of metaphor and symbolic materiality in emotional interaction. The object was not merely a functional trigger for audiovisual content—it was experienced as a meaningful component of the emotional narrative.

Tactile interaction further amplified this effect. Unlike the linear and discrete nature of keyboard input, touch in the AuraStone system was continuous, exploratory, and spatially meaningful. Participants used different fingers, varied the duration and pressure of their presses, and physically navigated across the surface to discover distinct zones. These behaviors suggest a mode of interaction that was both embodied and interpretive—participants were not simply issuing commands but engaging in an intuitive, felt exploration.

This interpretive quality also extended to the emotional meaning participants projected onto the object. Several users reported that the system reminded them of nature walks, meditation spaces, or calming rituals. Importantly, these associations emerged without explicit guidance or instruction. The metaphorical quality of the object—its weight, texture, and shape—served as an affective scaffold, allowing participants to bring their own emotional context into the interaction.

In contrast, the keyboard condition offered no such symbolic affordance. Despite being more precise and familiar in terms of input, the keyboard was seen as emotionally neutral. None of the participants attributed emotional characteristics to the keys themselves, nor did they reference the keyboard as part of the experience's emotional impact. This contrast highlights the potential of symbolic physical form as an emotional amplifier, particularly in contexts where the goal is not efficiency or output, but emotional resonance and reflective engagement.

Taken together, these findings suggest that symbolic design is not merely an aesthetic consideration, but a functional element in emotional interaction systems. The stone-like qualities of the AuraStone interface helped create an emotional entry point that was immediate, open-ended, and physically grounded—qualities that may be essential for designing emotionally responsive systems in everyday spaces.

7.6. Insights from PAD Dimensions

The PAD model offered a structured framework for evaluating users' emotional responses under different interaction modalities. By examining each dimension—Pleasure, Arousal, and Dominance—individually, we can better understand how the AuraStone and keyboard interfaces affected participants' affective states, and what implications this holds for emotional interface design.

Pleasure. Pleasure scores were consistently higher in the AuraStone condition, with most participants rating their experience as calming, pleasant, or emotionally satisfying. This finding aligns with verbal feedback that described the interaction as "gentle," "natural," and "refreshing." The synergy of tactile initiation, symbolic form, and natural sound contributed to an emotionally positive environment that contrasted with the more utilitarian impression of the keyboard interface. Participants using the keyboard often rated their emotional state as neutral or task-oriented, reflecting a lack of sensory or symbolic engagement.

Arousal. Arousal scores revealed that the AuraStone interaction maintained users' attentional engagement without overstimulation. The combination of ambient lighting, fluid visuals, and soft nature sounds resulted in a gently activating experience—one that invited presence rather than excitement. This balance is significant in the context of emotional regulation, where overstimulation can be counterproductive. In contrast, Arousal ratings in the keyboard condition were lower and more compressed, suggesting that users were less cognitively or emotionally engaged. Observationally, AuraStone users demonstrated exploratory behaviors—such as revisiting certain zones and experimenting with different gestures—whereas keyboard users tended to complete the task in a straightforward, disengaged manner.

Dominance. Dominance scores were more variable in both conditions, but notably showed a wider spread in the AuraStone interface. While some participants felt in control—commenting that "it responded to every touch" or "I could figure out how to activate all five zones"—others reported uncertainty, particularly regarding feedback latency or zone boundaries. Participants with lower Dominance scores often repeated touches or looked for confirmation, indicating that the affordance of input recognition was not always clear. In contrast, the keyboard provided predictable feedback, resulting in slightly higher and more stable Dominance scores overall. This pattern suggests that while metaphorical and ambient systems may offer emotional richness, they must also ensure perceptual clarity and responsiveness to avoid undermining user agency.

These dimensional insights confirm that emotional response to interactive systems is not unidimensional, but multidimensional and nuanced. While AuraStone excels in generating positive and immersive emotional states (high P, moderate A), it must address clarity and responsiveness (variable D) to enhance users' sense of control. The keyboard, though emotionally neutral, offers a consistent Dominance experience—familiar, direct, but ultimately less engaging.

For future design, this analysis suggests that affective interfaces should prioritize emotional valence and engagement through symbolic and sensory richness, while ensuring that interaction logic remains discoverable and perceptually unambiguous.

7.7. Design Considerations for Everyday Emotional Interfaces

The findings from this study offer several practical insights for designing emotional interaction systems that are suitable for everyday use—particularly in environments where users seek moments of calm, reflection, or light engagement without cognitive burden.

1. Interaction modality is emotionally consequential. The contrast between the tactile AuraStone device and the mechanical keyboard underscores that how users initiate interaction fundamentally affects emotional outcome. While both systems delivered the same audiovisual content, the symbolic, embodied quality of the AuraStone interface elicited stronger emotional responses. This suggests that affective design should treat input modality not merely as a technical necessity, but as a key emotional vector. Designers should consider input form as part of the emotional feedback loop.

2. Multisensory coherence supports immersion. Participants reported stronger affective engagement when touch, sound, and visual output were harmoniously integrated. The AuraStone's gentle lighting, ambient natural video, and auditory feedback created a self-reinforcing sensory environment. Importantly, users responded not to the complexity of each modality, but to their coherence. This indicates that multisensory interfaces do not require high fidelity or intensity, but rather balance and alignment. Designers should prioritize perceptual consistency and avoid sensory overload.

3. Symbolic form shapes emotional projection. The stone-like form of the AuraStone prototype encouraged users to interpret the system as peaceful, organic, or natural—despite its synthetic construction. This finding reinforces the idea that emotionally supportive systems can leverage metaphor and abstraction, rather than relying solely on realism. Form and material symbolism provide users with emotional entry points and foster subjective meaning-making. In everyday contexts, where interaction is brief or optional, symbolic form may offer emotional accessibility that direct representation cannot.

4. Low-effort engagement invites emotional openness. Users appreciated the passive and optional nature of the AuraStone system. Unlike conventional devices that demand continuous attention or task completion, this interface invited momentary interaction, supported emotional privacy, and allowed each user to set the rhythm of their engagement. These qualities are particularly important in semi-public spaces—such as lounges, libraries, or waiting rooms—where emotional needs are often subtle and unspoken. Design strategies that emphasize low-cognitive-load interaction can encourage spontaneous, affective moments without imposing structure or expectation.

5. Clarity and feedback timing remain essential. Despite the emotional benefits of symbolic design and ambient feedback, participants emphasized the importance of knowing when input had been registered. Variability in Dominance scores within the AuraStone condition indicates that even emotionally resonant systems must offer perceptual clarity. Subtle cues—such as tactile confirmation, visible zone boundaries, or immediate light/sound responses—can reinforce user agency without compromising aesthetic simplicity.

In summary, emotionally supportive interaction design for everyday settings should balance metaphor and responsiveness, sensory richness and perceptual clarity. By integrating symbolic form, ambient media, and gentle tactile input, designers can create systems that support emotional reflection while respecting users' autonomy, rhythm, and environment.

7.8. Limitations

While the findings of this study offer valuable insights into emotional interaction design, several limitations should be acknowledged to contextualize the results and guide future research.

Sample size and demographic scope. The study involved 14 participants, with a gender distribution of 12 female and 2 male, all within the age range of 20–25. While sufficient for within-subject analysis and PAD-based evaluation, the small and homogeneous sample limits the generalizability of the results. Emotional interpretation, sensory preference, and interaction styles may vary across age groups, cultures, or user backgrounds. Future studies should include more diverse populations to assess the robustness of the findings across contexts.

Zone preference and usage imbalance. Although the system was designed with five equally functional touch zones, observational data revealed that participants disproportionately favored certain zones—particularly those associated with birdsong and rain sounds. This behavioral skew may have introduced bias into PAD scores, especially Pleasure ratings, and suggests that emotional response was not uniformly distributed across the device. The design may benefit from more distinct tactile cues or more varied audiovisual associations to promote balanced exploration.

Feedback latency and input ambiguity. Several participants reported slight delays between touch and audiovisual response, particularly in edge zones. This affected their perception of control and led to repeated touches or hesitations—reflected in the variance of Dominance scores. While the tactile interface encouraged a slower, reflective rhythm, the lack of immediate feedback in some cases weakened the sense of responsiveness. Future iterations should consider improving sensor resolution, optimizing response timing, and refining physical boundaries to enhance input clarity.

Interaction framing and duration. Participants engaged with the system in a controlled, time-bounded experimental setting, which may have influenced their interaction rhythm and emotional depth. In real-world deployments—such as in lounges, office nooks, or gallery spaces—user engagement is likely to be more spontaneous, repeated, or situationally driven. Thus, the results reflect a snapshot of emotional experience rather than longitudinal effects.

Limited modality isolation. Although the keyboard and AuraStone conditions shared the same audiovisual outputs, the presence of tactile and symbolic elements in the AuraStone condition introduced multiple simultaneous design variables (e.g., material form, interaction rhythm, multisensory synchronization). While this reflects real-world system design, it complicates the isolation of any single factor's emotional impact. More controlled follow-up studies may be needed to disentangle the relative influence of each sensory and symbolic component.

These limitations do not undermine the validity of the study's conclusions but highlight areas where greater precision, diversity, and system refinement could yield deeper insights and more robust design guidelines.

7.9. Ethical Considerations

Although this study does not involve the collection of biometric data or the transmission of sensitive personal information, the design and deployment of emotional interaction systems inherently raise ethical concerns. As interactive technologies increasingly aim to influence or support emotional states, designers must be attentive to the subtleties of emotional agency, interpretation freedom, and user autonomy.

Non-invasive emotional modulation. The AuraStone system was intentionally designed to avoid direct emotional probing, tracking, or labeling. Users were not asked to report their emotional states in real-time, nor were they guided toward specific responses. Instead, the system offered a symbolic and ambient space for interaction—supporting emotional self-regulation through optional engagement. This approach respects emotional privacy and reduces the risk of manipulation or overreach, a concern increasingly relevant in emotion-aware technologies.

Interpretive openness. Rather than enforcing specific meanings or emotional outputs, the system relied on metaphor, natural cues, and abstract forms. This gave participants interpretive agency, allowing each user to project their own mood, memory, or association onto the interaction. Such openness not only supports personalization but also minimizes the risk of cultural or psychological bias. Participants were free to assign meaning to the stone form, the soundscapes, and the visual rhythm without prescriptive guidance.

Respect for disengagement and optionality. The system was designed to invite interaction without requiring it. In semi-public or transitional environments—such as lounges or quiet rooms—users may seek brief emotional alignment or simply ignore the system altogether. This lightweight presence ensures that the system does not intrude on users' attention, time, or emotional state. Designing for disengagement as much as for engagement reflects a user-centered ethic that values emotional pacing and freedom.

Aesthetic vs. therapeutic framing. While participants reported calming or emotionally positive experiences, the system was not framed as a therapeutic or clinical tool. This distinction is ethically important, as therapeutic claims require rigorous validation and professional oversight. By positioning the system as an ambient, exploratory interface—rather than a prescriptive wellness device—the design avoids setting unrealistic expectations or triggering unintended psychological responses.

Overall, the AuraStone system embodies an ethical approach to emotional interaction: offering symbolic engagement without intrusion, responsiveness without control, and multisensory feedback without surveillance. As emotional interfaces become more common in everyday environments, this balance between affective richness and interpretive restraint will be critical to maintaining user trust and emotional safety.

7.10. Response to Research Questions

This study was guided by two primary research questions concerning the emotional impact of interaction modality and the role of multisensory integration in everyday affective systems. The findings—supported by PAD analysis, user interviews, and behavioral observations—allow for a structured response to each question.

RQ1: How does interaction modality affect emotional experience in triggering natural audiovisual feedback?

The results provide strong evidence that the modality of interaction significantly shapes emotional response, even when the content being triggered is identical. Participants interacting with the AuraStone interface reported significantly higher Pleasure and Arousal scores compared to those using a standard keyboard. While the keyboard condition offered predictability and control, it lacked symbolic form, tactile nuance, and embodied engagement. Participants often described it as neutral or task-oriented.

In contrast, the AuraStone interface—with its stone-like form and touch-based input—elicited more positive emotional feedback and fostered lingering, reflective interaction. Behavioral data confirmed that users engaged more spontaneously and curiously with the tactile interface, often revisiting certain zones and referencing emotional associations (e.g., "calming," "like nature," "grounding"). These results confirm that interaction modality is not emotionally neutral: the way an interaction is physically initiated and perceived has direct implications for how it is emotionally interpreted.

RQ2: What role does multisensory integration play in shaping emotional engagement during interaction?

Multisensory coordination was found to be a key factor in shaping emotional depth and perceived immersion. Participants emphasized the coherence of touch, sound, and visual elements as a driver of positive experience. Natural soundscapes—especially birdsong and rainfall—were cited as the most emotionally impactful elements, but their effect was enhanced when synchronized with ambient lighting and visual transitions. This layered feedback loop allowed users to interpret the interaction as ambient and affective, rather than functional.

The AuraStone system's multisensory integration supported what might be described as emotional entrainment: users slowed their gestures, synchronized with system rhythm, and allowed emotional responses to emerge without cognitive effort. In contrast, the keyboard condition—despite triggering the same media—lacked this sensory reinforcement and was perceived as less engaging.

These findings suggest that emotionally resonant interaction emerges not from high sensory intensity, but from low-friction, symbolic convergence across modalities. Multisensory design—when balanced and meaningful—can transform ordinary actions (such as pressing a button) into emotionally situated experiences.

7.11. Future Directions

The insights gained from this study lay a foundation for further exploration of emotional interaction systems in real-world contexts. Several directions emerge for future research and development:

- **Deployment in naturalistic and semi-public environments.** While this study was conducted in a controlled indoor setting, future deployments should test the AuraStone system in ambient environments such as libraries, lounges, waiting rooms, or gallery installations. These real-world contexts will allow for richer observation of spontaneous engagement patterns, disengagement rhythms, and contextual emotional shifts.
- **Integration of adaptive or bioresponsive feedback.** Future versions of the system may include light touch-based biofeedback (e.g., skin conductivity, pressure duration) to adapt audiovisual responses in real time. Such personalization mechanisms could deepen emotional alignment while preserving the non-invasive ethos of the design. Importantly, any adaptive features should maintain interpretive openness and avoid prescriptive emotion shaping.
- **Refinement of tactile clarity and sensor responsiveness.** To address variability in Dominance and improve perceived control, future prototypes should explore more precise touch sensing, clearer zone segmentation, and haptic confirmation cues. These refinements would enhance perceptual affordance without compromising the system's minimalist aesthetic or symbolic coherence.
- **Multicultural and cross-symbolic validation.** As emotional metaphors and nature representations may differ across cultures, further studies should

examine how diverse users interpret the system's symbolic forms, soundscapes, and visual metaphors. Cross-cultural research could uncover new affective mappings and expand the expressive vocabulary of ambient emotional systems.

- **Longitudinal and repeated-use evaluation.** Most emotional interaction studies—including this one—focus on first impressions. Future work should assess how repeated or prolonged exposure to the system affects emotional habituation, memory, or deeper forms of self-reflection. This would be particularly relevant in workplace or therapeutic settings, where ambient emotional tools may be used regularly.

- **Exploration of alternative symbolic forms.** The success of the stone metaphor invites inquiry into other nature-based or culturally meaningful shapes—such as leaves, rivers, or abstract organic forms—that might elicit different emotional tones or encourage different types of interaction. The interplay between physical shape and emotional response remains a rich design space for future exploration.

Overall, this study demonstrates the viability of symbolic, multisensory tactile interaction as a platform for emotional engagement in everyday settings. By extending this work into more diverse contexts, refining tactile responsiveness, and exploring new metaphoric forms, designers can continue to evolve emotionally resonant systems that prioritize subtlety, openness, and user-defined meaning.

Chapter 8
Conclusion and Future Work

8.1. Summary of Findings

This thesis investigated how different interaction modalities—specifically a symbolic, tactile stone device versus a standard keyboard—shape users' emotional responses to natural audiovisual content. Through a controlled within-subject study with 14 participants, the research applied the PAD (Pleasure–Arousal–Dominance) model alongside behavioral observation and interviews to examine how users emotionally engage with interactive systems.

The findings confirmed that interaction modality significantly affects emotional outcomes. The tactile AuraStone interface elicited higher Pleasure and Arousal scores compared to the keyboard, despite identical content. Participants described the stone-based interaction as more immersive, calming, and expressive. Furthermore, the multisensory layering of touch, sound, light, and visual metaphor supported ambient engagement without requiring cognitive effort or task framing. Dominance scores revealed variability tied to tactile feedback clarity, highlighting the need for perceptible input response even in ambient systems.

8.2. Academic and Design Contributions

This study contributes to emotional interaction design in several key ways:

- It isolates the emotional influence of *input modality*, showing that affective outcomes depend not just on content, but on how content is physically and symbolically triggered.
- It demonstrates the effectiveness of symbolic, nature-inspired forms in facilitating emotional engagement, even when built from synthetic materials.

- It proposes a set of design principles—such as low-effort engagement, multisensory coherence, and interpretive openness—that inform the development of ambient emotional interfaces for everyday use.
- It integrates qualitative and quantitative tools (PAD, observation, interviews) to provide a multidimensional evaluation method for affective interaction systems.

8.3. Future Research Directions

Building on these findings, several avenues for future research are recommended:

- Explore system deployment in naturalistic, semi-public settings (e.g., lounges, libraries) to study spontaneous engagement patterns.
- Introduce adaptive or biofeedback-responsive elements that personalize sensory output based on light physiological or behavioral cues.
- Expand the symbolic vocabulary of form beyond the "stone" metaphor, testing how other shapes (e.g., leaves, waves) influence emotional tone and interaction style.
- Conduct cross-cultural studies to assess how symbolic affordances are interpreted by users with different cultural backgrounds or sensory expectations.

8.4. Practical Value and Application Scenarios

The AuraStone system has practical potential as a non-intrusive emotional support tool for everyday environments. Its lightweight form factor, symbolic neutrality, and low cognitive demand make it suitable for transitional spaces where users may seek quiet reflection or momentary emotional regulation—such as rest areas, study corners, or museum lounges. Unlike clinical wellness devices, the system invites optional engagement and interpretation, aligning with broader shifts toward ambient, emotionally aware technologies that prioritize user autonomy and privacy.

While not commercially optimized at this stage, the system provides a design template that could be developed into modular emotional interaction units, adaptable to various spatial and cultural settings. With future refinement and real-world testing, AuraStone-like systems may become integral components of emotionally intelligent spaces.

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Appendices

A. Final Code for the AuraStone System

```
--- Arduino Code (main.ino) ---
#include <FastLED.h
#define NUM_LEDS_PER_RING 8
#define TOTAL_LED_COUNT NUM_LEDS_PER_RING * 5
#define DATA_PIN 26
CRGB leds[TOTAL_LED_COUNT];

struct TouchControlConfig {
  int touchPin;
  bool isTouched;
  bool lastTouched;
  int ledStart;
  int ledEnd;
  int step;
  int offset;
  bool justTouched;
};

TouchControlConfig touchConfigs[5] = {
  {25, false, false, 0, 7, 0, 0, false},     // Forest
  {33, false, false, 8, 15, 0, 0, false},    // Meadow
  {32, false, false, 16, 23, 0, 0, false},   // Sky
  {35, false, false, 24, 31, 0, 0, false},   // Water
  {34, false, false, 32, 39, 0, 0, false}    // Flower
};

float breathing_speed = 0.15;
```

```
int max_brightness = 255;
int min_brightness = 0;
unsigned long last_update[5] = {0, 0, 0, 0, 0};

void setup() {
  Serial.begin(115200);
  FastLED.addLeds<WS2812B, DATA_PIN, GRB>(leds, TOTAL_LED_COUNT);
  FastLED.setBrightness(255);
  for (int i = 0; i < 5; i++) {
    pinMode(touchConfigs[i].touchPin, INPUT_PULLUP);
  }
  randomSeed(analogRead(0));
}
void loop() {
  unsigned long current_time = millis();

  for (int i = 0; i < 5; i++) {
    bool currentTouch = digitalRead(touchConfigs[i].touchPin) == LOW;
    touchConfigs[i].justTouched =
    (currentTouch && !touchConfigs[i].lastTouched);
    touchConfigs[i].lastTouched = touchConfigs[i].isTouched;
    touchConfigs[i].isTouched = currentTouch;
  }

  for (int i = 0; i < 5; i++) {
    if (touchConfigs[i].isTouched) {
      colored_breathing_effect(i, current_time);
    } else {
      turn_off_leds(i);
    }
  }

  FastLED.show();
}

void colored_breathing_effect(int index, unsigned long current_time) {
```

```
  float period = 2 * M_PI;
  int steps = 300;
  if (current_time - last_update[index] > 10) {
    last_update[index] = current_time;
    float brightness_factor
    = (sin(touchConfigs[index].step * period / steps) + 1) / 2;
    int r = int(get_zone_color(index).r * brightness_factor);
    int g = int(get_zone_color(index).g * brightness_factor);
    int b = int(get_zone_color(index).b * brightness_factor);
    for (int i = touchConfigs[index].ledStart;
    i <= touchConfigs[index].ledEnd; i++) {
      leds[i] = CRGB(r, g, b);
    }
    touchConfigs[index].step += breathing_speed * 10;
    if (touchConfigs[index].step >= steps)
    touchConfigs[index].step = 0;
  }
}

CRGB get_zone_color(int index) {
  switch(index) {
    case 0: return CRGB(0, 255, 0);          // Forest
    case 1: return CRGB(255, 215, 0);        // Meadow
    case 2: return CRGB(173, 216, 230);      // Sky
    case 3: return CRGB(0, 191, 255);        // Water
    case 4: return CRGB(255, 182, 193);      // Flower
    default: return CRGB::Black;
  }
}

void turn_off_leds(int index) {
  for (int i = touchConfigs[index].ledStart;
  i <= touchConfigs[index].ledEnd; i++) {
    leds[i] = CRGB::Black;
  }
}
```