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Master's Thesis
Academic Year 2024

# Sense Halo: Enhancing Emotional Expression for Heavily Masked Cosplayers through Visual Cues

Keio University
Graduate School of Media Design

Kangping Chen

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

Kangping Chen

Master's Thesis Advisory Committee:

| | |
|---|---|
| Professor Kazunori Sugiura | (Main Research Supervisor) |
| Professor Matthew Waldman | (Sub Research Supervisor) |

Master's Thesis Review Committee:

| | |
|---|---|
| Professor Kazunori Sugiura | (Chair) |
| Professor Matthew Waldman | (Co-Reviewer) |
| Professor Nanako Ishido | (Co-Reviewer) |

Abstract of Master's Thesis of Academic Year 2024

# Sense Halo: Enhancing Emotional Expression for Heavily Masked Cosplayers through Visual Cues

Category: Design


## Summary

Non-verbal communication is essential to human interaction, yet often limited when facial expressions are obscured. This study introduces Sense Halo: a wearable device that uses color and light variations to represent distinct emotions—serenity, fatigue, vitality, affection, and exuberance.

Participants interpret these cues without facial or verbal guidance, relying solely on the device's visual output. Preliminary analyses suggest certain emotions may be more easily identified than others. Statistical results will gauge accuracy rates and guide design refinements, aiming to validate the Sense Halo as an effective tool for enhancing non-verbal emotional communication.



Keywords:

wearable technology, non-verbal communication, emotional expression, human-computer interaction



Keio University Graduate School of Media Design

Kangping Chen

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# Chapter 1
# Introduction

## 1.1. Overview

Cosplay, a portmanteau of "costume" and "play," originated within the vibrant milieu of Japanese pop culture and has since burgeoned into a global cultural phenomenon [1]. Enthusiasts meticulously replicate and embody iconic characters from anime, manga, video games, and other media, striving not merely for a superficial resemblance but for an authentic evocation of the character's inner essence—its nuanced emotional subtleties, behavioral idiosyncrasies, and distinctive personality traits. However, this relentless pursuit of verisimilitude is inherently fraught with communicative challenges, particularly in contexts where elaborate costumes and heavy masking obfuscate conventional channels of non-verbal expression, such as facial cues and vocal nuances [2]. Such constraints significantly attenuate the richness of interpersonal communication, creating a critical gap in authentic self-expression. In response, the present study introduces the Sense Halo—a wearable device that harnesses precise chromatic gradients and controlled luminance modulations to reinstate a multifaceted emotional lexicon [3], thereby restoring and even enhancing the expressive capacity of cosplayers within these constrained environments.

### 1.1.1 Masked Emotions in the Context of Kigurumi Cosplay

A striking example of this challenge is found in kigurumi, a specialized form of cosplay where performers wear full-body suits and stylized, rigid masks that completely cover their faces. In kigurumi, every visible inch of human skin is hidden beneath meticulously crafted materials. While this method achieves a

Figure 1.1 Cosplayers fully immersed in a kigurumi costume, complete with a rigid face-covering mask.

seamless visual fidelity—often essential for non-human or otherwise fantastical characters—it simultaneously restricts the performer's ability to convey emotion through facial expressions or even subtle vocal inflections [2, 4].

Kigurumi masks, typically molded from thick, rigid materials, are designed to replicate the exact features of a character's face. However, this precision in appearance comes at the cost of non-verbal communication. Smiles, frowns, raised eyebrows, and other facial cues vanish behind the mask's unchanging surface [2]. Consequently, the wearer cannot rely on facial expressions as a primary mode of emotional conveyance, severely limiting their ability to engage and interact meaningfully with others [4].

Moreover, to maintain character authenticity, kigurumi cosplayers often refrain from speaking—either because their natural voice does not align with the character's voice or the character is known for silence [5]. Removing the mask or breaking character to communicate verbally is seen as disruptive, requiring significant time and effort to reassemble the costume. As a result, many kigurumi cosplayers remain entirely non-verbal, compounding the communication barrier.

The combination of concealed facial expressions and muffled or absent speech places kigurumi cosplayers at a communicative disadvantage. Even fundamental intentions—such as friendliness, fatigue, or willingness to engage—become difficult to convey. Without these non-verbal signals, misunderstandings may arise, social interactions may falter, and the cosplayer's overall experience can be diminished [6]. This situation highlights the need for innovative solutions that restore a layer of emotional expression and improve communication dynamics [2, 4].

### 1.1.2 Communication Barriers in Heavy Masks and Their Impact

While kigurumi represents one of the most extreme examples of facial coverage, similar constraints exist in other heavy-mask scenarios found in performance arts, themed events, or even protective gear environments. In all such cases, the absence of facial and vocal cues disrupts the natural flow of human interaction. Participants find it challenging to convey or interpret emotional states—whether they are calm, eager, affectionate, or uninterested. This lack of emotional transparency can lead to awkward encounters, social withdrawal, and a general sense of isolation [7, 8].

In the cosplay community specifically, these constraints can undermine one of the hobby's core appeals: the chance to step into a character's persona and share that experience with like-minded enthusiasts. Instead of enabling a more immersive portrayal, the mask can create an unintended emotional barrier. What should be a moment of camaraderie—exchanging compliments, playfully teasing in-character, or simply showing enthusiasm—can be lost when the audience cannot read the cosplayer's emotions and the cosplayer cannot easily convey them.

### 1.1.3 Introducing the Sense Halo

This study introduces the *Sense Halo*, a wearable device designed to counteract the communicative limitations imposed by heavy masks like those used in kigurumi. By translating emotional states into carefully orchestrated patterns of colored light and intensity, the Sense Halo provides an alternative, non-verbal channel for emotional expression. Unlike facial expressions, which are hidden behind the mask, these visual cues are external, immediately visible, and can be understood even in dimly lit settings common in cosplay events.

The Sense Halo focuses on five primary emotional states—serenity, fatigue, vitality, affection, and exuberance—each represented by distinct color and lighting patterns. The device aims to restore a degree of emotional fidelity that facial expressions typically provide. If successful, cosplayers in heavy masks will be able to convey their moods and intentions clearly, reducing misunderstandings, encouraging more meaningful interactions, and ultimately enriching the cosplay experience.

### Kigurumi Characteristics and Design Justification

Ethnographic studies of cosplay reveal that kigurumi cosplayers face unique challenges due to their complete facial and bodily coverage. Research by Mason-Bertrand [5] and Winge [6] demonstrates that the immersive nature of kigurumi performances enforces a strict adherence to character, which precludes the spontaneous use of facial expressions and vocal cues. In kigurumi, every aspect of the performer's body is transformed into a meticulously crafted persona, resulting in a performance flow where emotional expression is entirely dependent on alternative communication channels. The deliberate maintenance of silence and the elimination of conventional non-verbal signals further exacerbate potential miscommunications among participants.

The *Sense Halo* is uniquely designed to address these challenges. By translating emotional states into dynamic patterns of colored light, the device offers kigurumi cosplayers a novel, non-verbal language that compensates for the absence of traditional facial cues. Its design—refined iteratively through extensive user feedback—ensures that the visual signals are both immediately perceptible and culturally resonant within the cosplay community. This dual functionality, enhancing non-verbal communication while preserving character authenticity, underscores the suitability and innovative nature of the *Sense Halo* in kigurumi contexts.

## 1.2. Research Objective

The central objective of this research is to develop and rigorously evaluate the *Sense Halo* as a tool for enhancing non-verbal emotional communication under conditions of extreme facial coverage. Although inspired by the unique challenges faced by the cosplay community—particularly kigurumi practitioners—this study is driven by broader theoretical concerns regarding non-verbal communication, color psychology, and human-computer interaction. The design principles underlying the *Sense Halo* are intended not only to restore emotional expressiveness for cosplayers whose facial expressions are completely obscured, but also to provide innovative insights applicable to any scenario in which traditional facial and vocal cues are restricted.

To achieve this objective, the study sets out the following goals:

1. **Design and Engineering:** Develop a wearable device that integrates seamlessly with heavy masks such as those used in kigurumi cosplay. This involves ensuring that the device is stable, comfortable, and unobtrusive, so as not to interfere with the cosplayer's performance. Special attention is paid to ergonomic design, efficient LED integration, and the development of a user-friendly interface.

2. **Emotional Encoding:** Construct a color-based emotional "language" by defining a mapping between specific hues, brightness levels, and lighting patterns and a spectrum of emotional states—including serenity, fatigue, vitality, affection, and exuberance. This encoding is built upon established research in color psychology and non-verbal communication, thereby providing a universally interpretable means for expressing internal emotional states.

3. **User Testing and Validation:** Implement a series of controlled experiments in which participants, primarily kigurumi cosplayers, interpret the device's visual signals without relying on facial or vocal cues. Both quantitative measures (such as recognition accuracy and response times) and qualitative feedback (including user confidence and satisfaction) will be collected to rigorously assess the system's performance before and after the introduction of explicit emotional labeling.

4. **Impact Assessment:** Evaluate whether the *Sense Halo* enhances user engagement, reduces misunderstandings, and enriches the social and emotional fabric of cosplay events. This includes assessing the impact on users'

perceived ability to express their emotions and the accuracy with which observers can interpret these visual cues.

5. **Broader Applicability:** Draw insights from the specialized kigurumi context to inform potential applications in other domains. For instance, the design may be adapted for performance arts, protective gear, or assistive communication technologies for individuals with social anxiety or selective mutism. Such broader applicability reinforces the societal relevance of the research and demonstrates the potential for the *Sense Halo* to bridge communicative gaps in a variety of settings.

Through these steps, the research aims to confirm that tangible devices like the *Sense Halo* can play a vital role in restoring emotional expressiveness when conventional facial and vocal cues are absent. Recognizing the importance of physical, visual tools in creating meaningful connections, this study not only validates the design within the niche context of kigurumi cosplay but also contributes a replicable framework for developing assistive communication technologies in diverse environments.

## 1.3. Thesis Structure

The structure of this thesis is designed to provide a comprehensive journey from identifying a critical communication gap in a specialized cultural domain—namely, the challenges of non-verbal communication in kigurumi cosplay—to the design, testing, and validation of an innovative solution: the Sense Halo. The thesis is organized into the following chapters:

- **Chapter 1 (Introduction):** This chapter establishes the research context by discussing the unique challenges associated with non-verbal communication in kigurumi and similar heavy-mask scenarios. It outlines the rationale for the Sense Halo and presents the overarching research objectives and expected contributions.
- **Chapter 2 (Related Works):** This chapter reviews existing literature on cosplay culture, non-verbal communication mechanisms, and wearable

technologies. It further examines cultural practices of exchanging tangible signals to facilitate interaction, thereby situating the current work within a broader academic and cultural context.

- **Chapter 3 (Design, Development, and Preliminary Experiments):** This chapter details the iterative design process of the Sense Halo—from initial concept through to the development of refined prototypes. It includes a description of Experiment 1, which provided initial user feedback and was instrumental in constructing the ten experimental scenarios. The data from Experiment 1 served as a foundation for both the third iteration of the design and for planning Experiment 2. Key topics discussed include material selection, LED integration, and user-centered refinements based on the preliminary experimental data, all of which are essential for addressing the unique challenges in kigurumi cosplaying.

- **Chapter 4 (Experimentation and Validation):** This chapter presents the main experimental methodology, which involves scenario-based tasks and the evaluation of the Sense Halo under different conditions (with and without explicit labeling). It provides a detailed analysis of user performance using both quantitative measures (such as accuracy rates and statistical tests) and qualitative feedback to assess the device's efficacy.

- **Chapter 5 (Discussion and Future Directions):** The final chapter interprets the findings in a broader context, discusses the implications of the Sense Halo for enhancing non-verbal emotional communication, and proposes design improvements. It also outlines future research directions and potential applications of the device in various settings, emphasizing its relevance not only in cosplay but also in other performance and social environments.

By following this structure, the thesis presents a logical and systematic progression—from identifying a specific communication gap in the niche domain of kigurumi cosplay, through the iterative design process (supported by Experiment 1 data and the creation of ten detailed scenarios), to the comprehensive evaluation of the Sense Halo. This approach ensures a rigorous exploration of the subject and lays a solid foundation for further research and adaptation of similar devices to enhance human connection wherever traditional non-verbal cues are constrained.

# Chapter 2
# Related Works

## 2.1. Introduction

This chapter reviews key literature and studies that inform the conceptual and cultural underpinnings of the *Sense Halo*. It focuses on three core areas: the historical and symbolic significance of halos, their use in contemporary media as indicators of internal states, and the psychological foundations linking color to emotional expression. By examining these dimensions, we establish a theoretical framework for the device's design and the rationale behind using halos and color-coding as a non-verbal communication medium. The insights gained here will guide the selection of color palettes, light patterns, and symbolic forms that the *Sense Halo* employs to convey emotional states effectively, even in contexts where traditional facial cues are concealed.

## 2.2. Symbolic Representation

### 2.2.1 Historical and Cultural Significance of Halos

Throughout history, halos have been powerful symbols across cultures and religions, representing divinity, holiness, enlightenment, and spiritual power. In religious iconography, halos are often depicted as circular bands of light encircling the heads of sacred figures, such as saints, angels, and deities, emphasizing their elevated spiritual status [9,10]. Early Christian art, for instance, adopted the halo (or nimbus) to signify sanctity—a practice that later spread widely in Western religious art during the Middle Ages and Renaissance [11,12]. Similarly, in Buddhist traditions, halos encircle the heads and bodies of enlightened beings, symbolizing their purity and spiritual radiance, and in Hinduism and ancient Egyptian art, luminous crowns and halos signify divine authority and transcendence [9].

This widespread cultural resonance suggests that halos carry innate symbolism recognized across different societies. By drawing on this established cultural code, the *Sense Halo* can tap into a visual language that conveys special qualities or inner states. Adopting the halo form situates the device within a lineage of symbols that represent illumination, transcendence, and a dimension beyond the purely physical.

### 2.2.2 Visual Metaphor for Emotional Aura

Beyond religious and historical contexts, halos function as a metaphor for an individual's aura, the subtle luminous field believed to reflect one's emotional, energetic, and spiritual condition. Variations in the aura's perceived color and brightness have been associated with different emotional states or personal attributes [13]. The circle, as a geometric form, represents unity and completeness, making it an ideal shape for symbolizing the totality of a person's internal experience.

Such metaphysical concepts align with psychological insights into non-verbal communication. Human interactions rely heavily on visual cues, with studies indicating that non-verbal signals significantly shape perceptions and responses [2]. By presenting emotional cues through a halo, the *Sense Halo* leverages an innate human sensitivity to visual stimuli, thus providing a direct and holistic way of expressing internal states externally.

### 2.2.3 Association with Light, Grace, and Emotional Expression

Light has long been associated with knowledge, purity, and grace, and halos often denote a state of enlightenment or favor. Research in environmental psychology shows that brightness and luminance can influence mood and perception, while variations in intensity and hue can evoke particular emotional responses [14]. By integrating controlled light patterns, the *Sense Halo* draws on these empirical findings, using brightness, saturation, and color changes to communicate emotional subtleties.

The halo's radiant effect thus becomes a conduit for emotional expression. Instead of relying on facial expressions, which are obscured, or speech, which may be restricted or unavailable, the *Sense Halo* uses variations in light quality to project emotional states outwardly. This approach ensures that even subtle changes can become readily interpretable signals, enhancing the richness of non-verbal interaction [2, 14].

## 2.3. Halos in Contemporary Popular Culture and Anime

### 2.3.1 Use of Halos in *Blue Archive*

Contemporary media frequently reinterprets halos in ways that maintain their symbolic power while adapting them to modern narratives. In the mobile game *Blue Archive*, for example, every character is depicted with a unique halo. These halos are not merely decorative; they serve a functional role in expressing consciousness, individuality, and emotional states. When a character is awake and aware, the halo illuminates, and when they lose consciousness, the halo dims or disappears. This mechanic establishes a direct link between the halo's visibility and the character's inner condition, reinforcing the notion that halos can convey psychological depth [15].

### 2.3.2 Emotional Expression Through Halos: The Case of Arona

Arona, a character from *Blue Archive*, exemplifies how nuanced emotional states can be represented via halo transformations. As Arona experiences different emotions—affection, excitement, serenity—her halo shifts colors, shapes, and intensities to signal these changes. For instance, affection might manifest as a gentle, warm pink hue, while excitement may appear as a vibrant green spike. These symbolic representations allow players to intuitively grasp a character's emotions without explicit dialogue or facial expressions [16].

### 2.3.3 Relevance to Cosplay and Anime Culture

The incorporation of halos in *Blue Archive* is not merely an aesthetic choice but a deliberate use of deep-rooted cultural and religious symbolism. Many anime and cosplay works integrate religious iconography, such as halos, to signify divinity, enlightenment, or otherworldly qualities. This intermingling of sacred symbolism with modern narratives creates a rich visual language that bridges historical iconography and contemporary cultural expression. In *Blue Archive*, halos serve not only as metaphors for internal emotional states but also as markers of character identity, drawing viewers into a narrative where myth and modernity coexist.

This cultural and symbolic approach is highly relevant to my research. Since the Sense Halo is designed to restore emotional expressiveness in contexts where traditional facial cues are suppressed (as in kigurumi cosplay), it leverages similar visual metaphors found in contemporary anime and cosplay. By using precise chromatic gradients and luminance modulations, the Sense Halo offers a visual language that is both intuitively understood by the target audience and deeply embedded in the cultural aesthetics of anime. Such an approach reinforces the device's applicability and suitability for cosplay environments, where visual authenticity and narrative depth are paramount.


Figure 2.1 Arona displaying a neutral-shaped blue halo, symbolizing calmness and serenity. The subtle blue hue aligns with established color-emotion links, aiding intuitive interpretation.


Figure 2.2 Arona's halo transforms into a vibrant green shape to reflect excitement or engagement. Such dynamic visual shifts demonstrate how color and form can effectively represent changing emotional states.


Figure 2.3 A pink, heart-shaped halo indicates affection or fondness. This instance illustrates that shape and hue combinations can convey specific emotional tones, enriching the character's non-verbal communication palette.

## 2.4. The Connection Between Color and Emotion

### 2.4.1 Color Psychology and Emotional Associations

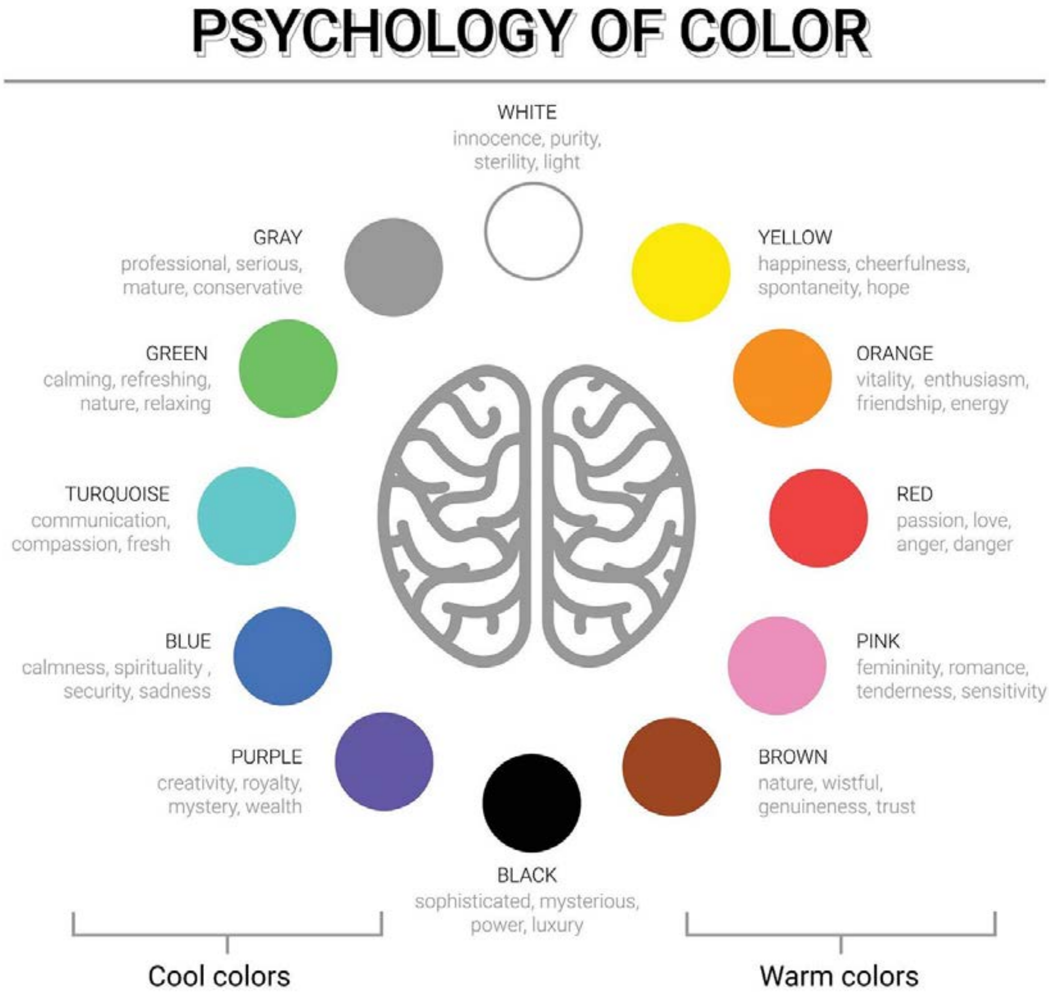
Color psychology posits that different hues can elicit distinct emotional responses, influencing human behavior and perceptions. For example, calmness is often associated with blues and greens, which can lower stress and evoke tranquility, whereas warm colors like red or orange may stimulate excitement or urgency. Research by Elliot and Maier [17] suggests that the emotional impact of a color is not inherent but is strongly shaped by its contextual associations. Similarly, Palmer and Schloss [18] propose that individuals' color preferences are linked to their affective experiences. These established associations provide a foundational vocabulary that devices like the *Sense Halo* can exploit. By carefully selecting color palettes aligned with common emotional interpretations, the device's signals become more universally understood.

### 2.4.2 Application in Non-Verbal Communication Devices

Empirical studies have repeatedly shown that colors can enhance non-verbal communication efficiency. In human-computer interaction (HCI), for instance, color-coded interfaces have been demonstrated to effectively convey status, warnings, and instructions without reliance on textual labels [19]. This capacity makes color an indispensable tool for designing intuitive, language-independent communication channels. Similarly, the *Sense Halo* relies on variations in color to express emotional states, thereby transcending linguistic and cultural barriers and offering a direct method to communicate internal states.

### 2.4.3 Implications for the *Sense Halo* Design

By drawing on the cultural significance of halos and well-documented emotional associations with color, the *Sense Halo* positions itself as an intuitive and impactful communication tool. Its form—rooted in historical symbolism—lends an inherent sense of significance and grace, while its color-based emotional coding leverages established psychological principles [2, 14, 17]. This design enables observers to quickly and accurately discern the user's emotional state. The synergy




(Source: Shania Kelly, *Color: How it Affects You*)

Figure 2.4 Psychology of Color: Color and Emotion Association Chart of form and function ensures that the *Sense Halo* not only meets practical communication needs but also resonates aesthetically with the cosplay community, where visual authenticity is highly valued. By integrating both visual metaphors and color psychology, the device stands poised to enrich non-verbal interactions, even in scenarios where conventional cues are absent.

## 2.5. Institutional Legacies and the Distinction

Although [20] delineates a kinetic floral display engineered to encode affective states predominantly along the valence-arousal continuum, the present study advances a distinct paradigm by addressing the communicative lacuna engendered by heavy masking in cosplay. In stark contrast to the fluid yet uni-dimensional kinetic expressions of Emolleia [20], the Sense Halo operationalizes precise chromatic gradients and luminance modulations to instantiate a multifaceted emotional lexicon, inherently aligned with anime aesthetics. This approach not only ameliorates the expressive constraints typical of motion-centric displays but also integrates culturally resonant semiotics, thereby facilitating a more rigorous and contextually appropriate transmission of nuanced emotional states.

In addition, recent work on bioresponsive avatars highlights the potential of integrating physiological feedback into visual communication. For example, Skiers et al. [21] introduce the concept of a *Transcendental Avatar* that generates a self-avatar based on real-time physiological signals—such as heart rate and electrodermal activity—to enhance cognitive and emotional functioning. This biofeedback mechanism allows users to gain awareness of their internal states and adjust their behavior accordingly. In a similar vein, the Sense Halo translates otherwise inaccessible emotional signals into dynamic visual cues, thereby offering an innovative solution for environments where conventional facial and vocal expressions are masked. By drawing on these institutional legacies and recent advances in bioresponsive design, the Sense Halo emerges as both a culturally informed and technologically sophisticated tool for enhancing non-verbal emotional communication.

## 2.6. Conclusion

The literature and examples discussed in this chapter create a strong conceptual foundation for the *Sense Halo*. Historically, halos have denoted spiritual elevation and purity. In contemporary settings, they can encode individuality, consciousness, or emotional states, as seen in examples like *Blue Archive*. Complementing this, the psychological literature on color associations provides a scientific basis for translating internal emotions into externally visible, universally interpretable cues.

By grounding the *Sense Halo* in these cultural, symbolic, and psychological frameworks, we lay the groundwork for a device that can effectively address the communication challenges faced by cosplayers wearing masks that obscure facial expressions. The insights gained from this review will guide the subsequent chapters on design, prototyping, and validation, ensuring that the *Sense Halo* emerges as both a culturally resonant and scientifically informed solution for enhancing non-verbal emotional expression.

# Chapter 3
# Design

## 3.1. Introduction

This chapter details the iterative design and development process of the *Sense Halo*, a wearable device intended to facilitate non-verbal emotional expression for cosplayers wearing costumes that obscure facial expressions and limit speech. The approach involved three major iterations of prototype refinement, each targeting improvements in aesthetics, structural integrity, lighting integration, and user experience. Initially, two prototypes were produced without LED integration to explore geometric forms and material properties (First Iteration). Subsequently, the Second Iteration introduced a simplified geometric shape, integrated LEDs, and diffusive layers, enabling the first user experiment (Experiment 1) to gather both qualitative and quantitative feedback. Insights from Experiment 1 then informed the Third Iteration, which adopted a circular frame and introduced a more ergonomic structure, culminating in a stable, refined, and user-informed design.

Additionally, after achieving the optimized form in the Third Iteration, a dedicated control system and graphical user interface (GUI) were developed. This GUI allows users to select from five distinct emotional modes directly, leveraging various platforms (laptop, smartphone, smartwatch) and interfacing via a CPS32-based controller and supporting hardware. The following sections detail each iteration, the experiments conducted, and the integration of the GUI and control systems, painting a comprehensive picture of how the *Sense Halo* evolved into a functional, versatile solution.

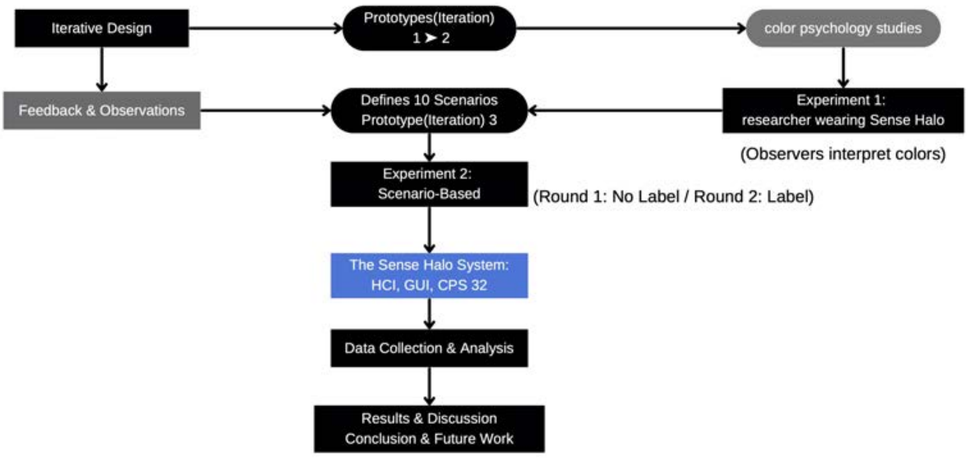



Figure 3.1 Research Roadmap

# 3.2. Design Process

## 3.2.1 Iterative Approach

### First Iteration: Intricate Geometry without LED Integration

The first iteration emphasized complex, visually striking geometry. Using Cinema 4D (C4D), a highly detailed 3D model was created to resonate with the elaborate aesthetics of cosplay attires. Two physical prototypes were fabricated on an Elecom Pro 5 3D printer:

1. **Black Filament Prototype:** Produced with standard black filament, this prototype accurately reflected the intricate geometry but lacked translucency and any LED integration.

2. **Semi-Transparent/Photoluminescent Prototype:** By using a fine-grade, glow-in-the-dark filament, a second prototype hinted at potential low-light aesthetics. Even without LEDs, the filament stored ambient light and emitted a gentle glow, reinforcing the halo-like quality.

These prototypes confirmed geometric feasibility but underscored the need for materials and forms more amenable to LED integration and light diffusion.

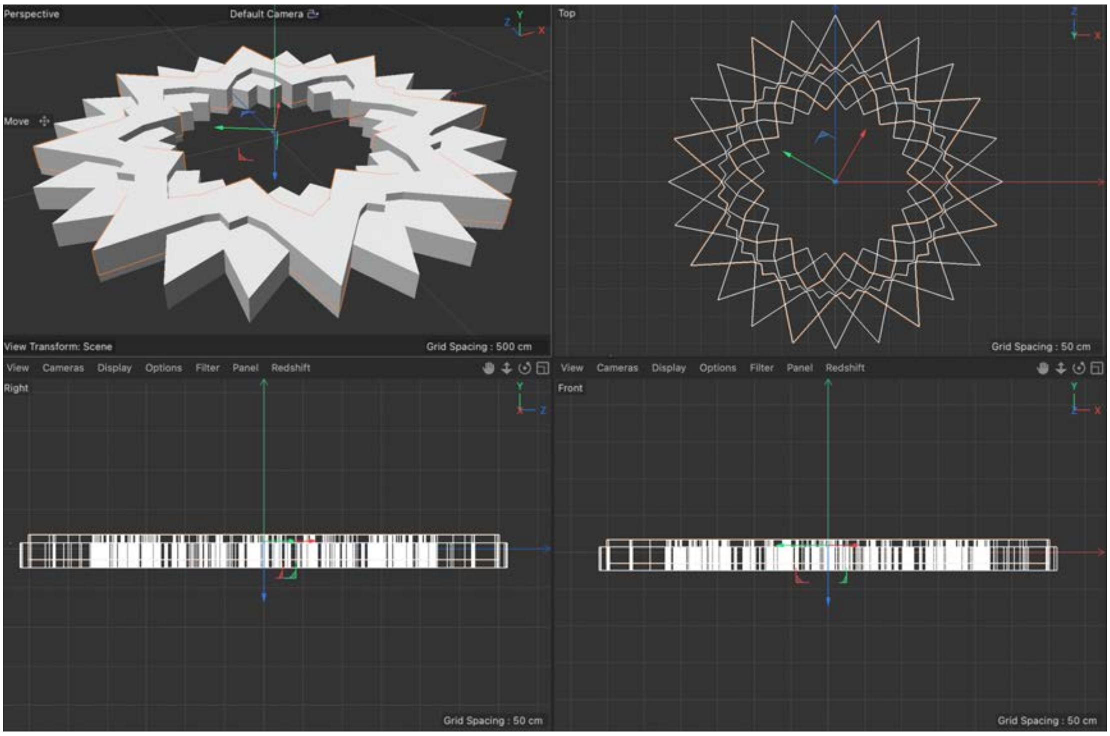



Figure 3.2 Four-view illustration of the 3D Sense Halo design created with Cinema 4D. The figure showcases the model from top, front, right, and bird's-eye views, highlighting geometric complexity and structural layout.

Figure 3.3 Initial physical prototype (first iteration) using black filament. Despite achieving the desired intricate geometry, this prototype lacked LED integration and sufficient translucency, indicating the need for iterative refinement.

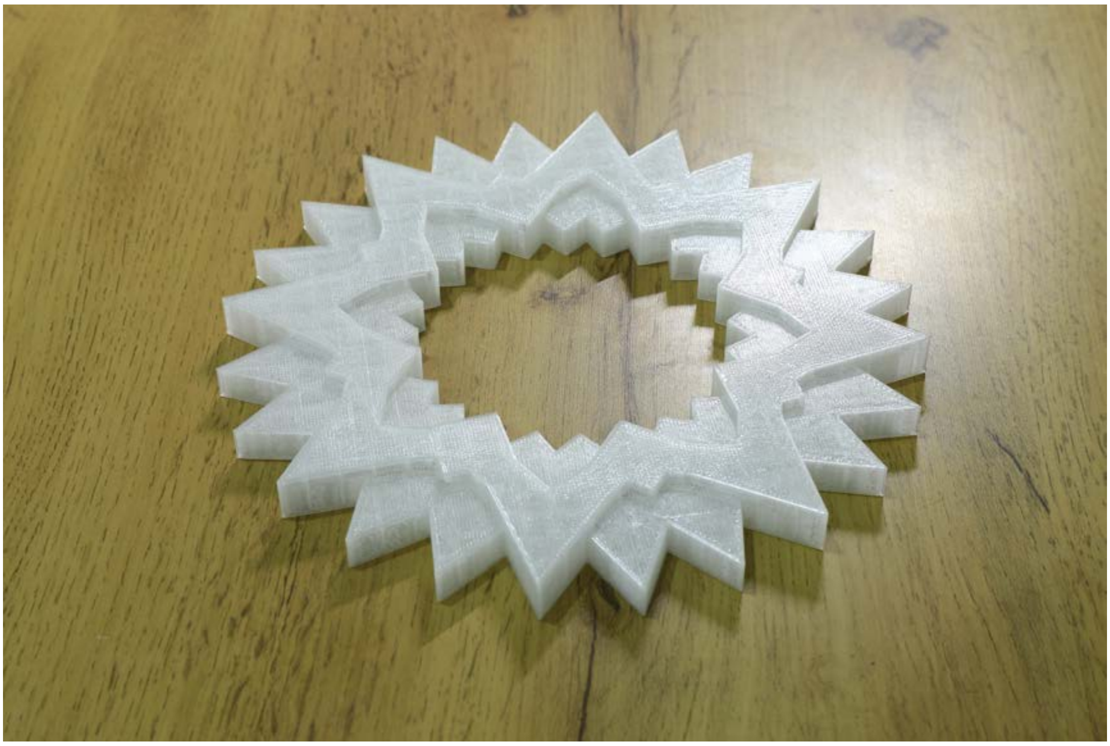


Figure 3.4 Another first-iteration prototype employing a fine-grade, semi-transparent filament. Though LEDs were not yet integrated, this material choice suggested improved future light diffusion potential.

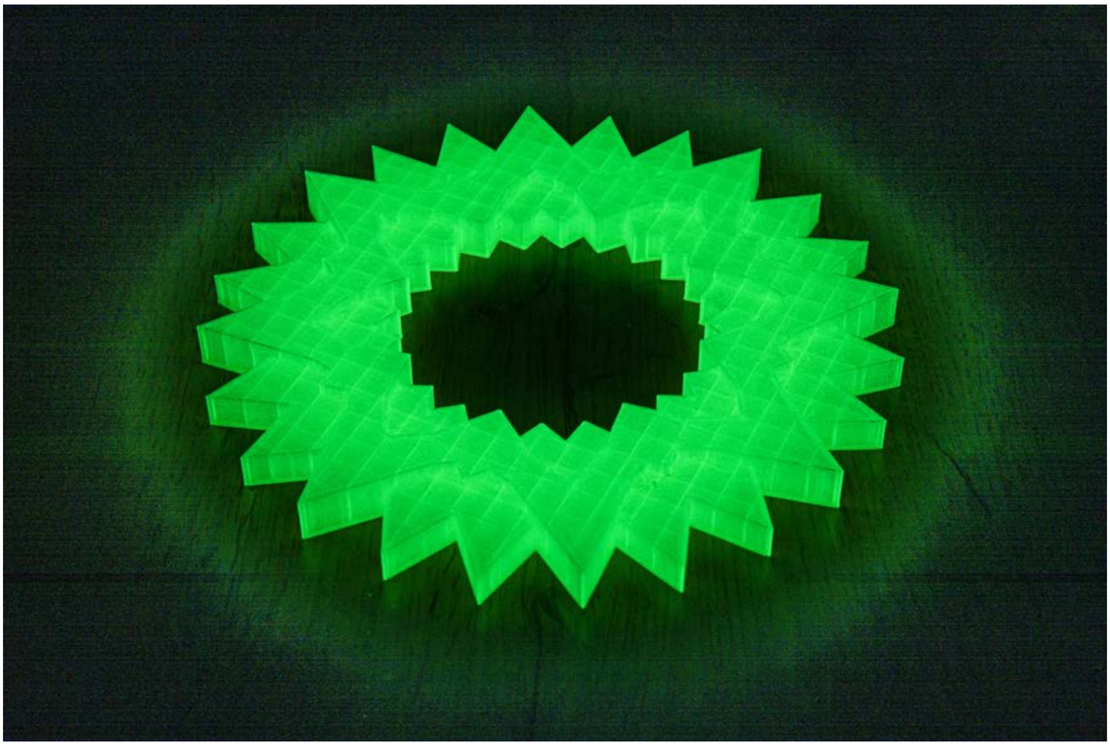


Figure 3.5 A photoluminescent filament prototype (first iteration). Without LEDs, the glow-in-the-dark effect offered insights into low-light halo aesthetics, informing future material selection.

### Second Iteration: LED Integration and Diffusive Layers

Guided by the lessons of the first iteration, the second iteration adopted a simplified geometric shape (e.g., an octagonal or similarly manageable form). Key advancements included:

- **LED Integration:** Actual LEDs were embedded to produce meaningful visual cues corresponding to various emotional states.
- **Diffusive Layers:** A carefully selected diffusive plastic film was added to soften and uniformly distribute the LED light, preventing harsh glare and ensuring smoother color transitions.

With this functional LED prototype, the second iteration facilitated the first user test (Experiment 1). Participants observed various light modes and provided feedback, enabling both qualitative insight (descriptive emotional terms) and a simple quantitative measure (word frequency analysis).

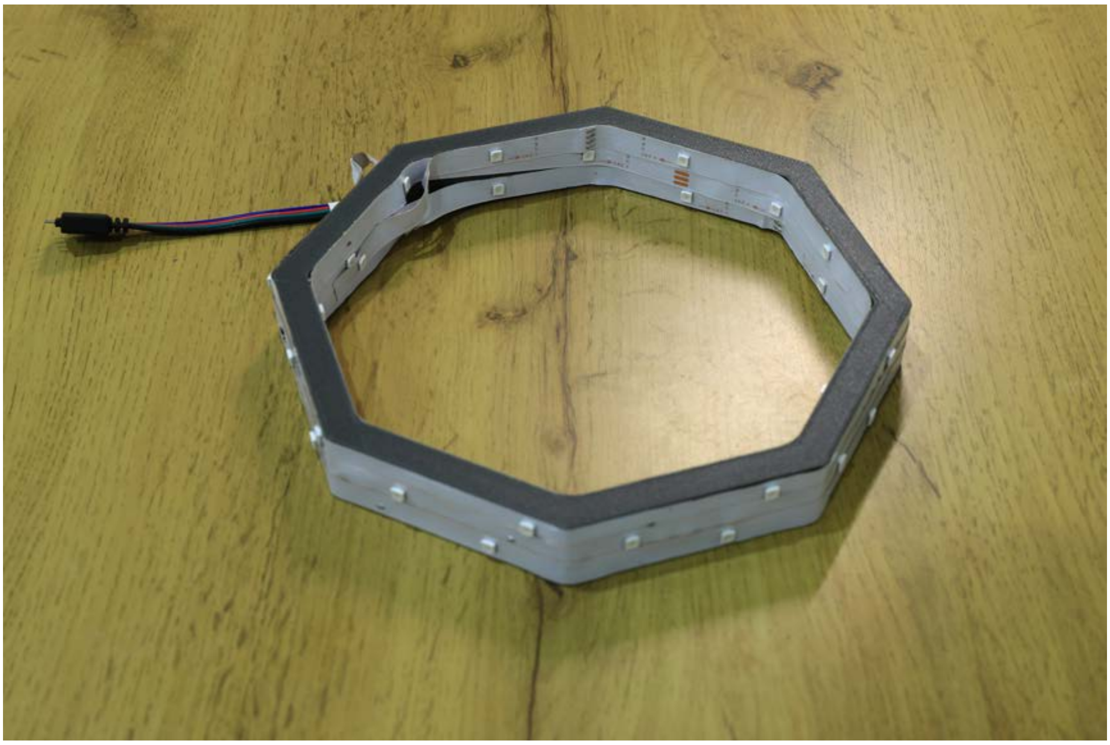


Figure 3.6 Second iteration frame: A simplified geometric structure was introduced to accommodate LEDs and wiring more efficiently.

Figure 3.7 Second iteration prototype before LED activation. The absence of glare and careful planning for LED placement allowed the device to be prepped for diffusive layers.

Figure 3.8 Second iteration prototype with the meticulously applied diffusive plastic film. This layer softened the LED light, resulting in gentler, more interpretable visual cues that closely matched intended emotional representations.

### User Feedback from Experiment 1 (Second Iteration)

**Qualitative Impressions:** Participants provided detailed qualitative feedback on the various lighting modes employed by the Sense Halo. Their responses linked specific modes to distinct emotional descriptors. For instance, when exposed to the **Calm (Blue Light)** mode, many participants described feeling "peaceful," "relaxed," and "serene," which aligns with the widely recognized association between blue hues and tranquility.

In contrast, the **Fatigue (Dim White Dotted)** mode elicited responses such as "distant," "tired," and "do not disturb," suggesting that the lower brightness and muted white dotted pattern effectively convey a sense of weariness and reduced energy.

For the **Vitality (Bright White)** mode, participants frequently mentioned descriptors like "energetic," "open," and "ready to talk," indicating that the high brightness of this mode successfully invokes a positive, invigorated state.

Meanwhile, the **Affection (Pink/Purple)** mode was consistently associated with words such as "warm," "friendly," and "inviting," reinforcing the idea that soft pink and purple tones can evoke feelings of intimacy and care.

Finally, the **Exuberance (Multicolor)** mode was described as "exciting," "lively," "party-like," and "eye-catching," reflecting its ability to capture high arousal and dynamic emotional states.

Overall, these qualitative impressions not only validate the intended emotional mapping of the Sense Halo's lighting modes but also offer important insights for future design refinements. Several participants noted that while the **Exuberance (Multicolor)** mode elicited very strong responses, the transitions between colors could be made smoother to enhance interpretability. In addition, many suggested that a brief explanation or training on the intended emotional associations would further improve user engagement. These detailed insights underscore the crucial role of diffusive lighting and careful color selection in effective non-verbal communication, and they will directly inform subsequent iterations of the device.

**Quantitative Word Frequency:** A rough frequency analysis of key descriptors revealed strong consensus for certain modes (e.g., Exuberance and Affection), while modes like Fatigue were understood but with moderate clarity:

Table 3.1 Mapping participant feedback from Experiment 1

| **Mode** | **Frequent Terms** | **Approx. Frequency** |
|---|---|---|
| Calm (Blue) | “calm” (80%), “peaceful” (50%) | Strong calm association |
| Fatigue (Dim White) | “distant” (60%), “tired” (40%) | Moderate correlation |
| Vitality (Bright White) | “open” (70%), “energetic” (60%) | Clearly positive and engaging |
| Affection (Pink/Purple) | “warm” (80%), “friendly” (70%) | High consensus on warmth |
| Exuberance (Multicolor) | “exciting” (90%), “lively” (70%) | Very high enthusiasm |

**Overall Interpretation:** The results confirm that diffusive lighting and mindful color selection significantly influence participants’ interpretations. While certain modes, such as Exuberance and Affection, evoked a strong and consistent emotional response, other modes like Fatigue demonstrated moderate clarity, indicating the need for further refinement. These findings underscore the critical role of visual cues in compensating for the loss of facial expression, as well as the importance of selecting appropriate color palettes for effective emotional communication. Additionally, several participants suggested that the inclusion of explicit emotional labels or brief training sessions could enhance interpretability, a recommendation that will be integrated into future design iterations. Overall, the feedback not only validates the design principles underlying the Sense Halo but also provides valuable insights for further optimization.

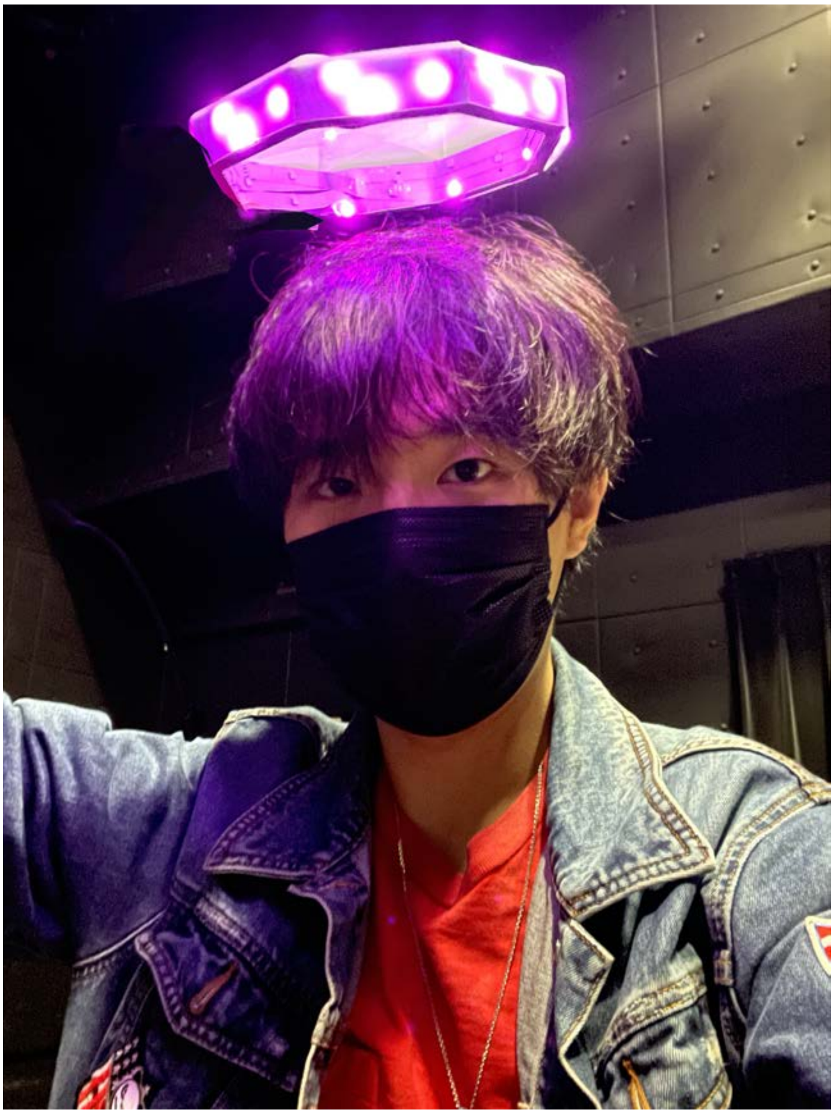


Figure 3.9 Second iteration prototype in action during Experiment 1. Under dim conditions, participants observed and interpreted the LED-driven emotional cues, providing crucial qualitative and quantitative feedback.

### 3.2.2 Third Iteration: Circular Frame and Enhanced Practicality

Armed with the insights from Experiment 1, the third iteration adopted a circular frame, symbolizing unity and ensuring better weight distribution and ergonomics. Key enhancements included:

- A more stable structure compatible with LEDs, wiring, and diffusers.
- Further refinement of LED brightness, hue, and diffusion thickness informed by user feedback.
- Improved attachment mechanisms for greater wearer comfort.

The third iteration represented the culmination of aesthetic refinement, functional adjustment, and user-driven optimization. By this stage, the *Sense Halo* was well-prepared for more formal validation trials.

## 3.3. Modeling and Fabrication Techniques

Cinema 4D's advanced modeling features facilitated rapid conceptual changes. The Elecom Pro 5 3D printer supported experimentation with various polymers—opaque, semi-transparent, and photoluminescent. LED integration demanded balancing brightness, color fidelity, and heat dissipation. Diffusive films played a crucial role, as confirmed by participant responses, ensuring gentle and coherent emotional cues.

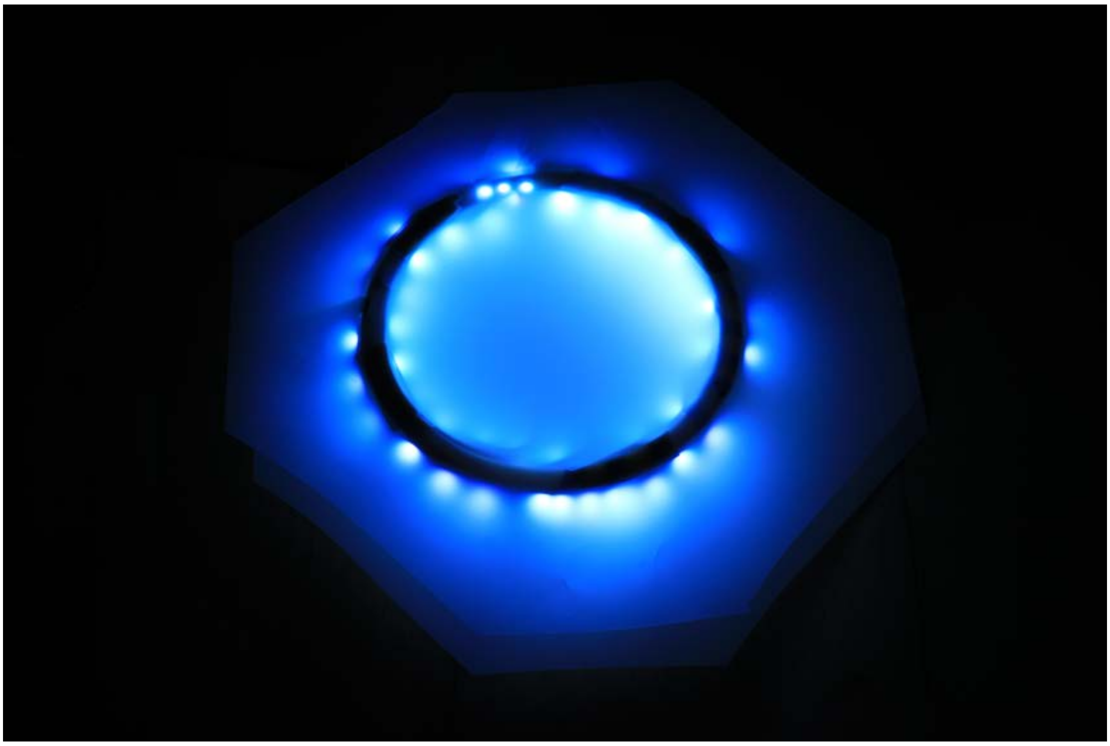


Figure 3.10 The third iteration's circular frame design. With a larger diffuser and refined LED placements, this iteration achieved a more stable, user-informed, and contextually appropriate configuration.

Figure 3.11 The side view of iteration 3 which added a part of structure to make it wearable

## 3.4. Integrating a Control System and GUI

After finalizing the third iteration's physical design, attention turned to usability and interaction. To allow users to select modes easily and adapt the *Sense Halo* to different scenarios, a dedicated control system and graphical user interface (GUI) were developed.

### 3.4.1 GUI Design and Platforms

A Figma-based design process resulted in an elegant and intuitive GUI, offering five distinct modes corresponding to different emotional states. The GUI's aesthetic aligned with the cosplay community's preferences—colorful, visually appealing, and straightforward. The interface could be deployed across multiple platforms:

- **Laptop Version:** Ideal for initial demonstrations and stable indoor setups, where users can quickly select modes from a larger screen.
- **Smartphone Version:** Suitable for mobile contexts, allowing cosplayers to change modes while moving around events or gatherings.
- **Smartwatch Version:** For maximum portability, enabling discrete, on-the-fly adjustments during live performances without disrupting the cosplay scenario.

Although demonstrated primarily on a laptop for simplicity, the GUI's scalable design ensured versatility, meeting users' varying operational needs.

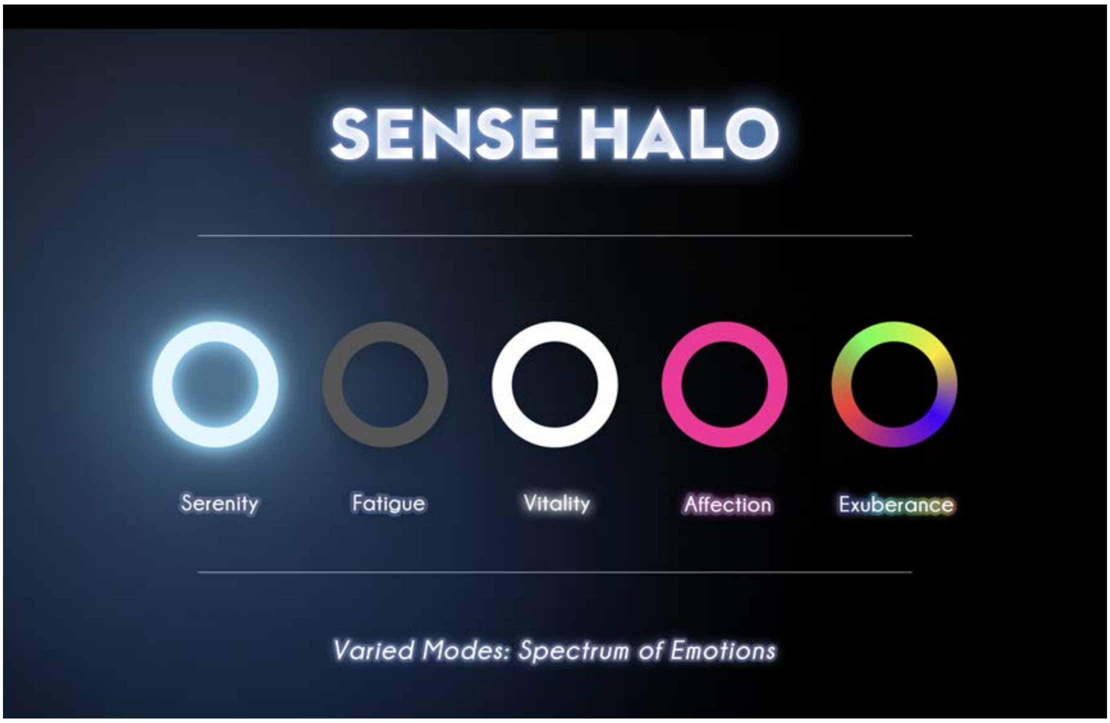



Figure 3.12 An example of the GUI interface designed in Figma. Users can select from five emotional modes at a click, enhancing operational convenience and adaptability.

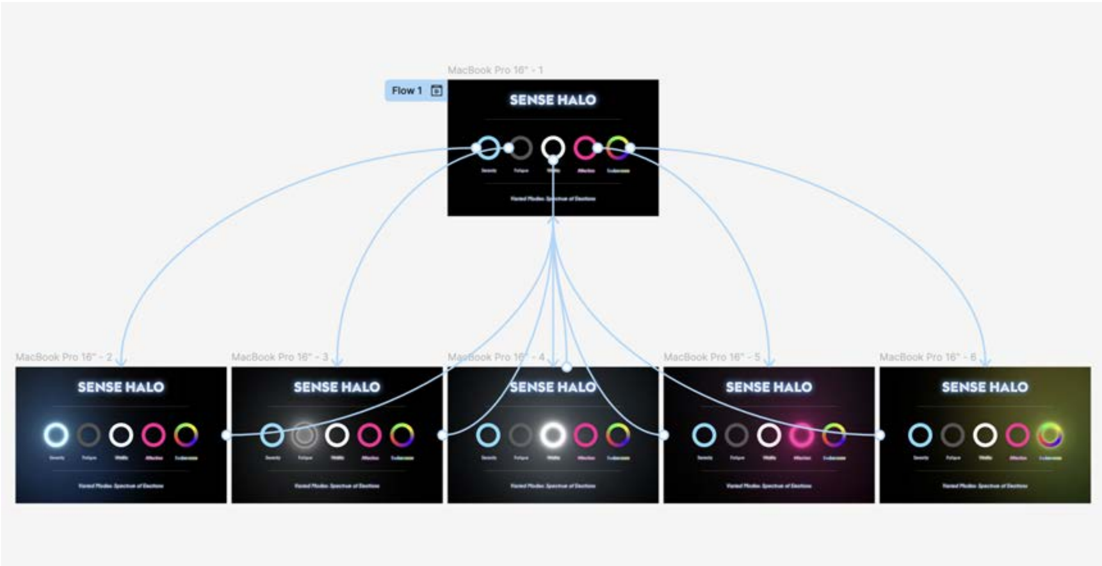



Figure 3.13 A flowchart depicting the GUI's operational logic. After initialization, users select a mode, which sends a command through the CPS32 interface to the Sense Halo, updating its LED pattern and color accordingly.

### 3.4.2 Hardware and Software Integration

To connect the GUI to the physical *Sense Halo*, a CPS32 controller and supporting electronics were employed. The implementation involved:

1. **CPS32 Microcontroller and Breadboard Setup:** A CPS32-compatible microcontroller and a breadboard were used to route signals from the GUI (running on a connected device) to the LED array embedded in the Sense Halo.

2. **Communication Protocols:** Using Processing and Arduino frameworks, the system translated GUI selections into digital signals. When a user clicked a mode on the GUI, the laptop (or smartphone) sent a command via USB or wireless interface to the microcontroller.

3. **LED Control Logic:** The microcontroller interpreted these commands and adjusted LED brightness, color, and patterns in real-time. Internal code handled transitions smoothly to avoid abrupt shifts that might confuse or distract the user.

This setup created a fully integrated system. Users could interact with the GUI to choose an emotional mode, and within milliseconds, the *Sense Halo* reflected that choice. This responsiveness ensured that cosplayers could dynamically adapt their emotional cues to changing social contexts, even when verbal or facial communication remained limited.

## 3.5. Qualitative and Quantitative Integration for GUI and Control System

The addition of a control system and GUI not only improved usability but also had implications for user studies. With an accessible interface, future experiments could test how quickly users learned mode meanings when guided by a labeled GUI, or how accuracy improved when participants could self-adjust brightness and color intensity to match their intuitive sense of a given emotion.

By correlating user choices on the GUI with subsequent emotional cue interpretations, the research could generate richer data. This included measuring response times (quantitative) and examining open-ended feedback on the GUI's ease of use and aesthetic appeal (qualitative). In essence, integrating the control system and GUI opened new avenues for both research and practical application.

## 3.6. Conclusion and Next Steps

Through three iterations, the *Sense Halo* progressed from a conceptual, LED-free form to a stable, user-informed, and LED-integrated device. Experiment 1 provided essential feedback, guiding adjustments that improved emotional expressiveness. The final addition—a comprehensive control system and a Figma-designed GUI—ensured that users could seamlessly operate the device, adapt it to different scenarios, and potentially improve accuracy and engagement.

This holistic approach—combining iterative design, user feedback, qualitative and quantitative data analysis, and a versatile control interface—set the stage for more formal validation. Subsequent chapters will detail the experimental setups, protocols, and analysis methods used to rigorously evaluate the *Sense Halo*'s efficacy in enhancing emotional communication for cosplayers and other users facing similar constraints.

# Chapter 4
# Validation

## 4.1. Introduction and Methodology

This chapter presents the validation phase of the *Sense Halo* research, focusing on how effectively the device enhances emotional communication when facial expressions and verbal cues are severely restricted. Unlike the initial informal test (Experiment 1)—where participants primarily observed the device's capabilities—this validation experiment (Experiment 2) requires participants to directly operate the Sense Halo through a customized Graphical User Interface (GUI). In this experiment, participants experience two rounds of scenario-based mode selection: the first without explicit emotional labels and the second with labels provided. By comparing participant performance across these two rounds, we can quantitatively and qualitatively assess improvements in accuracy, confidence, willingness to communicate, and overall satisfaction once participants understand each mode's intended emotional meaning.

The primary objectives of this validation are:

- To determine whether familiarity with each mode's emotional significance enhances participants' ability to accurately select appropriate modes for given scenarios.
- To assess if the combination of labeling and a user-friendly GUI improves communication clarity, user satisfaction, and participant engagement.
- To confirm that the Sense Halo can convey a wide spectrum of emotional states—from subtle neutrality and mild fatigue to exuberant enthusiasm and strong affection—in conditions where facial expressions and speech are not available.

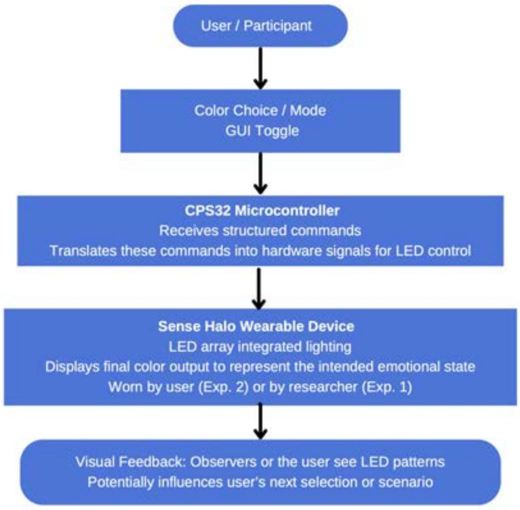



Figure 4.1 System Architecture

## Experimental Context

Participants were instructed to imagine themselves in conditions similar to wearing a heavy, face-obscuring mask (e.g., a kigurumi headpiece), which prevents the use of facial expressions and verbal cues. The experiment was conducted in a dimly lit environment, emphasizing the visual impact of the Sense Halo's LED-based cues. Under these constraints, participants relied entirely on the device's color and light patterns to communicate their emotional states and willingness to interact.

## Experiment Procedure

The validation experiment consisted of three main steps:

1. **Pre-Experiment Survey:** Participants completed a pre-survey measuring their baseline willingness to communicate under masked conditions, their perceived difficulty in conveying emotions without visible facial expressions, and their initial expectations of a wearable visual-cue device like the Sense

Halo. This survey established a baseline against which we could measure changes after the experiment.

2. **Scenario-Based Mode Selection (Two Rounds):** Ten scenarios were introduced, each describing a distinct emotional or social context. Initially, in **Round 1 (Without Emotion Labels)**, participants selected the mode they felt best matched the scenario using only intuition. Their choices were recorded on the back of each scenario card. In **Round 2 (With Emotion Labels)**, after participants were informed of each mode's intended emotional meaning, they repeated the selection process for the same scenarios. By comparing accuracy and choice patterns between Round 1 and Round 2, we could assess the impact of labeling.

   Participants operated the Sense Halo through a laptop-based GUI featuring five selectable modes. This direct interaction allowed collecting both qualitative impressions (feedback on device use) and quantitative data (mode choices per scenario).

3. **Post-Experiment Survey:** After completing both rounds, participants filled out a post-survey. This measured changes in willingness to communicate, perceived clarity of the device's emotional cues, overall satisfaction, and the influence of labeling. Open-ended questions encouraged participants to provide detailed feedback and suggestions for refinement.

## Pre-Experiment Survey Summary

A total of 12 participants took part. Key findings from the pre-experiment survey included:

- **Past Experience:** Most participants (about 83.3%) had never attended a cosplay event wearing a mask that significantly obscured their face. Only a few had done so once.
- **Willingness to Communicate Under Masked Conditions:** Responses varied widely on a 1–5 scale, reflecting diverse baseline comfort levels. Some participants rated themselves low (indicating reluctance), while others indicated moderate to high willingness.

- **Difficulty in Conveying Emotions:** Most participants rated conveying emotions without facial cues as moderately to highly challenging (many scoring 3–5 on a 5-point scale).
- **Perceived Usefulness of a Visual Cue Device:** Participants generally believed that a wearable device providing visual cues (like the Sense Halo) would be useful (many rated around 3–4 out of 5), indicating positive initial expectations.
- **Confidence in Others' Interpretation:** Confidence was not high; few participants felt strongly that others could interpret their masked emotions accurately.
- **Greatest Challenge and Priority for Improvement:** Neutral or low-engagement states were reported as hardest to convey. Participants prioritized improvements in clearly signaling these subtle emotional conditions.

The pre-survey thus set the stage: participants entered the experiment with limited confidence, moderate expectations for assistance, and specific challenges in communicating nuanced emotional states under masked conditions.

## 4.2. Scenarios and Data Collection

To evaluate the efficacy of the Sense Halo in conveying emotional states, a set of ten distinct scenarios was carefully devised. These scenarios represent a broad spectrum of emotional and interactional states, ranging from subtle fatigue to highly energetic engagement, ensuring a comprehensive assessment of the device's interpretability. All scenarios were presented in English to avoid any character encoding issues. The following tables summarize the ten scenarios along with their corresponding detailed descriptions.

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Table 4.1 Description of Experimental Scenarios (1–5)

| **Scenario** | **Description** |
| --- | --- |
| Scenario 1: Mild Fatigue | The participant has been active for an extended period, resulting in a state of mild fatigue. They feel slightly tired and prefer minimal interaction, showing reluctance to initiate conversations. |
| Scenario 2: Neutral Observer | The participant experiences a neutral emotional state, feeling calm without a strong desire to either engage or withdraw from social interaction. They simply observe their surroundings without significant emotional involvement. |
| Scenario 3: High Energy and Enthusiasm | The participant is filled with energy and enthusiasm, feeling open and eager to engage with others. This state is characterized by a readiness to actively participate in conversations and social interactions. |
| Scenario 4: Friendly Affection | The participant expresses warm and friendly feelings toward someone they admire, conveying a sense of affection and inviting interaction through gentle, welcoming cues. |
| Scenario 5: Reserved and Private | The participant consciously opts for solitude, not due to fatigue but to enjoy a calm, introspective moment. They deliberately avoid social engagement to preserve a sense of privacy and personal space. |

Table 4.2 Description of Experimental Scenarios (6–10)

| **Scenario** | **Description** |
|---|---|
| Scenario 6: Overjoyed and Delighted | The participant has received positive feedback or good news, leading to a state of genuine happiness and elation. This state motivates them to share their joy openly and engage more readily with others. |
| Scenario 7: Strong Affection or Liking | The participant feels a deep emotional connection or fondness towards someone or something, aiming to express strong positive feelings and foster a closer bond through non-verbal cues. |
| Scenario 8: Intense Engagement | The participant is highly absorbed in an ongoing conversation or activity, demonstrating strong interest and eagerness to continue the interaction. This reflects a deep level of engagement and focus. |
| Scenario 9: Slight Discomfort but Open | Despite feeling a mild discomfort (e.g., due to the heaviness of a mask), the participant remains open to social interaction, albeit in a cautious or restrained manner. |
| Scenario 10: Playful and Fun Mood | The participant is in a cheerful and vibrant environment, experiencing a playful mood that invites others to join in lighthearted and fun interactions. |

These scenarios form the basis of the experimental design. Each participant was exposed to all ten scenarios, and their mode selections and responses were recorded for subsequent quantitative and qualitative analysis. The careful construction and varied nature of these scenarios are essential for assessing the effectiveness of the Sense Halo in conveying nuanced emotional states.

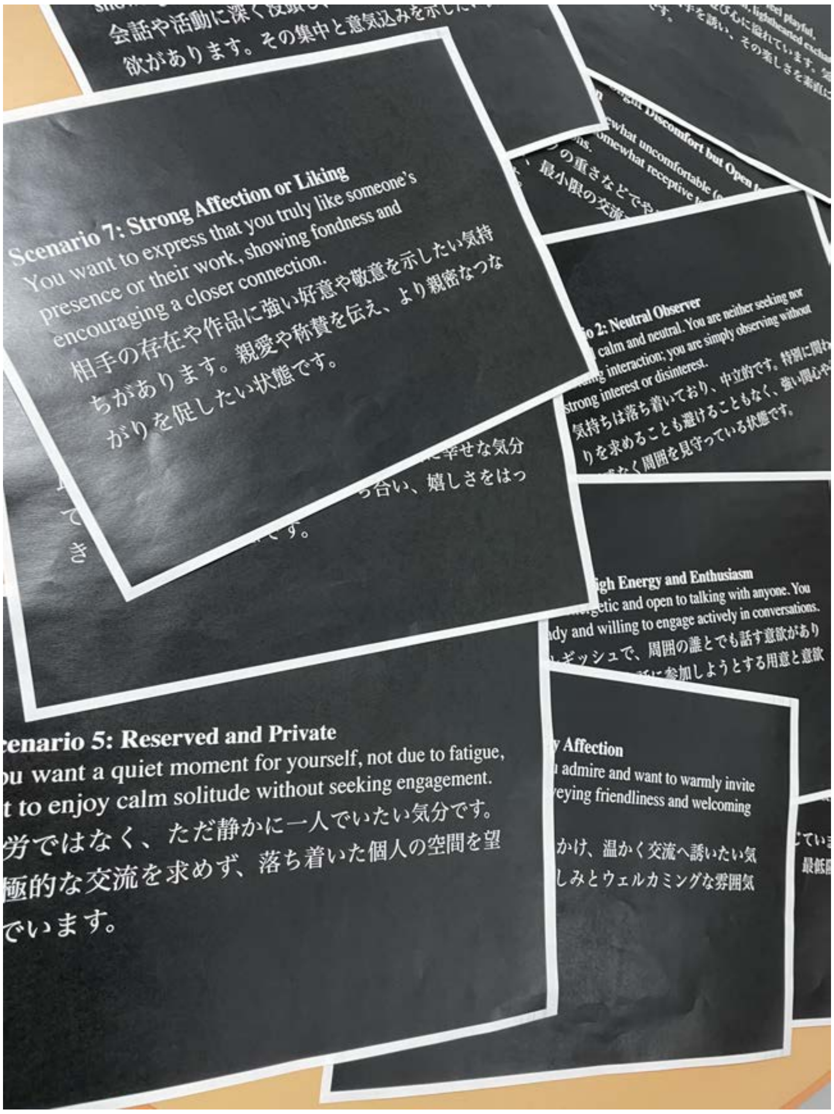


Figure 4.2 A set of ten scenario cards, each describing a unique emotional or interaction context.

## 4.4. Raw Mode Selection Data (Round 1 and Round 2)

Each participant (P1 to P12) selected modes for each scenario twice: Round 1 (no labels) and Round 2 (with labels). The notation "A/B" indicates "Mode chosen in Round 1" = A and "Mode chosen in Round 2" = B. This comprehensive raw data is crucial for understanding how labeling influenced participant decisions.

Table 4.3 Raw Mode Selection Data for Each Scenario

| **Scenario** | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 | P12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mild Fatigue | 2/2 | 2/2 | 2/1 | 2/2 | 2/1 | 1/1 | 2/2 | 2/2 | 2/2 | 2/2 | 2/2 | 2/2 |
| Neutral Observer | 1/1 | 2/1 | 1/3 | 3/1 | 3/2 | 3/1 | 3/1 | 2/1 | 3/1 | 2/1 | 2/2 | 1/1 |
| High Energy and Enthusiasm | 3/3 | 5/5 | 5/4 | 5/3 | 5/5 | 1/3 | 5/5 | 5/3 | 5/5 | 5/3 | 5/5 | 3/4 |
| Friendly Affection | 3/4 | 1/1 | 5/5 | 4/4 | 4/4 | 4/4 | 3/5 | 4/4 | 4/4 | 3/4 | 1/5 | 3/4 |
| Reserved and Private | 1/1 | 3/1 | 3/1 | 1/1 | 1/1 | 1/1 | 1/1 | 2/1 | 1/1 | 2/2 | 3/1 | 2/1 |
| Overjoyed and Delighted | 5/5 | 5/5 | 4/4 | 5/5 | 5/3 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 |
| Strong Affection or Liking | 3/4 | 3/3 | 5/5 | 4/4 | 1/4 | 4/4 | 4/4 | 4/4 | 4/4 | 4/4 | 5/4 | 4/4 |
| Intense Engagement | 3/4 | 3/3 | 1/3 | 4/3 | 3/3 | 2/1 | 3/3 | 1/1 | 4/3 | 3/3 | 1/1 | 3/3 |
| Slight Discomfort but Open | 2/2 | 2/2 | 2/1 | 3/2 | 3/2 | 1/1 | 2/2 | 2/2 | 3/2 | 1/1 | 3/1 | 2/2 |
| Playful and Fun Mood | 5/5 | 4/4 | 4/3 | 5/5 | 1/5 | 1/3 | 5/5 | 5/5 | 5/5 | 3/5 | 5/5 | 5/5 |

This raw data allows for detailed analysis. By identifying the "intended" mode for each scenario (as defined in the research design), we calculate accuracy rates for both Round 1 (without labels) and Round 2 (with labels). Descriptive statistics, including mean accuracy rates and standard deviations, are computed to illustrate overall performance differences. Furthermore, appropriate statistical tests (e.g., paired t-tests) are applied to assess whether the improvements observed with labeling are statistically significant. The integration of these quantitative results with qualitative feedback provides a comprehensive understanding of how explicit labeling influences the interpretation of emotional cues.


Figure 4.3 A participant engaging in the validation experiment. Under dim lighting, the participant uses the GUI on a laptop to select modes on the Sense Halo, aiming to convey emotions non-verbally.

## 4.5. Post-Experiment Survey and Feedback

After completing Round 2 of the experiment, participants completed a post-survey designed to capture their subjective experiences and overall satisfaction with the Sense Halo. The survey focused on several key areas:

- **Increased Willingness to Communicate:** Participants reported that gaining a clear understanding of the Sense Halo's functionality increased their comfort in initiating interactions under masked conditions.
- **Improved Perceived Clarity and Satisfaction:** The emotional cues were perceived as significantly clearer when accompanied by explicit labeling. Participants found the GUI for mode selection intuitive, contributing to an overall increase in satisfaction with the device.
- **Observer Interpretation Confidence:** Participants believed that observers would have a higher likelihood of accurately interpreting their emotional states, as the more deliberate and informed mode choices provided by the Sense Halo enhanced clarity.
- **Open-Ended Feedback:** Qualitative feedback revealed suggestions for further refinements, including the incorporation of more nuanced color gradients, adjustable brightness controls, and additional modes to capture subtle emotional intensities. Some participants also recommended exploring alternative wearable formats (e.g., bracelets or pendants) that might integrate more seamlessly with various costumes and personal styles.

The comparative analysis of pre- and post-survey responses indicated a positive shift in participants' perspectives. They entered the experiment with uncertainty and moderate expectations, and emerged with increased confidence, higher satisfaction, and a stronger willingness to engage. These findings underscore the effectiveness of the Sense Halo in enhancing non-verbal emotional communication and provide valuable insights for guiding future design improvements.

## 4.6. Conclusion and Future Directions

This validation phase confirms that providing explicit emotional labels and an intuitive GUI interface significantly enhances the Sense Halo's effectiveness in bridging non-verbal communication gaps. The scenario-based tests demonstrate that participants, when properly informed, align more closely with the intended emotional modes, leading to improved accuracy, interpretability, and user confidence. The integration of quantitative performance data with qualitative user feedback robustly validates the core design principles of the Sense Halo, confirming its potential to transform opaque, inaccessible emotional states into visible, dynamic expressions of color and light.

Moreover, the Sense Halo's success in controlled experimental conditions suggests broader applicability beyond cosplay. In environments where facial expressions and speech are restricted—such as performance arts, immersive events, or specialized communication contexts—the device's ability to convey a rich emotional palette through light patterns is invaluable. Its portability and adaptability, combined with iterative refinements driven by user feedback, position the Sense Halo as a versatile tool for enhancing non-verbal interactions.

Future work will focus on several key areas:

- **Enhanced Emotional Nuance:** Incorporate adjustable brightness levels, subtle color gradients, and more intricate lighting patterns to represent a broader spectrum of emotions with greater precision.

- **Refined Wearable Formats:** Explore alternative designs such as wristbands, necklaces, or integrated costume components to ensure seamless integration into various cosplay outfits, as well as to improve comfort and aesthetic appeal.

- **Larger-Scale Evaluations:** Conduct studies at actual cosplay events or other large gatherings to validate the device's real-world effectiveness, encourage further user-driven innovations, and spark new forms of creative expression.

In essence, this validation confirms that the Sense Halo, complemented by clear labeling, a user-friendly GUI, and iterative user feedback, can significantly enhance emotional communication in masked contexts. As its features continue to be refined and its applications broadened, the Sense Halo stands poised to redefine how individuals express and interpret emotional signals, ultimately fostering richer, more inclusive, and emotionally attuned interactions in diverse social environments.

# Chapter 5
# Conclusion

This research set out to enhance emotional communication under conditions where conventional non-verbal cues—such as facial expressions and speech—are severely constrained. Grounded in the context of cosplay and the unique challenges posed by kigurumi masks, the study introduced the *Sense Halo*: a wearable device designed to convey emotional states through color and light. Drawing on human-computer interaction principles, color psychology, and user-centered design, this project aimed to restore expressive depth and meaningful interaction in masked scenarios where emotional signals are otherwise hidden.

## 5.1. Summary of Findings

The initial surveys revealed that participants faced considerable difficulties in expressing nuanced emotional states—mild fatigue, neutrality, subtle affection, reserved solitude—when their faces were covered and verbal communication limited. Despite these challenges, participants held moderate to high expectations that a wearable visual-cue device might help bridge the communication gap.

In the core validation experiment, participants underwent two rounds of scenario-based mode selection. In the first round, they relied solely on intuition, resulting in uncertainty and guesswork. However, after explicit emotional labeling of each mode, participants in the second round achieved markedly higher accuracy, greater confidence, and increased willingness to engage with others. Qualitative feedback supported these improvements, indicating that once users understood the emotional meanings behind specific color and light patterns, the Sense Halo transitioned from an enigmatic accessory into a clear emotional lexicon.

These findings confirm that even minimalistic, well-structured visual cues can compensate for absent facial and verbal signals. The Sense Halo effectively restored a dimension of emotional transparency, enabling richer, more satisfying interactions in contexts that traditionally lack them.

## 5.2. Contributions and Significance

This research offers multiple contributions:

**1. Methodological Integration:** By combining pre- and post-surveys, scenario-based tasks, and mixed qualitative-quantitative analyses, this study provides a replicable framework for evaluating similar assistive communication technologies. This approach ensures rigorous empirical grounding and iterative refinement informed by user feedback.

**2. Emotional Nuance in Masked Interactions:** The Sense Halo demonstrates that users can adopt a new, non-verbal language of colors and lights to convey complex feelings. Beyond cosplay, this insight is applicable in various fields where masks or coverings impede traditional non-verbal cues.

**3. Universal and Context-Transcending Potential:** Because color perception and brightness are broadly intuitive, the Sense Halo's emotional vocabulary can transcend cultural and contextual boundaries. With proper labeling and brief training, people from diverse backgrounds can quickly internalize this visual language.

**4. User-Centered Innovation:** From conceptual design to final validation, this research exemplifies user-centered innovation. Iterative refinement, based on participant input, ensured that the device evolved into a more stable, comprehensible, and emotionally expressive tool.

## 5.3. Beyond Cosplay: Towards Performance Arts, Live Entertainment, and Daily Life

Although initially conceived for cosplayers, the Sense Halo's conceptual framework extends into performance arts, live entertainment, and even everyday environments. Consider a live stage performance—such as a DJ set, theatrical play, or dance show—where performers already use masks or headgear. Integrating the Sense Halo can help them convey emotional shifts, narrative progressions, or thematic moods. As colors and brightness intensities dynamically respond to the music's cadence or the storyline's tone, audiences gain a richer emotional experience. This transformation can enhance immersion, encourage audience participation, and foster a deeper connection between performer and observer.

Parallel technologies like "Nickface" have explored projecting actual facial expressions onto masks. In contrast, the Sense Halo offers an abstract, universal, and symbolic approach, relying on color-coded emotional cues rather than mimicking real facial features. Such symbolic representation can resonate subconsciously, appealing to cross-cultural audiences and opening new creative possibilities. Multiple performers wearing Sense Halos could synchronize their displays, creating evolving emotional landscapes that reflect collective states of engagement, tension, or harmony.

Beyond artistic performances and cultural events, the Sense Halo concept could also enrich daily life. Imagine offices or shared co-working spaces where individuals wear subtle color indicators to represent their current mood or openness to interaction. A calm blue glow might signal that someone is focused and prefers minimal disruption, while a gentle green hue might indicate willingness to collaborate. In social gatherings, festivals, or educational environments, these visual cues can help manage expectations, reduce misunderstandings, and make interactions smoother, more engaging, and more harmonious.

In all these scenarios—whether on a theater stage, a bustling convention floor, a dimly lit club, or a casual community meetup—color-based emotional communication can improve atmosphere, mitigate uncertainty, and enhance the quality of interpersonal and group engagements.

## 5.4. Further Iterations: Integrating Past Lessons into Future Design

The iterative design process undertaken here can inspire further refinements. Currently, the Sense Halo's evolution spanned three major iterations, each addressing key challenges and informed by user feedback. Building on these experiences, we can envision a **fourth iteration** that synthesizes the best elements of all previous iterations:

- From the first iteration, we retain the intricate geometric aesthetics, striving for a form that is both visually impressive and conducive to LED integration. - From the second iteration, we incorporate the LED-based emotional cues and diffusive layers that proved essential for clarity and user comprehension. - From the third iteration, we preserve the stability, ergonomic design, and user-informed refinements that resulted in robust, reliable performance.

This fourth iteration would aim to merge complexity, aesthetics, stability, and usability into a seamless whole. If we push even further, a **fifth iteration** could explore entirely new morphologies and dynamic shapes, challenging conventional assumptions about wearable design. Such advanced forms might allow the device to adapt its contours or textures dynamically, although these innovations pose substantial engineering and material science challenges.

As we push the boundaries of shape and form, we maintain a laser focus on functional effectiveness. After all, the Sense Halo must remain intuitive, comfortable, and comprehensible. Technological sophistication must not detract from the device's central goal: improving emotional communication.

## 5.5. Future Research Directions

Several directions emerge for future exploration:

**1. Enhanced Emotional Granularity:** Incorporate dynamic brightness controls, gradients, and blinking patterns to represent a broader emotional spectrum. More nuanced visual cues could differentiate between shades of affection or varying levels of enthusiasm, further enriching users' emotional "vocabulary."

**2. Alternative Wearable Formats:** Exploring wristbands, pendants, or integrated costume components could increase adoption and cultural resonance. Different formats may also prove more suitable for particular performance styles, daily interactions, or professional contexts.

**3. Cultural and Environmental Adaptations:** Cross-cultural testing can reveal how universal color emotional associations truly are. Similarly, varying lighting environments (e.g., outdoor festivals, dim indoor theaters) could influence perception and guide design tweaks, ensuring that cues remain legible and meaningful in all conditions.

**4. Longitudinal and Group Dynamics:** Long-term studies may show that with practice, users need no labeling to interpret cues effortlessly. Additionally, examining groups wearing multiple Sense Halos could reveal emergent properties—coordinated emotional "dialogues" that transform a space's collective atmosphere.

**5. Real-World Deployment and Commercialization:** Collaborations with performers, event organizers, and cultural institutions could test the Sense Halo in real-world scenarios, from music festivals to educational workshops. Commercializing the device might spur creative entrepreneurs to design new content, events, or performances tailored to this unique emotional signaling method.

## 5.6. Potential Applications for Enhancing Emotional Expression in Individuals with Social Anxiety and Selective Mutism

Beyond its commercial applications in performance arts and entertainment, the *Sense Halo* holds significant promise as an assistive tool for individuals who face challenges in expressing their internal emotional states. Populations such as those with social anxiety or selective mutism often experience difficulties in conveying subtle emotional cues, which can further isolate them and impede effective social interaction. Recent research has demonstrated that technology-based interventions can help alleviate these challenges by providing real-time, objective feedback that supports emotional self-regulation and encourages verbal engagement.

For instance, Bunnell's investigation into the incorporation of mobile applications in the treatment of selective mutism showed that technology-enhanced interventions can reduce anxiety levels and promote verbal interaction in individuals with Selective Mutism [22]. Similarly, Xu et al. [23] presented a clinical perspective on the use of passive audio vocal measurement in the evaluation of selective mutism, highlighting the potential of wearable devices to objectively assess and support improvements in emotional expression. Furthermore, Mohr et al. [24] discussed the concept of personal sensing in mental health, emphasizing that wearable devices can capture and modulate affective states, thereby offering a pathway to enhanced self-awareness and social engagement among individuals with social anxiety.

These findings suggest that the *Sense Halo* could be further adapted to serve as a practical, assistive tool that empowers users to better manage their emotional expressions and engage more confidently in social contexts. Such an adaptation would not only broaden the application scope of the device but also contribute to addressing the wider mental health challenges associated with impaired emotional expression.

## 5.7. Conclusion

In essence, this research demonstrates that the Sense Halo can effectively restore emotional expressiveness in environments that limit facial expressions and verbal cues. By integrating labeling, careful LED calibration, and user-centered refinements, the device transforms opaque, inaccessible emotional states into visible, dynamic, and easily interpreted patterns of color and light. This enhanced emotional transparency fosters richer interactions, greater user satisfaction, and a more confident willingness to engage.

Furthermore, the rigorous design process and iterative development underlying the Sense Halo underscore its unique contribution to the fields of human-computer interaction and wearable technology. This research specifically addresses the communicative challenges faced in kigurumi cosplay, where complete facial coverage not only suppresses spontaneous emotional expressions but also disrupts the natural flow of interpersonal communication. By carefully analyzing the characteristics of kigurumi and the flow of cosplayer interactions, the study justifies the design of the Sense Halo as a tailored solution that restores lost non-verbal cues while preserving character authenticity.

As we look beyond the realm of cosplay, the Sense Halo's potential expands into performance arts, immersive events, and everyday social settings. Its flexible design principles, cultural adaptability, and capacity for future iterative improvements underscore its promise. With further iterations that merge complexity, aesthetics, and robust functionality, the Sense Halo stands poised to redefine how humans express and interpret emotional signals, ultimately enriching communal experiences and making emotionally attuned interactions the norm rather than the exception.

Moreover, the implications of this research extend to supporting individuals who face challenges with emotional expression, such as those with social anxiety or selective mutism. By offering an alternative, non-verbal language based on color and light, the Sense Halo may serve as an innovative assistive tool that enhances self-expression and social connectivity in various contexts. The broad applicability of the device reinforces its societal relevance and opens new avenues for future research in cross-cultural emotional communication and assistive technology.

In a world where masks, stage lights, crowds, and differing cultural backgrounds can obscure our inner states, the Sense Halo symbolizes a pathway forward: a world where emotions, through the universal language of color and light, become visible beacons of understanding, connection, and shared humanity. This work not only advances our understanding of non-verbal emotional expression but also inspires further exploration and innovation aimed at creating richer, more inclusive human interactions.

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# Appendices

This appendix provides supplementary materials supporting the main research, including additional figures, diagrams, or other visuals that further illustrate the Sense Halo's design iterations, internal wiring strategies, diffusive layer configurations, and experimental testing setups. These elements serve to enhance the reader's understanding of the technical details and user testing procedures discussed in the core chapters of the thesis.

## A. information-poster

### A.1 concept information poster vertical with thorough information

### A.2 concept information poster horizontal with key information

## B. Survey Results

### B.1 Pre-Experiment Survey Results

### B.2 Post-Experiment Survey Results


Figure A.1 concept information poster vertical with thorough information

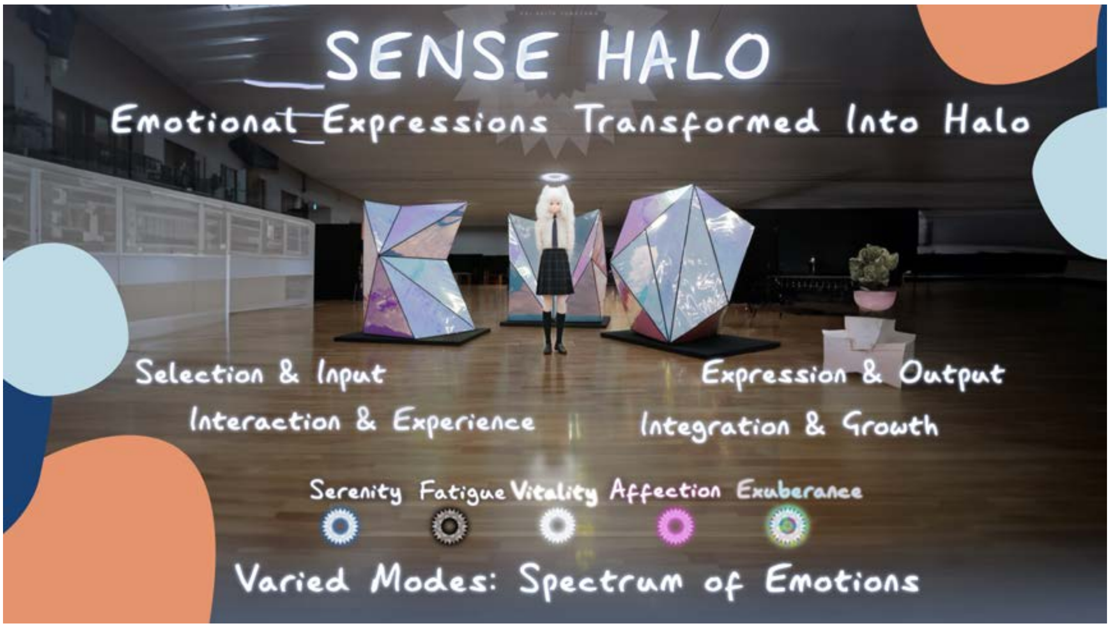



Figure A.2 concept information poster horizontal with key information

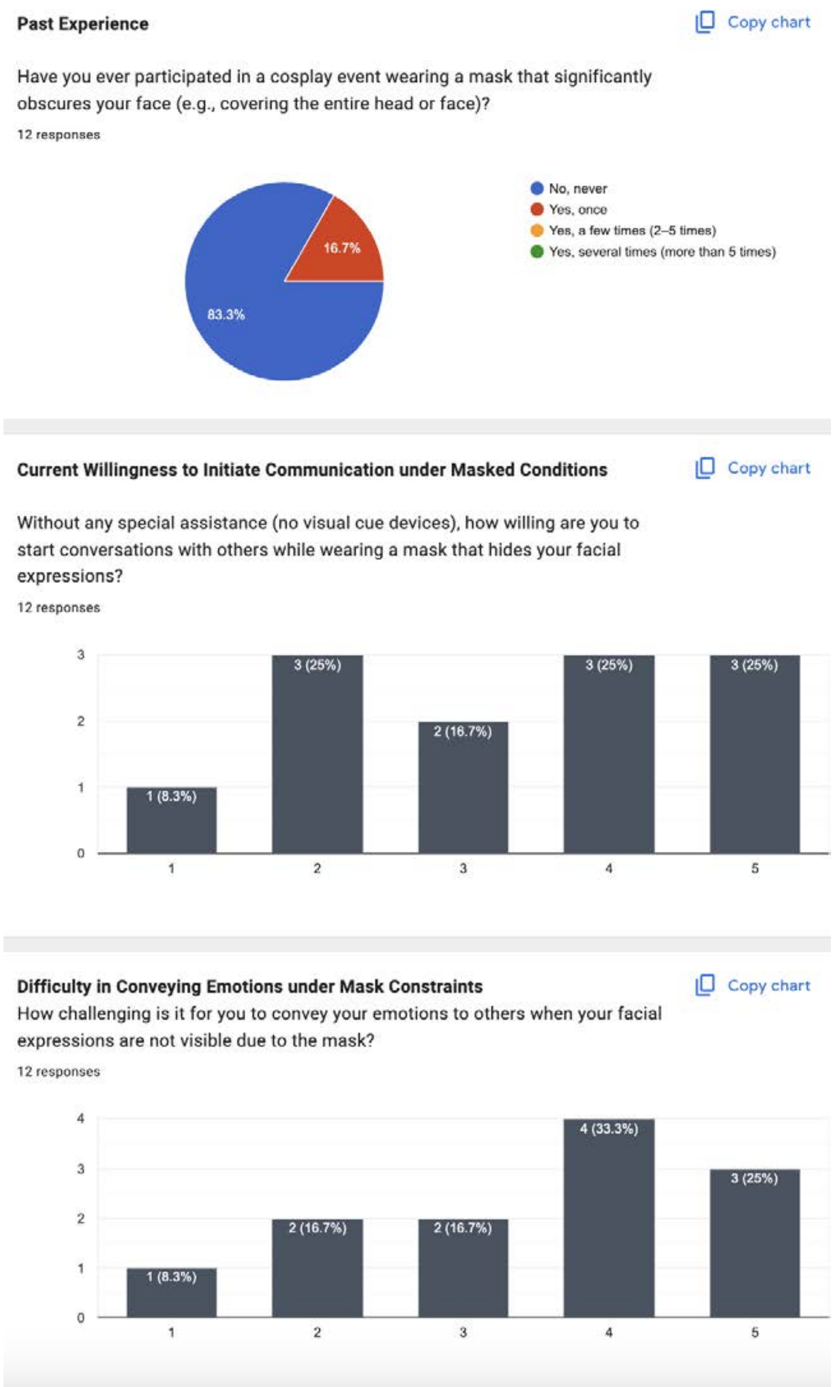



Figure B.1 Pre-Experiment Survey Results Part 1

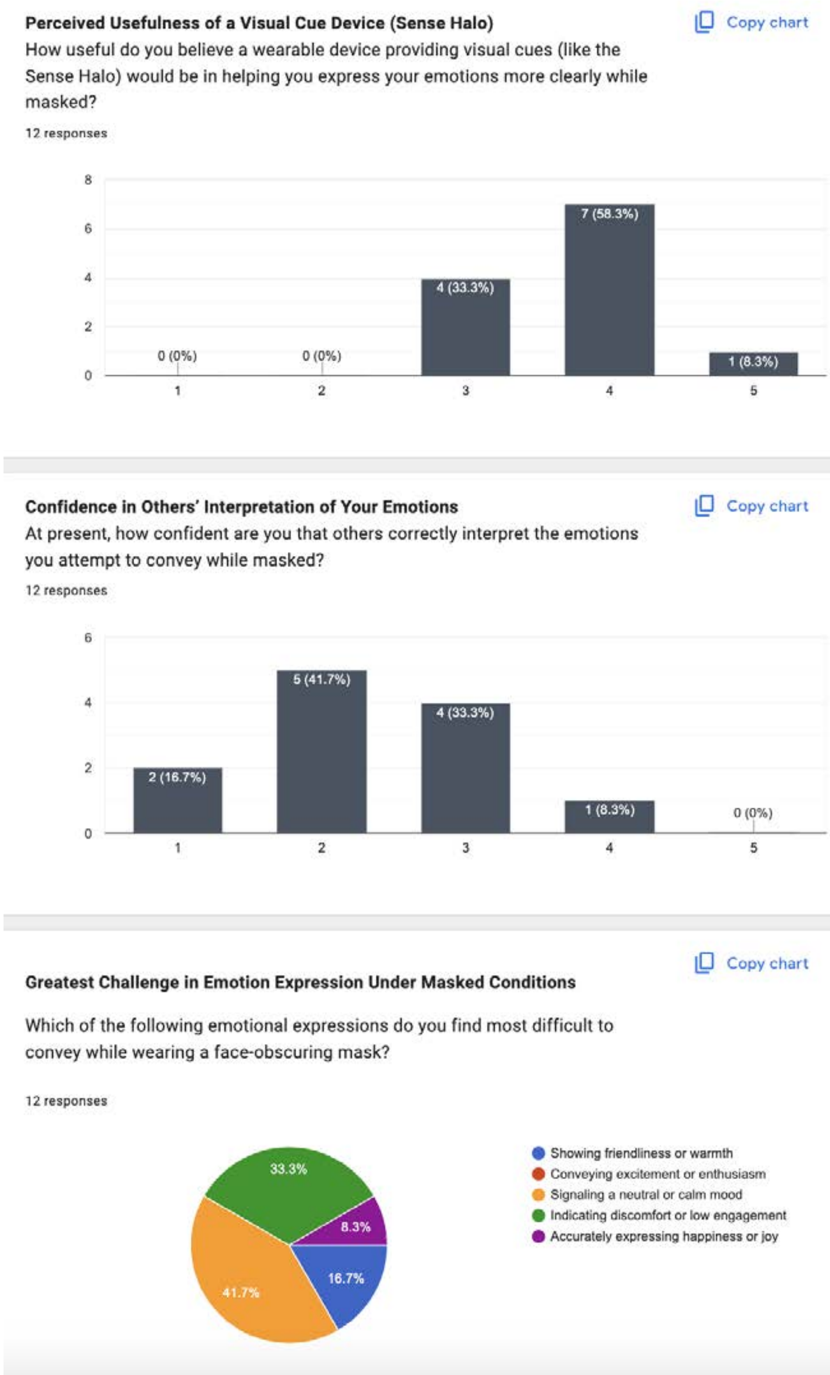



Figure B.2 Pre-Experiment Survey Results Part 2

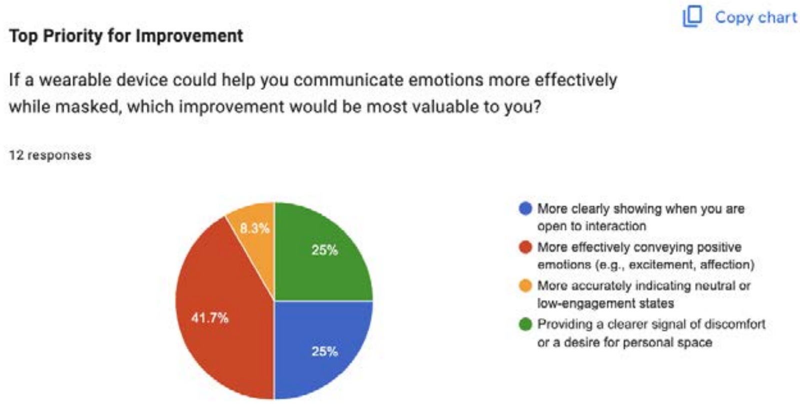



Figure B.3 Pre-Experiment Survey Results Part 3

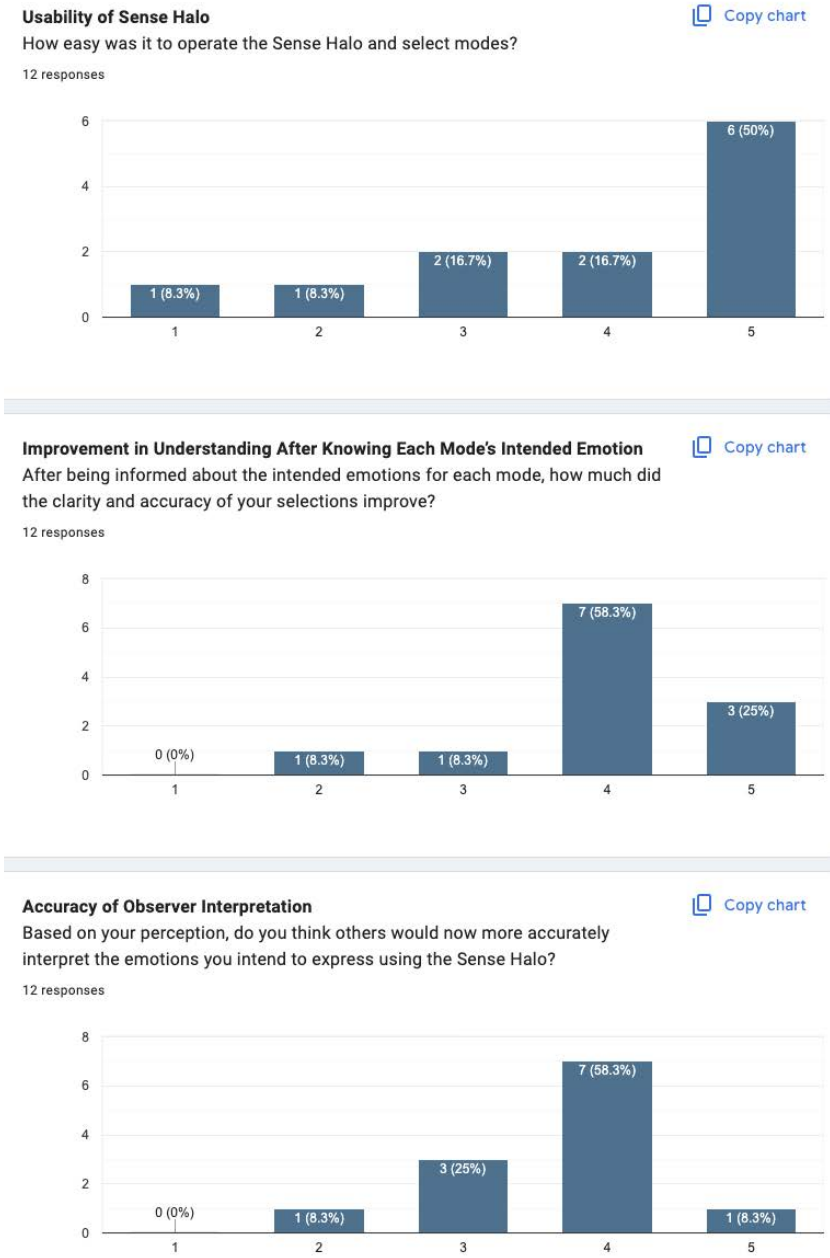
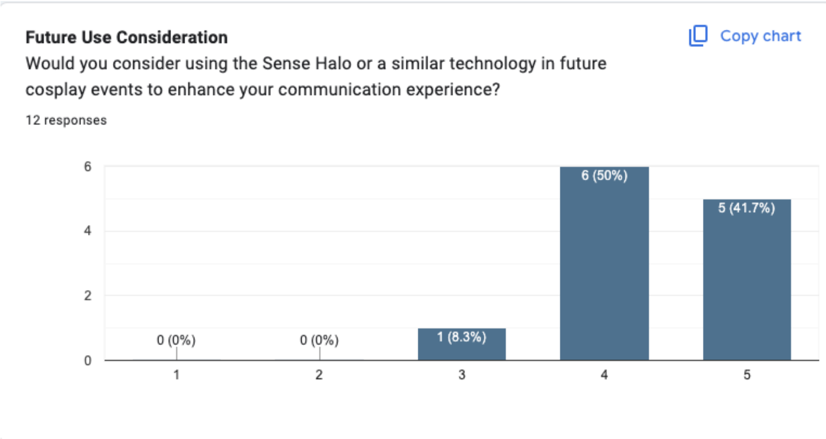



Figure B.4 Post-Experiment Survey Results Part 1


Figure B.5 Post-Experiment Survey Results Part 2



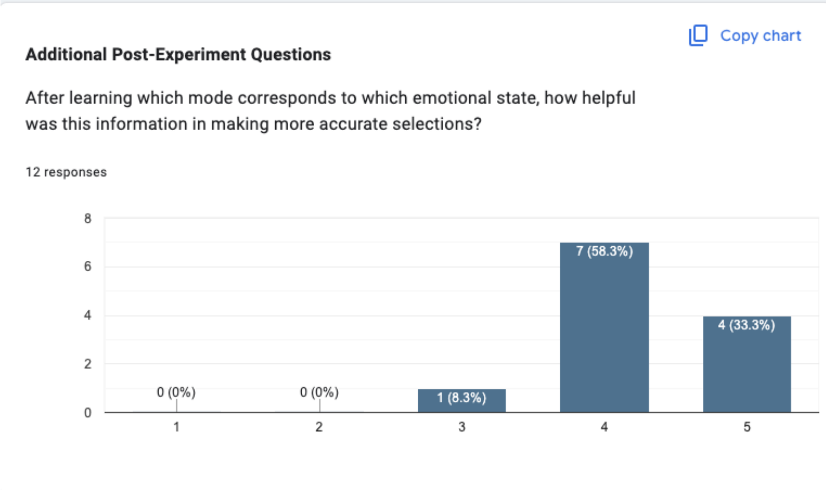




Figure B.6 Post-Experiment Survey Results Part 3

# C. Sense Halo CPS32 Controller Control Code

Below is the Python source code for the Sense Halo control application. This code demonstrates how to integrate with the CPS32 controller module, provide a user-friendly GUI, and control the Sense Halo's modes in real-time. Adjust paths, configuration, and hardware connections as per deployment requirements.

```
#!/usr/bin/env python3
# -*- coding: utf-8 -*-
import sys
import os
import logging
import tkinter as tk
from tkinter import messagebox, font as tkfont

# Logging configuration
LOG_FILENAME = "sense_halo_control.log"
logging.basicConfig(
    filename=LOG_FILENAME,
    filemode='a',
    format='%(asctime)s %(levelname)s: %(message)s',
    level=logging.DEBUG
)
console_handler = logging.StreamHandler()
console_handler.setLevel(logging.DEBUG)
console_formatter = logging.Formatter('%(asctime)s %(levelname)s: %(message)s')
console_handler.setFormatter(console_formatter)
logging.getLogger().addHandler(console_handler)
logging.info("Launching Sense Halo Control Application.")

# Define modes
MODES = {
    1: "Mode 1: Light Blue (Moderate Brightness)",
    2: "Mode 2: Very Dim, Bluish-White",
    3: "Mode 3: Bright White (Max Brightness)",
    4: "Mode 4: Purplish-Red (Bright)",
```

```
    5: "Mode 5: Multi-Color (Sequential Flashing)"
}

# Optional configuration loading
CONFIG_FILE = "sense_halo_config.txt"
USER_CONFIG = {}
if os.path.exists(CONFIG_FILE):
    try:
        with open(CONFIG_FILE, 'r', encoding='utf-8') as cf:
            for line in cf:
                line_stripped = line.strip()
                if line_stripped and '=' in line_stripped:
                    key, val = line_stripped.split('=', 1)
                    USER_CONFIG[key.strip()] = val.strip()
        logging.info("User configuration loaded from file.")
    except Exception as e:
        logging.warning(f"Could not read config: {e}")

DEFAULT_MODE = None
if 'default_mode' in USER_CONFIG:
    try:
        potential = int(USER_CONFIG['default_mode'])
        if potential in MODES:
            DEFAULT_MODE = potential
            logging.info(f"Default mode set from config: {DEFAULT_MODE}")
        else:
            logging.warning("Invalid default_mode in config.")
    except ValueError:
        logging.warning("default_mode in config not an integer.")

# Attempt to import CPS32 controller
try:
    from cps32control import initialize, close_connection, set_mode
    logging.debug("CPS32 control module imported.")
except ImportError as e:
    logging.error(f"CPS32 module not found: {e}")
```

```
    print("ERROR: cps32control module missing. Cannot proceed.")
    sys.exit(1)

def set_halo_mode(mode, status_label):
    logging.debug(f"User selected mode {mode}, calling set_mode.")
    try:
        set_mode(mode)
        status_label.config(text=f"Current Mode: {mode}")
        logging.info(f"Sense Halo set to mode {mode}.")
    except Exception as exc:
        logging.error(f"Error setting mode {mode}: {exc}")
        messagebox.showerror("Error", f"Failed to set mode {mode}. Check logs.")

def on_application_close(root):
    logging.info("Application close requested.")
    try:
        close_connection()
        logging.debug("CPS32 connection closed on exit.")
    except Exception as exc:
        logging.warning(f"Error closing CPS32: {exc}")
    root.destroy()
    logging.info("Application closed.")

def create_main_gui():
    root = tk.Tk()
    root.title("Sense Halo Mode Selector")
    default_font = tkfont.Font(family='Helvetica', size=12)
    root.option_add("*Font", default_font)
    root.protocol("WM_DELETE_WINDOW", lambda: on_application_close(root))

    instruction_label = tk.Label(root, text="Select a mode for the Sense Halo:")
    instruction_label.pack(pady=10)

    initial_status = "Current Mode: None"
    if DEFAULT_MODE is not None:
        initial_status = f"Current Mode: {DEFAULT_MODE} (Initial)"
```

```
    status_label = tk.Label(root, text=initial_status)
    status_label.pack(pady=10)

    button_frame = tk.Frame(root)
    button_frame.pack(pady=20)

    for mode_number, mode_desc in MODES.items():
        btn = tk.Button(button_frame, text=mode_desc,
            command=lambda m=mode_number: set_halo_mode(m, status_label))
        btn.pack(pady=5, fill='x')

    return root, status_label

def initialize_system():
    logging.debug("Initializing CPS32.")
    try:
        initialize()
        logging.info("CPS32 initialized.")
    except Exception as exc:
        logging.error(f"CPS32 init failed: {exc}")
        messagebox.showwarning("Warning", f"CPS32 init failed: {exc}")

def set_default_mode_if_applicable(status_label):
    if DEFAULT_MODE is not None:
        logging.info(f"Applying default mode {DEFAULT_MODE}.")
        try:
            set_mode(DEFAULT_MODE)
            status_label.config(text=f"Current Mode: {DEFAULT_MODE}")
            logging.debug("Default mode applied.")
        except Exception as exc:
            logging.warning(f"Could not set default mode {DEFAULT_MODE}: {exc}")

def main():
    logging.debug("Main execution start.")
    initialize_system()
```

```
    root, status_label = create_main_gui()
    set_default_mode_if_applicable(status_label)

    logging.debug("Entering TK main loop.")
    root.mainloop()

    try:
        close_connection()
        logging.debug("CPS32 closed after mainloop.")
    except Exception as exc:
        logging.warning(f"Error closing CPS32: {exc}")

    logging.info("App terminated.")

if __name__ == "__main__":
    main()
```