

## Emotional Fluctuation Expression of Participants in Virtual Interactive Environments Color Composition and Harmony

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### Abstract

In today's fast-paced society, individuals often grapple with immense work stress and a high-pressure lifestyle, making it harder to alleviate anxiety. This not only affects work efficiency and life quality but also may delay seeking timely medical assistance. Many struggle to understand and analyze their emotions, finding traditional emotional scales complex and confusing. Consequently, most people tend to ignore their emotional issues, with only a few seeking psychological or medical help. This study introduces an innovative method using an Arduino connected to a Galvanic Skin Response (GSR) sensor. This device analyzes participants' resistance fluctuations, indicative of emotional intensity. High skin resistance signals significant emotional changes. These are then visually interpreted and represented in a virtual interactive space using Touch Designer, transforming emotions into visual elements like colors, shapes, and waveforms for effective categorization. Additionally, the CIEL\*a\*b\* color space can be matched to Russell's circumplex model of affect. This approach enables participants to intuitively perceive and comprehend their emotional shifts, simplifying the complexity of conventional scales. It offers a rapid self-assessment tool, providing others insights into the participant's emotional state. The study has successfully developed a prototype for simple emotional fluctuation analysis, allowing real-time monitoring and regulation of emotions. This tool represents a significant advancement in emotional analysis and adjustment in our high-pressure society, facilitating better emotional understanding and management.

Keywords: Interactive Design, Emotional Analysis, Emotional Granularity

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## Introduction

According to research conducted by the Institute of Labor, Occupational Safety and Health under the Executive Yuan, the work pressure on male workers increased from 7.6% in 1994 to 13.8% in 2008, while for female workers, it rose from 6.5% to 13.5%. On average, there are 13 out of every hundred workers experiencing significant work pressure. This figure is approximately twice as high as that of 1994, indicating a growing trend of severe work pressure among domestic workers. Workplace stress not only affects individual employees but also has a significant impact on organizational development. Currently, stress management in domestic workplaces focuses more on changes in employees' behaviors, with less emphasis on organizational change initiatives (Chen et al., 2010).

In light of the high-pressure environment in contemporary society, appropriately establishing healing environments in workplace settings can induce self-healing of the body and facilitate positive transformation to enhance the holistic well-being of space users (Wu, 2011). Traditionally, the design of workplace break areas seldom considers individual emotions. Through the translation of design elements such as spatial colors, sounds, and images in virtual interactive spaces, it is hoped that the conventional and unchanging nature of workplace break areas can be disrupted, enabling the quick assessment and analysis of individual emotions.

## Objectives of the Study

Based on the research motivation outlined above, the utilization of Arduino connected to Galvanic Skin Response (GSR) sensors and interactive visual design software such as Touch Designer facilitates the construction of digital content and environments. This enables the visualization of emotional granularity and the correlation with the CIE Lab\* color space and emotional experience models, as well as the emotional labeling of audiovisual elements. Through this approach, participants can visually observe their own emotional granularity, allowing users to monitor and adjust their emotions in real-time.

## Emotion Definition

Emotion refers to the physiological or psychological response generated by internal or external stimuli in the human body. It is a subjective perceptual experience, whereby observers can infer but cannot fully empathize with it through facial expressions and behavior. Emotion is not easily controlled by self-awareness and is related to the concept of motivation; emotions can influence motives, and motives can trigger emotions. Mehrabian & Russell (1974) proposed a framework for human emotional responses to environmental stimuli, describing them along three independent dimensions: arousal/nonarousal, pleasure/displeasure, and dominance/submissiveness. This framework is used to predict behavioral responses to environmental stimuli, as depicted in Figure 1 (Mehrabian & Russell, 1974).

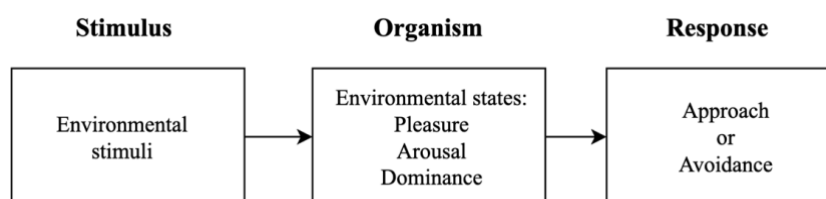


Figure 1: Mehrabian-Russell Model (Mehrabian & Russell, 1974)

Pleasure reflects the degree of happiness and satisfaction experienced by the human body in response to environmental stimuli, arousal refers to the vigor and alertness with which the body responds to environmental stimuli, and dominance indicates the sense of control over the situation. Mehrabian & Russell (1974) developed a set of bipolar scales of emotion, consisting of opposite adjectives, which can serve as effective indicators of emotional feedback in response to environmental stimuli (Mehrabian & Russell, 1974).

1. High arousal + pleasure + high dominance: Excited emotion.
2. High arousal + pleasure + submissiveness: Anxious emotion.
3. Low arousal + pleasure + high dominance: Exciting emotion.
4. Low arousal + pleasure + submissiveness: Relaxed emotion.
5. High arousal + displeasure + high dominance: Worried emotion.
6. High arousal + displeasure + submissiveness: Irritated emotion.
7. Low arousal + displeasure + high dominance: Melancholic emotion.
8. Low arousal + displeasure + submissiveness: Depressed emotion.

Table 1: Bipolar Scales of Emotion with Opposite Adjectives  
(Source: Data compiled by this study)

### Classification of Emotions

The types of emotions are quite diverse, with several different emotions derived from basic ones. Scholars such as Phillip Shaver et al. categorized 135 different emotional terms in 1987, identifying six basic categories of emotions: Love, Joy, Surprise, Anger, Sadness, and Fear. Among them, the first three belong to positive emotions, while the latter three belong to negative emotions (Cindy & Phillip, 1986). Osgood et al. and subsequent psychological studies conceptualized the classification of emotions mainly into two components: Arousal and Valence (Osgood, 1969).

1. Arousal: high or low, represents the intensity of emotions, ranging from no emotional response or calmness to excitement.
2. Valence: pleasure or evaluation, indicates the positivity or negativity of emotions, determining whether the emotional state is positive or negative.

Russell and Pratt, along with other scholars, proposed the "Emotion Structure Model" in 1980 (Russel, 2003), which identified two primary dimensions of human emotion: "Arousal" and "Pleasure" (Russel, 2003). They suggested that all emotions can be represented on this two-dimensional coordinate system. In 1981, Russell and other researchers found that "Dominance" belongs to a cognitive dimension and is not as crucial as "Arousal" and "Pleasure". Therefore, they advocated for using only "Arousal" and "Pleasure" to explain the characteristics of environmental emotions (Ward & Russell, 1981). This classification standard has since been widely adopted by scholars, as depicted in Figure 2.

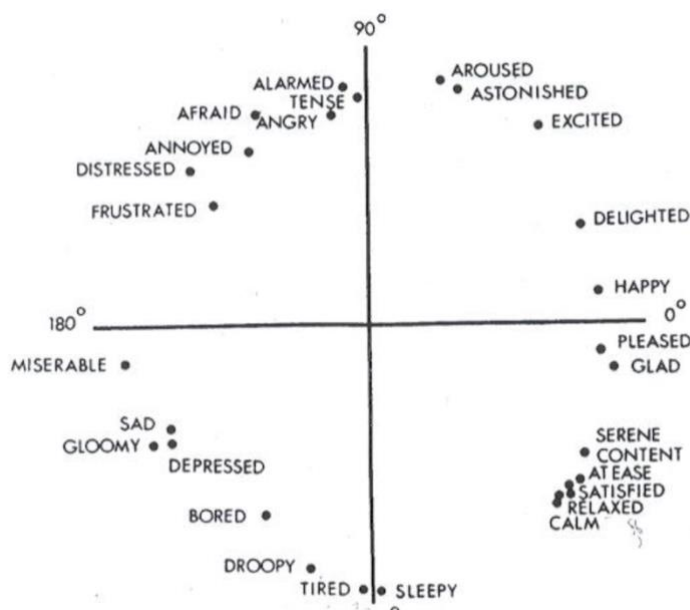


Figure 2: Circumplex Model of Emotion (Ward & Russell, 1981)

### Emotional Granularity and Affect Labeling

Individuals vary in their ability to create precise and context-specific instances of emotions, a skill known as emotional granularity (Tugade et al., 2004) or emotional differentiation (Barrett et al., 2001). Emotional granularity emphasizes the ability to differentiate emotional experiences based on current or anticipated circumstances. This ability allows us to more accurately understand and express our emotions, thereby better managing our emotional responses. For example, a person with high emotional granularity may differentiate between being "angry" or "sad" rather than just "unhappy". This differentiation can help them find more effective coping strategies, as dealing with anger and sadness may require different approaches. Over time, emotional granularity not only varies between individuals but also within individuals (Tomko et al., 2015; Erbas et al., 2018, 2021), suggesting that emotional granularity may be shaped or even improved. Moreover, an increasing body of research demonstrates that high emotional granularity is typically associated with positive and healthy coping attitudes. Therefore, the manifestation of emotional granularity is crucial for mental and emotional well-being, as different levels of emotional granularity determine one's emotional state.

### Emotional Expression

Internal emotional states can be conveyed outwardly through both verbal and non-verbal forms of communication. In terms of communication channels, these can be divided into verbal and non-verbal categories. Non-verbal modes of communication include body language, facial expressions, and physiological responses. Additionally, personal thoughts, feelings, and intentions can be conveyed through written text and verbal communication during interactions with others. Therefore, to interpret people's emotions, one can assess their emotional state through written and non-written messages, physiological responses, and body language. Researchers have identified three main avenues through which humans express emotions: physiological responses, expressive behavior, and cognitive expressions of emotion.

- "Physiological responses": Changes in respiration, heart rate, blood pressure, blood volume in muscles, pupil dilation, and electrodermal activity caused by sweating. However, current research suggests that physiological responses alone cannot serve as a single indicator for detecting and categorizing emotions.
- "Expressive behavior": Facial expressions, body posture, tone of voice, and gestures, with facial expressions being a cross-cultural means of emotional expression. Compared to involuntary physiological responses, expressive behavior can be controlled and concealed.
- "Cognitive expressions": Involves the recognition and description of emotions. When individuals perceive their emotional states, they classify them into emotion terms within the language system or express them through metaphors using language or writing.

Therefore, the carriers of "cognitive expressions" are words and language. While linguistic expression may appear varied and ambiguous through metaphors, compared to physiological responses and expressive behavior, cognitive expressions are relatively easier to record, write, disseminate, and perpetuate over time, affecting broader aspects and having a longer-lasting impact.

### Galvanic Skin Response (GSR)

The Grove-GSR (Galvanic Skin Response) sensor, developed by Seeed Studio, is a modular kit designed to measure skin conductance. It can be connected to Arduino or Raspberry Pi to collect data. Its operation principle lies in the fact that different emotions stimulate the sympathetic nervous system, leading to varying degrees of sweat secretion from the body's sweat glands. The Grove-GSR detects and identifies intense emotions by using two simple and non-invasive electrodes attached to two fingers on one hand. This electronic device can be used for academic research on emotion recognition or related equipment, such as sleep quality monitoring or lie detectors (IOT, 2018). The theoretical basis of GSR is that when a person is tense or anxious, the body's sweat glands naturally secrete sweat. As we pass a small electrical current through the skin surface, the resistance value measured by the device decreases. The higher the tension level, the stronger the skin's conductivity. The setup and wearing method of the GSR device are illustrated in Figure 3.

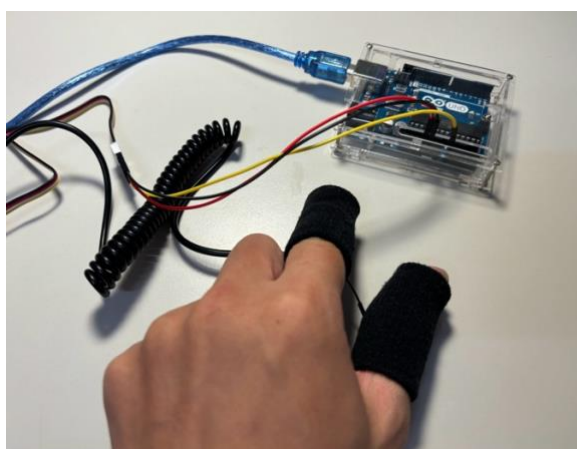


Figure 3: Grove-GSR wearing configuration

Typical GSR emotional responses are illustrated in Figures 4, 5, 6, and 7, representing four different emotional states: emotional fluctuation (emotion regulation), relaxation, anxiety, and tension. Early psychologists primarily used observational analysis methods with GSR to analyze emotional changes, and this intuitive measurement method has been able to provide initial insights into the emotional changes revealed by the body's sweat glands.

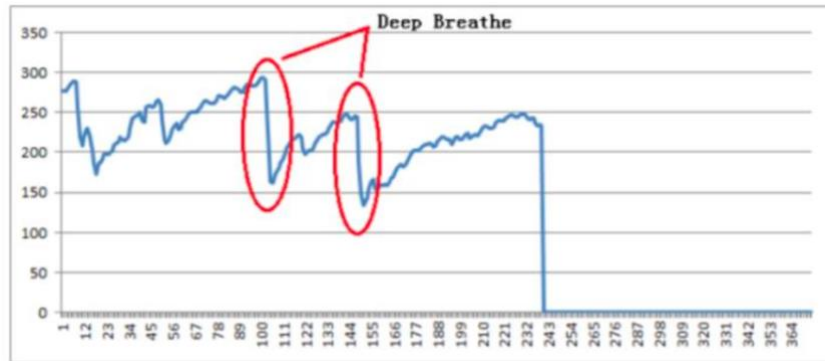


Figure 4: GSR curve of emotion regulation (IOT, 2018)

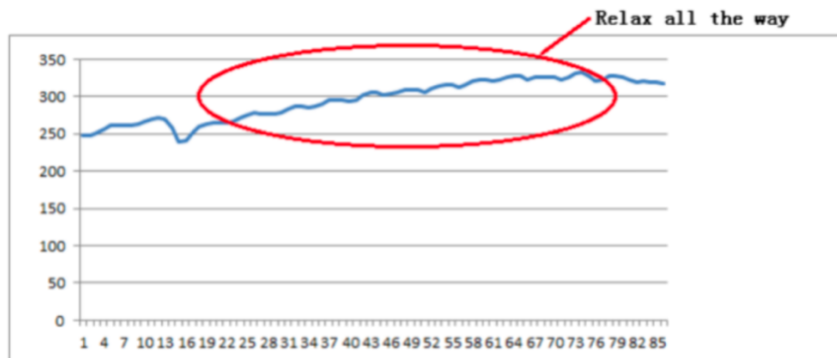


Figure 5: GSR curve of relaxation state (IOT, 2018)

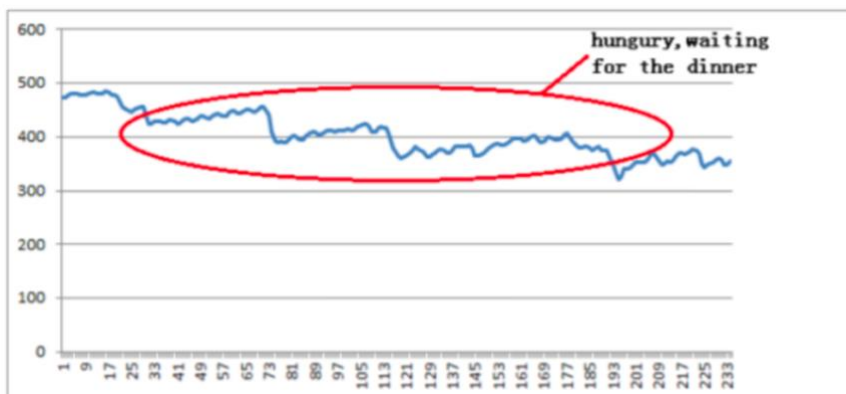


Figure 6: GSR curve of anxiety state (IOT, 2018)

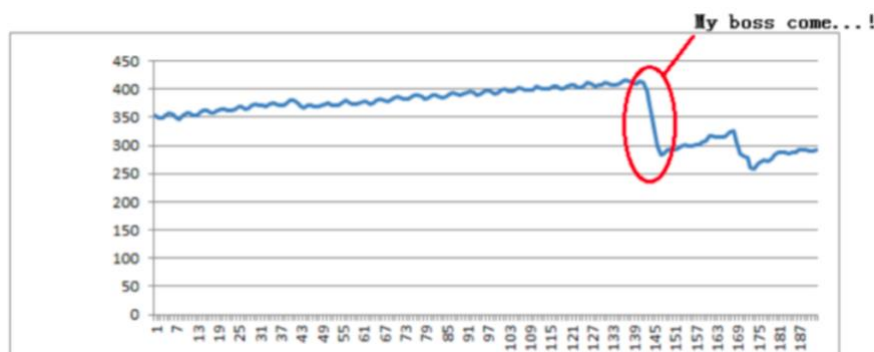


Figure 7: GSR curve of tension state (IOT, 2018)

## Color Composition

The perception of color by the eyes results from the stimulation of different wavelengths of light. The components of color include hue, brightness, and saturation, among other fundamental attributes. The following will be described separately (Dazhi Hao, 1969 / translated by Xiaojiong Chen, 1983; Yihui Lai, 1993; Jieying Zhu, 1998).

1. Hue
 

Hue refers to the appearance of color and is used to distinguish the names of various colors, such as red, orange, yellow, green, blue, and purple, which describe the appearance of colors. The differences in hue are mainly due to the different wavelengths of light. Light with longer wavelengths will evoke colors such as red, orange, and yellow, while light with medium wavelengths will evoke green, and light with shorter wavelengths will evoke colors like blue and purple. Depending on the different wavelengths, six main hues can be distinguished from the continuous spectrum from purple to red. The range of hues is quite extensive, and based on the positions of the primary colors in the hue circle, hundreds of colors can be derived. Generally, for ease of understanding and explanation, the 12-hue circle is most commonly used, with the 12 basic hues being yellow, yellow-orange, orange, red-orange, red, red-purple, purple, purple-blue, blue, blue-green, green, and yellow-green.
2. Brightness
 

Brightness refers to the lightness or darkness of a color. Each color reflects variations in brightness due to the intensity of light. The difference in brightness of colors of the same hue is mainly related to the amplitude of light or the reflectance of the object's surface. In short, when the incident light is bright, we perceive brightness, indicating a higher brightness, whereas when the incident light is dim, we perceive lower brightness.
3. Saturation
 

Saturation, also known as color intensity or purity, refers to the vividness or richness of a color. In color systems, saturation is measured from the achromatic axis (with a saturation of 0) towards the outer circumference of the circle. The farther away from the achromatic axis, the higher the saturation, and thus, the more vibrant the color. Pure colors on the spectrum have the highest saturation, but when mixed with other colors, the saturation decreases.

## Color Space

### *CIELab\* Color Model*

The CIELab\* color model translates light wavelengths into brightness and color, based on the characteristics of the human eye. It is commonly used to describe all colors visible to the human eye and is considered the most comprehensive color model. In the Lab\* space, colors are represented using three basic coordinates. The L\* value represents brightness, ranging from black to white. The a\* value represents the relationship between green and red, ranging from -a\* to +a\*. The b\* value represents the relationship between blue and yellow, ranging from -b\* to +b\*. Because the CIELab\* color space is constructed based on the visible spectrum of the human eye, it encompasses the colors generated by screens and printing, making it the closest representation to human vision. Additionally, the L\* component closely matches human brightness perception, allowing for the correction of a\* and b\* values to achieve more accurate colors. As CIELab\* describes color appearance rather than specifying proportions of colorants needed to produce a particular color on a specific device, it can be considered a device-independent color model.

## Color Harmony

Past research on color harmony has identified three major factors influencing color harmony: psychological effects, physiological effects, and physical effects. Psychological effects include color association and attitude; physiological effects include color order, configuration, area, interaction, and similarity; physical effects include color tone (Burchett, 1991, 2002).

Determining color harmony involves not only using traditional color wheels but also analyzing differences in hue, brightness, and saturation between two or more colors to gauge the degree of harmony (Chuang & Ou, 2001; Ou et al., 2004c; Ou & Luo, 2006; Solli & Lenz, 2009). The interaction between colors in color harmony is a complex process, often investigated by combining pairs or groups of color chips. Generally, the more colors involved, the greater the interaction between them, making predictions more challenging. Additionally, colors can have multiplicative effects on each other, which researchers have utilized to independently analyze and compute color harmony (Ou & Luo, 2006; Solli & Lenz, 2009; Ou, Chong, Luo, & Minchew, 2011). However, there are various methods for calculating color harmony, with current studies often using uniform and easily controllable color chips as a medium. Nevertheless, color exists in heterogeneous ways in our living spaces, and using only homogeneous color chips may not comprehensively discuss the overall color composition of the environment. Therefore, this study returns to the basic concept, exploring the overall color composition of images using differences in color perceived by humans and physical quantities.

Color harmony can indeed be influenced by the color preferences of the subjects themselves. Some studies have shown that although colors may be harmonious, subjects may dislike them, and vice versa. This contradiction may be due to the individual characteristics of the subjects, but it cannot be denied that there is a strong correlation between preference and harmony. Gender, age, and whether one has received professional training can also lead to different perceptions of color harmony. Studies investigating color psychological factors, such as preferences, across different types of images, such as landscapes, portraits, and food, have found that color harmony is the most important psychological factor influencing image

preferences (Chuang & Ou, 2001; Ou et al., 2004c; Ou & Luo, 2006; Solli & Lenz, 2009; Schloss & Palmer, 2011; Guan & Hung, 2010).

## Color and Emotional Experience

The process of generating color emotions and emotional experiences involves receiving physiological stimuli through the eyes from the external environment, which then connect to the brain to produce psychological responses. In this complex sequence of events, various individual characteristics come into play, such as past memories and experiences, cultural background, and living environment. Therefore, we perceive emotions as independent and unique symbols. Through literature review, the difference between color emotions and emotional experiences lies in the fact that color emotions mainly target an individual's singular perception of color, whereas emotional experiences are feelings generated through stimulation and experiences in spatial environments. The former is generated through the stimulation of color chips, combined with past experiences and associations, while the latter involves a crucial concept of "experience."

This study references the experimental results of Hsu and Lin (2014), which demonstrate that emotional experiences are indeed influenced by the composition of colors, consistent with previous research on emotional perception (Ou et al., 2004a, 2004b, 2004c; Xin et al., 2004; Gao & Xin, 2006; Solli & Lenz, 2011). Mapping the CIELab\* color space onto the environmental mood experience proposed by Russell (1980) Figure 8, it is found that there is a high correspondence between color space and certain emotional experiences. For example, participants stimulated by natural landscapes with a predominant red color domain are more likely to experience tension and fear; in environments with a predominance of green color domains, feelings of relaxation and tranquility are relatively enhanced; conversely, in natural environments with a predominance of blue color domains, feelings of melancholy are more likely to occur.

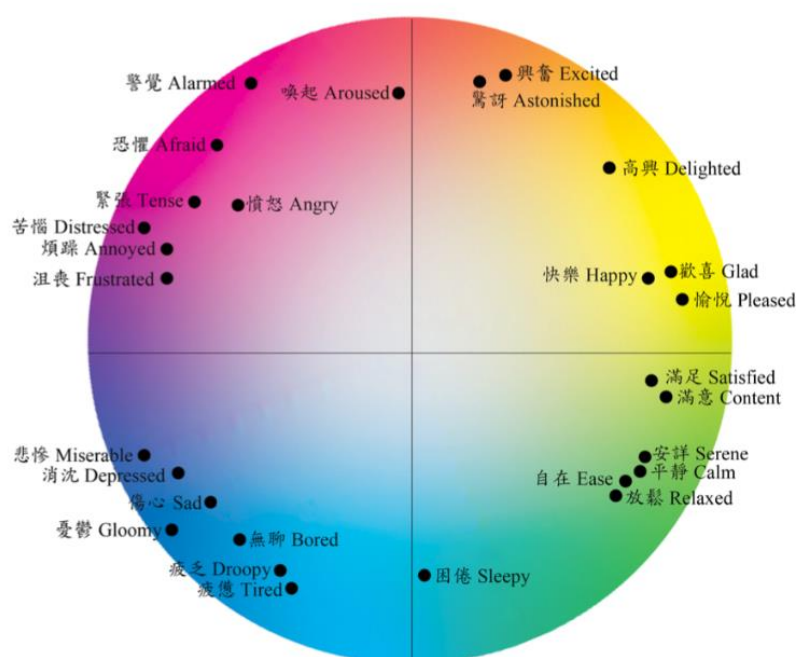


Figure 8: Relationship between CIEL\*a\*b\* color space and Russell's emotional experience

## Geometric Shapes and Emotional Experience

"Form is the perception of visual objects" (Yang, 1997). Through vision, the external world's visual forms are transformed into meaningful structural entities (Qiu, 2001). According to the research of British visual psychologist Dr. M.D. Vernon, our visual recognition of the existence of objects depends on the differences in "form," "color," and "brightness" of the object compared to those of surrounding objects (Wang, 1999). Form and color often influence perceptual judgments (Leyssen et al., 2012). The combination of all objects is related to form and achieves visual balance and aesthetic beauty (McManus et al., 2011).

According to the principles of perception, the perception of form requires confirmation from "past experiences." As Arnheim pointed out: "Form is not determined solely by the stimuli received by the eyes at that moment" (Arnheim, 2001). Proponents of direct perception theory believe that perceptual information alone is sufficient for an individual to perceive the world correctly. This concept is sometimes referred to as the "ecological validity" theory, with Gibson being its most representative figure. This school of thought holds that research on perception must be conducted in real-world situations, where people can accurately perceive real objects. Indirect perception theory, proposed by Helmholtz and others, is related to the indirect perception and top-down processing of visual stimuli, which drive our perception. Both of these theories are plausible because our brains are highly complex thinking tools, filled with interconnected memories, and accustomed to using reasoning and imagination to solve problems (Solso, 2004).

In the exploration of emotional representation in form, domestic scholars mostly focus on color as the main axis of research. Scholars believe that visual stimuli include both color vocabulary and image form elements, and that the sensation of color is greatly influenced by image form (Leyssen et al., 2012), with some kind of objective balance relationship between them (McManus et al., 2011). For example, when presenting the same color vocabulary with different geometric images, there is a noticeable difference in the perception of the color vocabulary. The perspectives of various scholars are summarized as follows:

Color Vocabulary	Image Shaping	Characteristic
red color words	Square	It has strong, solid, distinct, weighty, opaque, and stable characteristics, with right angles corresponding to the feeling of red.
orange color words	Rectangle, Trapezoid	Orange is toned from yellow and red; in terms of visual form, it compromises between squares and triangles to form rectangles and trapezoids, lacking the sharpness of red and the vividness of yellow, corresponding to the feeling of orange.
yellow color words	Equilateral Triangle	Possessing sharp, energetic, expansive, keen, and vibrant characteristics, it corresponds to the feeling of yellow.
green color words	Hexagon, Curvilinear Triangle	Providing a calm, natural feeling, green is created by blending yellow and blue. In terms of visual form, it is a compromise between a equilateral triangle and a circle, resulting in a hexagon and arc triangle, which aligns with the sensation of green.

blue color words	Circle	Having smooth, light, soft, and flowing characteristics, it corresponds to the sensation of blue.
purple color words	Ellipse	Having soft, feminine, and non-sharp characteristics. Purple is toned from blue and red; in terms of image formation, it is a compromise between circular and square shapes, forming an ellipse that corresponds to the sensation of purple.

Table 2: Exploration of Relevant Studies (Source: Wang, L.T., & Huang, S.P., 2016)

### Positive and Negative Affect Schedule (PANAS)

The Positive and Negative Affect Schedule (PANAS), developed by Watson et al. in 1988, is a scale that measures positive and negative emotions. It consists of two subscales, one for positive affect and the other for negative affect, each containing 10 items. The PANAS is primarily used to assess individuals' emotional states or general tendencies at different time points. The positive affect subscale measures experiences such as excitement and joy, while the negative affect subscale measures experiences such as tension and fear. Responses are scored on a Likert scale ranging from "0" (not at all) to "4" (extremely), with higher total scores indicating stronger positive or negative emotional traits. This scale is widely used in research in the field.

		Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
1	Interested	1	2	3	4	5
2	Distressed	1	2	3	4	5
3	Excited	1	2	3	4	5
4	Upset	1	2	3	4	5
5	Strong	1	2	3	4	5
6	Guilt	1	2	3	4	5
7	Scared	1	2	3	4	5
8	Hostile	1	2	3	4	5
9	Enthusiastic	1	2	3	4	5
10	Proud	1	2	3	4	5
11	Irritable	1	2	3	4	5
12	Alert	1	2	3	4	5
13	Ashamed	1	2	3	4	5
14	Inspired	1	2	3	4	5
15	Nervous	1	2	3	4	5
16	Determined	1	2	3	4	5
17	Attentive	1	2	3	4	5
18	Jittery	1	2	3	4	5
19	Active	1	2	3	4	5
20	Afraid	1	2	3	4	5

Table 3: Positive and Negative Affect Schedule (PANAS) (Watson, 1988)

## Research Structure

Based on the literature, it is evident that the proportion of workplace stress is increasing annually. Understanding one's own emotions and regulating them is considered essential in modern times. The prototype of the "Virtual Interactive Environment for Emotional Fluctuations" device allows users to intuitively experience their own emotional changes and fluctuation frequencies. This study is divided into three main stages. The first stage involves investigating the granularity and expressive ability of emotional expression among users. This is done through literature review and interviews to identify potential users. The second stage focuses on the design and production of the virtual interactive environment prototype. Drawing from the findings of the first stage, the use of Galvanic Skin Response (GSR) sensors and the Positive and Negative Affect Schedule (PANAS) for emotional fluctuation detection is identified. The data is then interpreted and visually presented using the TouchDesigner software. The third stage involves evaluating the prototype of the virtual interactive environment and providing subsequent recommendations. Expert interviews are conducted to gather insights into the prototype's operation and to gather suggestions for further development, serving as a reference for future iterations of the "Virtual Interactive Environment for Emotional Fluctuations" device prototype.

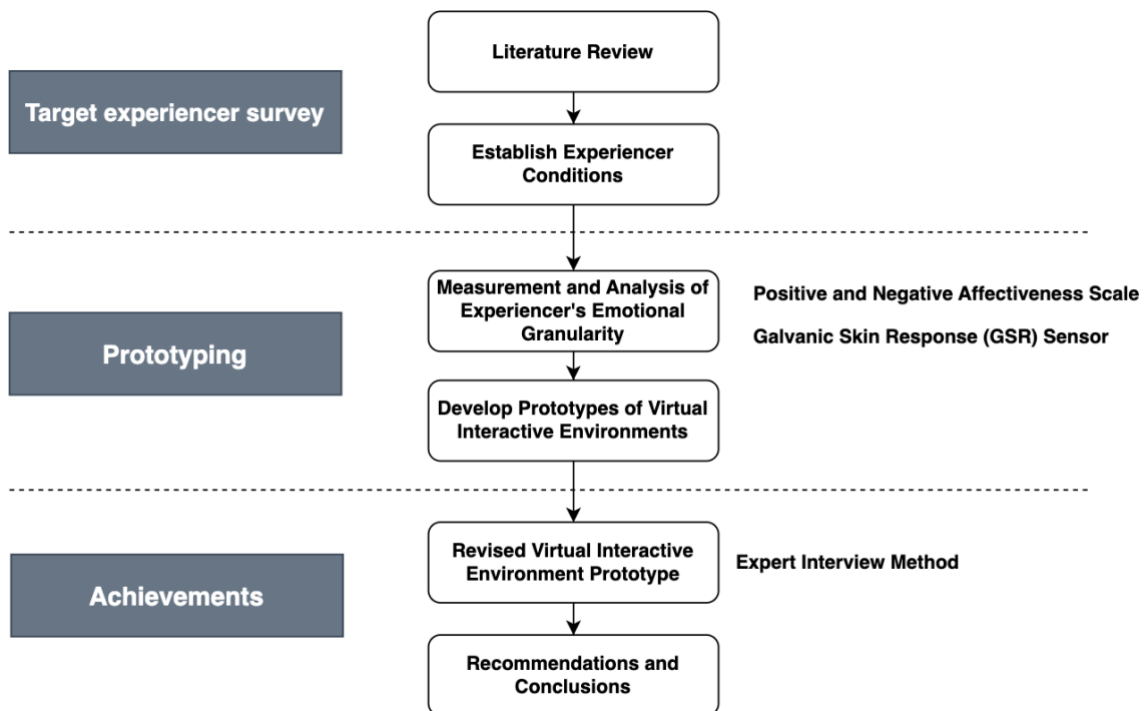


Figure 9: Research Framework Flowchart (Source: Prepared by the present study)

## "Prototype Architecture of Virtual Interactive Environment for Emotional Fluctuation Representation"

In this phase, Arduino is used to connect to the Galvanic Skin Response (GSR) sensor, establishing communication with the TouchDesigner software. The physiological data collected by the GSR sensor is then transmitted to the TouchDesigner software for interpretation and visual representation. Subsequently, expert interviews are conducted to assess and optimize the credibility and validity of the interactive experience.

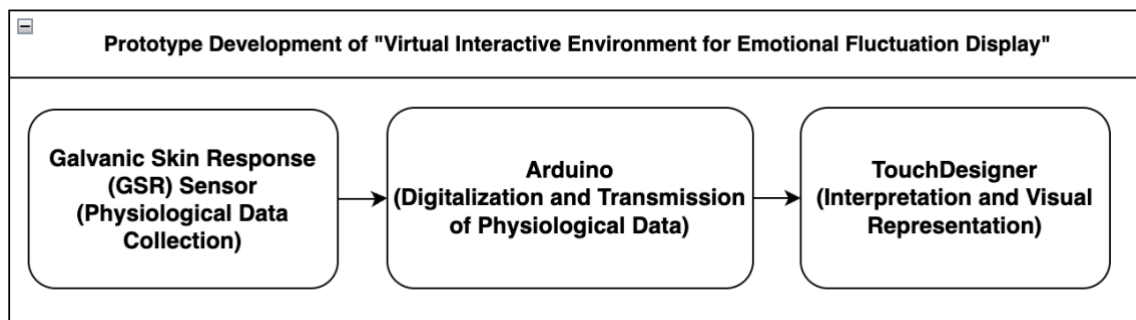


Figure 10: Schematic Diagram of Prototype Architecture  
(Data Source: Created by this study)

### Expert Interview Method

In this stage, the expert interview method is utilized to conduct in-depth interviews with experts and scholars from various fields, including psychologists, long-term care center managers, and associate professors in digital media design departments at universities. The interviews cover a range of topics from basic interactive design concepts to deeper analyses of emotional granularity, providing diverse recommendations for the prototype and future development. The main focus of the interviews includes identifying target audiences, understanding user needs, evaluating the prototype architecture, and planning for future development.

Interviewee	Interaction Design	Emotion Analysis	Expertise/ Experience	Date	Location/ Format
Mr. Weng	Shallow	Deep	Psychologist	2023/12/5	Online interview
Ms. Huang	Shallow	Medium	Long-term Care Base Manager	2023/12/9	Online interview
Mr. Zhang	Deep	Medium	Digital Media Design	2023/12/19	Face-to-face interview

Table 4: Expert Interview List  
(Data Source: Created by this study)

### Research Analysis

According to literature, Russell and other scholars believe that the characteristics of environmental emotions can be explained using only Arousal / Nonarousal and Pleasure / Displeasure. By mapping the CIELab\* color space to the environmental emotional experience circle proposed by Russell (1980), a simple emotional indicator can be created

with the Pleasure / Displeasure axis as the X-axis and the Arousal / Nonarousal axis as the Y-axis.

In Figure 12, the level of resistance in the Grove-GSR skin conductance sensor is used to determine the degree of Arousal / Nonarousal (Y-axis). The positive and negative scores on the positive and negative emotional scales are each divided by 5 to correspond to the scale on the X-axis, determining the degree of Pleasure / Displeasure. Based on the distribution of points on the X-axis and Y-axis, the corresponding representation in TouchDesigner is derived.

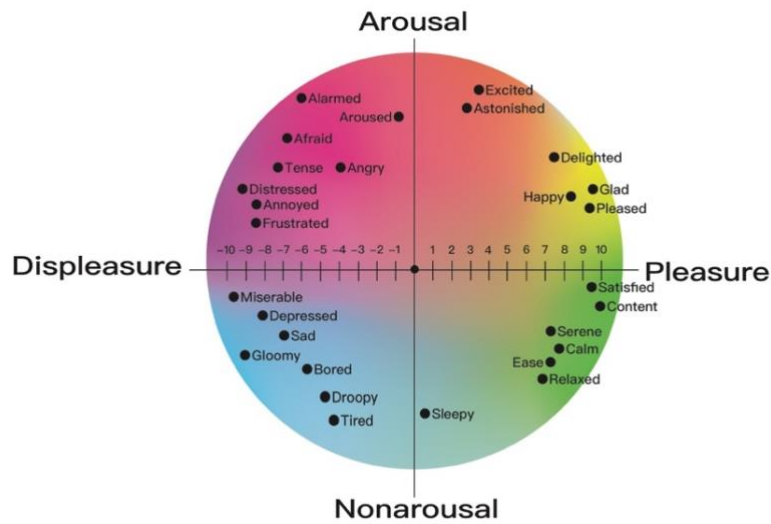


Figure 11 Relationship between CIEL\*a\*b\* color space, PANAS and Russell’s emotional experience

The resistance level sensed by the Grove-GSR skin conductance sensor determines the color variation in the CIELab\* color space, where higher resistance values indicate relative relaxation by the participant. In Figure 13, during the testing process, the participant's deep breathing caused a sudden rise in the waveform of the Grove-GSR on the Arduino, affecting the performance of the Touch Designer interactive visual software. This allows the participants to observe their own emotional expressions visually.



Figure 12: The waveform presented by Grove-GSR on Arduino

In this stage, based on the previous phases' integration of emotional color, form definitions, and participant processes, the "Virtual Interactive Environment for Emotional Fluctuations" participant flow and prototype are designed. Participants undergo measurements using positive and negative affect schedules and wear Grove-GSR skin conductance sensors on their fingers. The waveform frequency presented on Arduino determines the size, shape, and color changes in Touch Designer software. This allows for the assessment of the current emotional fluctuations, frequency, and stability.

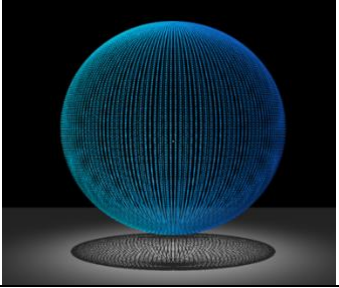
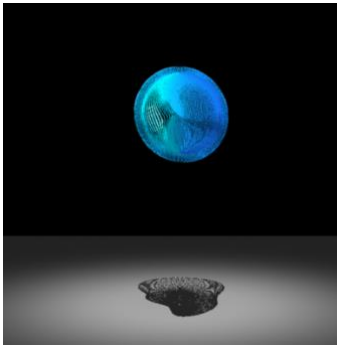
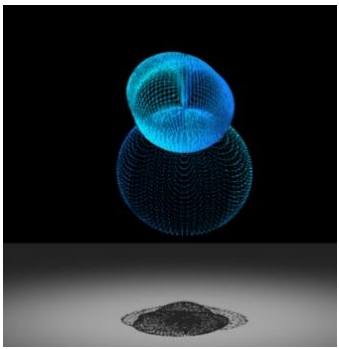
Arousal	Model Size	Magnitude of Fluctuation	Emotional Description	Prototype Screen
Low arousal	Large	Small	The resistance value is high, indicating a mild level of tension, while maintaining normal breathing.	
Moderate arousal	Medium	Medium	The resistance value decreases, indicating a moderate level of tension, with an increase in skin conductivity. The model shrinks, and there is a slight increase in the amplitude of fluctuation.	
High arousal	Small	Large	The resistance value is extremely low, indicating a high level of tension, with a significant increase in skin conductivity. The model shrinks, and there is a large amplitude of fluctuation.	

Table 5: Prototype Waveform Variations in the "Virtual Interactive Environment for Emotional Fluctuations"  
(Data Source: Created by this study)

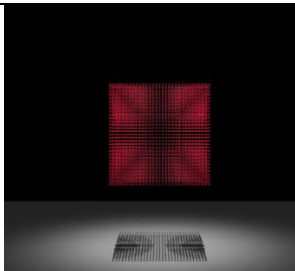
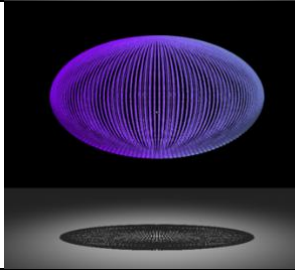
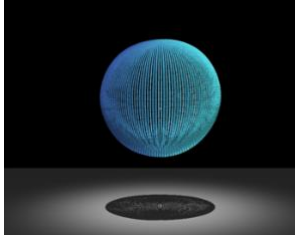
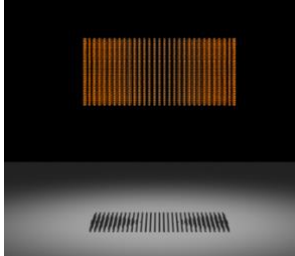
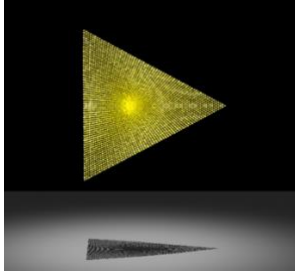
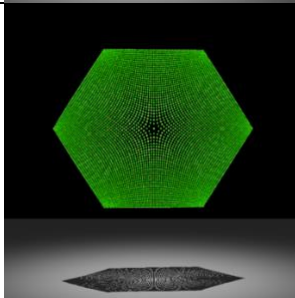
Emotion Identification	Color Variation	Shape Variation	Emotional Description	Prototype Screen
Alarmed Afraid	Red	Square	Based on the results from the Positive and Negative Affect Schedule, the pleasure score ranges from negative 0 to negative 3.	
Distressed Frustrated	Purple	Ellipse	Based on the results from the Positive and Negative Affect Schedule, the pleasure score ranges from negative 4 to negative 6.	
Miserable Depressed	Blue	Circle	Based on the results from the Positive and Negative Affect Schedule, the pleasure score ranges from negative 7 to negative 10.	
Excited Astonished	Orange	Rectangle	Based on the results from the Positive and Negative Affect Schedule, the pleasure score ranges from 0 to 3.	
Glad Happy	Yellow	Triangle	Based on the results from the Positive and Negative Affect Schedule, the pleasure score ranges from 4 to 6.	
Content Serene	Green	Hexagon	Based on the results from the Positive and Negative Affect Schedule, the pleasure score ranges from 7 to 10.	

Table 6: Prototype Model and Color Changes in the "Virtual Interactive Environment for Emotional Fluctuations"  
(Data Source: Created by this study)

## Research Findings and Recommendations

The research analysis reveals that the majority of participants provided positive feedback regarding the association between emotions and color changes in the prototype of the "Virtual Interactive Environment for Emotional Fluctuations." Additionally, they also responded positively to the correlation between color and shape variations. However, the correlation between emotional fluctuations and shape changes appeared less evident. Participants intuitively responded positively to the presentation of fluctuations and emotional dynamics.

The current study findings indicate that the association between emotions and shape changes did not evoke corresponding associations in participants. Future research will focus on improving and expanding this aspect.

## Results and Conclusion

This study explores emotional expression through the "Virtual Interactive Environment for Emotional Fluctuations" with the goals of self-healing and creativity. The research outcomes include:

1. Creating a novel emotional interpretation space to facilitate self-reflection and regulation of emotions, thereby enhancing work efficiency.
2. Meeting the psychological needs of specific groups, encouraging emotional expression, and boosting confidence.
3. Providing new insights into virtual interactive spaces, emphasizing their immersive nature, interactivity, and imaginative potential, while reducing design and development costs.

The anticipated research value of this study, conducted through the "Virtual Interactive Environment for Emotional Fluctuations," aims to provide the following academic references:

1. Creation of a novel emotional interpretation space: This space facilitates self-reflection and emotion regulation, ultimately enhancing work efficiency.
2. Meeting the psychological needs of specific groups: The device's openness and inclusivity encourage individuals to express their emotions without the constraints of fixed standards. This aspect is particularly beneficial for individuals with unique psychological needs, fostering self-expression and boosting confidence.
3. Providing new insights into virtual interactive spaces: Virtual interactive spaces, which mimic real-world environments, are defined from the subjective experience of users. The elements of immersion, interactivity, and imagination in virtual spaces can significantly reduce time and spatial costs for designers and developers.

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