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Exploring Emotional Transitions Triggered by Color Changes: A Multidimensional Analysis

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Abstract: This study investigates the emotional responses triggered by color changes, utilizing both discrete and continuous video stimuli to explore the theory that color influences emotional states. Nineteen participants from the IHHSJF-30201 class were exposed to color pairs derived from the Berkeley Color Project 37 (BCP-37), specifically examining transitions between saturated and medium hues of red, blue, yellow, and purple. Through Spearman's Rho correlation analysis and differential emotion intensity measurements, the study evaluates how sudden versus gradual color changes affect emotional perception. Results demonstrate significant differences in emotional responses between the discrete and continuous color transition groups, highlighting the impact of transition mode on emotional dynamics. The findings support existing theories on the relationship between color and emotion and suggest the potential for personalized color applications to enhance user experience in digital interfaces. Future research directions include integrating machine learning techniques and expanding biometric data collection to further refine the understanding of color-emotion interactions and their practical applications.

Keywords: Color-emotion theory, emotional response, visual stimuli.

1. Introduction

The association between emotions and colors has profoundly influenced humans since ancient times, as evidenced by the symbolic use of colors in various cultural contexts. The different emotion triggered by color variation are particularly significant when observing impressionist paintings, such as Monet's "Haystack" series. This suggests that color is a pivotal factor in influencing human emotions.

Humphrey proposed the evolutionary/behaviorally adaptive theory, which posits that color preference was built on the "approach" or "avoid" signals conveyed by nature through color, and that such preferences are deeply ingrained in human genetic code [1]. Hulbert and Ling further suggested that color preference is coded into the human color vision system, potentially enhancing performance in tasks of evolutionary significance, thereby supporting Humphrey's theory [2]. Ou et. al provided an initial interpretation of the color-emotion association, indicating that observers tend to experience positive emotion when exposed to their preferred color. A positive coloration exists between the color preference and emotion evocation [3]. Palmer proposed the evolutionary valence theory, which

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considers a shorter timescale where the color preference can build, suggesting that individual differences in color preference are influenced by unique personal experience [4].

Most previous studies build their color theories on three dimensions: hue, saturation and and lightness.

2. Methods

2.1. Participants

Participants. Nineteen participants (4 males and 15 females) are members of teachers and students in IHHSJF-30201 class. The age ranges from 15 to 35. All had normal color vision and signed the informed consent form.

2.2. Design and stimuli

Colors. Three pairs of colors are selected from the Berkeley Color Project 37 (BCP-37) studied by Palmer et al., saturated red-saturated blue, saturated yellow-saturated purple and medium yellow-medium purple. Four saturated color are all the most saturated colors from the Munsell Space, while medium ones are halfway between the saturated color and grey [5]. The yellow-purple group is used to set control group on different saturation.

Color-changing videos. Six color-changing videos are made for two groups of experiment. All six videos last about 4 seconds and involve 30 frames per seconds. In the discrete group, three pairs of colors are made into discrete-changing clips [6]. The first color lasts 2 second first and transfer to the other one suddenly. In the continuous group, the three pairs of colors are made into continuous-changing clips by python program. In each frame, the RGB value of colors change simultaneously. Human's neural limit reaction time is 0.1 seconds, which equals to 10-12 frames per second. That means the 30-frame changing video clips can be regarded as a continuous changing.

Questionnaires. Respondents' emotional transition are measured by an emotion rating scale questionnaire. Initially, Respondents are asked to rank their preference for four colors. Then, for each video, there are two emotion rating scales both at the beginning and the end. Each emotion rating scale includes three pairs of emotion (positive and negative, calm and anxiety, dreary and lively) with values ranging from -3 to 3 and the overall emotion intensity [7].

2.3. Experimental tasks

During the whole experiment, two control groups were set to compare whether the change of color discrete or not can evoke the emotional transition. Group A is the discrete color-changing video group including three tasks and Group B is the continuous color-changing video [8]. Both two groups of videos completed by the same groups of participants who are trained in advance.

Group A: discrete color-changing videos. Initially, participants were required to fill in their name and test group and rank the preference of four colors (red, blue, yellow and purple) as preparation. Next, the examiner instructed the participants to calm down and to concentrate on their emotion and the 5-second color-changing videos. After examiner count down three seconds, the first discrete color-changing displayed (saturated red-saturated blue,) on slides [9]. Then, participants were asked to answer five questions of their emotion rating scales, the intensity of emotion and whether the emotion changed while seeing the first color (at the beginning of the video) and the second color (at the end of the video). The task circulated 2 times with other 2 discrete video clips (saturated yellow-saturated purple, medium yellow-medium purple).

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Group B: continuous color-changing videos. The experiment procedure repeated while discrete color-changing videos were replaced by continuous one. Between two groups of experiment participants were given at least fifteen minutes to relax [10].

2.4. Statistical analysis

All correlations were calculated through Spearman's Rho.

Ratio of emotion intensity generated by discrete group and continuous group was calculated through the formulas [11].

$$\begin{aligned} \text{Change}_{\text{con}} &= |\ \text{Emotion}_e - \text{Emotion}_b\ | \\ &= |P_e - P_b| + |A_e - A_b| + |E_e - E_b| \\ \text{Change}_{\text{dis}} &= |\ \text{Emotion}_e - \text{Emotion}_b\ | \\ &= |P_e - P_b| + |A_e - A_b| + |E_e - E_b| \\ \text{D / C} &= \text{Change Con}_{\text{con}} / \text{Change}_{\text{dis}} \end{aligned} \quad (1)$$

Figure. The intensity of emotion transition (Change, subscript con/dis means values from continuous/discrete group) equals total emotion intensity value at the end minus value at the beginning (subscript e/b means end/beginning value) [12]. Total emotion intensity equals the sum of the absolute values of three emotion ratings (P-positive, A-anxiety, E-lively), corresponding to 3 pairs of different bipolar emotion selections and the intensity (positive3-negative3) in the questionnaire [13].

3. Results and Discussion

3.1. Results of hue changing tasks

The hue changing tasks revealed significant emotional transitions when participants were exposed to the saturated color pairs. Participants demonstrated a stronger emotional response to the red-blue transition, likely due to these colors' strong cultural and psychological associations. The intensity of emotion was notably higher at the transition point, suggesting that stark hue contrasts can elicit stronger emotional reactions. Discussion: The results support the hypothesis that specific color hues can trigger distinct emotional responses due to ingrained psychological and cultural meanings. Red, often associated with arousal and alertness, and blue, typically linked to calmness and stability, may explain the heightened emotional contrasts observed.

3.2. Results of saturation level tasks

The tasks involving variations in saturation, particularly between saturated and medium hues of yellow and purple, showed less pronounced emotional changes compared to the hue tasks. However, the medium yellow to medium purple transition still facilitated a noticeable shift, skewing towards a more dreary emotional state. Discussion: This suggests that while saturation changes induce emotional responses, they might be subtler compared to hue changes. The emotional impact of saturation could be influenced by its less direct association with specific psychological triggers compared to hue [14].

3.3. Results of discretion-continuity group

Comparing the discrete and continuous groups, the continuous color transition resulted in smoother emotional changes, which were less intense but more stable across the experiment. The discrete group exhibited sharper spikes in emotional intensity, indicating abrupt changes might trigger more immediate and robust emotional responses. Discussion: These findings illustrate that the manner of color transition plays a crucial role in emotional dynamics. Continuous changes might be more suitable for environments requiring stable emotional conditions, while discrete changes could be beneficial in scenarios where strong, immediate emotional impact is desired. This distinction is crucial for designing user interfaces and experiences where emotional engagement is key.

4. Machine Learning and Future Experiment Design

The integration of machine learning (ML) into the study of emotional transitions triggered by color changes presents exciting opportunities to enhance the precision and depth of emotional analysis. Advances in ML, particularly in neural networks and deep learning, can be leveraged to analyze and predict emotional responses more effectively. For instance, convolutional neural networks (CNNs) could be utilized to process and classify emotional states from physiological signals such as skin conductance and heart rate, which could be recorded alongside visual stimuli.

Machine learning models like recurrent neural networks (RNNs) and long short-term memory networks (LSTMs) are especially suited for analyzing time-series data, making them ideal for studying the dynamics of emotional transitions over time. These models can learn the sequences of emotional states in response to color transitions, providing insights into how discrete and continuous color changes affect emotional trajectories.

To further explore the impact of color on emotional transitions, future experiments could integrate more sophisticated ML models to analyze a broader array of biometric data. This could include eye-tracking to measure attention and pupil dilation as indicators of emotional arousal. Additionally, integrating electroencephalography (EEG) data could offer deeper insights into the neural correlates of color-induced emotions, enhancing the understanding of how certain colors can trigger specific emotional responses at the neurological level.

4.1. Data collection enhancement

Expand the participant pool to include a more diverse demographic to generalize findings across different age groups and cultural backgrounds. Incorporate multi-sensory data collection, including visual, auditory, and tactile responses, to explore multi-modal emotional responses to color changes.

4.2. Model deployment

Use supervised learning to train models on labeled emotional response data, allowing for the prediction of emotional states based on color stimuli.

Implement unsupervised learning algorithms to discover unknown patterns or clusters in emotional responses, which could reveal novel insights into human emotional dynamics influenced by color perception.

4.3. Experimental design innovations

Employ adaptive experiments where the color stimuli are modified in real-time based on the participant's emotional state to explore more dynamically the relationship between color changes and emotional responses. Design experiments to include virtual reality (VR) or augmented reality (AR) environments to study the effects of color in more immersive settings, which could mimic real-world interactions more effectively.

4.4. Ethical considerations and ml bias

Address potential biases in machine learning models, ensuring that the algorithms are trained on balanced data sets to avoid skewed results. Incorporate ethical considerations, particularly regarding the privacy and consent of participants when collecting and analyzing sensitive biometric data. By integrating these advanced ML techniques and experimental designs, future research can provide more comprehensive insights into the emotional effects of color changes, paving the way for applications in areas such as therapeutic environments, educational tools, and user interface design, where emotional impact is crucial.

5. Conclusion

This study explored the nuanced relationships between color changes and emotional transitions, utilizing both discrete and continuous video stimuli to better understand how variations in color can impact emotional states. Our findings corroborated the longstanding theory that colors not only influence mood but also evoke distinct emotional responses based on their hue, saturation, and the manner of their transition.

The study demonstrated that sudden shifts in color (discrete changes) tend to elicit more intense and immediate emotional responses compared to gradual changes (continuous transitions). This was particularly evident in the hue-changing tasks where transitions between saturated colors induced stronger emotional reactions, likely due to their more pronounced psychological and cultural connotations. On the other hand, variations in saturation produced subtler emotional shifts, suggesting a complex interplay between color properties and their perceptual and emotional impacts.

There are numerous avenues for further research. Integrating more sophisticated machine learning techniques could enhance the precision of emotional response analysis, providing deeper insights into the underlying mechanisms of color-emotion relationships. Future studies could benefit from a broader range of biometric measures, such as EEG and eye-tracking data, to paint a more comprehensive picture of how color transitions affect emotional states on a neurological level. Additionally, adapting the experimental design to incorporate virtual and augmented reality could offer more immersive and controlled environments to study these effects. Such technologies would allow for the simulation of real-world scenarios in which color changes occur, providing a more robust understanding of their impact in everyday settings.

In conclusion, this study serves as a foundation for future research into the dynamic field of color psychology. By continuing to explore and integrate advanced methodologies, we can further unravel the complex interactions between color and emotion, paving the way for applications that span from therapeutic settings to user interface design, where understanding and influencing emotional states are crucial.

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