

Color Palette Variations in Discrete Emotions Using Virtual Reality Technology

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ABSTRACT

Previous studies have sought to investigate the meanings of colors, categorize human emotions elicited by colors or conduct experiments on the influence of color on psychological functioning. However, there is a paucity of literature studying color emotions in different cultures and how these emotions elicited can be influenced. Virtual reality (VR) provides an alternative world to perform empirical tests on the impact of a virtual environment on emotional color perception. This paper reports an hypothetical study of participants n=12 selected from different ethnic and racial groups to perform a VR experiment session to measure color emotion. The impact of VR on color emotion is measured using a pre-questionnaire and post-interview. The expected results are described based on works of previous researchers that show the correlation between color emotions, culture, and virtual reality.

1 INTRODUCTION

The different meaning attached to colors are influenced by a variety of factors such as age, sex, cultural background, geographical locations, such that the differences conflict? In western cultures, white is associated with purity, deity, innocence, and hope. While in parts of Asia, white is associated with death, mourning or bad luck. In 1810, German poet Johann Wolfgang von Goethein stated in his book, Theory of colors, that particular colors excite particular states of feelings [1]. Setting precedence, he linked hues to feelings, yellow was linked to warmth and pleasant excitation, blue to coldness, and green to calmness, among others. Following his work in 1810, researchers have studied human emotional responses to colors, under a term known as color emotion. Color emotion is defined as a feeling or emotion induced in our brains when we look at colors[2,3]. Therefore, it can be concluded that colors elicit disparate emotions across a group of people.

According to psychologists, 80 percent of the color impact is processed by the nervous system, and only

the remaining 20 percent- by the visual system [4,5]. The nervous system which is also responsible for emotions generation, expression, experience, and recognition. Thus, color not only induces emotions, but primarily influences emotions. This physiology impacts design because it has the capacity to trigger different emotions in users as already established. Recent focus on human centered computing provides an opportunity to research how designers can create designs that support better user experience.

Interestingly, the majority of work in this area has studied emotional perception of color based on colored cards or colors displayed on monitors[6]. The limitations of the methods of these studies are evident in the lack of control for the variables presented by the surrounding setting, as the colors show only a portion of the overall setting that the person is experiencing while participating in the study. Whereas the emergence of virtual reality technology offers an exciting chance to immerse people within carefully controlled virtual environments featuring chosen colors to directly monitor contextual factors. Virtual reality (VR) is a simulation that creates an alternate realistic-looking world using computer graphics [7], users are introduced to a new perspective.

Human centered computing is mainly concerned with building usable and effective systems with focus on the user. This focus should consider the personal, social, and cultural contexts in which such systems are being utilized. The purpose of the current study is to address the impacts of virtual reality on color emotions in individuals' from different cultural backgrounds after experiencing test colors in a virtual environment. To explore these impacts, we aim to collect empirical evidence using prequestionnaire and

a short interview (post) to record participants' emotional perception towards a color before and after experiencing test color in VR. We hypothesize that experiencing a color virtually can influence the color emotion. Such findings would support the design of color palette guidelines for specific emotions.

2 RELATED WORK

Emotional perception of color: Early work on color association with its effect on emotion was based upon personal experience and observation. It was mostly focused on emotional arousal [1, 20, 21, 22]. Later, qualitative and quantitative methods were adapted to find the association of color with that of emotions. These studies included psychiatric patients as participants [21, 23]. Charles Féré [23, 24] focused on the influence of color on psychological functioning and physiological arousal. Their findings were similar; the color red was associated with stimulation and excitement, and the color blue was associated with calmness and relaxation. As Féré focused on physiological aspects, he found that the stimulating effect of red was implied by an increase in pulse rate, physical strength, and alteration in the respiratory pattern. However, these studies did not consider the influence of color properties (hue, lightness, and chroma), background color and illumination in which the focal color is viewed [25, 26]. For instance, Burnham et. Al., [27] shows the influence of adaptation of illumination on color perception by using binocular septum method.

Similar to the influence of color properties, background and illumination on color perception, there are some other factors such as culture, religion, race, gender and ethnicity that influence our perception of color and its associated meaning. Madden et al., [15] carried out a study to explore meanings of color in eight different cultures (Austria, Brazil, Canada, Colombia, Hong Kong, PRC, United states, and Taiwan) by using a semantic differential scale based on which participants rated each color. They found that blue, green and white are associated with peace, gentleness, and calmness across all countries. Although, they also have unique meanings in each country such as beautiful is associated with Blue in Brazil, Hong Kong, PRC and US, whereas in Austria, Colombia, and US it is associated with pleasantness. Similarly, Red is associated with

pleasantness in PRC and Taiwan. In Brazil, Colombia, PRC and Taiwan black and brown are associated with being formal, whereas in Austria, Hong Kong and the US it is associated with masculinity [15]. In another study, Sokolova and Caballero reviewed the role of color and light in affective computing [31]. They found that color influences emotions irrationally or “mildly”. However, as color is always present in our environments, its influence is constant, like in the cases of painted rooms or colored lighting. On the contrary, light is an active factor in comparison to color, which could be labeled as a more proactive and energetic factor. Therefore, a combination of both light and color is beneficial for the aims of affective computing.

Color perception in Virtual Reality: Different models such as digital model, virtual reality models also influence the perception of color. Bilger et al. [28] carried out a study to find the difference between perception of color and space in real room, digital, and virtual reality models. Their study showed that large color variations in real rooms had a strong effect on each other by reflections which was not the case in virtual reality. It had more meaning as compared to the digital model. Also, there is a difference between perceived color of light in the real room as compared to digital and virtual reality models. The light in the room was associated with cold or neutral meaning as it was in the white fluorescent illumination. Whereas, in digital and virtual reality models there was no color for light. Authors suggest that improvement in the current technology is needed to perceive colors that we see naturally.

As shown in Bilger et al's study, humans experience color differently in real life and in virtual reality. Wong [29] used biosensors to measure emotional response to colors in virtual reality. For the purpose of exploring responses to different colors, the author chose blue and red for the skybox in a video game as they are contrasting colors. Based on the heart rate data, the average heart rate was lower for blue than that of red. This was because the color red evoked emotions thereby stimulating the physical body by raising heart rate and respiration. Whereas the color blue was found to be calming with lower heart rate [29].

3 APPROACH / METHOD

Research Question: What is the impact of virtual reality on color emotions in individuals' from different cultural backgrounds after experiencing a virtual environment?

Participants: The study will take place at the University of Maryland, Baltimore County (UMBC), where we will recruit at least 12 participants between the ages of 20 and 40 making sure that there is at least one male and one female representing each racial/ethnic group. The gender variation is based on findings that males and females have distinct preferences for tonal values, irrespective of saturation or brightness levels [8]. The list of ethnic groups considered for the purpose of this study comes from the Office of Management and Budget (OMB) [9], which defines each racial and ethnic group into five categories as follows: American Indian or Alaska Native, Asian, Black or African, American Hispanic or Latino, Native Hawaiian or Other Pacific Islander. Each participant will be screened for any vision problems or color blindness during the enrollment phase of the study to ensure zero compromise in the data collected.

Study: The study would involve a within-subjects design, gathering would be done over the course of 6 days with a frequency of 2 participants per day. Each experimental session would involve a participant reading and signing a consent form, filling a short demographics form which will be followed by a survey-style pre-questionnaire (questions attached in the appendix A) which will help gather the participant's color perception towards test colors before they experience the three colors in an immersive environment. A brief tutorial to acquaint them with the experiment and the VR equipment will be administered to ensure an undisturbed following experience. The tutorial would consist of a 5-minutes verbal script explaining what color emotion is, basic instructions on how to adjust the VR headset and volume will be demonstrated and a 5-minute test VR session.

Following the tutorial, the participant would put on the VR headset and when ready, the researcher would

inform them of the color they are about to experience and then start the experience by pressing play on the desktop. In order to clearly distinguish colors, the chosen colors for this experiment have to be contrasting visually. Hence, we have chosen red, blue and green which are part of the most contrasting color pairs proposed by opponent process theory [10]. Each color is represented singly in a virtual environment video of 5 minutes for participants to watch. During the VR experience, two researchers would observe the participant and take notes on any visible behavioral responses during the virtual experience. Following each VR experience, audio recorded interviews (questions attached in the appendix B), would be conducted to gather information on how they felt about the color, what they thought about their experience, and what emotion they associated with the color before and after the experience. These queries would be important to confirm if there was an influence of VR technology on color perception and as well as understand the meaning of expressions and movement detected in relation to emotions felt by participants.



Fig 1: Participant During VR Session [32]

Each experiment is estimated to span around 40 minutes allocating 5 minutes per VR session (2 sessions per participant), 10 minutes for the pre-questionnaire, and 15 minutes for the post-interview. In a day, it is expected that 1 hour 15 minutes would be spent on data gathering. The data gathering process would be spread across multiple days to account for possible interference such as fatigue, current general mood, and mental wellbeing.

Devices and Technology: The virtual environments will run on a portable computer (Pentium-4 3.20-GHz), with Microsoft Windows 10 pro and a graphic

Due to the novelty and hypothetical nature of this study, we derived hypothetical results by analyzing the meanings of the test colors (red, green, and blue)

	Red	Green	Blue
Positive responses	number of positive responses - 60.2%	number of positive responses - 95.9%	number of positive responses given - 79.6%
Induced positive feelings	happiness and love	relaxation and calmness	happiness, comfort, peace, and hope
Induced negative feelings	fear and anger	insects and poison danger	sadness, depression, and loneliness
Quotes	<i>"it reminds me of being in love"</i>	<i>"green is refreshing and beautiful"</i>	<i>"it makes me feel blue"</i>

Table 1: Emotional responses and quotes from reviewed study [15,16,19]

card Nvidia GeForce GTX 2080 Super. The environments will be virtualized using an immersive Head Mounted Display (HTC Vive Pro) available at the User Studies Lab, UMBC. For locomotion within the environment participants will employ the use of a wireless joystick (HTC Vive controller joystick). For video playing we will use the vive video. This is a video player for virtual reality compatible with the latest version of HTC Vive VRH. It supports 2D, 3D, 180° and 360° content. Finally, to conduct the interviews and transcribe the contents we will use the Temi Record and Transcribe Application.

4 ANALYSIS AND RESULTS

The data collected will be analyzed qualitatively. Due to the small participant size, no software will be used to manage the data. Upon obtaining the transcribed interview, we will begin categorizations and theme generation. We will perform open coding using Microsoft Word to create a code book, which entails collecting all keywords from all the interviews to a different document and crossing all duplications. We will review use content analysis, during which participants' behaviors will be inductively coded according to themes. Further, these categories will be compiled into overlapping and similar categories to produce a final coding framework. This final coding system will be used to divide up all the interviews. Two researchers will complete the coding to ensure inter-rater reliability [33]. Too, quantitative data will be derived from qualitative data to prove the strength of the findings.

Results

in desktop computer program generated color notation and across the various ethnic groups, colors as an affective stimulus, studies that have considered virtual reality alongside emotions and virtual reality versus traditional 2D film.

Color and Meanings in Desktop Computer Programs

Generally, the color blue is mostly associated with water, ocean, and the sky, indicating its association with positive emotions such as calm and relaxing [15]. Although it has been also associated with cleanliness and trust [16]. However, few participants in a study associated blue with dark night sky which indicated the presences of negative emotion [19]. While, the color Red has a unique meaning and mostly been associated with love, passion, romance, wine, and Christmas time [15]. But some participants associated red with negative emotions such as anger and fear by tying correlations to blood, danger, fight, and evil [19]. Unlike blue and red, uniquely the color green is associated with nature (positive emotions) mainly. Table 1 is a summary of positive responses, induced feelings, and quotes from the participants of a study who were asked to indicate their emotional responses to five colors(red, yellow, green, blue, purple).

Color and Meanings Across Ethnic and Racial Groups

Next, table 2 summarizes the different meanings attached to red, green, and blue within the chosen ethnic groups of study. The ethnic groups American Indian/Alaska Native and Asian have few similarities

of perception of the color red. Both the groups symbolize the color red with success and happiness. A

an experience itself, including emotional perception of the color [13].

	RED	GREEN	BLUE
American Indian/Alaska Native	Violence, War, Blood, Wounds, Strength, Energy, Power, Success, Happiness, Beauty	Harmony, Healing Power	Confidence, Wisdom, Authority
Asian	Heroic, Heat and Fertility, Courage, Loyalty, Honor, Success, Passion, Happiness	New Beginning, Harvest, Happiness, Wealth, Growth	Immortality, Bravery, Healing, Trust, Long Life
Black/African	Life, Health, Mourning, Death	Spiritual Growth, Harvest	Love, Harmony, Peace
American Hispanic/Latino	Religion	Death	Mourning, Trust, Serenity
Native Hawaiian or Other Pacific Islander	Goddess of Fire	Commoners	N/A

Table 2: Different meanings of test colors (red, green, and blue) across the chosen ethnic groups

stark contrast is evident amongst the Black/African and American Hispanic/Latino ethnic groups as they associate death and mourning with the colors red and blue, respectively. As well in China, red is associated with positive aspects: passion and energy, while in India and the US it represents anger and danger.

Color as an Affective Stimulus for Discrete and Mixed Emotions

Besides esthetic meanings, colors influence our perception and attitude towards particular objects [19]. While being immersed in a single color can potentially evoke specific behavior, multicolored pictures can induce a set of the emotions or poignancy [17]. According to the study of Hal Ersner-Hershfield et al. colors induced mixed emotions in both younger and older adults. However, older adults tend to express their mixed emotional state more naturally than younger ones [18]. But, if the image is represented only by shades of the same color, people tend to describe one evoked assumption about image properties. The results of a study by Kim et al. showed that mono-color image is interpreted as old, traditional or professional [18]. Moreover, if the single-color environment is immersive, the quality of the picture, size of the screen and other qualitative properties influencing the image do not affect realism. Therefore, the set of emotions is evoked by

Further, emotions induced by an immersive colored environment are characterized as positive and negative or metaphorical and literal [19]. While the color palette represented by cold colors induces calmness, relaxation, freshness, it is also associated with forest for green and ocean for blue [19]. Thus, mixed emotions can be induced by a single color. Table 1 shows the color blue can evoke calmness and happiness, and at the same time induces sadness and depression. The same patterns were described for the color green. It can be perceived as excitement and hope, as well as a strong depiction of danger from insects or poison [19].

Virtual reality as an Affective Medium

Much is still to be discovered on the influence of VR on human emotion. A study conducted by Riva et al. showed the possibility of virtual reality as an affective medium to induce specific emotions. In their study, a one-way ANOVA analysis to evaluate the effectiveness of virtual reality in eliciting emotions showed significant differences exists in emotional levels after experiencing a series of affectively designed virtual environments. This result is supported by a study conducted by Felnhofer [11] to determine the efficacy of different virtual parks in eliciting intended emotion. The self-report and physiological measures analyzed showed that almost

all conditions induced targeted affective state except for the sadness condition. The results suggest the possibility of designing for an affective experience in virtual reality. Also, analyses of the data using pairwise post-hoc comparisons exposed the presences of other elicited emotions aside the target emotions in each park. According to Anderson et al. [12], negative emotions are usually in coexistence with other negative emotions. Further, the result of their analyses indicated that small changes in the virtual environment lightening condition can result in different affective appraisals.

Likewise, a similar study [13] conducted to verify the use of virtual reality systems to induce an emotional change showed the capability of virtual reality to induce a change of emotion. Statistical results of the PANAS scale taken showed that 77% of the participants reported that the VR system was able to induce an emotion.

Affective Experience in Virtual Reality Versus Traditional 2D

Too, another study conducted to investigate the influence of cinematic virtual reality (CVR) on human emotion by comparing CVR against traditional 2d film showed: a) stronger emotional effect than the traditional 2D film and b) in CVR specific emotions vary with significant differences between pre-test and post-test [14].

5 DISCUSSION

The results of the current study suggest that in a virtual environment a negative emotion is usually accompanied by other negative emotions. Applying this principle, researchers can test for other negative emotions in user experience by designing studies to exclusively target negative emotions. Additionally, designers when making palette choices are more aware that one bad emotional perception can lead to other negative consequences that tampers with the entire user experience.

Also, results suggest a link between the virtual lightening conditions and affective appraisals. In color palette design the lightening condition would mean on the opacity of the color. Thus, indicating that the opacity level of the color (between 0.0 (fully

transparent) and 1.0 (fully opaque)) has impact on the emotional response of users. Additionally, basic meanings of colors (red, green blue) can guide a designer's choice of combination between these colors to maintain desired complex influence on user's affective state.

Correspondingly, to our knowledge, a study is yet to be carried out on the subject of color emotion perception in virtual reality with a cultural context in the forefront. Given that we are the first to attempt this study, there are inherently some limitations that result. The first of these limitations is the restricted choice of colors to test virtually. Strictly red, blue, and green were chosen because of their contrasting differences. Also, it was not expected that there would be a correlation between the opacity of the color and the affective appraisal. Therefore, in the future, researchers should attempt to use a wider range of colors at different opacity levels.

Another limitation of the proposed study is that the United States of America (authors current location at time of study) officially recognizes five different ethnic groups. Based on the selected ethnic groups, not all cultures from different countries are covered in this paper. Lastly, although emotions are described based on the categorical and dimensional models of emotion [30], this study focused mainly on discrete emotions. It is possible that considering affective dimensions could have affected the results of the current study.

6 FUTURE WORK AND CONCLUSIONS

In the current study, we sort investigate whether virtual reality could influence emotional perception of color in individuals from different cultural background. Given past research on virtual reality [11,12,13], we hypothesize that experiencing a color virtually can influence the color emotion. By synthesizing results from previous studies, we were able to show that a correlation between emotions, colors and virtual reality exist. However, further research is needed to, first, to ascertain whether this study design described would replicate similar results, second, determine to what extent virtual reality can influence emotion.

Furthermore, we would implement a comparative study by modelling single color

immersion in different virtual contexts (indoor versus outdoor) along the affective dimensions. Such study would point out how the various virtual context experiences impact color emotion. Finally, to account for internal states of participants, we would measure physiological responses and check for correlation with self-report.

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APPENDIX A: PRE-QUESTIONNAIRE

Part 1: Demographics Form

1. Email address: _____
2. Which category below includes your age?
3. What is your gender?
 - Female
 - Male
4. Which race do you belong to?
 - White or Caucasian
 - Black, African American or Coloured People
 - American Indian or Alaska Native
 - Latino or Hispanic
 - Asian
 - Pacific Islander or Hawaiian
5. What country are you from?
6. Religion: _____
7. What is the highest level of school you have completed or the highest degree you have received?
 - Less than high school degree
 - High school degree or equivalent (e.g., GED)
 - Some college but no degree
 - Associate degree
 - Bachelor degree
 - Graduate degree
8. Do you have visual impairments?
 - Yes
 - No

Part 2: Familiarity with Technology and VR devices

1. How many times a week do you use a computer?
 - Everyday
 - Once in a week
 - Two-Three times a week
 - Never
2. Have you experienced VR devices like HTC Vive or Oculus?
 - Yes
 - No
 - Maybe

3. Select the device you have used:
 - HTC Vive
 - Oculus
 - Microsoft HoloLens
 - Google cardboard
 - Other (Specify) _____
4. Describe your VR Experience _____

Part 3: Questions on Color Theory

1. Do people from your racial/ethnic group associate specific emotions to specific colors?
 - Yes
 - No
 - Maybe, I don't know
2. Do you agree with the associated emotion to specific color?
 - Yes
 - No
 - Maybe, I don't know
3. What do the following colors signify to you personally?
 - Red _____
 - Blue _____
 - Green _____
4. What is the reason behind the color perception you previously mentioned?
 - Red
 - Blue
 - Green

APPENDIX B: INTERVIEW QUESTIONS

1. How did you perceive being immersed in a single color?
2. What was the dominant emotion you felt?
3. Did you experience mixed emotions? (If yes, explain)
4. Do you think experiencing the video in VR influenced your emotion?
5. Do you expect to have the same reaction watching it as a regular video?
6. Is there a change in your emotional perception of the experienced color? (**Follow-up:** If yes, how would you describe that change?)