Understanding the Meaning of Color Environments: A Virtual Environment Exploratory Study

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ABSTRACT

Color in one's environment is known to bring emotional, social, and physiological reactions to people. Despite its significance, understanding meaning of color in environments is challenging mainly because of the difficulty in testing real color environments with virtually unlimited possible color combinations. As the context of color usage changes its impact on human responses, studying color and human responses has limited value if colors are isolated from actual environments (Mahnke, 1999; Hard & Sivik, 1999). To challenge these complications, this study explores Shigenobu Kobayashi's color image scale with real-scale, high-fidelity computer simulations. The goal of this study is to provide a practical framework for empirical research on the psychological/emotional relationship between color environments and people's perceptions of these environments.

The study utilizes Kobayashi's color theory (Kobayashi, 1981, 1987, 1990) focusing on the association of colors and words (i.e., adjectives) describing feelings and psychological emotions. Kobayashi provides a 180 "Image Word Database" of feelings connected to over 1000 color combinations devised by the use of multiple statistical analyses using the semantic differential method. While the large amount of color research has focused on emotional effects of single colors, the Color Image Scale deals with color combinations for practical application. During the last four decades,

Kobayashi's color image scale has been widely adopted throughout major industries in many eastern countries including Japan and Korea.

A focus group consisting of six professional interior designers deducted twelve adjectives via an iterative examination process to carefully select adjectives and color schemes that best present distinguished color environments suitable for a bedroom setting. The twelve adjectives selected were cheerful, domestic, elegant, feminine, fresh, natural, pleasant, robust, simple and appealing, sunny, tranquil, and vivid.

A QuickTime VR environment was developed to represent a bedroom setting. Computer mediated 3D models were created and rendered in Autodesk 3D Studio Max 9 with Vray for photorealistic simulation of color and light. They were then converted into QuickTime VR enabling real-time navigation. The simulation was projected on a large screen. Participants were asked to browse the simulated space using a joystick that allowed them to "look around the room".

Self-report questionnaires and interviews were used to obtain response data. Participants were asked how well the selected words describe the color environment using a 7-point adjective rating scale. Additional data about the acceptability of the Virtual Environment was obtained via post-experiment survey. Multiple statistical analyses were used to examine the association of adjectives and color schemes. Findings and implications are presented along with preliminary work for a subsequent follow-up sample of elders.

NARRATIVE

1. Purpose

This study is part of the larger quest to gain evidence-based knowledge of the meaning of color environments for the elderly residing in a long-term care facility. For researchers and practitioners, the ultimate aim of this study is to test the color image scale developed by Kobayashi using interactive 3D graphics technology (VR) technology with a college student sample prior to a follow-up study with elderly subjects.

Despite the literature acknowledging the significance of color effects to people emotionally and psychologically, little is proven by empirical testing of what different color environments mean to people. The impact of color can be amplified so design practitioners and facility administrators have a basis to make informed decisions in color application. Empirical studies on color environments are complicated due to two main factors: (1) there are virtually unlimited numbers of color combinations that can be tested and (2) there are difficulties in testing in a real environment with subjects. Addressing these complications, our study explores Shigenobu Kobayashi's Color Image Scale with life-size, high-fidelity computer simulation. With the current study, we attempt to provide a practical framework for empirical research on the psychological/emotional relationship between color environments and people who perceive the environments.

2. Research Method

Kobayashi (1981, 1987, 1990, 1998) of Nippon Color & Design Research Institute has developed the “Color Image Scale” to understand how a single color and combinations affect people’s emotion with 180 words describing feelings and psychological emotions. His systematic research methodology and practical application guidelines have been widely accepted by major industries in many countries in Asia as well as Europe. With the 180 “Image Word Database”, Color Image Scale suggests over 1,000 associated color combinations in four application fields: fashion, interior design, product design, and visual media.

In our study, we designed a controlled experiment in which we examined the subjects’ responses to 12 color schemes. The computer generated color environments were displayed on a 96” wide rear-projection screen. Human-Computer Interaction research has established that increased display size provides a higher sense of realism (Ni et al., 2006).

Our goal was to investigate how subjects perceive different color environments in relation to Kobayashi’s theory and suggested adjectives associated with the color combinations.

2.1. Environment

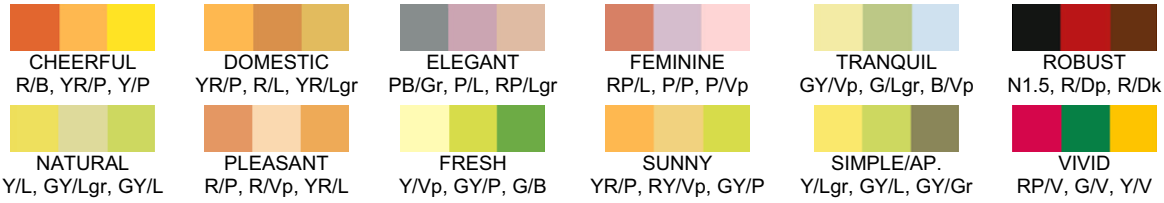
In order to develop color environments, 12 color palettes were extracted from Kobayashi’s Color Image Scale (1990) by a focus group consisting six interior design professionals. First, the focus group drew adjectives from the 180 image word database that considered suitable for elderly residential environments. Each word is associated with nine 3-color palettes. A color palette for each adjective was selected by interior

design professionals. The rationale for color selection was to find a combination that best matches with the adjective. Then, the chosen color palettes were digitized and applied to 3D computer models. The colors used in the Color Image Scale are in a hue/tone system consisting 12 tones in 10 chromatic colors and 10 achromatic colors. While the Munsell system uses the Hue Value/Chroma (H V/C), the Color Image Scale uses only two terms of Hue and Tone (H/T). Table 1 shows the codes for the 11 hue-12 tone system. The 12 color palettes for the current study are presented in Table 2.

Table 1. Notation system for Color Image Scale (H/T)

Hue	R(red), YR(Yellow-Red), Y(Yellow), GY(Green-Yellow), G(Green), BG(Blue-Green), B(Blue), PB(Purple-Blue), P(Purple), RP(Red-Purble), Neutral
Tone	V (Vivid), S(Strong), B(Bright), P(Pale), Vp(Very pale), Lgr(Light grayish), L(Light), Gr(Grayish), Dl(Dull), Dp(Deep), Dk(Dr), Dgr(Deark graysh)

Table 2. Color palettes selected for the study



Based on room layout and measurements of a local retirement home facility, we developed a room with basic bedroom furniture in 3DS Max 9 and Vray, a photorealistic rendering engine for accurate color and light simulation. Selected colors were assigned to floor, walls, and furniture. An Xrite color calibrator was used to accurately display the colors in rendering via computer monitor as well as the projection screen.

Figure 1. Sample color environments with different viewing angels:
(left-pleasant, middle-cheerful, right-tranquil)

The environment was displayed on an 8'X6' screen with a 1024X768 dpi rear-projection system (ANSI 2500). Using Quicktime VR, also known as 'immersive imaging', photographic renderings of the 3D computer model was converted into real-time interactive scenes at 360 º. The scene was rendered with a wide-angle lens to provide a 65 º field of view for a higher level of immersion and more spatial awareness (McCreary & Wiligies, 1998). In addition, a rear-projection system allows viewers to approach much closer to the screen without casting shadows on the screen.

To check the manipulation of the room simulation, participants were asked to rate how closely they perceive the simulated environment is to a real room on a scale ranging from 1 to 7. Result indicated that the VR simulation was perceived as a real room (*M=5.53*, *SE=0.14,* $p<0.001$).

2.2. Experiment

Participants

Voluntary student subjects were recruited at a Midwestern university: 34 subjects (17 males and 17 females) aged 19 to 25 participated in the study. Subjects were very homogeneous in travel and ethnic background.

Procedures

Upon arrival at the VR lab experiment site, a participant was asked to sit on the chair placed 48” from the display to achieve a 90º physical field of view. The participant was asked to “look around” the simulated room using a mouse and to answer a series of survey questions.

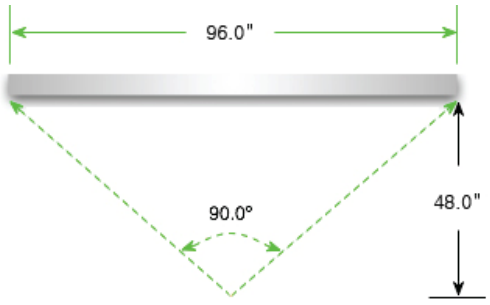


Figure 2. Experiment setup

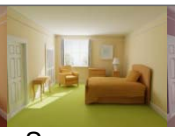
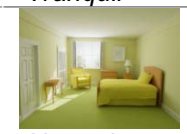
The survey questionnaire was composed of 12 adjectives with a 7-point rating scale from 1(totally disagree) to 7 (totally agree) for each color environment. The experiment took about 10 to 20 minutes to complete for each participant. To reduce carry-over effects, alternate orders of 12 color schemes were randomly assigned to participants.

3. Results and Discussion

This study investigated if and to what degree subjects agree with suggested adjectives associated with each color palette when applied to a bedroom environment. Collected data was statistically analyzed using SPSS. A series of one-sample t-tests were performed to determine how the adjectives and color environments were statistically correlated. In addition, to test the significance of the mean differences between male and female participants, a series of one-way analysis of variance (ANOVA) were calculated. If, and to what extent, the adjectives associated with corresponding color schemes were examined with alpha set at .01. Based on the level

of statistical significance and calculated mean scores of ratings, we identified four groups in terms of the association between the color schemes and adjectives: 1) not significantly agreed, 2) strongly agreed, 3) somewhat agreed, and 4) disagreed. Table 3 shows the t-test results on the adjective ratings for different color schemes.

Table 3. T-test results

Adjective-color scheme One-sample t-test, *p*=.01		Color schemes 1=totally disagree, 4=neutral, 7=totally agree
Not significant		 *Robust*  *Simple & Appealing*
Significant	Strongly agreed	 *Feminine*  *Vivid*  *Fresh*
	Somewhat agreed	 *Tranquil*  *Pleasant*  *Domestic*  *Sunny*  *Elegant*
	Disagreed	 *Natural*

'*Robust*' and '*Simple & appealing'* color schemes were not statistically related to the suggested adjectives. Instead, the closest word to '*Simple & appealing'* color scheme was 'vivid' (*M*=5.91, *SE*=.22), *t*(33)=8.77, *p*=.000. Strong associations between the adjectives and color schemes were observed for '*Feminine*' (M=6.43, SD=1.01), t(33)=14.248, p=.000, '*Vivid*' (M=5.80, SD=1.45), t(33)=2.82, p=.008, and *Fresh* (M=5.54, SD=1.27), t(33)=7.20, p=000. Respondents reported significantly disagreed with '*Natural'* color scheme looking natural.

A profile analysis was conducted to present and analyze data from the adjective rating scale for the 12 color schemes. By plotting computed means, it is possible to compare overall differences or similarities in responses among the color environments.

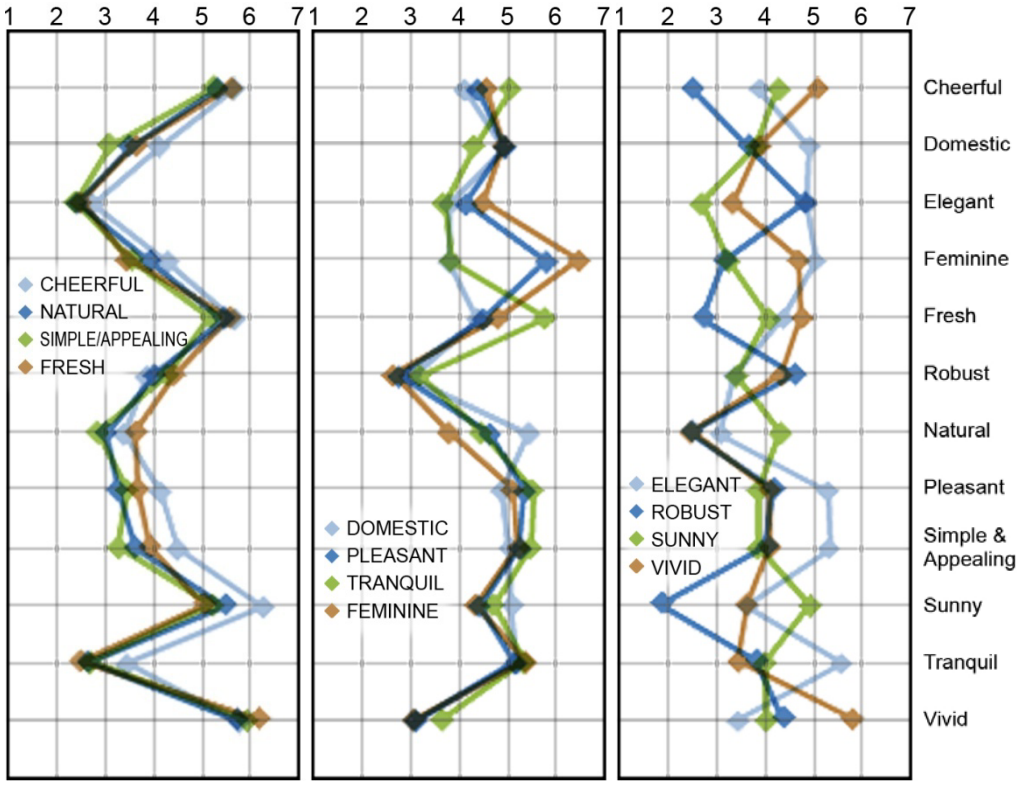


Figure 3. Profile analysis results (1=Totally disagree, 7= totally agree)

The profile analysis results (Table 3) demonstrated that respondents had similar feelings for '*Cheerful', 'Natural', 'Simple & Appealing'* and '*Fresh*'. These four color schemes had consistently higher rating scores for cheerful, fresh, and vivid ratings while lower scores for elegant and tranquil. '*Domestic', 'Pleasant', 'Tranquil'* and '*Feminine'* exhibited a similar pattern in the ratings with low scores for robust and vivid. *'Elegant', 'Robust', 'Sunny',* and '*Vivid'* profiles did not display significant similarities in the ratings. No gender effect was found among the ratings on feelings. However, a significant gender difference regarding interests in color environments was found. A result of a one-way analysis of variance (ANOVA) displayed that female participants (*M=6.59,*

SD=.48) are more strongly interested in color environments than males (*M=5.50, SD=.98*). *F*(1,32)=16.85, *p*=0.00. Participants reported that the experiment was very enjoyable (*M*=5.97, *SD*=.81), fun (*M*=5.94, *SD*=.81), and they would like to voluntarily participate in this type of experiment in the future (*M*=5.88, *SD*=.91).

Phase one of this study allowed us to test the feasibility of our new research method using advanced computer graphics technology to realistically represent color environments and Kobayashi's theory for our future research with elders. Our future phase two study will include a satisfaction factor to further explore the meaning of color environments.

Acknowledgements

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