Preferred memory and accent colors shown on the display and their size effect

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Abstract

The preferred green grass and red(apple, lipstick, sports car) colors shown on the display are investigated using two different image sizes i.e. 2.4" and 7.7". Ten test images were used in the experiment and each image was transformed using memory color transformation algorithm to have different nine green grass or red colors. The pair comparison method was used to find out the most preferred green grass and red colors. It is found that there is little preference change by the image size change. The green grass colors are preferred as the average hue angle becomes closer to 130 degree (65% green and 35% yellow) in CIECAM02 hue angle with high chroma. In the case of red colors, apple images shows the high preference when the reproduced red is closer to the unique red (20.14 degree). The artificial objects such as red lipsticks and sports cars are preferred when reproduced with highest chroma regardless their hues.

1. Introduction

When people watch TV, they do not observe every single object and its color on the screen to judge the image quality. People are more sensitive to the object colors familiar to them such as human skin, green grass, blue sky etc., which are normally known as memory colors. Also there are so called accent colors catching the viewer's eye very easily. A sport car with strong red color on the road can be a good example. Therefore good color reproduction of those eye-catching colors becomes an important issue to enhance the image quality on imaging devices.

The major TV manufacturers have been developing the color control algorithms transforming a specific color to the other colors to reproduce the preferred memory or accent colors [1-4]. Such algorithms become ineffective if it is not known which colors are preferred by the viewers. There have been many studies to find out the color ranges and the typical colors of memory colors [5-7]. However most of the studies are based on the experiment using the color patch. For the real application on TV the experiment using the complex image is more important.

In this paper, the preferred memory colors are investigated along with the preferred accent colors using the complex images. Also it is investigated the size effect of the preferred colors. Nowadays, screen sizes are developed to both extremes i.e. very small and very large. Note that the mobile having small screen size such as 2" or 4" has become the main device to enjoy images such as broadcast TV or pictures captured by camera-phone while people start to enjoy large screen TV at home. Therefore, it would be an important research issue figuring out if there are any perceptual hue changes by the screen size changes.

Colors of green grass and red apple are investigated as memory colors and red sports car and red lipstick colors are used as the accent colors, in this study. The pair-comparison method was applied to find out the image with the most preferred memory or accent colors. Complex images were used in the experiment that manipulated by memory color transformation algorithm [2] developed by the authors to have various green grass or red colors. The same experiments are repeated for small size (2.4") and large size (7.7") images to compare the preferred color changes by the image size. The images chosen as having the most preferred memory or accent colors were used to analyze the most preferred memory or accent colors.

2. Psychophysical Experiments

The psychophysical experiment was conducted to find out the preferred green grass and red colors using the pair comparison method. During the experiments, the pairs of images with slightly different green grass or red colors were shown to the observers who were asked to choose the image they prefer. The experiments using the same test images were repeated for 2.4" and 7.7" test images to study the change of the preferred green grass colors by the image size. In the case of red color experiment, only 7.7" image was used in the experiment.

2.1 Experimental set-up

Figure 1 illustrates the test pattern shown to the observers during the experiment. The image was shown in the center of a screen with a black background and there were two buttons to toggle between a pair of images and to select one of them each observer preferred.

The sizes of the images were adjusted such that having 3.9cm(W)x4.6cm(H) (≈2.4", diagonal) for the small size image and 11.9cm(W)x15.4cm(H) (≈7.7", diagonal) for the large size image.

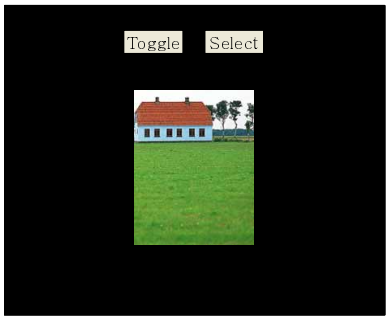

Figure 1 *Experimental test patterns*

The experiment was conducted in a dark room. Therefore the observers could see the image only because of the black background. It was to simulate the condition that 7.7" or 2.4" display was shown in the dark.

Figure 2 represents the color gamut and tone characteristics of the monitor used in the experiment. The monitor had color gamut similar to sRGB and the gamma value of the tone curve was 2.3. The monitor has a good additivity as shown in Table 1and good chromaticity constancy. Therefore simple PLCC model was used to analyze the experimental data.

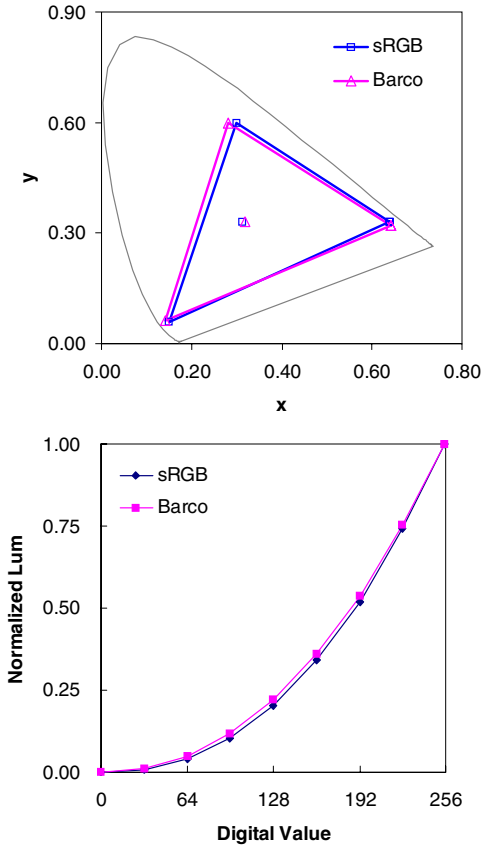

***Figure 2**. Color gamut and tone characteristics of the Barco monitor used in the experiment*

Table 1 Color characteristics of the monitor used in the experiment

	X	Y	Z	x	y
White	72.60	75.80	79.91	0.3180	0.3320
Black	0.01	0.01	0.01	0.2730	0.3330
Red	36.40	18.20	2.10	0.6420	0.3210
Green	24.45	52.40	10.48	0.2800	0.6000
Blue	11.99	5.32	67.13	0.1420	0.0630
Additivity	0.33%	0.16%	-0.25%		

2.2 Experimental Procedure

Ten test images were chosen for green grass and red color experiments separately. Each image was rendered to have 9 different green grass or red colors. Thus 36 pairs (=9x8/2) were compared for each image. The experiment was divided into three sessions i.e. 7.7" green grass, 2.4" green grass and 7.7" red. For each session, the pair of images was randomly displayed to each observer. Experiments were conducted in a dark room and 10 observers participated in the experiments. The distance between the screen and the eye was recommended to be 30 cm but observers are allowed to move their position.

2.3 Preparation of the test images

Among 10 test images for the green grass experiment, seven images show the grass covering the most of the image, two images contain trees and one is showing the gourds. In the case of red color test images, six of them are red apples, two of them are red lipsticks and remaining two are red sports car images. Figure 3 shows the part of test images used in the experiment.

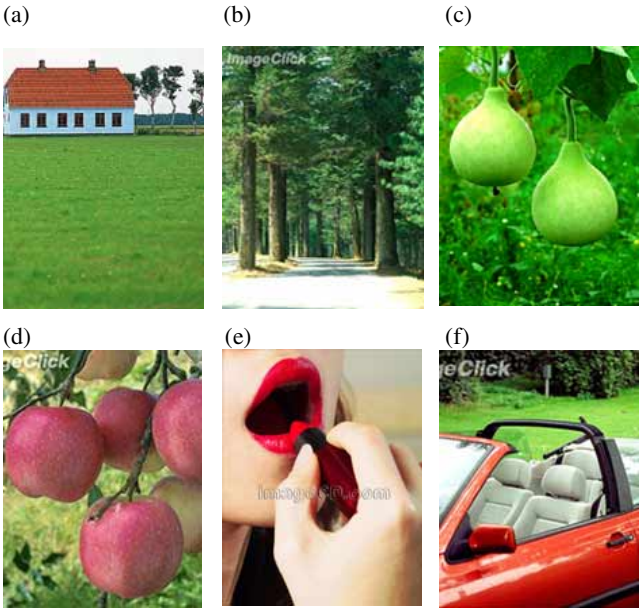

***Figure 3.** Examples of the test images used in the experiment*

Also the average color values of green grass or red color area of the test images are considered to choose the test images. They were chosen such that the average color values are widely distributed in the color spaces as shown in Figure 4.

The each test image was then transformed to have slightly different nine green grass or red colors using memory color reproduction algorithm developed by the authors in Ref [2]. (refer Figure 4) According to the color transformation algorithm used in this study, the input pixels detected as a green grass or red color are gradually transformed toward a target point located inside the boundary while there is no color change for a target color and colors outside the boundary. There was no visible artifact on the transformed images. Also other colors apart from the green grass or red color were not changed at all by the algorithm.

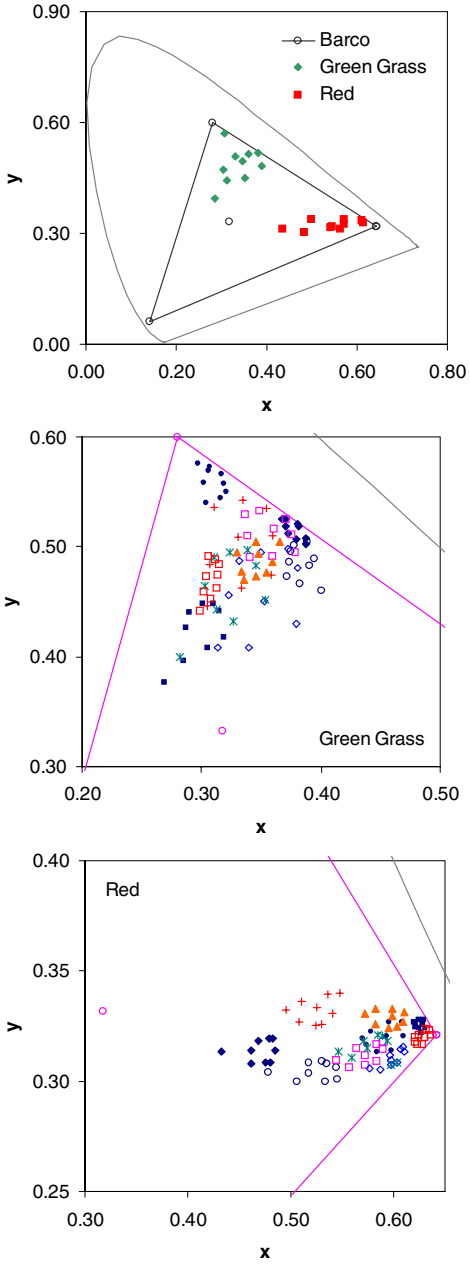

Figure 4 *Distribution of the average green grass and red colors of test images*

3. Experimental Results

The pair-comparison experimental data were analyzed and the results were calculated using z-score. The final z-score was adjusted such that the minimum value is set to zero.

3.1 Preferred green grass color change by the size of images

The preferred green grass colors were investigated for two different image sizes. During the experiment, the observers asked more time to finish the experiment with the small size images indicating that distinguishing the colors of small images takes longer time. However the overall result shows that there is little preference difference between two image sizes as shown in Figure 5, which represents z-scores calculated using the accumulated data for (a), (b) and (c) images in Figure 3 by 10 observers.

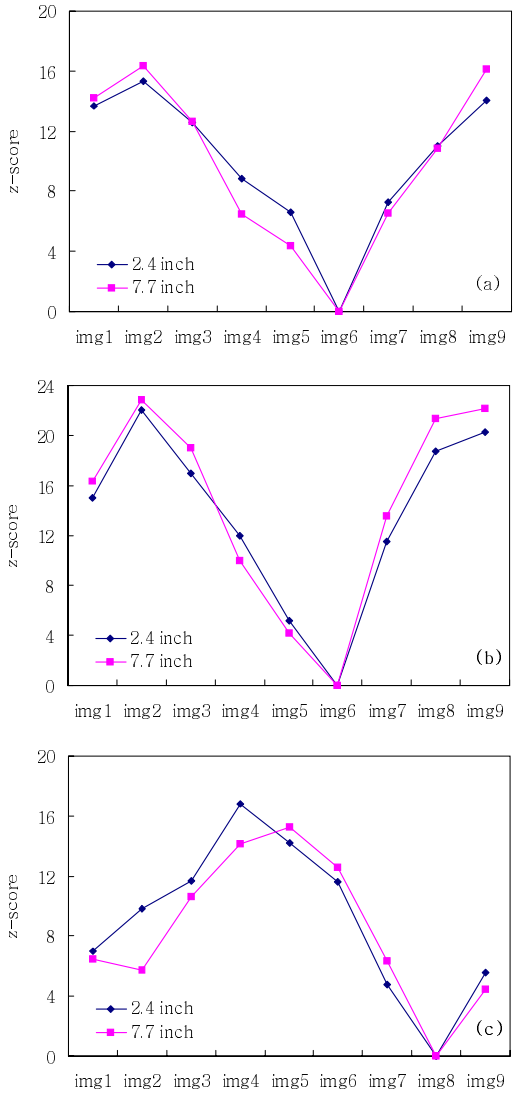

Figure 5 *Psychophysical experimental results for preferred green grass colors*

3.2 CIECAM02 hue angle and chroma of the preferred green grass colors

The average green grass colors of each transformed images in Figure 4 are analyzed using CIECAM02 color appearance model to define the preferred green grass colors as color appearance attributes. Figure 6 depicts CIECAM02 average chroma and hue angle of each transformed images. The filled symbols represent the most preferred images selected from the experiment using 7.7" image. If there was little difference between the best and the second best images, both of them are represented using the filled symbol.

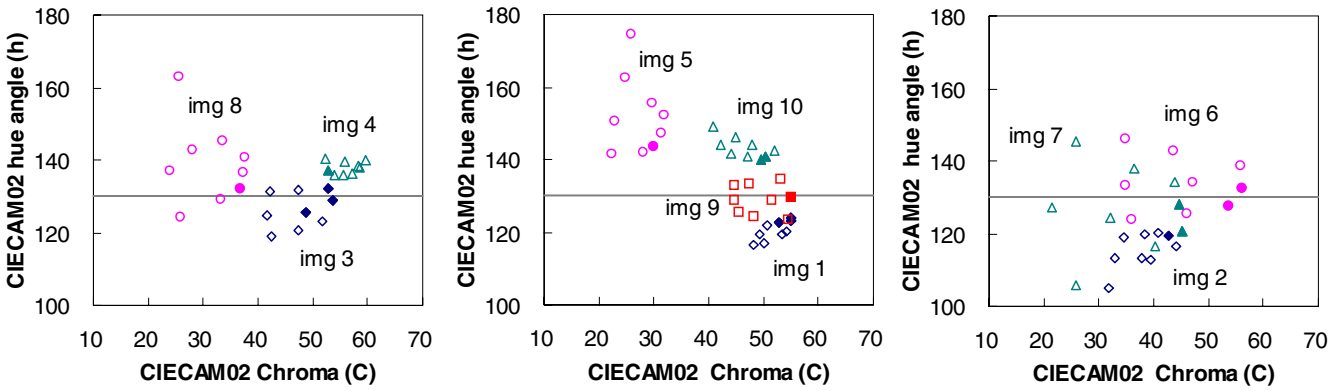

Figure 6 *CIECAM02 chroma and hue angle of the average green grass colors of the test images (filled symbol: the most preferred image)*

The most notable feature in Figure 6 is that the images are preferred having the highest chroma with their hue closest to the hue angle 130 i.e. around 165 (65% green and 35% yellow) in terms of hue quadrature. The only exception was image 4 experiment where the lower chroma was preferred. The main object of the image 4 was a vegetable indicating the possibility that the preferred green for vegetables might be different from those for green grass or foliages. The optimal chroma for green grass colors couldn't be induced from the current experimental data since the observers preferred the images having the highest chroma among the transformed images.

The preferred green grass hue found here is compared with those in the previous studies. Table 2 summarizes the memorized or preferred green grass colors from the Ref [5], [6] and [7]. The result of each study is converted to CIECAM02 hue angle for the comparison. Figure 7 compares the result using bar chart. Our result is very similar to that by Bodrogi et al., while Bartleson's experiment shows more greenish grass colors than others. The differenc might be induced by the light source differences. Note that Bartleson used illuminant A while our study and Bodrogi use the white point having the higher color temperature. The study by Perez-Carpinell et al. clearly shows the memory color shift by the light source change. More greenish colors are preferred under illuminant A than illuminant D65 for both watermelon and lettuce colors. Perez-Carpinell et al. used more specific objects i.e. watermelon and lettuce to judge the memory color. It might be the main reason for the differences with ours and Bodrogi's studies.

3.3 The preferred accent colors vs. memory colors

The experimental data for red color experiments are analyzed with the same method for the green grass color experiments described in Section 3.2. Figure 8 represents the distribution of CIECAM02 chroma and hue of the average red color values of the transformed images. The most preferred transformed images are shown using the filled symbols. As mentioned in Section 2.3, six images (img1~img6) are for the apple colors and other four images (img7~img10) are for the accent colors.

In the case of apple images (left graph in Figure 8), hue was the major factor for the preference judgment. The most preferred red hue for each image is directing the unique red i.e. hue angle 20.14. The experimental results for img4 and img5 imply that too much enhanced chroma for the apple can be judged as the image quality deterioration.

As shown in the left graph of Figure 8, the most preferred red colors have the highest chroma regardless their hues. It indicates that the observers preferred the image having the highest chroma with no specific preferred hue in the case of artificial objects, i.e. lipstick and sports car. It was the expected result since the artificial objects have no prototypical colors.

4. Conclusion

The preferred green grass and red colors are investigated using the complex images. Nine transformed images having different green grass colors are compared to each other using the pair comparison experimental method. Total ten different test images are used. The experiment was repeated using 2.4" and 7.7" images to evaluate the preference color changes by the display size.

The overall result showed that there is little preference changes by the image size. However the size differences in this study was not large enough. More research for different TV screen size will be required in the future.

For the green grass images, the hue angle 130 (65% green and 35% yellow) in CIECAM02 is the most preferred hue for the grass area with high chroma.

In the case of red colors, the experimental results for natural object and the artificial object colors show the differences. An apple having a hue closer to the unique red is preferred while too high chroma is not preferred. The images with highest chroma for red objects are preferred for the red lipsticks and sports cars regardless their hues.

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Author Biography

Youngshin Kwak received her BSc (physics) and MSc (physics) degrees in 1995 and 1997 from Ewha Womans University, Seoul, South Korea. From 1997 until 1999 she worked as a researcher at the Ewha Colour and Design Research Institute. After completing her PhD study at Colour & Imaging Institute, University of Derby, UK in July 2003, she joined the SAIT, South Korea. Her main research interests include color appearance modeling and image quality enhancement.

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Chang Yeong Kim received his B.S.degree in Aerospace and Mechanical Engineering from The Hankuk Aviation University in 1984. He received the M.S. degree and the Ph.D. degree both in electrical engineering and computer science from The Korea Advanced Institute of Science and Technology(KAIST), in 1987 and in 1998, respectively. He joined the SAIT in 1987 as a researcher and is currently a vice president of SAIT. His research interests include color imaging, image processing, and human visual perception.

Table 2 The memorized or preferred green grass colors from the previous studies[5-7] described using CIECAM02 hue angle

	Data set	Object name	mode	Illuminant / white	x	y	CIECAM02 h
GG_A	Bartleson [5]	green grass	reflec.	A	0.4065	0.4822	153.77
GF_A	Bartleson	green foliage	reflec.	A	0.4159	0.4425	167.79
GW_D65_phy	Perez-Carpinell [6]	green watermelon	reflec.	D65	0.294	0.409	150.11
GW_D65_arts	Perez-Carpinell	green watermelon	reflec.	D65	0.294	0.406	150.58
GW_A_phy	Perez-Carpinell	green watermelon	reflec.	A	0.403	0.467	162.15
GW_A_arts	Perez-Carpinell	green watermelon	reflec.	A	0.403	0.465	163.15
GL_D65_phy	Perez-Carpinell	green lettuce	reflec.	D65	0.369	0.487	117.05
GL_D65_arts	Perez-Carpinell	green lettuce	reflec.	D65	0.367	0.483	117.26
GL_A_phy	Perez-Carpinell	green lettuce	reflec.	A	0.463	0.482	120.99
GL_A_arts	Perez-Carpinell	green lettuce	reflec.	A	0.466	0.477	119.11
Plant_P	Bodrogi [7]	Plant	self-lum	(0.299,0.267)	CIELAB h = 129.70		130.63
SAIT_GG	SAIT	green grass	self-lum	(0.318,0.332)	N/A		130.00

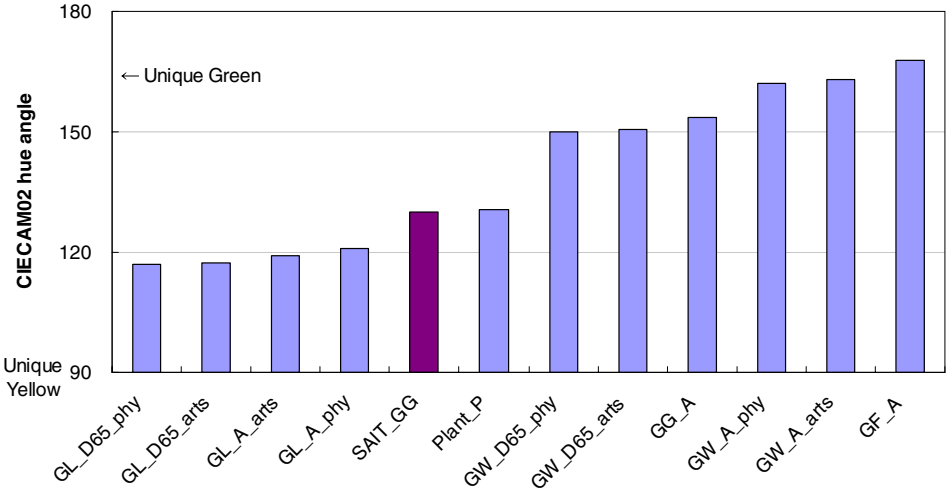

Figure 7 *Comparison of the memorized or preferred green grass colors from the previous studies [5-7] using CIECAM02 hue angle*

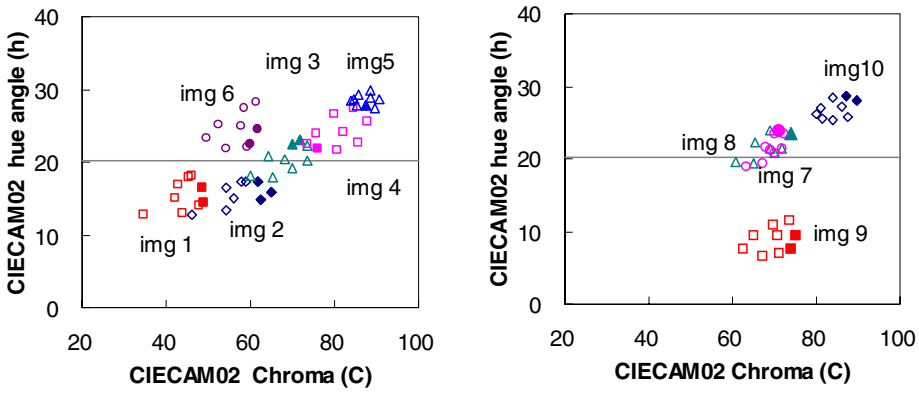

Figure 8 *CIECAM02 chroma and hue angle of the preferred red colors (filled symbol: the most preferred image)*