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A STUDY ON COLOR-SHIFT OF LCD WITH VISUAL JUDGMENT METHOD

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ABSTRACT:

The purpose of this study was to evaluate the perceptual motion image quality on LCD through color combination analysis and visual judgment task. In this study, the method to execute was using method of psychophysical experiment. We attempted at exploiting the relationship between the four levels chroma, six colors for color combination task, and four differential response time of LCD (those were 25ms, 16ms, 8ms, and 4ms). Results of this study showed that the key factor to affect the result of visual judgment was color combination not physical response time of LCD. And when the saturation of the color combination was higher, the result of the judgment will much approach to the background color. Furthermore, we found when the LCD response time was faster; the time that the user spent to answer was longer. If the color saturation was higher, the judge time to answer was longer.

1. INTRODUCTION

Nowadays, liquid crystal display (LCD) was becoming popular than cathode ray tube (CRT) when design motion picture task with computer. And, related studies report the LCD had better performance than CRT (Wright et al., 1999; Shieh and Lin, 2000). But, there were a number of points worth consideration it, those were color depth for color reproduction, response time of liquid crystal for motion image. Although the LCD was close to CRT when display complex color. Miseli (2004) has pointed out that motion artifact for LCD is an important performance quality determinant, one of the final major frontiers for LCD. The issues of evaluation for motion image have often been limited to response time of LCD. In recent years, the images quality research of LCD was getting more attention in color reproduction of LCD for display motion image, but there were focus on view angle of still image (Samei & Wright, 2006) and physical measurement from image capture system at most of studies (Oda et al., 2002; Yoshitomo, et al., 2002). A critical color reproduction problem of LCD is the estimation of image quality from human visual system (HVS), because the viewers' visual performance is one of the most important factors for information communication (e.g. processing visual information). Although much work has been done to date, more studies need to be conducted to ascertain human's perception of the color-shift and acceptability of the image quality by their visual judgment. The purpose of this study was focusing on color combination with different pairs of them and to affect color-shift of motion images on LCD. Thus, in this paper, a color-shift evaluation task was examined to judge the quality of motion images with subjective visual judgment method. At the same time, its needed to set up the method and design experiment procedure to explore color-shift on the moving image and subjective visual judgment task.

2. METHOD

2. 1. MATERIALS

The method to carry out in this study was using laboratory experiment design. The bases of four types of 17-inch LCD monitor (1024 multiplied by 768 pixels on them) were selected from four level of response time (see Table 1). At the same time, we discussed the difference on four levels of response time that will effect to subjective judgment. In order to obviate the possibility of a confounding variable from light of environment and the others, the surround of lab was dark and quiet (Kurita and Saito, 2002). The viewing distance was 50 cm from display to the subjects, and subjects would be ask to answer the numeral of scale after viewing the stimulus task (figure 1). In order to stabilize the speed of moving image, the computer was set with Intel Pentium 4 (working frequency was on 2.0 GHz) and 3D acceleration graphic card (memory modulate was 256 megabytes) for display the trial stimulus.

Table 1: Specification of LCDs set for experiment.

Item / Spec.	LCD-1	LCD-2	LCD-3	LCD-4
Screen Size	17”	17”	17”	17”
Response time	**25ms**	**16ms**	**8ms** (Tr+Tf)	**4 ms**(G to G)
Contrast(max)	450:1	600:1	500:1	700:1
Lightness(max)	300cd/m^2	300cd/m^2	300cd/m^2	350cd/m^2
View angle(H/V)	170° / 170°	170° / 170°	170° / 170°	160° / 160°

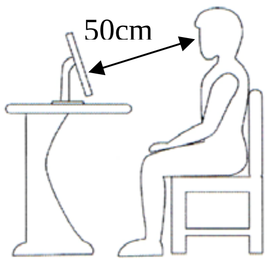

Figure 1: Subject would view one LCD at a time.

2. 2. STIMULUS

Seven color chips for scale were being set from background color to foreground color, and every color chip was square of one hundred pixels in the monitor. For example, the background color is primary color of blue, then that will be set to left of scale. The foreground color is primary color of yellow, then that will be set to right of scale in figure 2. Thus, we calculated three formula of regression for scale of background color to foreground color with *CIEL*a*b** value that include numerical ΔL, Δa, Δb value.

There were six primary colors would be set to background and foreground color base on *CIEL*a*b** value by using ‘Adobe Photoshop’ software. Moreover, the four levels of chroma would be separate by 25% ratio of chroma. Those were 25%, 50%, 75% and 100% ratio of chroma set to four levels (figure 3). The color combination of background color (Red, Green, Blue, Cyan and Magenta) and foreground color (Green, Blue, Cyan, Magenta and Yellow) would be set straightly with six primary colors. Moreover, the stimulus of experiment, seven color chips were set to square of 100 pixels on top of screen. The rectangle of 100 multiplied by 595 pixels was set to foreground color, and move from left to right about 30 pixels per frame on background color by using ‘Macromedia Flash’ software in figure 4. In general, the color-shift will come into existence in left edge of bar when it moves from left to right on the screen that the color filter of panel would transfer from yellow to blue base on the response time of LCD. In this study, we assumed that it would have significant difference of color-shift on different pairs of color and different level of response time.

Table 2: Color set for experiment.
(six primary colors and two monochromic with black/white for background color)

Hue		CIEL*a*b* value		
Color	Name	L*	a*	b*
R	Red	57.60	79.76	64.69
G	Green	87.46	-89.88	76.08
B	Blue	33.88	69.87	-104.54
C	Cyan	90.28	-52.81	-15.28
M	Magenta	64.06	93.63	-55.35
Y	Yellow	98.15	-20.12	87.71

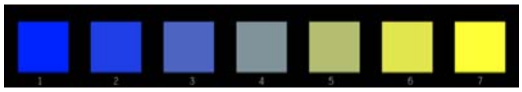

Figure 2: The scale set from background color to foreground color with left to right on top of screen. Each color chips is square of 100 pixels on top of screen.

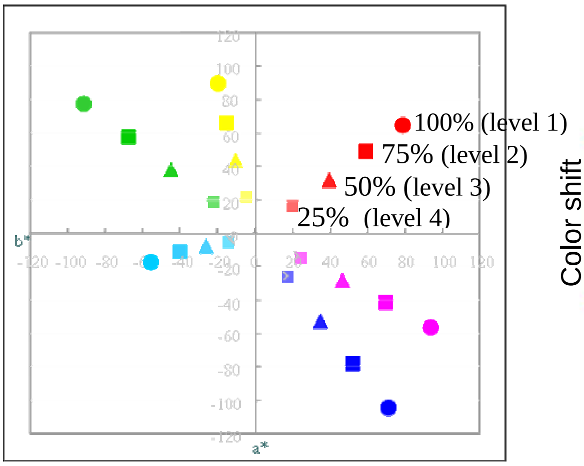

Figure 3: Four levels of chroma separated by 25% ratio of chroma base on *CIEL*a*b** color space.

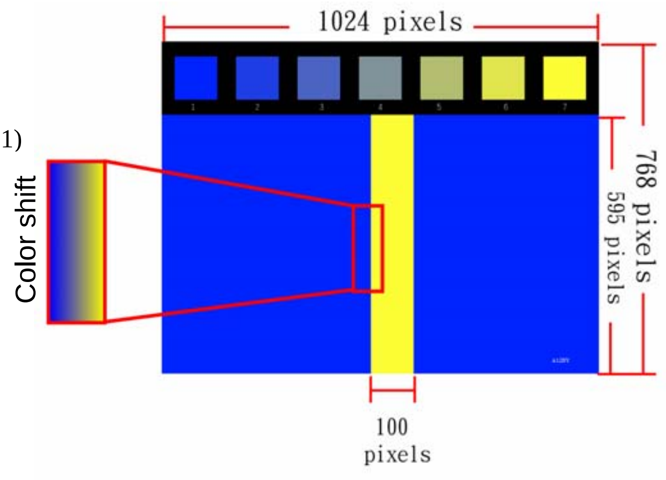

Figure 4: The stimulus set for experiment.
(The bar move from left to right on the screen. In this sample, the background color is blue, the foreground color is yellow)

Thus, we propose the following different color combinations for experiment. First, fifteen pairs of color combination would be set with single ratio of chroma, and sixty pairs of color combination would be set with four levels of chroma (A:100%, B:75%, C:50%, and D:25% of chroma), totally. Those pairs were R-G, R-B, R-C, R-M, R-Y, G-B, G-C, G-M, G-Y, B-C, B-M, B-Y, C-M, C-Y and M-Y (figure 5).

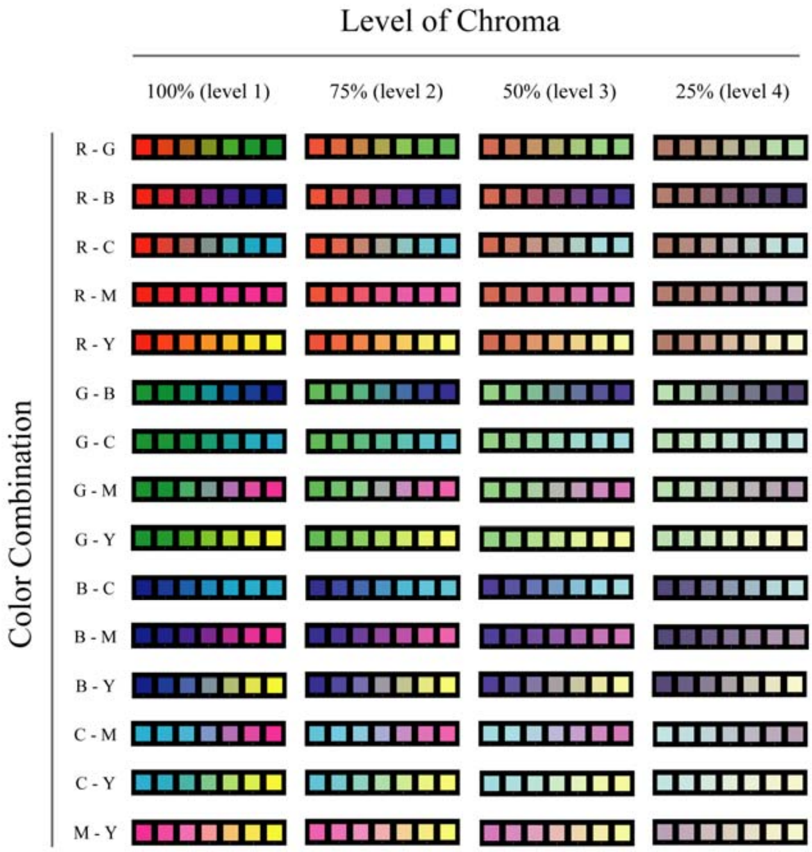

Figure 5: Sixty pairs of color combination set for experiment (That were include fifteen pairs of color combination with single ratio of chroma, and four levels of chroma.)

2. 3. SUBJECTS

The participants in this study were thirty-five students with normal color vision and normal vision from department of design in National Yunlin University of Science & Technology by using convenient sampling.

2. 4. TASK OF EXPERIMENT

Two hundred and forty trials were being randomly set from four (ratio of chroma) multiplied by fifteen (color combinations) on four types of LCD. Subjects were asked to focus on blur edge of moving bar's left, and subjective answer the color of edge compared to seven color chip for scales on top of screen. The experiment design was a with-in subject design. So, every subject should finish all of those trials. During the experiment procedure, the subject would be asking to read introduction of experiment, then there were three trials for exercise. When the formal experiment was running, a mask image of randomize noise would be shown one second between each trials (figure 6).

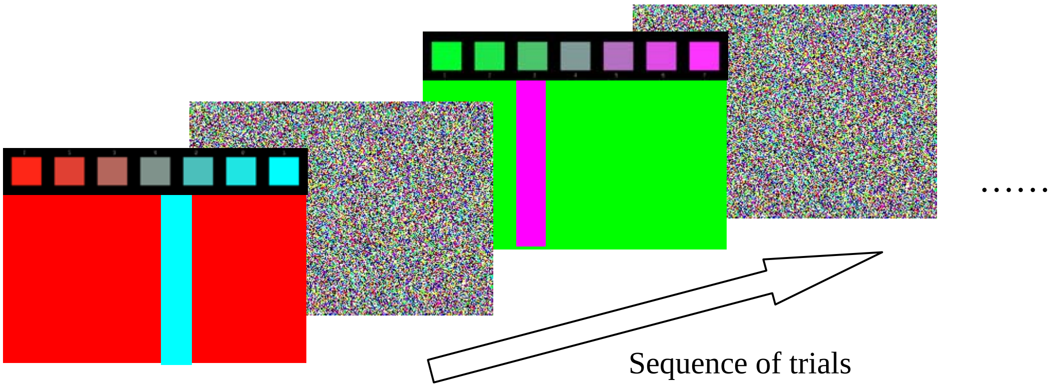

Figure 6: The sequence of trials was randomly set for experiment. (In order to clear after image in human visual system, that would be shown a mask image between trials.)

3. DATA COLLECTION AND ANALYSIS

Analyses of variance (ANOVA) were used to detect significant difference among levels of chroma, normalize hue angle of colors and response time of LCDs. Data were collected primarily by means of self-report with score that was target color by subjects after viewing. The scores set from 1 to 7 were being from background color to foreground color. Target color would be transfer to *CIE a** and *b** value from score by regression formula, and hue angle would be calculate between target color and foreground color with $LCH_{(ab)}$ value base on the transfer by Eq. (1). The different of hue angle between target and foreground color in this study was ΔH_a (delta hue angle). Furthermore, the normalizing ΔH_a would be compare those color combinations from the result of visual judgment in Eq.(2). Thus, when the target color was similar to foreground color, the ΔH_a between target and foreground color was small or close to zero. Contrariwise, the target color was similar to background color when different hue angle closed to numeral 1 (figure 7).

$$L = L$$
$$C = \sqrt{a^2 + b^2}$$
$$H = \tan^{-1}(b/a)$$

Eq. (1): Formula set for CIEL*a*b* color space transfer to LCH value in calculated hue angle (ΔH_a) in this study.

$$Normalize\ Angle = \frac{\Delta Ha}{A_{bf}}$$

Eq. (2): ΔHa was the different of hue angle between target color and foreground color, A_{bf} was the different of hue angle between background color and foreground color in this study.

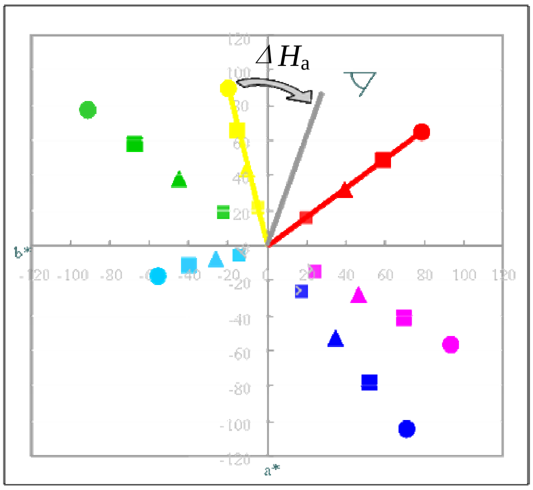

Figure 7: ΔH_a was the different of hue angle between target (gray line) color and foreground color(Yellow) on R-Y pair.

Table 3: The result of Tukey test showed that four color pairs ratio of chroma from the result of visual judgement. ($\alpha = .05$)

Level	Ratio of chroma	Subset	
		1	2
1	100%-100%	.3614	
2	50%-50%	.3766	
3	75%-75%	.3775	
4	25%-25%		.4137
	Sig.	.375	1.000

Table 4: The result of Tukey test showed that four response time of LCD for result of spent time (second) by judge the task. ($\alpha = .05$)

LCD	Response time	Subset	
		1	2
3	8ms	102.08	
1	25ms	102.40	
2	16ms	103.35	
4	4ms		106.75
	Sig.	.748	1.000

4. RESULTS AND DISCUSSION

4. 1. RESULTS

The result of the ANOVA showed that there is a significant main effect of 'level of chroma' for result of visual judgment ($F_{(3,\ 8400)}$ = 9.773, p<.001). The Tukey test showed the significant difference was between level 4 on the one hand and level 1, 2 and 3 on the other (table 3). Thus, an integral result of level 4 was close to background color than the others. On the other hand, the result of the ANOVA showed that there is no significant main effect of 'response time of LCD' for result of visual judgment ($F_{(3,\ 8400)}$ =.563, p=.639). Nevertheless, that a significant main effect for judge time that the main of subject spent to fifteen trials ($F_{(3,\ 8400)}$ = 5.743, p<.001). The result of thg Tukey test showed that a significant difference was between LCD-4 on the one hand and LCD-1 on the one hand and LCD-1, LCD-2 and LCD-3 (table 4). Thus, an integral whole the result of LCD-4 that subject spent time to judge the task was more than the others when the response time of LCD was faster. In addition, there were to analysis the color combinations in different ratio of the chroma. The result of the ANOVA showed that a significant main effect of ‘color combinations’ for result of visual judgment ($F_{(14,\ 2100)}$ =39.051, p<.001). The Tukey test showed the significant difference was between pairs of R-M (background color was Red, foreground color was Magenta) and R-B (background color was Red, foreground color was Blue) on the one hand and the others. Therefore, R-M and R-B pairs were close to foreground color than the others (table 4).

Table 4: The result of Tukey test showed that fifteen pairs for normalize result of visual judgment (α = .05).

Pairs	1	2	3	4	5	6	7	8	9	10
R-M	.073									
R-B	.084									
C-M		.202								
M-Y		.260	.260							
G-M			.311	.311						
C-Y				.367	.367					
R-G					.382	.382				
R-C					.391	.391				
G-Y					.412	.412	.412			
B-Y					.426	.426	.426	.426		
G-B						.453	.453	.453		
B-C							.477	.477	.477	
R-Y								.491	.491	.491
G-C									.527	.527
B-M										.558
Sig.	.738	.087	.132	.095	.120	.062	.081	.078	.163	.060

4. 2. DISCUSSION

For the result of the color-shift analysis of the moving image quality in this stage, we find the key factor to affect the visual judgment was color combination not physical response time of LCD. And when the saturation of the color combination was higher, the result of the visual judgment will much close to the background color. Furthermore, we find when the LCD response time was faster; the time that the user spent to answer was longer. If the saturation of color was higher, the judge time that the user spent to answer was longer. On the other hand, we tried to analyze color-shift with hue angle, and find out which is the most or least color-shift on color combination in figure 8. In the further study, we recommend to study the relation between lightness and hue angle, and their interactive on color-shift. A critical problem in the image color reproduction of LCD was the estimation of image quality from visual judgment. We put emphasis on analysis of color-shift for LCD in this study. We further confer the relationship between the saturation difference of the color combination and the results of visual judgment in the different color sample pairs. The method to carry out in this study was using experiment method of psychophysical. We expect the evaluation method to be more practical, as the important basis that the domestic industry which produces LCD products can follow when they execute the evaluation of image quality.

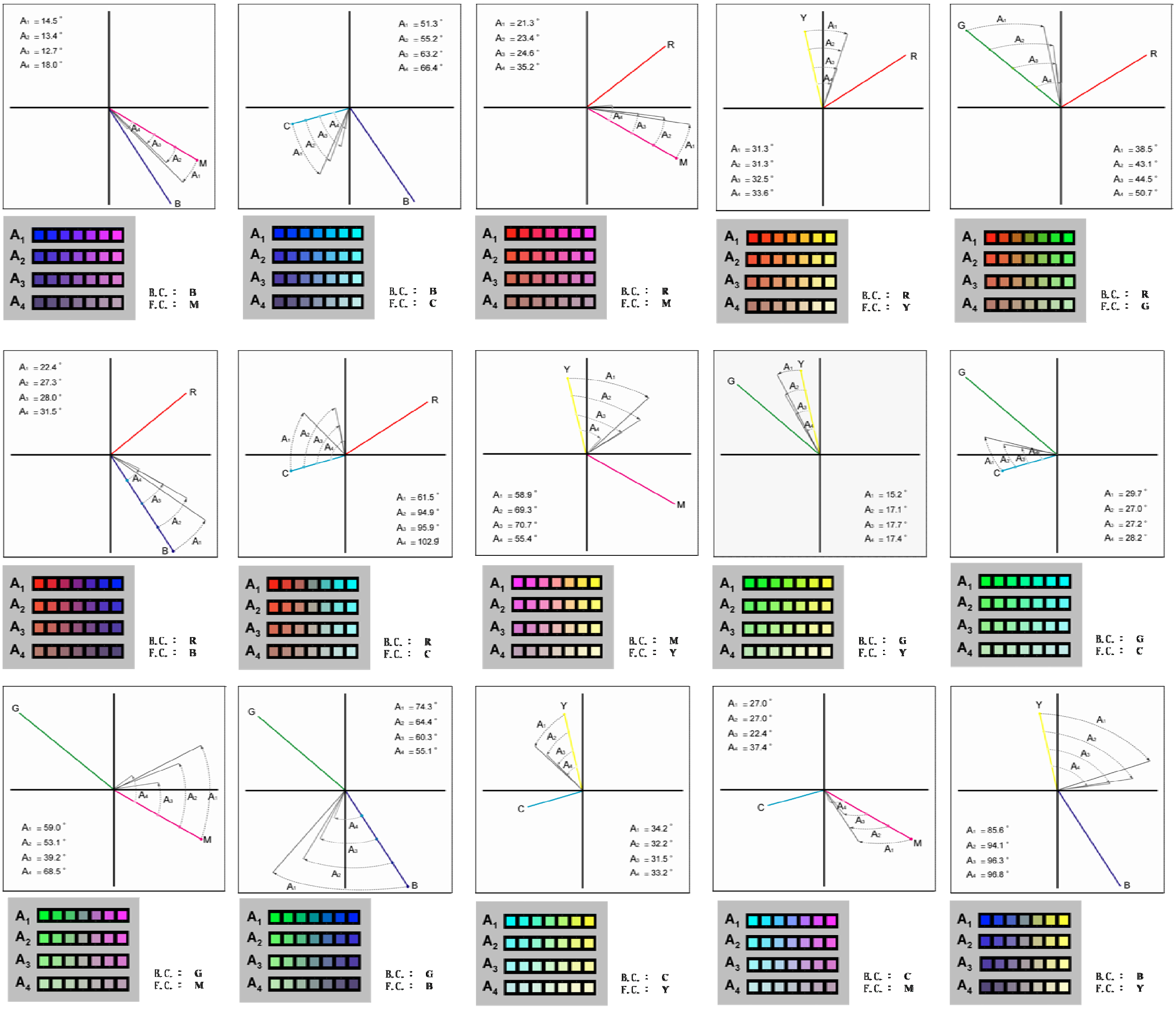

Figure 8: The results of visual judgment experiment with differential color combinations.
(The B.C is background color; F.C is foreground color. A1 is the level of 100% chroma; A2 is the level of 75% chroma; A3 is the level of 50% chroma; A4 is the level of 25% chroma.)

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