ELSEVIER International Journal of Industrial Ergonomics 26 (2000) 527–536

International Journal of
Industrial Ergonomics

www.elsevier.nl/locate/ergon

Effects of screen type, ambient illumination, and color combination on VDT visual performance and subjective preference

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Received 2 March 2000; received in revised form 10 May 2000; accepted 11 May 2000

Abstract

This study investigated the effects of screen type, ambient illumination, and target/background color combination on visual identification performance and subjective preference for visual display terminal (VDT) screen characteristics. Screen type significantly affected visual performance. Subjects performed better with the thin film transistor liquid crystal display (TFT-LCD) than with the cathode ray tube (CRT). Visual performance was better under 450 lx ambient illumination, versus, 200 lx. Color combination also significantly affected visual performance, with blue letters on a yellow background resulting in the best performance and purple-on-red the worst. Subjective preference was significantly affected by color combination. Blue-on-yellow resulted in the greatest subjective preference, while purple-on-red the worst. Thus, subjective preference and visual performance for color combinations were related. In summary, the TFT-LCD screen seemed to be the preferred technology for identifying letters on VDTs.

Relevance to industry

The VDT is the primary medium through which humans and computers interact. Screen type, ambient illumination, and color combination are factors that affect VDT performance. The application of the results from this study may not only improve VDT performance, but also enhance worker satisfaction by taking into account workers' preference for VDT screen characteristics. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Screen type; Ambient illumination; Color combination; VDT; TFT-LCD; CRT

1. Introduction

With the advances in computer technology, the tasks which humans rely on computers to execute have increased immensely – both in time and scope. The visual display terminal (VDT) is the primary medium through which humans and computers interact. The most popular VDT is the cathode ray tube (CRT). However, notebook computers have come into use in many workplace settings inaccessible to the CRT. The liquid crystal display (LCD) is one of the most popular and highly developed flat panel displays (FPD) used in notebook computers. The thin film transistor

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PII: S0169-8141(00)00025-1

liquid crystal display (TFT-LCD) has increased its competitiveness and importance today due to its improved viewing angle, high-gain, better optical diffuser (compared with conventional LCDs), and decreased cost (Warner, 1993). Lessin (1992) pointed out the TFT-LCDs' equivalent or superior performance to CRTs in many areas, such as weight, power consumption, viewability, response time, color gamut, and cell brightness.

Much research has addressed visual performance for VDT work using CRTs (Bergqvist and Knave, 1987; Dillon, 1992), but ergonomic evaluations of LCDs have been relatively few, especially for TFT-LCDs. Compared with the CRT, the LCD screen can be moved around to a greater extent and is reported to be more satisfying by its users (Ahlström et al., 1992). However, Saito et al. (1993) found that working with LCD screens might be the least comfortable, because of slow accommodative velocity of eyes for the users. This result may arise from the limited luminance contrast and limited viewing angle for LCD screens (Snyder, 1988). Contrarily, Ahlström et al. (1992) investigated 56 telephonists working for 9 weeks on CRT and LCD screens. The questionnaire results showed that, in general, the subjects felt more comfortable working with the LCD screen than with the CRT. One reason for the inconsistent results obtained by these researchers may be that certain characteristics of the CRTs and LCDs, e.g., resolution, viewing angle, and luminance contrast, differed among these studies.

The LCD and CRT have different optical characteristics. First, in the CRT an energized beam of electrons bombards a thin layer of phosphor material to produce images. The beam is activated while scanning across the visible portion of the image and deactivated when scanning where there is no image. The image must undergo periodic refreshing so that it remains stable to the eye of the user (MacKenzie and Riddersma, 1994). Through LCD technology, an image is created by a varying voltage that controls the transparency of thin capsules of liquid crystals. These voltage changes turn capsules lighter or darker when viewed by reflected light (Stix, 1989). Secondly, the LCD is a subtractive-color display, whereas the CRT is an integrative-color display. The image quality of a subtractive-color display was superior to that of a comparable integrative-color display (Post and Reinhart, 1997). Thirdly, unlike the CRT, the picture on the LCD is flicker-free (Andersen, 1986). Flicker will make user feel the image flopping-over and unstable.

Ambient illumination is an important consideration in VDT workplace design. Many recommendations exist regarding level of ambient illumination. For CRT workstations, an ambient lighting of 200 to 500 lx is generally suggested. The choice of illumination level greatly depends upon the task (Helander and Rupp, 1984). Ostberg (1980) reported that a lower ambient illumination might be more appropriate for CRT work. Xu and Zhu (1990) studied the effect of ambient illumination and found that performance deteriorated as ambient illumination increased. Studies about ambient illumination for LCD are rare. Helander and Rupp (1984) presciently mentioned that, the specifications for an ambient illumination standard would become even more confusing in the future as LCDs and other FPDs become more popular.

Color combination is another important factor that may affect visual performance. Color can be an effective means to improve human–computer communication (Pastoor, 1990; Shieh et al., 1997, Silverstein, 1987) and to provide an additional subjective benefit by making displays more pleasant (Pastoor, 1990). However, inappropriate use of color can result in poor performance and a higher incidence of visual strain (Bruce and Foster, 1982; Luria et al., 1989; Matthews, 1987; Radl, 1982, Shieh and Chen, 1997).

In summary, the use of TFT-LCDs is becoming more popular, but studies about visual performance and subjective preference of TFT-LCD workers are rare. Because the optical characteristics of CRTs and TFT-LCDs differ, the effects of ambient illumination and color combination on performance and user preference regarding CRT use as found in many studies may not apply to TFT-LCDs. There is a need to empirically evaluate the performance and user preference for the use of TFT-LCDs. Two experiments were conducted in the present study. Visual performance was investigated in experiment 1; subjective preference was addressed in experiment 2.

2. Experiment 1: visual performance

2.1. Experimental design

The present study evaluated three independent variables: screen type, ambient illumination, and color combination.

Two VDT screen types were used: a CRT and a TFT-LCD. Two levels of ambient illumination were employed: 450 lx (which is the normal lighting level for ordinary office), and 200 lx (which is the lower lighting level recommended by ANSI/HFS 100-1988 (1988) and by Ostberg (1980)). The ambient illumination was produced by fluorescent lamps. No glare appeared on the VDT screen.

The four screen colors used were selected based on the following criteria: the colors could be shown by both screen types; their luminances would be at least 10 cd/m^2; and the colors should be distributed evenly and widely in the chromaticity space. Table 1 shows the CIE color coordinates (L, x, y) of the four colors. The values were measured with a Minolta CA-100 color analyzer.

Each of the four colors was combined with every other color to make the 12 target/background color combinations. Table 2 shows the 12 color combinations and their luminance ratios and polarities. Four subjects were randomly assigned to each of the 12 levels of the between-subjects factor, color combination. Every subject completed the four combinations (2 screen types×2 ambient illuminations) of the within-subject factors.

Table 1
CIE (1931) chromaticity coordinates of the four colors used in this study

Coordinate	Color			
	Blue	Yellow	Red	Purple
x	0.144	0.423	0.584	0.343
y	0.112	0.445	0.323	0.203
L (cd/m^2)[a]	10.0	45.0	15.0	22.5

[a] L is the luminance.

2.2. Subjects

The 48 subjects were male college students. All had 0.8 corrected visual acuity or better and normal color vision. A Topcon SS-3 screenscope and standard pseudo-isochromatic charts were used to test the visual acuity and color vision of the subjects.

2.3. Apparatus

The 17-in CRT was a Philips Brilliance-107, with a 384-mm diagonal screen that provided an active viewing area of 327 mm horizontally and 246 mm vertically. The pixel resolution was 1024 horizontally and 768 vertically, and the center-to-center pixel spacing was 0.32 mm. The screen images were refreshed at a rate of 72 Hz. The maximal contrast ratio ($L_{\max}/L_{\min}$) was 60, and the maximal luminance was 150 cd/m^2. The screen surface was coated with SiO_2 to reduce glare.

The 12.1-in Mitac TFT-LCD with a 305-mm diagonal screen provided an active viewing area of 246 mm horizontally and 183 mm vertically. The pixel resolution was 800 horizontally and 600

Table 2
The 12 target/background color combinations and their luminance ratios and polarities

Color combination	Luminance ratio	Polarity
Yellow-on-blue	4.50	Negative[a]
Red-on-blue	1.50	Negative
Purple-on-blue	2.25	Negative
Blue-on-yellow	4.50	Positive[b]
Red-on-yellow	3.00	Positive
Purple-on-yellow	2.00	Positive
Blue-on-red	1.50	Positive
Yellow-on-red	3.00	Negative
Purple-on-red	1.50	Negative
Blue-on-purple	2.25	Positive
Yellow-on-purple	2.00	Negative
Red-on-purple	1.50	Positive

[a] "Negative" means lighter target on darker background.
[b] "Positive" means darker target on lighter background.

vertically, and the center-to-center pixel spacing was 0.3075 mm. The screen images were refreshed at a rate of 60 Hz. There was one backlight in the TFT-LCD, the maximal contrast ratio was 25, and the maximal luminance was 70 cd/m^2. The screen surface was coated with a TAC (triacetate cellulose) polarizer to reduce glare.

2.4. Workplace conditions

The VDT was positioned on a table 73 cm in height. The distance from the front edge of the table to the center of each screen was 40 cm. The inclination angle of each VDT screen was 105° with respect to the vertical axis. Before the experiment, the subjects were permitted to adjust their seating positions to make themselves as comfortable as possible.

Due to the different pixel sizes of the two screen types, slightly different viewing distances were required to keep the subtended visual angles constant across screens. The heights for the 12-point letters were 3.84 mm on the CRT and 3.69 mm on the TFT-LCD. The viewing distances for the CRT and TFT-LCD were 53 and 51 cm, respectively. The subtended visual angle of the letters was 25 min of arc. A headrest restrained the subjects' head 30 cm above the table and kept their viewing distance constant during the experiment.

2.5. Task and procedure

Subjects performed an visual identification task in this experiment. At the beginning of each trial, a warning tone was initiated to instruct the subject to visually fixate the "X" at the center of the screen. One second later, a stimulus composed of five capital English letters was presented in the central area of the screen for 200 ms (approximately one eye-fixation duration). One letter was presented at the center and the other four at the corners of an area which was approximately 2×2 cm. The subjects were required to write down as many letters as they could identify. There were 52 trials for each experimental treatment. To familiarize the subjects with the identification task, they performed 20 training trials for each treatment. The experimental session lasted about 40 min. For each subject, the four within-subject treatments were administered randomly on four different days.

2.6. Dependent measures and data analysis

The percentage of correctly identified letters was the visual performance measure. Analysis of variance was conducted on the collected data using the statistical analysis system (SAS).

2.7. Results

The mean percentages correct under each level of the independent variables are shown in Table 3. The results of analysis of the variance (Table 4) indicated that screen type had a significant effect on percentage correct ($F(1, 36) = 32.67$, $p < 0.01$). The percentage correct for the TFT-LCD (55.3%) was significantly greater than that for the CRT (50.8%).

Ambient illumination also significantly affected identification performance ($F(1, 36) = 52.63$, $p < 0.01$). The percentage correct for 450 lx

Table 3
Mean percentages correct under each level of the independent variables

Independent variable	n	Mean
Screen type		
12.1 in TFT-LCD	192	55.3
17 in CRT	192	50.8
Color combination		
Yellow-on-blue	32	57.3
Red-on-blue	32	51.2
Purple-on-blue	32	42.9
Blue-on-yellow	32	62.3
Red-on-yellow	32	51.2
Purple-on-yellow	32	52.2
Blue-on-red	32	52.2
Yellow-on-red	32	60.9
Purple-on-red	32	36.0
Blue-on-purple	32	60.0
Yellow-on-purple	32	54.4
Red-on-purple	32	55.7
Ambient illumination		
200 lx	192	51.4
450 lx	192	54.7

ambient illumination (54.7%) was greater than that for 200 lx (51.4%).

The screen type×ambient illumination interaction was statistically significant ($F(1, 36) = 15.57$, $p < 0.01$). Tests of simple main effect within the interaction showed that for the CRT the difference between 450 lx ambient illumination (51.5%) and 200 lx ambient illumination (50.1%) was not significant, whereas for the TFT-LCD, the percentage correct identification for 450 lx (57.9%) was significantly greater than that for 200 lx (52.7%). Fig. 1 shows the screen type×ambient illumination interaction.

The effect of target/background color combination was statistically significant ($F(11, 36) = 3.02$, $p < 0.01$). The percentage correct identification

Table 4
ANOVA for percentage correct of the independent variables

Source	DF	SS	MS	F-value	p[a]
Between subjects					
Color combination (C)	11	9964.3	905.8	3.02	0.0060
Subject within group	36	10813.1	300.3		
Within subject					
Screen (S)	1	970.9	970.9	32.67	0.0001
$C \times S$	11	675.6	61.4	2.07	NS
S×subject within group	36	1069.9	29.7		
Ambient Illumination (A)	1	519.1	519.1	52.63	0.0001
$C \times A$	11	172.6	15.6	1.59	NS
C×subject within group	36	355.0	9.8		
$S \times A$	1	172.8	172.8	15.57	0.0004
$C \times S \times A$	11	120.0	10.9	0.98	NS
$S \times A$×subject within group	36	399.5	11.1		

[a] $p < 0.05$ significant level.

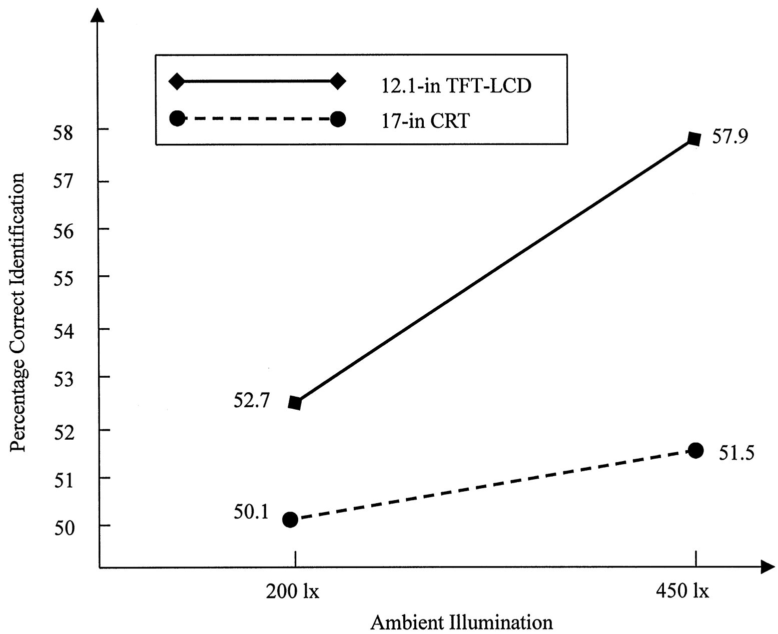

Fig. 1. Screen type×ambient illumination interaction for percentage correct visual identification performance.

was greatest for blue-on-yellow (62.3%), followed by yellow-on-red (60.9%), blue-on-purple (60.0%), yellow-on-blue (57.3%), red-on-purple (55.7%), yellow-on-purple (54.4%), blue-on-red (52.2%), purple-on-yellow (52.2%), red-on-blue (51.2%), red-on-yellow (51.2%), purple-on-blue (42.9%), and purple-on-red (36.0%). The critical difference for paired comparisons as determined by the least significant difference (LSD) method was 6.1 (at 0.05 the level of significance).

The luminance ratio and polarity components of color combination (see Table 2) were analyzed to determine their effect on visual identification performance. Results showed that the effect of luminance ratio was statistically significant ($F(1, 36) = 9.16$, $p < 0.01$). Subjects performed better as luminance ratio increased. The percentages correct were 48.8%, 52.9%, 51.5%, 56.0%, and 59.8% for the luminance ratios 1.5, 2, 2.25, 3.0, and 4.5, respectively. The effect of polarity was also statistically significant ($F(1, 36) = 4.24$, $p < 0.05$). Lighter targets on darker backgrounds resulted in a lower percentage correct (50.4%) than did darker targets on lighter backgrounds (55.6%). After adjusting for luminance ratio and polarity, the effect of color combination became marginally significant ($F(9, 36) = 2.20$, $p < 0.05$). No interaction involving color combination was statistically significant.

3. Experiment 2: subjective preference

3.1. Method

One week after the completion of Experiment 1, the same 48 students served as subjects for experiment 2.

The experimental apparatus and workplace conditions were the same as those used in experiment 1, except as noted below. In this experiment, screen type, ambient illumination, and color combination were again independent variables. However, screen type and color combination were within-subject factors, and ambient illumination was the between-subjects factor. Twenty-four subjects were randomly assigned to each of the two levels of ambient illumination. Each subject completed 24 combinations (2 screen types $\times$ 12 color combinations) of the within-subject factors.

Subjects were required to perform a preference rating task in this experiment. For each of the 24 within-subject combinations (trials), a screen page of randomly chosen English words was presented. Subjects were asked to rate the displayed words on a 10-point scale, with 1 representing "very poor" and 10 representing "excellent". They were instructed to emphasize the clearness, aesthetic appearance, and visual comfort of the screen pages in forming their overall preference rating. The 24 combinations were presented in random order with a 2-min viewing time for each. There was a 1-min break between trials to avoid successive contrast effects. The whole experiment lasted about 1.5 h, including regular intermissions to reduce fatigue.

3.2. Results

The mean preference rating under each of the independent variables are shown in Table 5. The results of the analysis of variance (Table 6) indicated that although the mean rating for

Table 5
Mean preference rating under each level of the independent variables

Independent variable	*n*	Mean
Screen type		
12.1-in TFT-LCD	576	5.75
17-in CRT	576	5.55
Color combination		
Yellow-on-blue	96	7.62
Red-on-blue	96	5.33
Purple-on-blue	96	4.24
Blue-on-yellow	96	8.49
Red-on-yellow	96	7.52
Purple-on-yellow	96	6.59
Blue-on-red	96	6.78
Yellow-on-red	96	5.22
Purple-on-red	96	1.44
Blue-on-purple	96	5.99
Yellow-on-purple	96	5.74
Red-on-purple	96	2.80
Ambient illumination		
200 lx	576	5.84
450 lx	576	5.46

Table 6
ANOVA for preference rating of the independent variables

Source	DF	SS	MS	F-value	p[a]
Between subjects					
Ambient illumination (A)	1	40.8	40.8	1.34	NS
Subject within group	46	1399.5	30.4		
Within subject					
Color combination (C)	11	4401.3	400.1	110.80	0.0001
$A \times C$	11	50.5	4.6	1.27	NS
$C\times$subject within group	506	1827.3	3.6		
Screen type (S)	1	11.0	11.0	1.40	NS
$A \times S$	1	8.5	8.5	1.07	NS
S$\times$subject within group	46	364.6	7.9		
$C \times S$	11	38.5	3.5	1.82	NS
$A \times C \times S$	11	18.9	1.7	0.89	NS
$C \times S\times$subject within group	506	973.7	1.9		

[a] $p < 0.05$ significant level.

the LCD (5.75) was slightly greater than that for the CRT (5.55), the difference was not statistically significant. Subjects also showed somewhat a greater preference for the 200 lx ambient illumination (5.84) than for the 450 lx (5.46), but the difference did not reach statistical significance.

Target/background color combination was the only factor that significantly affected preference rating ($F(11, 506) = 110.80$, $p < 0.01$). The greatest preference rating was for blue-on-yellow (8.49), followed by yellow-on-blue (7.62), red-on-yellow (7.52), blue-on-red (6.78), purple-on-yellow (6.59), blue-on-purple (5.99), yellow-on-purple (5.74), red-on-blue (5.33), yellow-on-red (5.22), purple-on-blue (4.24), red-on-purple (2.80), and purple-on-red (1.44). The critical difference for paired comparisons as determined by the least significant difference (LSD) method was 0.55 (at the 0.05 level of significance). Further decomposition of the effect of color combination showed that luminance ratio had a statistically significant effect on preference rating ($F(1, 506) = 539.7$, $p < 0.01$). Subjects' preference ratings generally increased as luminance ratio increased. The ratings were 4.09, 6.17, 5.11, 6.37, and 8.05 for luminance ratio 1.5, 2, 2.25, 3, and 4.5, respectively. The effect of polarity was also statistically significant ($F(1, 506) = 163.6$, $p < 0.01$). The preference rating for darker targets on lighter backgrounds (6.36) was significantly greater than that for lighter targets on darker backgrounds (4.93). After adjusting for luminance ratio and polarity, the effect of color combination was still significant ($F(9, 506) = 57.2$, $p < 0.01$). The effect of color combination on preference rating was similar to that on visual performance. Blue-on-yellow resulted in both the best performance and the greatest preference rating, while purple-on-red the worst for both measures. A Pearson product-moment correlation computed between the two measures was significant ($r = 0.64$, $p < 0.05$) for the 12 color combinations.

4. Discussion

The results of the two experiments are discussed below with regard to screen type, ambient illumination, and color combination.

4.1. Screen type

A major objective of this study was to compare visual identification performance and preference rating for the TFT-LCD screen with that for the CRT screen. Results of the two experiments showed that both visual performance and preference rating were better for the TFT-LCD than for the CRT. The results were contrary to previous findings that working with an LCD screen might be less comfortable because of slow accommodative velocity for the users (Saito et al., 1993). Snyder (1988) also proposed that poor visual performance for LCD screens might result because luminance contrast and viewing angle were more limited. Two explanations for the inconsistent results are offered. Firstly, the resolution, luminance, and viewing angle for the TFT-LCD screen used in this study were comparable to those of the CRT, whereas the LCD technologies used in the previous studies were less developed. Secondly, the TFT-LCD uses subtractive-color, whereas the CRT uses integrative-color. Post and Reinhart (1997) showed that the image quality of a subtractive-color display was superior to that of a comparable integrative-color display. Because of the superiority of the image quality of the TFT-LCD screen, better visual performance and higher preference rating were obtained with it.

However, as mentioned in the previous section, the comparison of visual performance and preference rating for LCDs with that for CRTs must take into account the factors of resolution, luminance, and viewing angle. The results of this study may not apply to other situations in which these factors differ. If the factors are comparable, visual performance and preference for LCDs seem to be better than that for CRTs. With the continuing advances in LCD technology, we expect visual performance for LCDs to improve even more, and the use of LCDs to increase in popularity in the future.

4.2. Ambient illumination

With the portability of LCDs, the ambient illumination for LCD work may vary. However, research on this subject is rare. Based on the experimental results for CRT screens, low ambient illumination might be more appropriate for VDT work (Ostberg, 1980) because high ambient illumination could cause the screen images to fade.

The results of the present study showed that subjects had slightly greater preference for the lower ambient illumination (200 lx) than for the normal ambient illumination (450 lx), but the difference did not reach statistical significance. As for visual performance, percentages correct under the 200 and 450 lx ambient illuminations for CRT screens were quite similar. But for the TFT-LCD screen, percentage correct under the 450 lx ambient illumination was better than that under the 200 lx. In addition to the possibility that the subjects may be more used to the normal ambient illumination, different screen technology may also play an important role. The glass surface of the CRT used in this study was more reflective than the TAC (triacetate cellulose) anti-glare treatment coating on the TFT-LCD screen (Choi and Miyasaka, 1993). Thus, the TFT-LCD may have an advantage over the CRT when the ambient illumination is high.

Based on the results of this study, it seems that the normal office ambient illumination level (450 lx) may not degrade visual performance or preference of VDT users, and the level appears to be appropriate for VDT work.

4.3. Color combination

Statistical analyses of the two experiments indicated that color combination had a profoundly significant effect on both visual performance and preference rating. The results were consistent with the findings of many studies (cf. Shieh and Chen, 1997). Color combination was the most influential factor among the three independent variables addressed in this study, particularly for preference rating. Percentages of total variance accounted for by color combination were 38% and 47%, respectively, for visual performance and preference rating. Blue and yellow combinations resulted in both the best visual performance and the greatest preference rating, while purple and red the worst. Results of the correlational analysis showed that visual performance and preference rating were significantly related. Subjects performed better for the color combination that they also rated as more preferable. This relationship suggests that preference rating alone may be an effective method for evaluating the appropriateness of color combinations.

The effect of color combination in this study can be decomposed into three components: luminance ratio, chromaticity contrast and polarity. As shown in the Results section, subjects' visual performance and preference ratings increased as luminance ratios of color combinations increased. Low luminance ratios are detrimental to visual work. Snyder (1988) suggested that the luminance ratio should be at least 3 : 1. In the present study, percentages correct were above 56.0% and the preference rating over 6.37 when the luminance ratio was 3 : 1 or more. Compared with luminance ratio, the effect of chromaticity contrast, though statistically significant, was smaller as shown by the F values. Its effect on visual performance was marginally significant. Many studies (Mills and Weldon, 1987; Shieh and Chen, 1997; Travis et al., 1990) have reported similar findings that luminance ratio was more important than chromaticity contrast for VDT performance. Among the four colors used in the present study, yellow seemed to combine quite well with the other colors. The combinations among red, purple, and blue did not work out well, especially those between red and purple, and purple and blue. One possible reason is that the purple was located nearly half-way between red and blue in the chromaticity space. Thus, it may be difficult to visually differentiate the target and its background when purple was combined with red or blue. Polarity is also an important consideration in VDT design (Pawlak, 1986). The present study found that polarity had a significant effect on both visual performance and preference rating for VDT work. Subjects performed better and had greater preference for darker targets on lighter backgrounds (positive polarity). The result is consistent with the findings of many studies (cf. Snyder et al., 1990). Sanders and McCormick (1993) suggested that a lighter background may have a further advantage under situations with glare or reflection problems because it may reduce the visibility of reflected light.

In short, color combination seems to have a profound effect on visual performance and preference rating. However, interactions involving color combination appear to be minimal. That is, the effect of color combination appears to be similar for both TFT-LCDs and CRTs. Therefore, the screen color design principles as proposed in much of the literature (cf. ANSI/HFS 100-1988, 1988) may also apply to LCD screens.

5. Conclusion

In conclusion, better visual identification performance and greater preference were obtained for the TFT-LCD than for the CRT. Though lower ambient illumination (200 lx) was rated slightly more preferable (not statistically significant) than normal ambient illumination (450 lx), subjects performed better under the latter condition, particularly for the TFT-LCD screen. Color combination significantly affected visual performance and subjective preference. But the effect of color combination appeared to be similar for the two screen types. Blue-on-yellow resulted in both best performance and greatest preference rating whereas, purple-on-red the worst. Further analysis showed that target/background luminance ratio and polarity were important components of color combination. Visual performance and preference rating improved as the luminance ratio increased and when darker targets were presented on lighter backgrounds. In summary, in addition to its portability, TFT-LCD screens seem to have both performance and preference advantages over CRT screens, and with the continuing advances in TFT-LCD technology, we may expect an increasing popularity of TFT-LCD screens in the future.

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