

Effects of Display Screen Type on Perception and Visual Performance

Does AMOLED screen perform better than LCD screen?

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Abstract—To compare the performance of AMOLED screen and LCD screen, the within subject design experiment was adopted in this study. In the dark booth, each of the 30 participants completed three tasks, including display screen brightness adjustment, subjective evaluation and visual object recognition. Paired-samples T-test and descriptive statistics were used in the data analysis. The result showed that 1) the luminance of AMOLED screen was significantly lower than the one of LCD screen when they achieved the same brightness adjusted by the participants ($t = -2.28, p = 0.03$); 2) most participants thought the pictures in AMOLED screen were more saturate and vivid, more than half of the participants preferred AMOLED screen; 3) participants' visual objects recognition performance on the AMOLED screen was better the performance on the LCD. It was concluded that AMOLED screen could save more power consumption and showed more saturate, vivid and clear pictures than LCD screen in the dark environment.

Keywords—AMOLED; LCD; brightness; color; visual performance

I. INTRODUCTION

With the development of communication technology, the information carriers have changed greatly. More and more information are presented on the display screen instead of paper and other forms. However the long term work with display screen may cause visual, physiological and psychological health problems called Video Display Terminal Syndrome (VDTS) [2]. It is reported that 50% to 90% visual display terminal users complained eye discomfort [1]. Large previous studies have been down to investigate the effects of ambient illumination, screen brightness and contrast on the users' visual task performance and fatigue. The high level of display luminance significantly affects eyestrain and psychological fatigue [3]. The effects of ambient illumination and contrast are significant on visual recognition performance on Thin Film Transistor Liquid Crystal Display (TFT-LCD) screen. At the normal ambient illumination, high luminance contrast is better for the visual recognition performance [4].

But some other research shows that the ambient illumination does not affect the visual recognition performance [5]. Most of the previous ergonomics researchers were conducted in the normal ambient illumination and using CRT and LCD screen.

Nowadays, Active matrix organic light-emitting diode (AMOLED) display holds great potential for the next generation visual technologies due to its high light efficiency, flexibility, lightweight, and low-temperature processing [6]. AMOLED screen does not require a backlight; the black pixels of AMOLED screen actually turn off [7]. As a result, the contrast ratios of AMOLED are significantly better than LCD in the low ambient illumination [8]. Besides, OLEDs exhibit a wide color gamut exceeding 100% of the National Television System Committee (NTSC) sRGB color gamut [9].

Regarding few ergonomics research investigates the advantages of AMOLED screen, we conducted the experiments consisting of three tasks to compare the performance of AMOLED screen and LCD screen in dark environment.

II. METHOD

A. Experiment Set-up

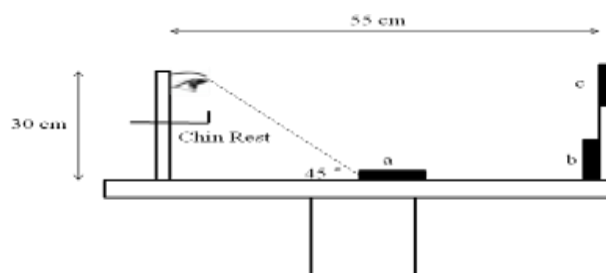


Figure 1. Experiment set-up

Fig. 1 shows the set-up of the experiment. The whole set-up was built in a totally dark booth with the side length of 2 meters. The bottom of the booth was blackened floor. The top and three sides were covered with black curtains.

The reflectance of the curtains and the floor was less than 10% to prevent light distraction. The display screens were placed in different place (Place a, Place b and Place c), according to the task which the participants were doing.

Two display screens were used in the experiments. One was AMOLED screen (Sumsung Galaxy S4 cell phone), the other one was LCD screen (Huawei Ascend D2 cell phone). The brand names of the cell phones were covered. Both of them were 5-inch large with resolution of 1920 pixels \times 1080 pixels. Fig 2 shows the spectrum of the two displays when they display the white (RGB 255, 255, 255).

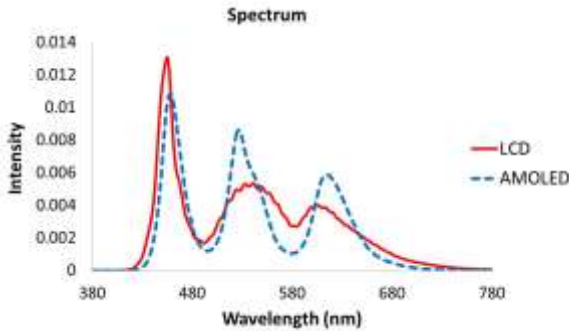


Figure 2. Spectrum of two display screens

B. Participants

30 participants were recruited from students of Fudan University: 12 male participants and 18 female participants joined the experiment, from age 18 to 26. All of them had a good corrected visual acuity as tested by vision chart, and were free from any form of color deficiency as screened by Ishihara Color Vision Test.

C. Experiment Procedure

This was a study for participants to completed three tasks with the two different display screens. The experiment was based on within subject design. Before the tasks started, five minutes dark adaptation was required.

Task 1 was Display Screen Brightness Adjustment. Both of the cell phones showed white desktop and installed screen brightness software called Lux Lite. Participants were instructed to hold one cell phone and adjust the display screen brightness by the software until they felt comfort and could clear see the characters on the screen. The percentage of the luminance was recorded, which was shown in Fig 3. When finishing the first display screen brightness adjustment, participants started to adjust the other one to achieve the same brightness. Half of the participants adjusted the AMOLED screen firstly, the others adjusted the LCD screen first. When the whole experiment was finished, the luminance of the display screens adjusted by participants was measured by Konica Minolta CS-2000 Spectroradiometer.



Figure 3. Display screen brightness adjustment

Task 2 was Subjective Evaluation. Both of the cell phones had the same six colorful pictures with of 1920 pixels \times 1080 pixels. Participants observed the two cell phones placed in Place a and Place b of Fig 1 at the same time and then complete a subject evaluation questionnaire. The questionnaire was a six point scale. Score “1” meant strongly preferring the Display Screen A, score “2” meant moderately preferring the Display Screen A, score “3” meant slightly preferring Display Screen A, score “4” meant slightly preferring Display Screen B, score “5” meant moderately preferring Display Screen B and score “6” meant strongly preferring Display Screen B. For half of the participants, Display Screen A was AMOLED screen. For the others Display Screen A was LCD screen. There were four questions in the questionnaire: “Which display screen’s pictures color is more saturate?”, “Which display screen’s pictures color is more vivid?”, “When the angle between the line of sight and the surface of the display screens is 45 degree, which display screen performs better?”, and “Overall, which display screen performs better?”. When the participants finished questionnaire, half of the scores were reversed to make sure that all the score “1” meant strongly preferring AMOLED screen and score “6” meant strongly preferring LCD screen.

Task 3 was Visual Object Recognition. The visual objects were Landolt rings with gap at various positions (left, right, bottom, and top). The Landolt rings’ diameter was 0.8 centimeter. There were ten groups pictures, each of which consisted of 15 pictures with a Landolt ring in the center of black background screen (RGB 0, 0, 0), shown in Fig. 4. The color of the Landolt rings varied from light grey (RGB 25, 25, 25) to dark grey (RGB 1, 1, 1). Both of the display screens were calibrated by Konica Minolta CS-2000 Spectroradiometer and at the same luminance (55 cd/m² showing white picture). The first cell phone was place in Place c of Fig. 1. Participants had to recognize the gap positions of the Landolt rings in five group pictures. After then, participants recognized gap positions of the Landolt rings in the other five groups with the second cell phones. For half of the participants, the first cell phone was the AMOLED screen cell phone. For the others, the first cell phone was the LCD screen cell phone. The accuracies were recorded.

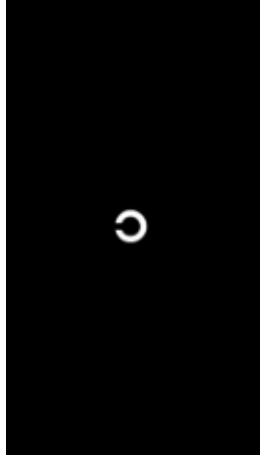


Figure 4. Landolt Ring picture

III. RESULTS AND DISCUSSION

A. Display Screen Brightness Task

TABLE I. DESCRIPTIVE STATISTICS OF TWO DISPLAY SCREENS' LUMINANCE

Screen	Descriptive Statistics (cd/m ²)			
	Minimum	Maximum	Mean	SD
AMOLED	0.21	198.50	29.19	48.84
LCD	0.74	297.40	44.42	78.48

The table shows the descriptive statistics of the two display screens' luminance when they achieved the same brightness adjusted by the participants. Repeated measure in SPSS 20 (Statistical Product and Service Solutions) was conducted to compare the means of the two displays screens luminance by gender. The results ($F = 0.17$, $p = 0.69$) showed that the interaction between the screens and gender had no significant effect. So the Paired-Samples T-test was conducted to compare the means of the two displays screens' luminance for the whole participants. The results ($t = -2.28$, $p = 0.03$) showed that the luminance of AMOLED screen was significantly lower than the one of LCD screen. The mean difference was -15.24 cd/m^2 .

The brightness was not affected only by the luminance but also the spectral power distribution (SPD) of light sources. The spectral characteristics of a light source are characterized by the S/P-ratio, which is defined as the ratio of the luminous output of the light source to the luminous output [10].

B. Subject Evaluation Task

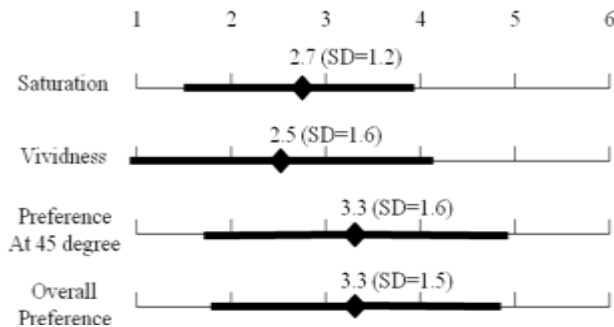


Figure 5. Means of subject evaluation

Fig. 5 shows the means of the subject evaluation scores of saturation, vividness, preference when observing at 45 degree angle and overall preference.

The neutral score was 3.5. All the above scores tended to the AMOLED screen. Especially for the saturation and vividness, 85.7% and 75% of the participants gave the score less than 3.5. For the preference when observing at 45 degree angle and overall preference, 53.6% and 60.7% of the participants evaluated less than 3.5.

Although most participants thought that the pictures in AMOLED screen were more saturate and vivid, the percentage of the participants preferring AMOLED screen was just over 50%. In the cell phone market, the market share of AMOLED screens is low at present. Perhaps some people were not used to such wide color gamut.

C. Visual Object Recognition

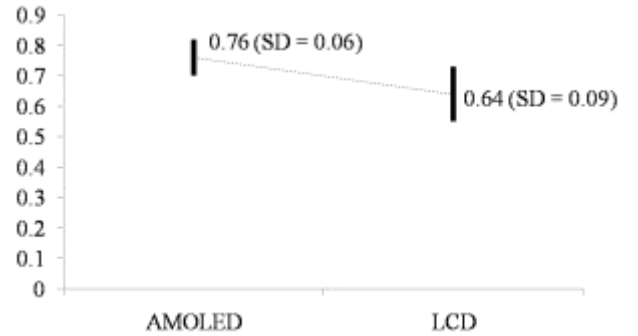


Figure 6. Means and standard deviation of accuracies

Fig. 6 shows the means and the standard deviation of the accuracies when recognizing the visual objects on the two display screens. Repeated measure was conducted to compare the means of the accuracies of visual objects recognition on the two displays screens by gender. The results ($F = 1.23$, $p = 0.28$) showed that the interaction between the screens and gender had no significant effect. So the Paired-Samples T-test was conducted to compare the means of the accuracies of Landolt Rings recognition on the two displays screens for the whole participants. The results ($t = 12.53$, $p = 0.00$) showed that the accuracy of visual objects recognition when using AMOLED screen was extremely significantly higher than the one when using LCD screen.

D. Further research

In this study, the experiment was conducted in the dark booth. Display screens are not only used in the dark environment. It also has to be applied in the normal daily life. The further research will compare the performance of the AMOLED screen and LCD screen in the normal ambient illumination.

Beside the preference and visual performance, the visual fatigue will be used to compare the two screens in the further study.

IV. CONCLUSION

According to the result that lower luminance was needed for AMOLED screen to achieve the same brightness as LCD screen in the dark environment, AMOLED screen could save more power consumption.

AMOLED screen showed more saturate, vivid and clear pictures than LCD screen in the dark environment.

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