https://doi.org/10.2352/ISSN.2169-2629.2017.32.142

Perceptually Equivalent Luminance Level of Large-screen TVs

Taeseong Han, Sungjin Kim and Dongwoo Kang
LG Display Co., Ltd., Paju-si, Gyeonggi-do, Korea

Abstract

Recently, large-screen televisions over 55-inch have been widely popularized. Display manufacturers need to know which luminance has great preference, familiarity, less fatigue and low power consumption for large-screen TVs. Most of earlier studies had focused on the proper luminance of TVs by considering a screen illuminance, visual angle and average picture level. On the other hand, it has been assumed that an amount of light and an average luminance on field of view of displays influence on a proper luminance. It has been focused on the perceptually equivalent luminance in large-screen TVs compared with current 55-inch TVs as mainstream. A physical measurement about amount of light and a subjective evaluation to examine the relationship of the perceptually equivalent luminance between a 55-inch display and large-screen displays have been conducted. The evaluation results show that average luminance on field of view is a major factor to influence the perceptually equivalent luminance. And it obtained the perceptually equivalent luminance of large-screen TVs is relatively low.

Introduction

A luminance in displays is one of the most important image quality attributes. Therefore various studies have been conducted to find out the proper display luminance by size. According to the study of Toshiyuki Fujine and coworkers [1], the preferred luminance of 55-inch displays is approximately 240 cd/m^2 where a distance 3 times of absolute display height (3H), screen illuminance 180 lux. Tatsuhiko Matsumoto et al. [2] conducted the ergonomic evaluation to investigate the effects of screen illuminance, angular screen size, and average luminance level of displayed image on preferred display luminance. According to the results, the preferred luminances of 55-inch displays and 75-inch displays are 156 cd/m^2 and 146 cd/m^2 respectively where a distance 3 meters, screen illuminance 200 lux, average luminance level 25%, young subjects group. And the preferred luminances of 55-inch displays and 75-inch displays for the elderly are 236 cd/m^2 and 214 cd/m^2 respectively. In this study, it has been assumed that an amount of light and an average luminance on field of view of displays influence on a proper luminance.

As a screen of TVs gets larger, the preferred luminance becomes lower [3]. Therefore, it may expect that the equivalent luminance of 65, 75-inch is lower than 55-inch. It has been assumed that the total amount of light exposed to the viewer's eyes affects the perceived luminance. It is because the physical size of TVs obviously influences the amount of light. The area where the viewer watches mainly affects the amount of light. The amount of light of displays is represented as

$$\text{Amount of light} = \text{candela} * \text{square radian} / \text{m}^2 \quad (1)$$

Equation 1 shows that size of displays is directly proportional to the amount of light when display luminance and viewing distance are constant. The amount of light output from the 55-inch than the amount of light output from the 75-inch is 1.86 times. The amount of light output from the display to compare with the result of subjective evaluation was measured.

Table 1. The comparison of size of TVs

Size(inch)	W(cm)	H(cm)	Area Ratio
75	166	93	1.86
65	144	81	1.40
55	122	68	1.00

And it has been assumed that the average luminance at fixed field of view also affects the perceived luminance. The effective field of view of people is known under 30 degrees [4]. Therefore, the average luminance at 30 degrees field of view with proper viewing distance (3H) was measured and compared with the result of subjective evaluation.

Methods

This paper deals with an optimum luminance of large displays. The goal of this study is to find the luminance of large displays which is equivalent to the luminance of 55-inch display having 400 cd/m^2. On the average, the luminance of 55-inch displays on the market is approximately the 400 cd/m^2. TV manufacturers prior to the popularization of large TVs should know the equivalent luminance based on the current 55-inch TVs as mainstream. Table 2 shows the luminances of popular 55-inch TVs.

Table 2. The luminances of 55-inch TVs

Product	Full-screen White Luminance
A	435 cd/m^2
B	365 cd/m^2
C	416 cd/m^2
D	370 cd/m^2
E	383 cd/m^2

In order to achieve this goal, the physical measurement and the subjective evaluation proceeded. Physical measurements were conducted to measure the amount of light, the average luminance. 55-inch and 65, 75-inch to look for perceptually equivalent

luminance were compared. Table 3 presents specifications of the displays used.

Table 3. Specifications of displays used in the experiments

Size (inch)	Luminance (cd/m^2)	Color Gamut (% of BT.709 @CIE1976)
55	400	120
65	100 ~ 500	120
75	100 ~ 500	120

Physical Measurement: Amount of Light

The amount of light was measured using an illuminance meter (Konica Minolta T-10A). The TVs at the center of a room were placed that were considered to be designed by the typical living room conditions. The screen outputted 400 cd/m^2 full screen white pattern. The illuminance meter was set at the center of the screen and measurement distance was set at 1 to 5 meter with 1 meter intervals. Ambient illuminance was set to 200 lux and below 1 lux in consideration of the living room environment. The measurement setup is shown in Figure 1.

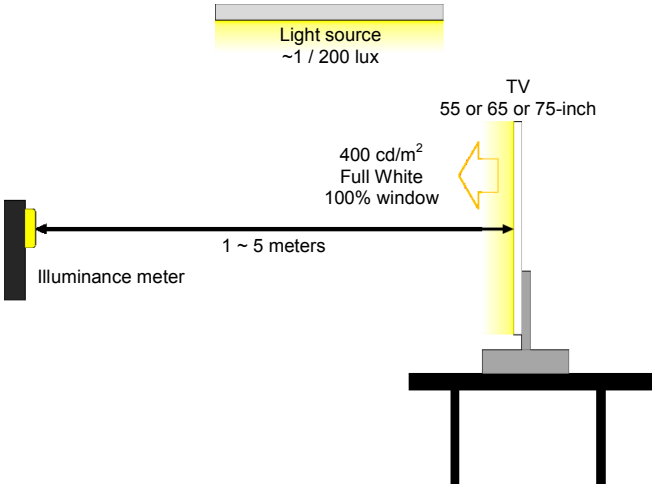


Figure 1. Setup for measurement of the amount of light of TVs

Physical Measurement: Average Luminance

The average luminance was measured in the range of 30 degrees field of view at 2 meter distance which is 3 times of absolute 55-inch display. It was measured according to the 9 points ICDM information display measurement standard. Figure 2 shows the measuring method.

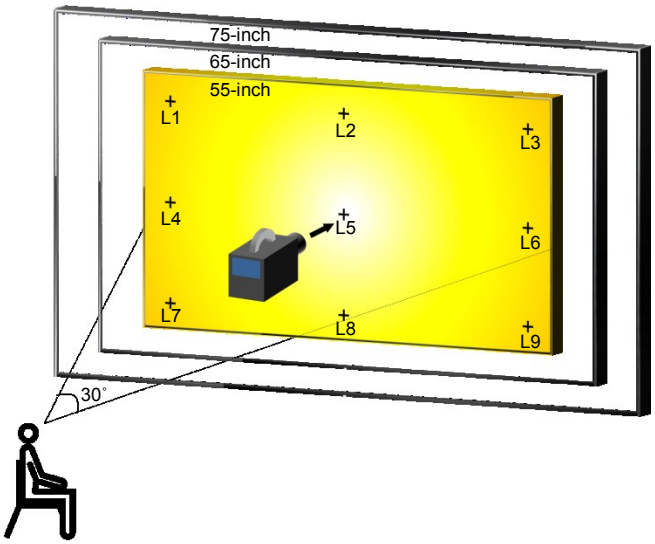


Figure 2. Setup for measurement of luminance uniformity of TVs

Subjective Evaluation

55-inch and 65, 75-inch to look for perceptually equivalent luminance were compared. 55-inch and the display of different size were placed on the left and right to allow a paired comparison. The viewing distance was 3 meters for typical living room and 5 meters for large living room. The luminance of 55-inch display was 400 cd/m^2 by reference. 65 and 75-inch displays have a remote controller for changing the dimming ratio of the backlight directly. Subjects were able to control the luminance of 65 and 75-inch to find the equivalent luminance. The luminance range was 100 to 500 cd/m^2 and interval was 5 cd/m^2. The Gamma and color temperature of every display were set equal to 2.2 and 11000K. Total eight images were used to evaluate the brightness. The images were carefully selected by considering average picture level (APL).

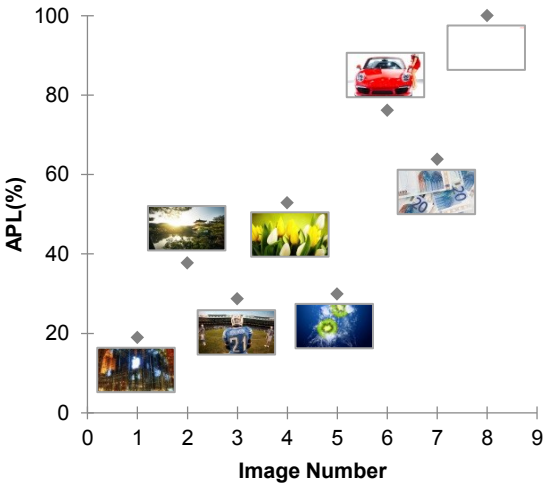


Figure 3. The 8 test images were used in subjective evaluation. From the left bottom image, the APLs of each image were 19.0%, 37.7%, 28.7%, 52.9%, 29.9%, 76.2%, 63.8%, 100%.

Table 4. The condition of Subjective Evaluation

Item	Value
Ambient illuminance	~1, 200 lux
Subjects	14 (11 men, 3 women)
Viewing Distance	3, 5 meters
Images	8
Question	Which luminance level is equivalent with reference?

Fourteen observers participated in the subjective evaluation. All of observers were research engineers in display field and aged 27 to 37. Eleven of the observers were male and three were female. Every observer has normal vision or corrected-to-normal vision. The ambient illuminance was approximately 200 lux which is common illuminance of general building areas by ISO 9241-307 standard [5] and below 1 lux which is common illuminance of a dark room.

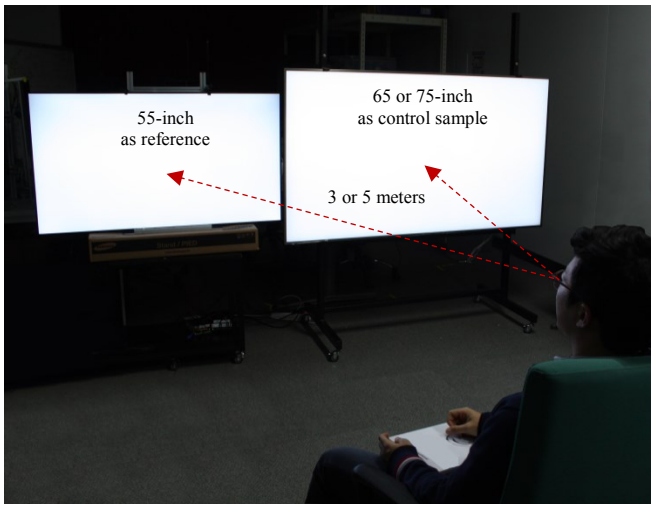


Figure 4. Experimental Setup for subjective evaluation

Physical Measurement Results

Amount of Light

The results of the amount of light are summarized in Figure 5 and show that the amount of light depends on both display size and viewing distance. In a dark room and 3 meters, it can be seen that the amount of light of 75-inch is 2.02 times more than 55-inch's. But it can be seen that the difference of the amount of light is remarkably reduced by the ambient illuminance of a bright room. In a bright room and 3 meters condition, the amount of light of 75-inch is only 1.07 times more than 55-inch's. Therefore perceived luminance is affected by display size, viewing distance and ambient illuminance respectively.

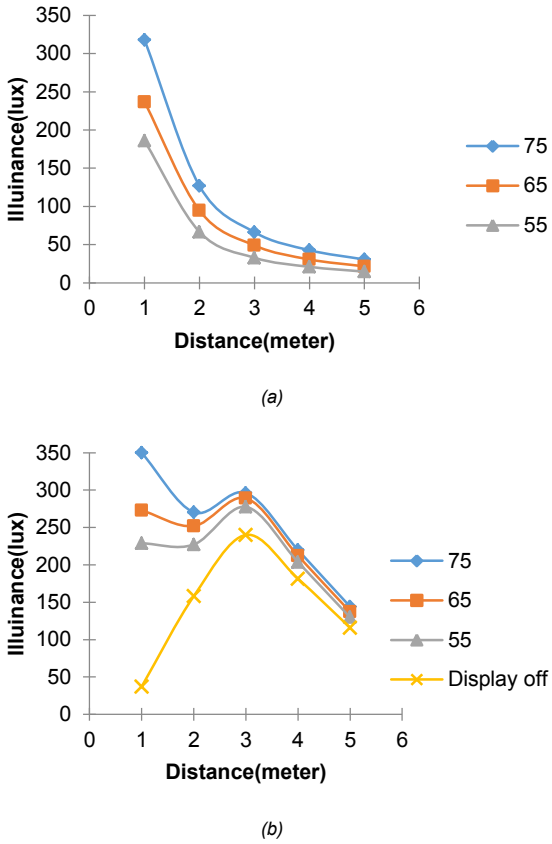


Figure 5. The result of measurement of the amount of light: dark room(a), bright room(b)

Average Luminance

The luminance of display is the highest at a center and is lowered toward edge. Figure 6 shows measured data of a typical LCD's luminance profile.

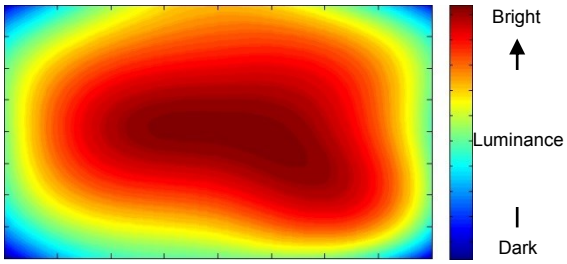


Figure 6. The luminance profile of a typical LCD

As the size of display becomes larger, average luminance of same area becomes higher. Resulting measurements of average luminance are shown in Figure 7. And it shows the results of this measurement are no exception. 65-inch and 75-inch have 11.4% and 14.8% higher average luminance in the same area. Accordingly if the perceived luminance is proportional to the luminance in the effective field of view, it will be obtained an equivalent luminance of 75 is relatively low.

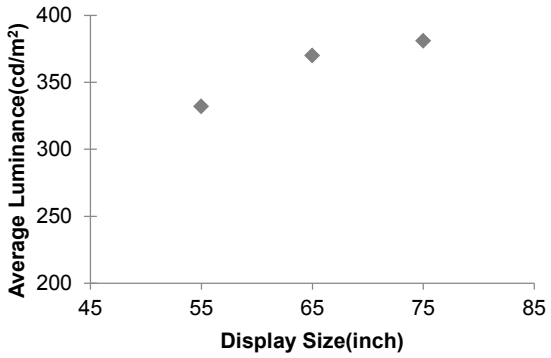
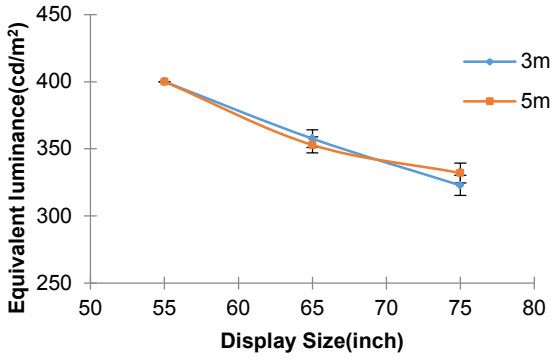


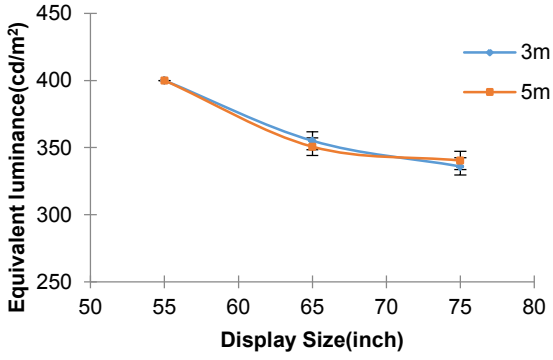
Figure 7. Average luminance of three different sized displays

Subjective Evaluation Results

Figure 8 plots the results of subjective evaluation from fourteen subjects for each viewing distance to show relationship between the size of the displays and the equivalent luminance. As seen Figure 8, at bigger displays, the equivalent luminance becomes lower. In other words, the subjects answered lower luminance of large displays is the same as the luminance of 55-inches.



(a)



(b)

Figure 8. The result of subjective evaluation to find the equivalent luminance: dark room(a), bright room(b)

The results of the evaluation in a dark room are statistically significant. At viewing distance 3 meters, the equivalent luminance of 75-inch is 19.3% lower than 55-inch in a dark room and 16.0% lower in a bright room, and 65-inch is 10.6% lower in a dark room and 11.2% lower in a bright room. At 5 meters, 75-inch is 17.0% lower in a dark room and 14.9% lower in a bright room, and 65-inch is 11.8% lower in a dark room and 12.3% lower in a bright room. In a dark room and 3 meters condition, equivalent luminance of large displays decreases almost linearly with increasing size, but in a bright room condition, equivalent luminance tends to be saturated. In 5 meters, equivalent luminance tends to be saturated equally a dark room and a bright room. Overall, equivalent luminance becomes decreased the greater the size of the display, but it can be seen that the viewing distance getting far and the ambient illuminance getting higher as decrement of equivalent luminance tends to be saturated.

Conclusion

The perceptually equivalent luminance of large-screen TVs using a physical measurement and a subjective evaluation had been evaluated. It had been assumed that an amount of light and an average luminance on field of view of displays are potential effect factors on the perceived luminance. The equivalent luminance in which consumers feel cognitively equal luminance with conventional TVs had been found.

The amount of light for the three displays was measured in a dark room and a bright room. In a bright room, 55-to-65 and 55-to-75 ratio for amount of light is lower than the ratio in a dark room. It shows that the amount of light of displays in a bright room could have a relatively small effect than the amount of light of displays in a dark room. But the physical measurements are not quite matched with subjective evaluations.

The average luminance of 55, 65, 75-inch was measured at the 55-inch reference area. The average luminance in the effective field of view is found out that in proportion to the size of displays. And it found similar trends and fewer differences between measurements and evaluations. It seems likely that this is a major factor in the perceived luminance of displays.

As the subjective evaluation results, the equivalent luminance of large-screen displays is decreased in proportion to the size, but the decrement tends to be saturated depending on the viewing distance and ambient illuminance.

References

[1] Toshiyuki Fujine, Yoshida Yasuhiro, and Sugino Michiyuki. "The relationship between preferred luminance and TV screen size," Electronic Imaging, International Society for Optics and Photonics, 2008.

[2] Tatsuhiko Matsumoto, et al., "Survey of actual viewing conditions at home and appropriate luminance of LCD-TV screens," Journal of the Society for Information Display, vol. 19, issue 11, pp. 813-820, 2011.

[3] Eunjung Lee, et al., "A study on the ergonomic aspects of the proper luminance level of displays," Journal of Information Display, vol. 13, no. 4, pp. 159-166, 2012.

[4] Sanders A. F., "The selective process in the functional visual field," 1963.

[5] ISO/FDIS 9241-307, "Ergonomics of human-system interaction – Part 307: Analysis and compliance test methods for electronic visual displays," 2008.

Author Biography

Taeseong Han received his BS in electronic engineering from the University of Inha, Korea (2011). He is a research engineer in the department of Image Quality Development of LG Display. His work has focused on the development of image quality of OLED, LCD.

Sungjin Kim received his BS and MS in electronic engineering at Hanyang Univerity, Korea. He is now a research engineer of LG Display. His main research area is the image quality of panel display devices such as LCD, OLED, 3D, transparent and flexible display.

Dongwoo Kang received his BS and MS in electronic engineering from the Kyungpook National University, Korea. Since then he has worked in the department of Image Quality Development at LG Display in Korea. His work has focused on the development of image quality of OLED, LCD.