Acceptable Luminance Levels of a LCD TV Based on Glare of Human Visual System

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Abstract

The visual perception tests were conducted to determine limits of luminance of a LCD TV from a viewpoint of glare. The results showed that people, who watch TV in their living room, perceive glare above 410 cd/m^2 at full window and 590 cd/m^2 at 1/25 window.

1. Introduction

Many people have believed that the brighter a LCD TV reproduces, the more people like. Because brighter one is more attractive than darker one in general, when we watch TVs at a home appliance store. Moreover the luminance of a LCD TV is lower than the luminance of a CRT TV. Therefore TV makers demand higher specification of luminance from LCD panel makers. However, some end users have already begun to complain about too much brightness of a LCD TV that they bought. What's wrong with it?

Most of LCD makers including our company are still developing high brightness technologies in order to meet demands of TV set makers . But an extremely bright a LCD TV may cause discomforts such as sore eyes, headache, etc., on the other hand, insufficient brightness makes people feel obscure. Nevertheless, we don't know how much brightness is appropriate for a LCD TV until we find out optimal brightness for a LCD TV. Fortunately lighting engineers have been concerned with luminance of light sources and acceptable ranges of luminance from a visual perception point of view. One of important themes in lighting engineering is to find out whether glare happens through installed lighting sources. Because glare is the worst adversary of good visual performance which lighting designers don't want to see.

The Illuminating Engineering Society of North America (IESNA) defines three forms of glare as disability glare, discomfort glare, and nuisance glare. When we see relatively intense light sources such as sun or headlamp at night, light, scattered into the eyes that shines on the retina, can interfere with visual function of human eyes. A temporal degradation of visual performance described above is called "disability glare". And nuisance glare, usually perceived in a bedroom, is illumination that causes complaints as in the case of light trespass conditions. The third is "discomfort glare" to which people object even though it does not interfere with their visual performance. The precise physiological mechanisms of the discomfort glare remain obscure, but light sources of excessive brightness may cause discomfort or intolerable feeling of pain. In this research we focused this discomfort glare according to their characteristics of three glare forms.

In lighting engineering, a variety of methods to determine if given light sources will produce discomfort glare has been developed empirically[1,2,3]. In North America, the visual comfort probability (VCP) system, which is a method used to predict a lighting system's potential for direct glare problems has been developed. The VCP is an estimate of the percentage of people that would consider a given lighting arrangement visually comfortable. The VCP of 70 percent is considered acceptable by IES Standards[4]. On the contrary, the visual discomfort glare is defined as (1-VCP).

$$VDP = 1 - \frac{100}{\sqrt{2\pi}} \int_{-\infty}^{6.374 - 1.3227 \ln DGR} e^{-t^2/2}\, dt \qquad (1)$$

The DGR shown in equation (1) represents discomfort glare rating and the formula is

$$DGR = \left\{ \sum_{i=1}^{n} \left(\frac{0.50 L_s Q}{P F_v^{0.44}} \right)_i \right\}^{n^{-0.0914}} \qquad (2)$$

where

n = Number of sources in the field of view,

L_s = Average luminance of the source in cd/m^2,

Q = Function of the solid angle, ω_s

P = Position index of a source,

F_v = Average luminance for the entire field of view.

The DGR is a metric of discomfort that increases as discomfort increases and related to luminance of light sources, luminance of entire field of view, sizes of sources, positions of sources, number of sources, and configuration of sources. Suppose LCD TV is one of light sources, we can say that DGR is affected by three dominant factors such as average luminance level of LCD TV, size of it, and ambient illuminance.

We executed visual perception test to determine what ranges of luminance levels of LCD TV that would not bring about discomfort glare under a couple of ambient conditions using this relationship.

2. Experimental Setup

2.1 Selection of illumination levels

It was already mentioned that ambient illumination was one of three dominant factors, which influenced discomfort glare. Firstly in order to settle ambient illuminance for experiments, we classified viewing environment into a dark room, a living room and a home appliance store, that we could experience in general.

The industrial standards recommend ambient illumination levels as shown in table 1.

Table 1. Recommendatory illumination levels

Environment	Living room	Home appliance store
Recommended illumination levels	70~150 lux	150~1500 lux

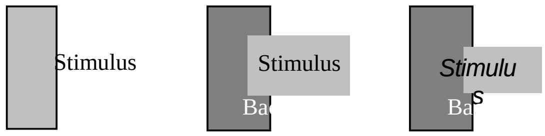
Table 2. Representative ambient illumination levels

Environment	Dark room	Living room	Home appliance store
Representative Illuminance	0 lux	100 lux	300 lux

We measured real illumination levels of each environment at eleven living rooms and seventeen home appliance stores in Korea. And then we carefully determined representative illumination levels of each environment considering recommended data. These illuminations are data measured at the center of LCD TV perpendicularly. Table 2 shows the ambient conditions.

2.2 Test image materials

Three artificial window images with WXGA resolution were represented as figure 1 and they had various luminance levels from 50 cd/m^2 to 750 cd/m^2 at 50 cd/m^2 intervals. The sizes of stimuli of them were full, 1/10, and 1/25 window patterns that correspond to 10-degree, 2-degree of visual angle, and background of stimuli was settled by neutral color of 36 cd/m^2.



(a) Full window (b) 1/10 window (c) 1/25 window

Figure 1 : Test patterns

2.3 Observers of experiments

Twenty men and women ten each in 20s to 40s participated in the experiments. Moreover we considered the sex ratio and educational backgrounds of the participants. All of them had good color vision, of course.

2.4 Test procedure

Experimental room was patterned after an ordinary living room in Korean apartments. Participants were seated at a distance of about 2.4 m from 30" LCD TV. The ambient lighting was adjusted to 0, 100, 300 lux each, measured at the center of TV perpendicularly to the direction of an observer.

An experiment was designed by nine sets, those are three window images as mentioned and three kinds of ambient illumination. One set consisted of 45 test images with 15 different luminance levels per window size and ambient condition. One instant of test set is represented in figure 2.

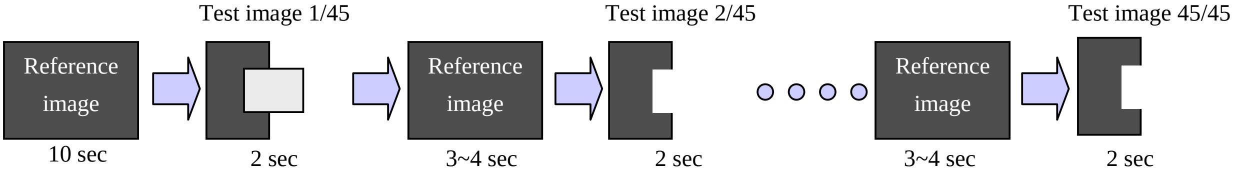


Figure 2 : Test procedure - 1 set, 1/10 window

3. Results

3.1 Visual discomfort probability

We analyzed these data statistically focusing on the relationship between VDP and luminance of LCD TV first. As shown in equation (2), we could predict that discomfort glare would increase as luminance of LCD TV increases.

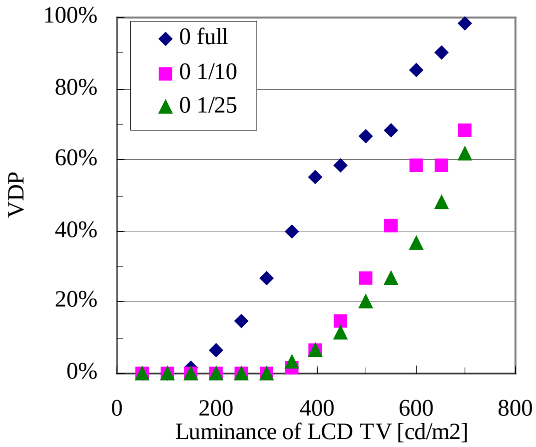
The results of these experiments are shown in figure 3. Basically the higher luminance levels it became, the higher VDPs were under every conditions. Nevertheless similar tendencies were shown under all of ambient conditions, the effect of stimulus size became smaller than under dark room condition as ambient illumination was brighter. Especially the difference between 1/10 and 1/25 window stimuli almost disappeared under 300 lux ambient lighting. However these results could not be explained by equation (2), we may speculate the reason was why a contrast effect between stimulus and background became bigger than stimulus size effect. That means we could regard stimuli smaller than 1/10 window as 1/10 window size stimuli when we would develop peak luminance technologies like CRT TV assuming TV was watched at an ordinary living room.

Hereon a criterion was needed in order to determine ranges of acceptable luminance of LCD TV. Because the VDP came from an estimate of the percentage of people that would feel visual discomfort from a given lighting installed, we had to fix what percentage of VDP would be reasonable. In lighting engineering, the VDP of above 30 percent is considered that it brought about discomfort glare from lighting installed by IES Standards. Herein we applied that criterion to this task.

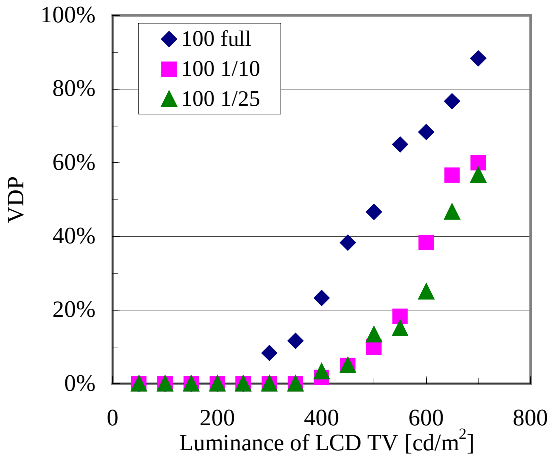
3.2 Luminance ranges without visual discomfort

We made 9 kinds of regression equations with luminance of LCD TV and VDP data under various conditions. With those regression relationships, acceptable luminance ranges of various conditions considering discomfort glare were calculated. Moreover, the regression analysis was done in order to calculate the acceptable maximum luminance, that is more than 30% of participants did not feel discomfort glare in various environments. The acceptable maximum luminance levels of 30 % VDP for various ambient illumination levels and size of window patterns are plotted in figure 4. This figure shows saturated characteristics of acceptable maximum luminance as illumination level grows larger, and as size of window grows smaller.

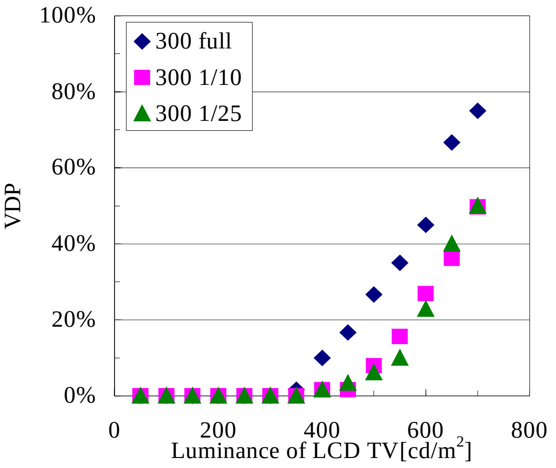
We can conclude the acceptable maximum luminance levels and their range for 30-inch LCD TV under various conditions as shown in table 3, applying VDP 30% criterion and 5% indistinguishable characteristics in lighting engineering to empirical VDP data[5]. If people watch TV sitting at the recommended distance of 6H-height of TV and this distance could be said more general that 3H- from TV, the acceptable maximum luminance for 30-inch LCD TV at an ordinary living room of 100-lux ambient light is about 400 cd/m^2 for full window sized images. If TV reproduces a partially bright image such as an explosion of bomb or a flash of lighting, which corresponds to peak luminance of CRT, the acceptable maximum luminance goes up to 600 cd/m^2.



(a) 0 lux ambient lighting



(b) 100 lux ambient lighting



(c) 300 lux ambient lighting

Figure 3: The relation between VDP and luminance levels of LCD TV according to various conditions

Consequently, it looks reasonable that the luminance of LCD TV is less than about 400 cd/m^2 at a full bright image and about 600 cd/m^2 at a partially bright image to avoid discomfort glare.

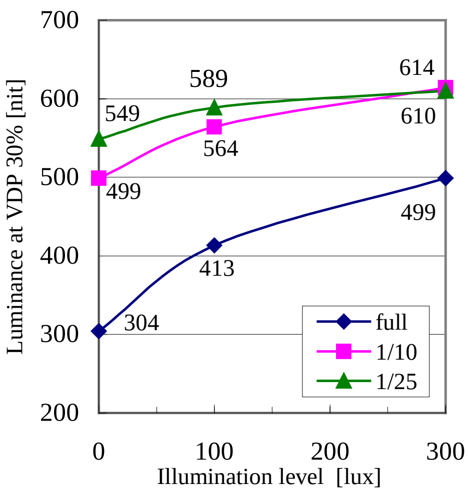


Figure 4: Luminance levels at VDP 30% according to various conditions

4. Conclusions

Now many LCD makers including our company are still actively developing high brightness technologies, but nobody knows how bright LCD TV should reproduce. In this task, we performed visual perception experiments to determine what ranges of luminance levels of LCD TV that would not bring about discomfort glare under various conditions.

The results of experiments revealed that people might perceive discomfort glare at about 400 cd/m^2 or above for a full window image and 600 cd/m^2 for a 1/25 window image under an ordinary 100 lux living room condition. In addition to that, we also did confirm these with some still pictures. We believe that these results can help engineers and end-users make a right decision about brightness of TV even though this paper has some restrictions such as artificial image materials.

Table 3. Acceptable maximum luminance without discomfort glare

Luminance range (cd/m^2)	0 lux	100 lux	300 lux
Full window	304	413	499
1/10 window	499	564	614
1/25 window	549	589	610

5. References

[1] Luckiesh, M., and S.K.Guth. "Brightness in visual field at borderline between comfort and discomfort (BCD)", Illum.Eng. 44(11), pp.650-670, 1949.

[2] Putman, R.C., and R.E.Faucett. "The threshold of discomfort glare at low adaptation levels", Illum.Eng. 46(10), pp.505-510, 1951.

[3] Marks.REA et al., "Lighting Handbook, 8th edition", Illuminating engineering society of North America, pp.402~404, 1995.

[4] IES. Committee on Recommendations for Quality and Quantity of Illumination. Subcommittee on Direct Glare, "Outline of a standard procedure for computing visual comfort rations for interior lighting", Report No.2. Illum.Eng. 61(10), pp.643-666, 1966.

[5] Levin, R.E. "An evaluation of VCP calculation", J.Illum.Eng.Soc. 2(4), pp.355-361, 1973.

[6] J.C. Stevens and S.S. Stevens, "Brightness function: effects of adaptation", J.Opt.Soc.Am., Vol.53, pp.375-385,1963.

[7] C.J. Bartleson and E.J. Breneman, "Brightness perception in complex fields", J.Opt.Soc.Am., vol.57, pp.953-957, 1967.

[8] H.W.Bodmann, P.Haubner, and A.M.Marsden, "A unified relationship between brightness and luminance", CIE Proceedings, kyoto Session 1979, pp.99-102, CIE Central Bureau, Paris, 1980.