The Effect of Extended Visual Angle on Flicker Perception using OLED Displays: Comparison with Flicker Indices

Hyosun Kim, Minkyung Kim, Hyungsuk Hwang, Youra Kim, Eunjung Lee, Dongyeol Yeom, Jaejoong Kwon

hs0411.kim@samsung.com
Samsung Display R&D Center, #1 samsung-ro, Giheung-Gu, Yongin-Si, Gyeonggi, South Korea
Keywords: Flicker, Size, Flicker index, JEITA, FMA

ABSTRACT

Simulating images with 30 Hz, we observed the size effect on display flicker with the extended range of 60°. Participants perceived flicker to be stronger as the size of stimuli increased. However, none of flicker indices reflected this tendency. Flicker indices need to be supplemented to include the size effect.

1 Introduction

Most displays present images with a refresh rate above 60 Hz. The perceptual issues introduced by a high display refresh rate have been studied in terms of image quality, which depends on how natural or how smooth a moving object is perceived on displays with a high refresh rate. Recently, however, the need for research on display flicker perception with a low refresh rate has also been raised. There are two reasons for this: 1) the latest monitors have properties (e.g. brightness and size) beyond the range of stimuli than those in the previous studies, 2) the intent to apply the new variable refresh rate (VRR) technology. Due to applying the lasted technology, called VRR or adaptive refresh rate[1-3], the cases that users see the images of screens with less than 60Hz has increased.

Considering the recent developments in displays with high properties and VRR, we will study display flicker perception at a refresh rate of 30 Hz, which is lower than the conventional refresh rate of 60 Hz. Before conducting the experiments, we analyze the flicker indices, which represent the amount of flicker visibility, because display makers use these indices as a reference. It is important to reveal the congruence between these indices and the results of subjective experiments. In this study, stimulus size was set as one of the important independent variables in this study. Espeicially, we focus the effect of extended visual angle on display. Thesedays, VRR has applied to various devices such as TVs, gaming monitors and mobiles. This means that users will experience VRR in various display size. Therefore, the study for flicker perception on the extended visual angle is required.

In this study, we conducted a subjective experiment in order to observe the size effect on perception of display flicker using an OLED monitor. Although stimulus size is known to influence the perception of display flicker[4,5], few studies have extended the range to 60 degrees of visual angle. Next, we will compare the experimental result with three flicker indices – JEITA, Flicker Visibility and Flicker Modulation Amplitude-, representing the amount of flickering.

2 Flicker indices

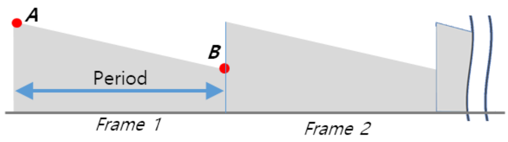
In the international standards, there are some indices that represent the amount of flicker in displays: JEITA and Flicker Visibility (F.V.) from IDMS (Information Display Measurement Standard)[6], released by ICDM (International Committee for Display Metrology), and Flicker Modulation Amplitude (FMA) from IEC (International Elecrotechnical Commission)[7]. Although the formulas for these three indices are different, all indices use the weighing functions that reflect the temporal characteristics of human perception. For example, JEITA's weighting function reflects the human sensitivity to temporal frequency, while those of F.V. and FMA reflect to temporal frequency and spatial contrast. However, none of these indices use a weighting function that takes stimulus size into account. Although the stimulus size is an imfortant factor affecting flicker perception, the flicker indices of displays do not reflect this effect. Therefore, the purpose of this study is to observe the discrepancies between three flicker indices and the result of the subjective experiment on OLED display flicker perception, including the stimulus size as an important indepent variable.

3 Experiment

3.1 Method

We used a display with a high refresh rate of 120 Hz (model: LG OLED 48'' 4K). By adjusting the luminance of four adjacent frames of 120 Hz to be alike, the waveforms at 30 Hz were created. Hence, participants were able to perceive four frames at 120 Hz as a single frame at 30 Hz. Using MATLAB, the flicker stimuli was created as a moving image format(avi), presenting bright and dark achromatic images on the monitor screen temporally.

There were five stimuli with different flicker visibilities. Test stimuli had a waveform that reduced the brightness within one frame of 30Hz. The four frames of 120Hz is equivalent to a one frame of 30Hz. Figure 2 shows the waveforme of five stimuli. The luminace of each stimuli. We controlled the amount of flicker as the percentage of the luminance difference (LD, %) between the 1st frame and the 4th frame of 120 Hz in Fig. 2. The waveform of LD0 was similar to the square waveform with duty cycles using PWM (pulse-with-modutaion). The control stimulus was made at 60Hz.



. LD (Luminance Difference) = (B/A) * 100 (%)

Fig. 1 Luminance Difference within 1 frame of 30Hz

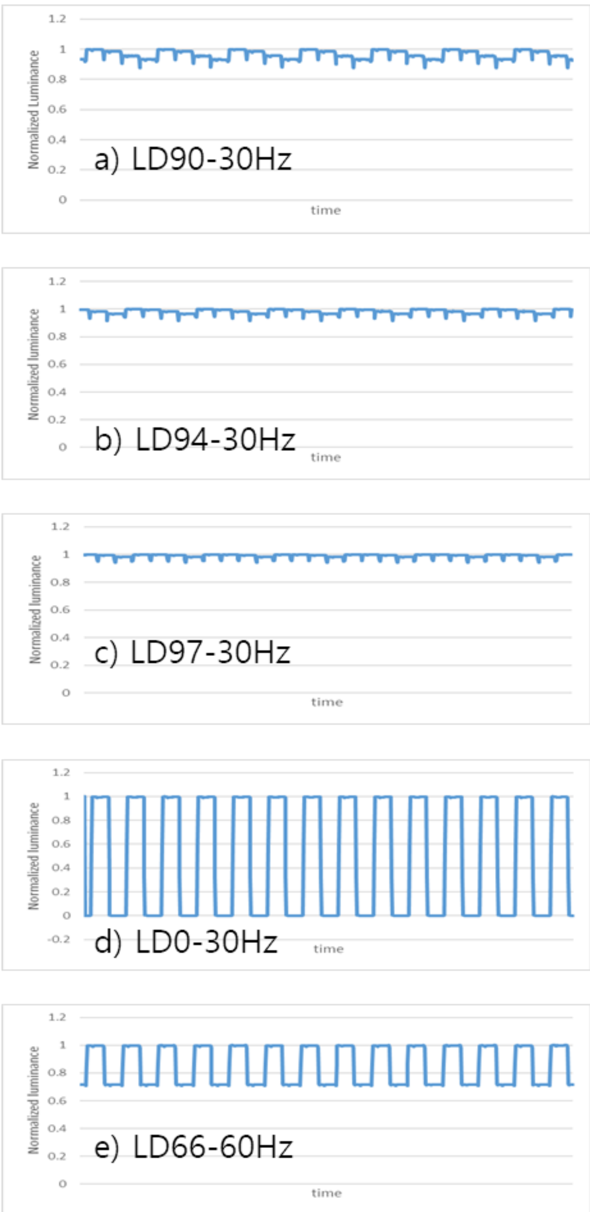


Fig. 2 the waveform of five stimuli

A reference stimulus was used to set criteria for the amount of flicker. When participants evaluated the flicker scores of the five test stimuli, they used these criteria. The reference stimulus was divided into two areas: on the left, the image without the flicker was presented, and on the right, the image with the flicker was presented. No flicker images were set to the score of 0, and flicker images of the reference were set to the score of 5. To block the ceiling and floor effects, the reference stimulus had an intermediate level of flicker among the six test stimuli. The reference stimulus was presented at another laptop screen (model: MSI GS75 Stealth 8SF, 144 Hz, 17.3-inch). The luminance of the reference was set to one condition: 119 cd/m^2.

To investigate the pure effect of size on display flicker perception, the stimuli should maintain the same shape of the waveform despite size. To adjust the size of stimuli, we used the differenct size of the hole in a black paper in front of the monitor in Fig. 3. There were 5 levels of size among test stimuli: visual angles 5°, 10°, 20°, 40°, and 60°, whereas the size of the reference was fixed at visual angle 15°. The presentation order of stimuli and the levels of size were randomized to avoid the order effect. Table 1 shows the luminance and temporal frequency of all stimuli in this experiment.

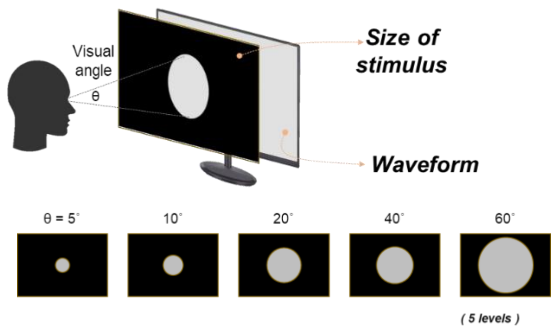


Fig. 3 the five levels of stimulus size

Table 1. The characteristics of five test stimuli and one reference stimulus (frequency, luminance)

	Stimulus	Hz	Luminance [cd/m^2]
Test	ES90_30	30	225.1
	ES94_30	30	226.3
	ES97_30	30	226.5
	ES0_60	60	109.1
	ES66_60	60	174.9
Ref.	ES88_36	36	119

The task of the participants was to specify the flicker score of five test stimuli by comparing them with the flicker of the reference image in Fig. 4. We explained that the reference image without flicker indicated a score of 0, and the reference image with flicker indicated a score of 5. The participants were asked to specify a rating more than 5-points when they perceived the flicker of the test stimulus to be stronger than that of reference and vice versa for less than the 5-points (i.e. when they perceived the flicker of the test stimulus to be weaker than that of reference). The upper boundary of the score was unlimited.

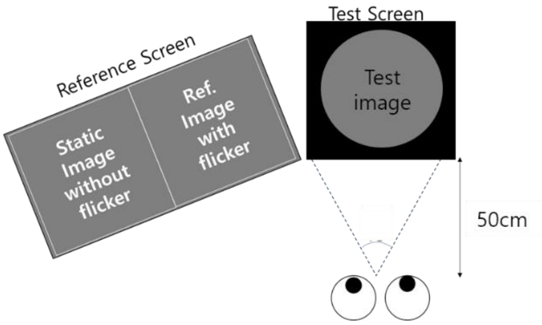


Fig. 4 The picture of experimental setup

The viewing distance was 50cm. Participants evaluated the flicker scores of five test stimuli seven times. The experiment was conducted in a dark room. A total of seven subjects with normal color vision participated in the flicker experiment.

3.2 Result

The result showed that the larger the stimulus, the stronger flicker perception in Fig. 5. As the result of repeated-ANOVA using Minitab, the stimulus size was statistically significant ($F(4, 1050) = 331.29$, $p < .001$).

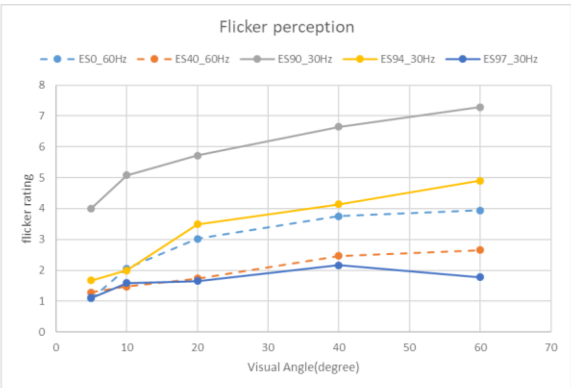


Fig. 5 The subjective experimental result depending on stimulus size

Figure 6 shows the three indices of all test stimuli based on the stimulus size. None of the flicker indices (JEITA, F. V., and FMA) reflected the size effect. This is because all three weighting functions of three indices don't have the stimulus size as a factor. Table 2 shows the correlation coefficient between the subjective result and three flicker indices. Although all three indices have low coefficients, especially, FMA has lowest coefficient that was not statistically significant. This may be because FMA seemed to overestimate the amount of flicker on "LD0-60Hz". The FMA weighting function may need to be adjusted corresponding to the subjective results.

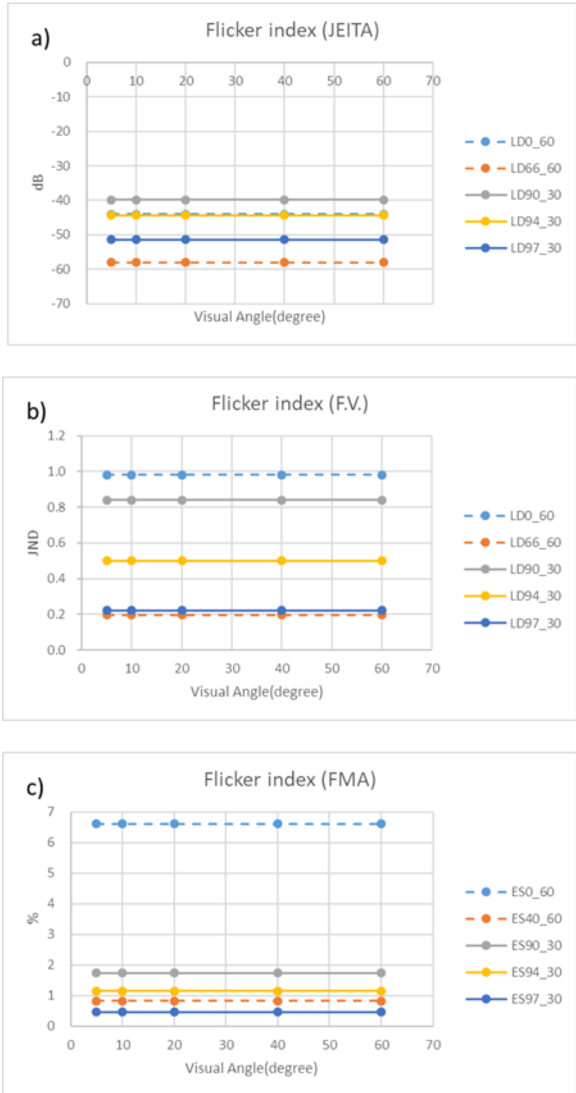


Fig. 6 the values of three flicker indices depending on stimulus size

Table 2. The correlation coefficients between the experimental result and three flicker indices

	JEITA (p value)	F.V (p value)	FMA (p value)
Flicker rating (raw score)	0.518 (< 0.01)	0.420 (< 0.01)	0.051 (0.074)

4 Discussion

In this study, we explored the effects of stimulus size on display flicker perception, considering the characteristics of the newest displays: large size and VRR technology. Since OLED displays have faster response times than LCD displays, the simulated stimulus waveforms of 30Hz on OLED displays differed from those on LCD displays[8]. Comparing the author's previous study, the experimental result was similar to the previous study. Flicker perception increased with increasing size of the stimulus including the extended visual angle of 60°. However, the values the two flicker indices (Flicker Visibility and FMA) changed slightly. It may be because the waveforms changes even with the same LD. Further study on the effect of waveform between OLED and LCD displays is required.

Moreover, the size effect appeared even at the visual angle of 60 degrees. If the size effect on flicker perception is similar to the eccentricity effect, the participants' flicker scores will converge without any further increase when the stimulus size exceeded 50 degrees since the temporal sensitivity peaks in the peripheral area at the eccentricity of 20~50°[9]. However, the subjective rating scores increased to the 60 degrees. It means that the size effect should be studied as a single independent major factor although the eccentricity effect on flicker perception is correlated with the size effect.

In addtion, the flicker indices, which are defined by the international standards do not consider this size effect, although they are used to depict the amount of display flicker. Therefore, the size should be included in the weighting function as the main factors. This is because the weighting function directly determines the value of the flicker index.

5 Conclusions

From the result of the subjective experiment, it was clear that the stimulus size was related to display flicker perception. However, the flicker indices, which are defined by the international standards do not consider this size effect, although they are used to depict the amount of display flicker. Therefore, the size should be included in the weighting function as a main factors. This is because the weighting function directly determines the value of the flicker. The international standard is need to be supplemented to include the size effect with the extended visual angle.

References

[1] B. You, H. Nam and H. Lee, "Image Adaptive Refresh Rate technology for Ultra Low Power Consumption," Proc. SID 2020, pp. 676-679 (2020).

[2] G. A. Slavenburg, M. Janssens, L. Lucas, R. J. Schutten and T. Verbeure, "Variable Refresh Rate Displays," Proc. SID 2020, pp. 669-672 (2020).

[3] J. Li, et al. "Novel OLED Low Frame Frequency Driving method with minimized Flicker," Proc. SID 2020, pp. 632-634 (2021).

[4] M. J. Wright, and A. Johnston, "Spatiotemporal contrast sensitivity and visual field locus," Vision Res., Vol. 23, No. 10,pp. 983-989 (1983).

[5] S. J. Anderson, K. T. Mullen, and R. F. Hess., "Human peripheral spatial resolution for achromatic and chromatic stimuli: limits imposed by optical and retinal factors," J. physiol., Vol. 442, No. 1, pp. 47-64 (1991).

[6] International Committee for Display Metrology (ICDM), Information display measurements standard (ver. 1.1). SID 135. (2021).

[7] IEC 62341-1-2:2012, Organic light emitting diode (OLED) displays – Part 6-3: Measuring methods of image quality(Ed.1).

[8] H. Kim, at al., "Effects of Size on Perception of Display Flicker: Comparison with Flicker Indices," Proc. LIM(London Imaging Meeting) 2022 (2022).

[9] B. Krajancich, P. Kellnhofer and G. Wetzstein., "A perceptual model for eccentricity-dependent spatio-temporal flicker fusion and its applications to foveated graphics," ACM Trans Graph, Vol. 40 No. 4, pp. 1-11 (2021).