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Psychological effects of ambient illumination control and illumination layout while viewing various video images

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SUMMARY Recently enhancing the visual experience of the user has been a new trend for TV displays. This trend comes from the fact that changes of ambient illuminations while viewing a Liquid Crystal Display (LCD) significantly affect human impressions. However, psychological effects caused by the combination of displayed video image and ambient illuminations have not been investigated. In the present research, we clarify the relationship between ambient illuminations and psychological effects while viewing video image displayed on the LCD by using a questionnaire based semantic differential (SD) method and a factor analysis method. Six kinds of video images were displayed under different colors and layouts of illumination conditions and rated by 15 observers. According to the analysis, it became clear that the illumination control around the LCD with displayed video image, the feeling of 'activity' and 'evaluating' were rated higher than the feeling of fluorescent ceiling condition. In particular, simultaneous illumination control around the display and the ceiling enhanced the feeling of 'activity,' and 'evaluating' with keeping 'comfort.' Moreover, the feeling of 'activity' under the illumination control around the LCD and the ceiling condition while viewing music video image was rated clearly higher than that with natural scene video image.

key words: *display device, illumination, subjective evaluation, semantic differential (SD) method, factor analysis*

1. Introduction

Recently, technological progress and transition of lifestyles have led to change in the everyday TV viewing environment. On the technical side, flat panel displays (FPDs) such as liquid crystal displays (LCDs) and plasma display panels (PDPs) have become significantly larger and thinner than before and been widely used instead of traditional CRT displays. Their popularity brings an important work to investigate the psychological effect of large-sized FPDs and viewing conditions. Masaoka et al. reported that realistic sensation was increased as increasing the size of an FPD and the number of pixels [1]. On the other hand, about standards of viewing television in a room environment, ITU-R has studied evaluation methods for many years and published recommendations [2],[3]. These recommendations describe methods for evaluating subjective image quality of a display device under constant viewing conditions, for example, a room illumination and a chromaticity behind the display device in home environment.

Nowadays, new dimensions such as colors of the ambient illumination are added to the display devices to enhance the viewing experience. Having improved spatial and temporal resolution, more saturated primary colors and lower power consumption, light emitting diode (LED) lighting systems can be used to design more attractive lighting atmospheres. There have presented commercial products and a proposal which actively control the lighting environment around a display [4],[5]. For instance, the color of the light surrounding a TV changes in accordance with the color of the content shown on the display to enhance the experience of watching TV. For improving the realistic sensation while viewing FPDs, some researches tried to change ambient illuminations by using the information of displayed images such as color and contrast [6]-[8].

In our previous research, we analyzed the relationship between ambient illuminations and psychological factors while viewing still image displayed on the LCD [9]. In the psychological experiments, observers watched the displayed images with changing brightness and chromaticity around the LCD. A factor analysis method was introduced to analyze the subjective evaluation. It was shown that 'realistic sensation' was enhanced with keeping 'comfort' under the illumination behind the LCD. However, since the ambient illumination was static while viewing displayed still image, psychological effects caused by dynamic lighting were not clarified. Moreover, the illumination was mounted with limited layout.

In this research, we analyze the psychological effects of ambient illumination control and illumination layout while viewing displayed various video images. The chromaticity of the ambient illumination changes dynamically in accordance with the colors of the video image shown on the LCD. Dynamic ambient illumination is expected not only to reduce visual fatigue

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but also to enhance the visual experience of the user. In addition, a psychological experiment is performed under several types of ambient illumination control by changing layouts of the illuminating devices. In the experiment, observers rate various adjective pairs which are prepared based on the semantic differential (SD) method [10],[11]. By applying the factor analysis to data, we clarify psychological effects caused by ambient illumination control and illumination layout.

2. Subjective Evaluation

In the psychological experiments, we used the SD method to analyze psychological effects by changing ambient illumination conditions. Observers rated impression of the displayed video images under different colors and layouts of illumination conditions around a display.

2.1 Experimental Setup

Fig. 1 shows an experimental setup decorated as a living room of approximately 3 by 3.5 m. Three kinds of illuminating devices were employed in our experiment (Table 1). One was a fluorescent light on the ceiling whose illuminance was modulated by a controller. The entire environment was illuminated in daylight color (color temperature: 5000K). The others were color LED illuminations on the ceiling and on both sides of the LCD. Each LED illumination contains three primary LEDs, red, green and blue. Its illuminance and colors can be controlled by adjusting the mixing ratio of RGB components. The employed display device was a 65-inch Wide Screen LCD-TV (Sharp LC-65GE1) which was positioned on a whiteboard. This LCD-TV has a 1920 by 1080 resolution. The video-screen was set at “standard mode.” The viewing distance was 240 cm that corresponded with the distance of three times the screen height (3H) of the LCD [3].

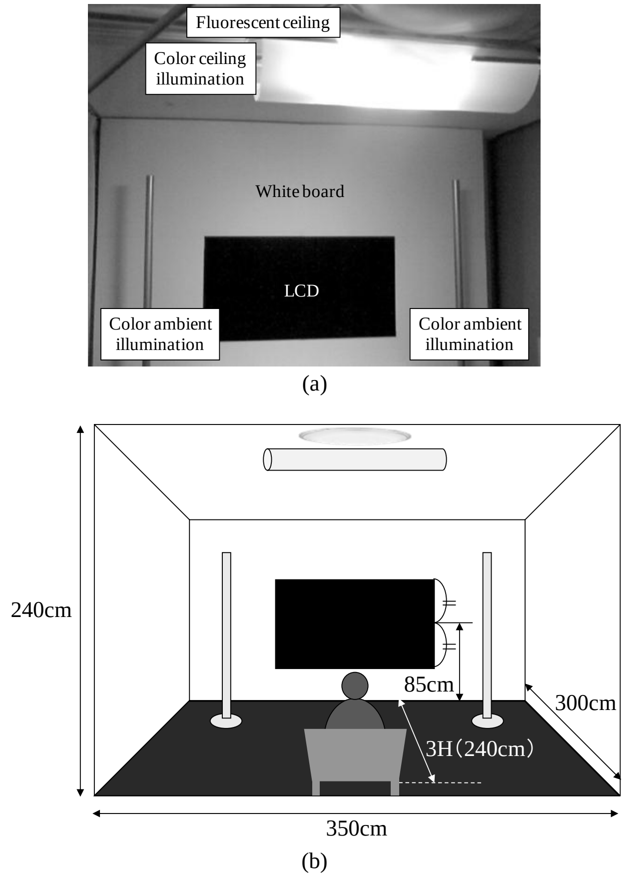

Fig. 1 Experimental set up.

Table 1 Illuminating devices.

	Fluorescent ceiling	Color ceiling illumination	Color ambient illumination
illuminance (lux) (measured 85 cm above the floor)	300	300	350
xy chromaticity value	(0.35, 0.36)	R (0.71, 0.30) G (0.18, 0.73) B (0.13, 0.07)	R (0.71, 0.30) G (0.18, 0.73) B (0.13, 0.07)

2.2 Evaluation Method

In our experiment, SD method [10],[11] was employed to analyze the subjective evaluation. Fig. 2 shows 20 adjective pairs (20 bipolar word pairs) prepared to analyze the psychological effects caused by the ambient illuminations. Initially, about 100 different adjective pairs used for image quality evaluation while viewing display device were collected. In order to reduce the large list of words, the words with a similar meaning were grouped. Finally, 20 practical adjective pairs for our experiment were selected. All experiments including a pilot study were conducted by using the Japanese adjective pairs because of the convenience for observers.

Each observer rated the impressions of a displayed video image under various illumination conditions. The experimental results were transformed into the values from 5 (positive) to 1 (negative) to apply factor analysis.

2.3 Experiment

Table 2 shows the ambient illumination conditions and displayed video images used in the experiment. The illumination control conditions applied the average color of the surrounding region of an image to the illumination color for each frame (Fig. 3). The illuminance on the screen of the LCD was less than 3 lux under dark room (No illumination). The illumination conditions changed in two ways (“Table 2: (a) → (b) → (c) → (d)” and “Table 2: (d) → (c) → (b) → (a)”).

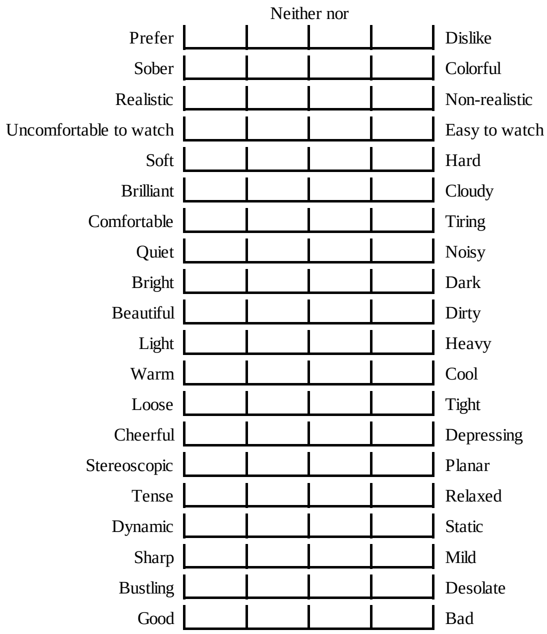

Fig. 2 Adjective pairs for psychological experiments.

Table 2 Illumination conditions and examples of displayed video image in the experiment.

Observers	15
Evaluation method	SD method (Scale: 1〜5)
Illumination conditions	(a) Illumination control (Color ambient illumination + Color ceiling illumination) (b) Illumination control (Color ambient illumination) (c) Fluorescent ceiling (d) Dark room (No illumination)
Examples of displayed video image	 #1  #2  #3

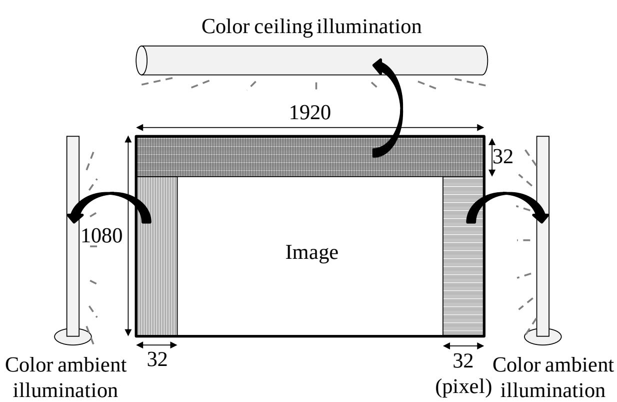

Fig. 3 Surrounding region of an image applied to the illumination color.

The stimuli were six video images with natural scene (#1:blue sky, #2:under water, and #3:people under cloudy sky) and music scene (#4:pop music, #5:healing music, and #6:rock music). The stimuli did not include background music. Table 2 shows the example of the stimuli (Video image #1 ~ #3). Four illumination conditions were used in each image. Each video image was shown for 30 seconds under one illumination condition. After showing the image, the observers rated their impressions and filled in the SD evaluation sheet. The observers totally rated 24 (= 6 × 4) kinds of the video images and the illumination conditions in the experiment. An 18% gray image was displayed for approximately 30 seconds before each illumination condition.

Thirteen males and two females participated in the experiment. Their age ranged between 25 and 41, and they were engineers engaging imaging technology, had no prior knowledge about the experimental setup. All observers reported normal or corrected to normal vision. They had filled in a SD evaluation sheet for practice before the experiment.

3. Results and Discussion

Fig. 4 shows SD profiles of the average experimental results of all video image with changing the ambient illumination conditions. Each profile of the illumination condition represents the average values of rated value for each adjective pair. There are highly rated values, such as “colorful,” “brilliant,” “dynamic,” “bustling,” and “noisy” under the illumination control around the LCD and the ceiling condition as compared to the other illumination conditions. In contrast, dark room condition affects the observers’ impressions such as “hard,” “dark,” “heavy,” “depressing,” and “sharp.” The results also show that the fluorescent ceiling condition brings impressions such as “sober,” “non-realistic,” “cloudy,” and “planar.”

Table 3 shows the factor loadings of each adjective pair by factor analysis with maximum likelihood method. In order to simplify the interpretation of the factors, a Varimax rotation technique was applied. The factor analysis revealed that the first three factors explained the contribution ratio, respectively 24%, 17% and 16%. We name the first factor ‘activity’ derived from the evaluation words “bustling,” “colorful,” and “dynamic.” The second factor is named ‘evaluating’ derived from the evaluation words “good,” “prefer,” and “easy to watch.” Moreover, the third factor is named ‘comfort’ derived from the evaluation words “relaxed,” “loose,” and “comfortable.”

In order to test the reliability of each factor, contribution was calculated for adjective pairs with a loading higher than 1 on that factor. Contribution was relatively high (4.9, 3.6 and 3.2 respectively), which demonstrates that participants interpreted the adjective pairs in a similar way. Therefore, the adjective pairs appears to be a reliable tool to distinguish three dimensions of human impression.

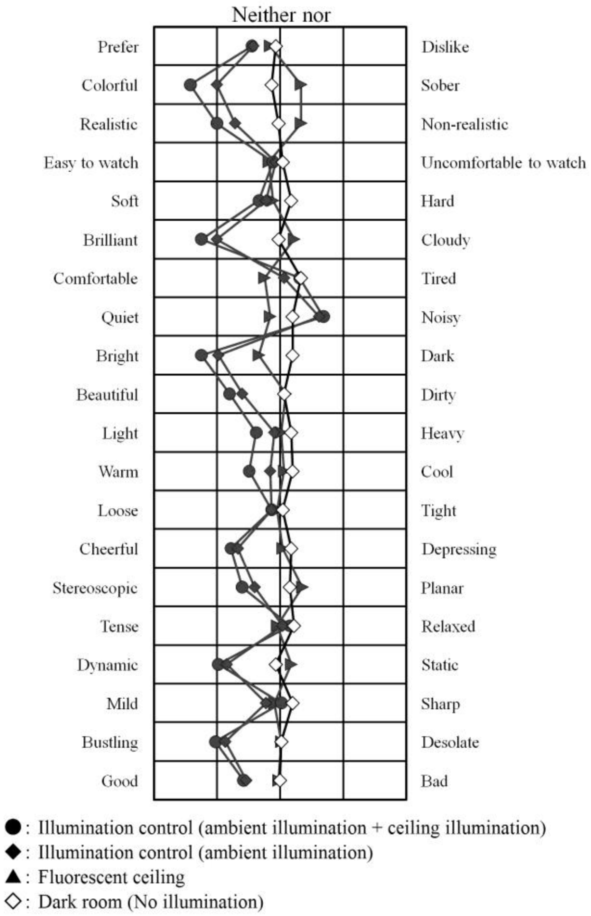

Fig. 4 SD profiles of the experiment.

Table 3 Factor loadings of the experiment.

Adjective pairs		First factor	Second factor	Third factor	Independent factor
Bustling	Desolate	**0.82**	0	0	0.13
Colorful	Sober	**0.776**	0.176	0	0.25
Dynamic	Static	**0.738**	0.15	0	0.342
Cheerful	Depressing	**0.724**	0.127	0.199	0.348
Brilliant	Cloudy	**0.701**	0.42	0	0.357
Bright	Dark	**0.655**	0.21	0.171	0.407
Stereoscopic	Planar	**0.514**	0.456	0.134	0.327
Warm	Cool	**0.405**	0.204	0.335	0.509
Good	Bad	0.327	**0.83**	0.27	0.318
Prefer	Dislike	0.203	**0.803**	0.253	0.407
Easy to watch	Uncomfortable to watch	0	**0.652**	0.466	0.43
Realistic	Non-realistic	0.542	**0.603**	0	0.364
Beautiful	Dirty	0.521	**0.581**	0.209	0.419
Relaxed	Tense	0.118	0.114	**0.796**	0.635
Loose	Tight	0.182	0.37	**0.651**	0.407
Comfortable	Tiring	0	0.512	**0.636**	0.34
Mild	Sharp	0	0	**0.597**	0.596
Quiet	Noisy	-0.476	0.233	**0.558**	0.583
Soft	Hard	0.238	0.32	**0.495**	0.498
Light	Heavy	0.45	0	**0.462**	0.682
Contribution ratio		24.7%	17.9%	16.0%	
Cumulative contribution ratio		24.7%	42.6%	58.6%	

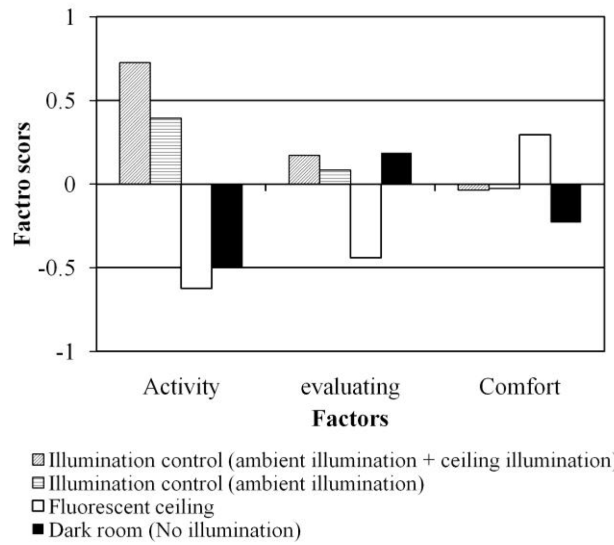

Fig. 5 Factor scores in the experiment.

Fig. 5 shows the factor scores of 'activity,' 'evaluating,' and 'comfort' which are calculated by using overall combinations of the stimuli and four illumination conditions (Table 2). On the illumination control around the LCD and the ceiling condition, the factor scores of 'activity' and 'evaluating' are rated higher than the score of fluorescent ceiling condition. Moreover, on the illumination control around the display condition, the factor scores of 'activity' and 'evaluating' are rated higher than the score of illumination control on ceiling condition. Therefore, it became clear that the appearance was well correlated to the illumination control from around the display. The factor score of a 'evaluating' is high for illumination control around the display and the dark room condition. In particular, the illumination control around the display and the ceiling condition increases the factor score of 'activity,' and 'evaluating' with keeping 'comfort.' In addition, since each stimulus was shown for 30 seconds per one condition, it is necessary to extend presentation time to investigate the influence of fatigue in a darkroom. Moreover, on the fluorescent ceiling condition, the factor score of 'comfort' are rated higher than the other illumination conditions. Therefore, "comfort" is considered to be a factor showing the characteristic of the brightness in the room.

Fig. 6 shows the factor scores of each movie genre in the experiment. Apart from a few points, the results have a similar tendency between (a) and (b). In Fig. 6(a), on the illumination control around the LCD and the ceiling condition, the factor score of 'activity' is rated high with keeping the factor scores of 'evaluating' and 'comfort.' Fig. 6(a) also shows the factor scores 'evaluating' are rated high under the dark room condition.

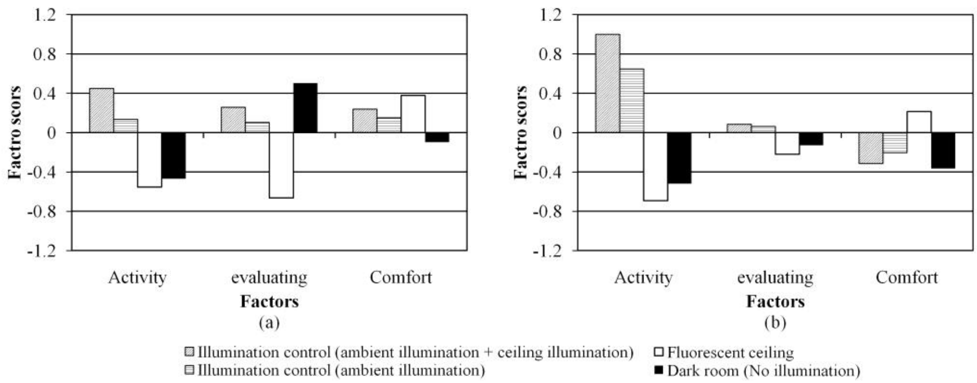

Fig. 6 Factor scores of each movie genre in the experiment.
(a) Natural scene (Video image #1~#3). (b) Music scene (Video image #4~#6).

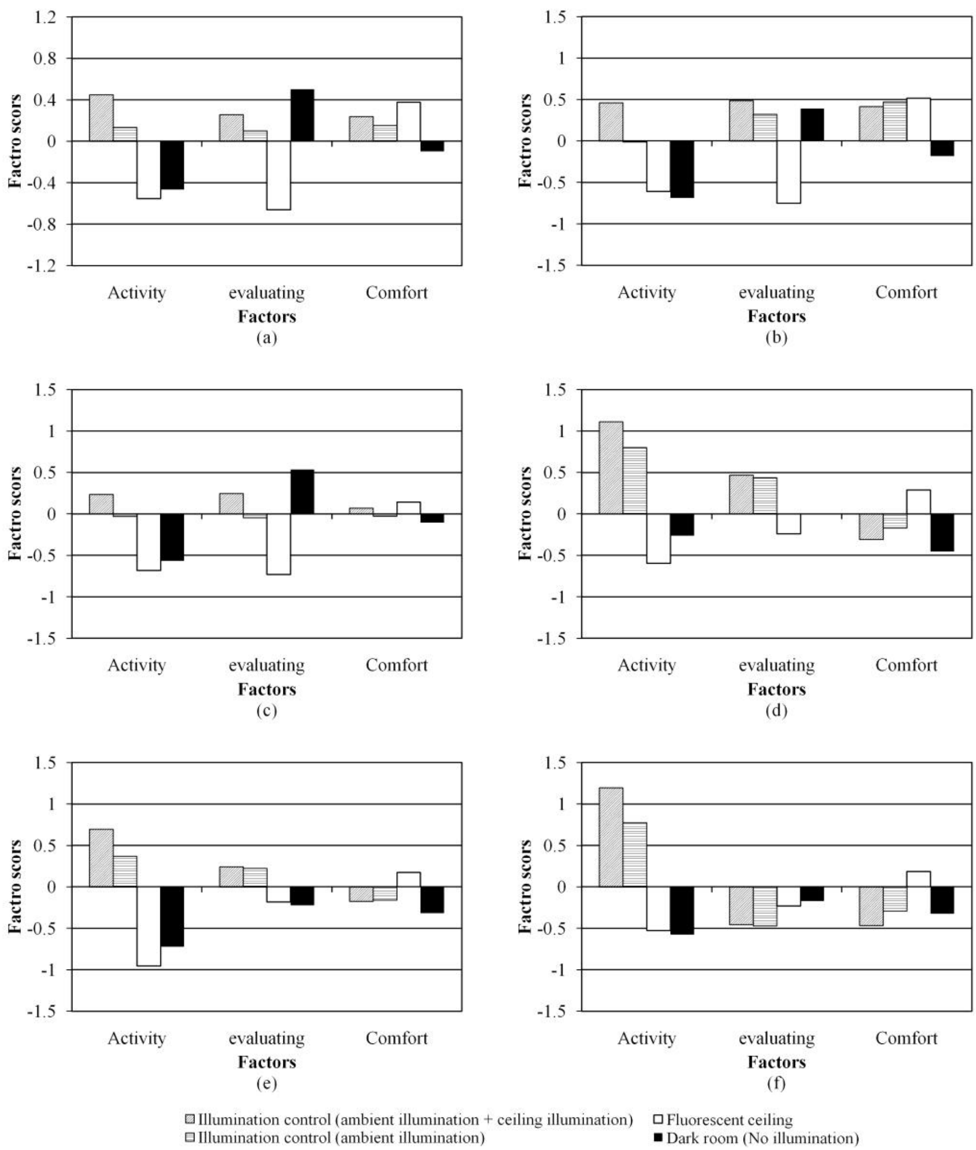

Fig. 7 Factor scores of each video image in the experiment.
(a) #1:blue sky. (b) #2:under water. (c) #3:people under cloudy. (d) #4:pop music. (e) #5:healing music. (f) #6:rock music.

However, the factor scores of ‘activity’ and ‘comfort’ are rated low under the dark room condition, which showed a similar trend of the factor scores in the dark room in Fig. 5. In Fig. 6(b), on the illumination control around the LCD and the ceiling condition, the factor score of ‘activity’ is rated clearly higher than those with the other illumination conditions. This result might be related to the observation that the chromaticity of the ambient illumination changes dynamically in accordance with the colors of the music video image. On the other hand, the scores for the dark room conditions are rated lower than those with the illumination control conditions.

Fig. 7 shows the factor scores of each stimulus in the experiment. Fig. 7(a), (b) and (c) show that the differences between illumination conditions are in fact relatively small under natural scene video images. However, Fig. 7(d), (e) and (f) show that the experienced impressions slightly depend on the type of music scene video images. It is shown that the factor scores of ‘activity’ for the pop music and the rock music video image are rated higher than those with the healing music video image under the illumination control around the LCD and the ceiling condition. These results might be related to the observation that the pop music and the rock music should motivate observers to become lively feeling, which corresponds to the ‘activity.’

4. Conclusions

In this research, we conducted an experiment to analyze the availability of ambient illumination conditions with keeping highly realistic sensation and comfort, and clarified the relationships between ambient illumination and psychological effects while viewing various video image displayed on the LCD. It was shown that the illumination control around the LCD with displayed video image, the feeling of ‘activity’ and ‘evaluating’ were rated higher than the feeling of fluorescent ceiling condition. In particular, simultaneous illumination control around the LCD and the ceiling enhanced the feeling of ‘activity,’ and ‘evaluating’ with keeping ‘comfort.’

The results of this study suggest that the presence of the illumination control with displayed video image does appear to provide a benefit with respect to visual comfort and activity with keeping high evaluating, over conventional television viewing without this feature.

However, the experiments of this study were performed mainly under natural scene video images and music video images. In actual fact, there are many types of video image genre, such as movies. In future, we plan to analyze the psychological effects while viewing different genres of video images. Moreover, it is a future task to clarify the relationship between texture and brightness of image and the ambient illumination condition.

References

[1] K. Masaoka, M. Emoto, M. Sugawara and F. Okano, “Presence and Viewing Conditions when Using an Ultrahigh-Definition Large-Screen Display,” Proc. of IEICE General Conference, IEICE, Osaka, JP, AS-7-3, Mar., 2005. (in Japanese)

[2] ITU-R Rec.BT.500-11, Methodology for the subjective assessment of the quality of television pictures, 2002.

[3] ITU-R Rec.BT.710-4, Subjective assessment methods for image quality in high-definition television, 1998.

[4] Philips Electronics, “Ambilight,” http://www.consumer.philips.com/c/televisions/33092/cat/gb/ #/cp_tab2, accessed Jun., 2010.

[5] Y. Tokumo, T. Iwanami, Y. Ogisawa, S. Watanabe, N. Ito, “Proposal for Representation of Sensory Effects (RoSE) metadata,” ISO/IEC, Hannover, DE, JTC 1/SC 29/WG 11 MPEG2008/M15681, Jul., 2008.

[6] I. Vogels, D. Sekulovski, B. Rijs, “Discrimination and preference of temporal color transitions,” Proc. of IS&T/SID’s 15th Color Imaging Conference, Albuquerque, US, pp. 118-121, Nov., 2007.

[7] C. Liu, M. D. Fairchild, “Measuring the relationship between perceived image contrast and surround illumination,” Proc. of IS&T/SID’s 12th Color Imaging Conference, Scottsdale, US, pp. 282-288, Nov., 2004.

[8] A. Kikuchi, K. Hirai, T. Kaneko, T. Iwanami, N. Yano, T. Nakaguchi, N. Tsumura, Y. Miyake, “Factor analysis of psychological effects by ambient illuminations while viewing display,” The Third International Workshop on Image Media Quality and its Applications, IEICE, Kyoto, JP, pp.151-157, Sep., 2008.

[9] T. Iwanami, A. Kikuchi, T. Kaneko, K. Hirai, N. Yano, T. Nakaguchi, N. Tsumura, Y. Yoshida, Y. Miyake, “The relationship between ambient illumination and psychological factors in viewing of display images,” Proc. of SPIE’s Electronic Imaging Conference, IS&T/SPIE, San Jose, US, Vol.7241, 72410L, Jan., 2009.

[10] C. E. Osgood, G. H. Suci, P. H. Tannenbaum, The measurement of meaning, Univ. of Illinois Press, 1957.

[11] C. E. Osgood, Studies of the generality of affective meaning system, American Psychologist, 17, pp.10-28, 1962.

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