The Effects of Stereoscopic Display Luminance and Ambient Illumination on Visual Comfort

Pei-Chia Wang[1], Sheue-Ling Hwang[1], Kuan-Yu Chen[1], Jinn-Sen Chen[2], Jinn-Cherng Yang[2], and Hung-Lu Chang[2]

[1] National Tsing Hua University, Industrial Engineering and Engineering Management Department, No. 101, Section 2, Kuang-Fu Road, Hsinchu, Taiwan
[2] Industrial Technology Research Institute, Electronics and Optoelectronics Research Laboratories, No.195, Section 4, Zhongxing Road, Zhudong Township, Hsinchu County, Taiwan
d9734815@oz.nthu.edu.tw, slhwang@ie.nthu.edu.tw, creailsator@gmail.com, {JIINSEN,OESJCY,hungluchang}@itri.org.tw

Abstract. In this paper, we investigated that display luminance and ambient illumination had significant effects on the perception of the imagery displayed, and their appropriate combination would be studied. The results showed display luminance and ambient illumination did not significantly influence on physiological fatigue. Ambient illumination statistically affected objective visual fatigue, but display luminance did not. Ambient illumination and display luminance significantly affected subjective comfort evaluation. However, the main effect of display luminance was statistically significant on visual discrimination performance, but ambient illumination was not significant. As for the combination effect of display luminance and ambient illumination, viewers felt the most comfortable and with the best visual performance in the high level of display luminance and the high level of ambient illumination. It is expected to find out the optimal condition to ensure the viewer's visual comfort. As for the future work, the dynamic image factor may be taken into account.

Keywords: display luminance, ambient illumination, visual comfort, fatigue, visual discrimination performance.

1 Introduction

1.1 Stereoscopic Vision

The difference of human eyes' horizontal distance induces the tiny discrepancy of image for seeing the same object, and this is the reason of the depth perception written in Euclid's manuscript [1]. It is also called "binocular disparity" in psychology. In 1838, Charles Wheatstone created the first stereo image via two separate mirrors with an angle. He found that disparity was a sufficient and compelling stimulus for the perception of depth [2]. From now on, 3D displays have

C. Stephanidis (Ed.): Posters, Part II, HCII 2011, CCIS 174, pp. 369–373, 2011.
© Springer-Verlag Berlin Heidelberg 2011

moved from a series of applications and become the mainstream as the development of the display technology.

1.2 The Relation of Display Luminance and Ambient Illumination

The inadequate of the display luminance or the ambient illumination or both two derives to the accommodation of the brightness level to the pupil and thus induce the visual fatigue and to decrease the image quality.

Several researches have studied the effect of ambient illumination in watching displays [3], [4], [5]. Visual comfort on CRT (Cathode Ray Tube) monitor was significantly decreased by enhancing the level from 300 Lux to more than 600 Lux of the ambient illumination [3]. Besides, the higher level of ambient illumination caused the display images to fade [4]. When subjects watched videos on an HDR (High Dynamic Range) display under the ambient illumination of 0.75 Lux, 8.5 Lux, 28 Lux, and 74 Lux, the visual comfort degree was the same. The viewer did not get visual fatigue under these four levels of environment illumination [5].

The contrast ratio decreases with increasing ambient illumination because the surface reflection makes the screen brighter [4]. As a result, the brightness of the display is also a factor of the visual fatigue.

2 Method

2.1 Subjects

The subjects were 15 experts who are engineers of 3D display division in Industrial Technology Research Institute, and 9 novices who were graduate students in National Tsing Hua University. All subjects had a normal visual acuity, were neither color blind nor stereo blind. Only the subjects who passed the test of basic visual acuity, stereoscopic ability, and color blindness could participate in the formal experiment.

2.2 Stimulus

Two kinds of materials were used in this study. They included 15 computer generated images which were created by 3ds MAX, and 15 photographic images which were taken by 3D camera. There were 10 experimental materials, which randomly displayed computer generated and photographic images, in the same treatment. Each experimental material contained two pictures with the same scene but included 10 differences between them.

2.3 Design of Experiment

The experiment was a 3×2 within-subject design. One half of subjects participated the experiment in the low level of ambient illumination, and the others were in the high level. All subjects took part in the experiment under three levels of display luminance one by one.

The independent variables were illustrated as follows.

1. Display luminance: there were 15, 35, and 55 of the scale of stereoscopic display itself, which was 0.38 nits, 6.73 nits, and 47.3 nits respectively.
2. Ambient illumination: there were one yellow light bulb and seven yellow light bulbs, which were 55 Lux and 300 Lux respectively.

There were four dependent variables.

1. Objective visual fatigue index: CFF (Critical Fusion Frequency).
2. Objective physiological fatigue index: HRV (Heart Rate Variability).
3. Subjective comfort evaluation: Likert's five scale on the degree of "eyestrain," "seeing the object clearly," "psychological fatigue," and "physical fatigue."
4. Visual discrimination performance: the total sum of the differences of 10 experimental pictures in each treatment for subjects to find.

2.4 Procedure

At first, the subjects read the purpose of the experiment and filled out the consent agreement form. Their HRV were measured by ANS Watch as the baseline in the beginning of experiment. There were three levels of display luminance. Each treatment took 20 minutes showing 10 experimental pictures with two minutes per experimental material on the stereoscopic display. Before and after watching 3D pictures in the same level of display luminance, the subjects took the objective visual fatigue by handy flicker. After each treatment, the HRV value was measured and subjective comfort evaluation was assessed. The picture and the level of display luminance and ambient illumination were randomly shown on the 3D display to eliminate any order effects. The duration of the experiment for each subject was about two hours.

3 Result

3.1 Objective Visual and Physiological Fatigues

A significant main effect of ambient illumination on CFF, $Z = -7.978$, p-value < 0.001, was found based on Wald-Wolfowitz Test. Nevertheless, the main effect of display luminance was not significant.

There was no significant interaction effect between display luminance and ambient illumination on objective physiological fatigue — namely, HRV — were found by MANOVA (Multiple Analysis of Variance). Moreover, no main effect of display luminance or ambient illumination was significant on HRV.

3.2 Subjective Comfort Evaluation

The significant main effect of ambient illumination on "eyestrain", $Z = -7.978$, p-value < 0.001, "seeing the object clearly," $Z = -7.750$, p-value < 0.001, "psychological fatigue," $Z = -7.978$, p-value < 0.001, and "physical fatigue," $Z = -$

7.978, p-value < 0.001, was found based on Wald-Wolfowitz Test. Moreover, the effect of display luminance was also significant on "eyestrain", chi-square (2) = 21.971, p-value < 0.001, "seeing the object clearly," chi-square (2) = 32.747, p-value < 0.001, and "physiological fatigue," chi-square (2) = 8.379, p-value < 0.001.

3.3 Visual Discrimination Performance

The results of ANOVA did not yield a statistically significant interaction between ambient illumination and display luminance on visual discrimination performance. A significant main effect of display luminance was found, F = 15.121, p-value < 0.001. However, no evidence was found indicating that the main effect of ambient illumination was significant.

4 Discussion

4.1 The Effect of Display Luminance and Ambient Illumination

The two-way interaction was not statistically significant on objective physiological fatigue (HRV) and visual discrimination performance. The effect of display luminance was significant on subjective comfort evaluations, which were eyestrain, seeing the object clearly, and psychological fatigue, and on visual discrimination performance. In addition, the effect of ambient illumination affected objective visual fatigue (CFF) and subjective comfort evaluations, which were eyestrain, seeing the object clearly, psychological fatigue, and physical fatigue.

4.2 The Best Combination Level of Display Luminance and Ambient Illumination

To consider the significant dependent variable of objective visual fatigue and subjective comfort evaluation, the average value of these variables was ranked by the degree of comfort. The highest sum number meant the best combination level of display luminance and ambient illumination.

For watching 3D static pictures, viewers felt the most comfortable in the highest level of display luminance (34.2 nits) and the highest level of ambient illumination (300 Lux). Moreover, the combination level of the lowest display luminance (0.38 nits) and the lowest ambient illumination (55 Lux) caused the most fatigue.

5 Conclusion

The result of this experiment did not show the significant physiological fatigue (HRV) in watching 3D static pictures for 20 minutes, but indicated significant objective visual fatigue (CFF) and subjective comfort evaluation. As a result, the duration of watching static pictures did not induce the discomfort feeling.

The effect of display luminance was significant on subjective comfort evaluation and visual discrimination performance. Moreover, ambient illumination affected

objective visual fatigue and subjective comfort evaluation. The combination of higher level of ambient illumination and display luminance was better for the viewer in watching 3D pictures.

Finally, the consequence of this study demonstrated that ambient illumination was the vital factor affecting the visual comfort. The dynamic images factor may be taken into account in the further study.

Acknowledgement. The work is supported by funding from Industrial Technology Research Institute (no.:9351AA4110) and National Science Council (no.:NSC99-2221-E-007-085-MY2).

References

1. Smith, M.A.: Ptolemy and the Foundations of Ancient Mathematical Optics: A Source Based Guided Study, p. 57. American Philosophical Society, Philadelphia (1999)
2. Wheatstone, C.: Contributions to the Physiology of Vision: 1, On Some Remarkable and Hitherto Unobserved Phenomena of Binocular Vision. Philosophical Transactions of the Royal Society of London, 128–371 (1838)
3. Arne, A., Gunnar, H., Hans-Henrik, O.B., Magne, R.T.: Musculoskeletal, Visual and Psychosocial Stress in VDU Operators Before and After Multidisciplinary Ergonomic interventions. Applied Ergonomics 29, 335–354 (1998)
4. Len, C., Huang, K.: Effects of Ambient Illumination and Screen Luminance Combination on Character Identification Performance of Desktop TFT-LCD Monitors. International Journal of Industrial Ergonomics 36, 211–218 (2006)
5. Remple, A.G., Heidrich, W., Li, H., Mantiuk, R.: Video Viewing Preferences for HDR Displays Under Varying Ambient Illumination. In: Proceedings of the 6th Symposium on Applied Perception in Graphics and Visualization, pp. 45–52 (2009)