·实验研究·

Measurement Contrast Sensitivity of Human Vision System under Different Office Ambience Luminance Condition on the CRT Display*

YAO Jun-cai

(College of Physics and Electronic Information Engineering, Shaanxi University of Technology, Hanzhong 723000, China)

ABSTRACT: The contrast sensitivity function (CSF) is one of important and special spatial characteristics of human vision system, which is to reflect the relation between the contrast sensitivity under different viewing condition and spatial frequency. Ambient luminance had much influence on the contrast sensitivity in the measurements. In order to investigate how the luminance of office lighting surround to a visual target affected the measurement of contrast sensitivity to rectangular gratings, six healthy young were examined under the ambient luminance of 153, 312, 470 cd/m^2 and the dark room condition. Measurements were carried out on a CRT monitor for 11 spatial frequencies at a viewing distance of 2m. Tested grating patterns were with two kinds of average luminance of 60 and 90 cd/m^2. Measurements results show that contrast sensitivity is reduced with ambient luminance increasing, and all contrast sensitivity under the lighting viewing condition was much smaller than one under the dark room viewing condition for the same frequency, but distinguishingly, observers are the most sensitive to gratings under the surround with the luminance of 312 cd/m^2 when viewing the gratings with average luminance of 60 cd/m^2.

Key words: Human Vision System; Contrast sensitivity function (CSF); Luminance; CRT monitor

Chinese Library Classification(CLC): Q632 Document code: A

Article ID:1673-6273(2012)14-2663-05

1 Introduction

The human eye as an optical instrument, the contrast sensitivity of the human eye to observed goals with different contrast caused by the luminance and color is to measure one of the main indicators of the human eye characteristics of the space vision. The contrast sensitivity function (CSF) of human vision system is one of important and special spatial characteristics of human vision system, which is to reflect the relation between the contrast sensitivity which is the reciprocal of contrast detection threshold value under different condition and spatial frequency [1-3]. Ambient luminance had much influence on the contrast sensitivity in the measurements. Much experimental research on it had been done, yet their experiments were almost carried out under the dark room states of adaptation[1-3]. A little was known about the function obtained by experiments under the different luminance surround. In 2007, Youn Jin Kim, M. Ronnier Luo and Peter Rhodes, et al. had measured perceived brightness and contrast sensitivity for outdoor condition[4]. Cox, Norman and Peter had investigated how the luminance of an immediate surround to a visual target affected the measurements of contrast sensitivity in 1999[5], where four young were examined under typical lighting condition with six ambient luminance of 5.6, 9.0, 30.0, 90.0, 300.0 and 900.0 cd/m^2 for each test at a viewing distance of 4m or 1m. The viewing target was a Pelli-Robson chart with two frequencies of 0.87 and 3.49cpd, but illuminated from the front by two 100W angle poise lamps which utilized shields and diffusers. And in 1999, Webster examined how contrast sensitivity was affected under natural states of adaptation, gratings with frequency ranged from 0.25 to 16cpd were displayed on a CRT monitor[6]. In above experiments, the results nearly were similar, which was that contrast sensitivity was reduced with ambient luminance increasing. What's more, there were numerous other descriptions in the literature of so-called parametric experiments in the field of spatial vision, which analyzed the influence of such experimental parameters as average luminance level, orientation, spatial position, spatial extent, and temporal extent on the sensitivity thresholds for rectangular luminance gratings[7-13]. Any variation in these parameters might change sensitivity thresholds, with the best performance resulting for a given range of spatiotemporal parameter values. However, ambient luminance was a key parameter of them affecting the detection thresholds of rectangular gratings. Luminance contrast threshold was a measurement of the recognition limits of low luminance contrast gratings. It was a function of the grating features and spatial frequencies, namely CSF. Contrast threshold was the lowest contrast value perceived at a given spatial frequency by a human. Gratings with lower or higher spatial frequencies were difficult to perceive for a human. Contrast threshold was the lowest in the event of medium space frequencies, whereas the threshold increased at very small or increasing space frequencies.

Further study were carried out in this experiment about the effects of different office ambient luminance on contrast sensitivity with a CRT monitor. Under different viewing luminance condition,

*Foudation Item:National Science and Technology Major Project(100447005);
Scientific Research Project of Shaanxi Prouince Education Department (12JK0959); National Science Foundation of Shaanxi Province (2011JE012)
Author Introduction:YAO Jun-cai(1979-), Male, master, mainly engaged in vision optics and photoelectrucity image research. E-mail:yjc4782@126.com
(Received: 2011-10-11 Accepted: 2011-11-05)

human eye's adaptation to the patterns in scenes (including luminance and contrast) was more different, so human contrast sensitivity on the patterns with the same luminance under different viewing condition was more different. So three kinds of lightings ambient with luminance of 153, 312, 470 cd/m² and the dark room in our test were selected. Results show that the screen of monitor reflected the light which made observers feel patterns lighter when viewing the patterns under lighting viewing condition, but the difference between the bright and dark stripes kept constant in the same pattern, while the sum increased. That was to say, actual contrast sensitivity of pattern was smaller than one computed. While actual contrast sensitivity couldn't be gotten, only get ones computed beforehand. So measured goal was to obtain relations of contrast threshold under four surround and effect of ambient luminance on them.

2 Instruments and Measurements

2.1 Experimental Instruments

In the test, gratings with the different spatial frequencies and the contrast were displayed by SONY-520 CRT monitor driven by a PC through a 3× 10 bit colour resolution MATROX video card which had been used for two years, approximately 4500 hours. the displaying effect maintains the new machine condition basically. The white point was set to luminance D65 calibrated by X-Rite colorimeter and resolution 1024× 768. The maximal luminance of the CRT monitor was set to luminance 100.28cd/m². To achieve accurate luminance results, the most accurate methods of LUT was adopted to characterise the CRT monitor, and studied the accuracy of the CRT' reproduction of colour and luminance in the short term, medium term and long term. The results showed the CRT monitor needed 2 hours to get to stabilize, accuracy of charactering the CRT with the methods of LUT and the CRT' reproduction of colour and luminance were 0.84CIELAB, 0.40CIE94, 0.42CIEDE 2000, and 0.08, 0.15, 0.26CIELAB in the short term, medium term and long term. The calibration procedure was repeated periodically to ensure accurate luminance reproduction. Screen photometer was the type of ST-86LA manufactured by Beijing Normal University Electro-optic Instrument plant, whose measuring luminance range was 0.01~19990cd/m².

2.2 Measurement Method

Before the measurements all patterns presented on CRT with different contrast and frequencies had finished beforehand. These patterns with average luminance of 60 and 90cd/m² were composed of bright and dark stripes with luminance of $L_{dark}=L-\Delta L$ and $L_{bright}=L+\Delta L$. The tested subject was seated 2m away from the screen. Tested patterns showed eleven spatial frequencies of 0.41, 0.82, 1.23, 1.97, 3.08, 3.79, 4.93, 7.04, 9.86, 16.43, 24.64cpd. The orientation of the grid was randomly set to be either horizontal or vertical. The size of every pattern was 85mm× 85mm, which was located at the centre of the monitor screen, and whose surroundings was medium ash background with brightness of 27.6cd/m². The viewing angle of one period was 2.43470. The procedure of the measurement was to choose spatial frequency as a fixed parameter and increased the contrast of two luminance stripes until the measurement subjects could identify the orientation of the grating. Measurements were taken on eleven different spatial frequencies, however, the highest frequency resulted in the size of a pair of bars being below the resolution threshold of the human eye, therefore none could accomplish this task. Three measurements were taken at each spatial frequency. Measurements were carried out in a dark room and three kinds of lightings. The background luminance behind the tested pattern was the same with average luminance. In order to assure equal luminance adaptation status and pupil size for each subject, they were adapted to the monitor white before each measurement. What's more, six observers must be adapted to every viewing condition for thirty minutes before each measurement, because ambient luminance adaptation played a constant role in regulating our perception[4-6].

2.3 Manufacture Tested Patterns

In the test, plenty of patterns finished beforehand with different contrast value and different frequencies need be displayed on a CRT monitor. Because common CRT monitor with 3× 8 bit colour video card only can produce 256 luminance levels, the luminance of pattern on the screen with decimal RGB value couldn't be measured accurately and luminance or contrast's controlling was more difficult if digital values 0 to 255 for RGB value were used. So in the test, the patterns were presented on the CRT monitor driven by a PC through a 3× 10 bit colour resolution MATROX video card. 1024 luminance levels can be produced. Three digital values can be interposed between continuous two RGB values. In the test, only luminance CSF was measured, RGB value corresponding to luminance of pattern is R=G=B. Many patterns were required in the measurements, which was manufactured according to the following. If common methods was adopted to characterize the monitor for forecasting or controlling luminance and contrast, the precision of measurement for contrast detection threshold wouldn't be able to be satisfied. So we adopt other method that the luminance of patterns was directly measured if RGB value of patterns was continuous integer and the luminance of patterns was interposed linearly if RGB value of patterns was decimal. In the experiment, a narrow range of luminance of patterns with RGB value of continuous integer would be obtained with the X-Rite colorimeter. Luminance of patterns with decimal RGB values was obtained with linear interpolation. Among the narrow range of luminance measured and interpolated, a medial luminance thought as average luminance would be selected, the corresponding RGB value was thought as central RGB value. According to these RGB values, two of them were selected at random as the RGB value of bright and dark strips, but the midpoint of two RGB values must be central RGB value. The contrast of pattern could be calculated when substituting the luminance for RGB value. With the method, many patterns needed in the test could be manufactured. In order to be able to carry out contrast value of pattern displayed on CRT to get to the minimum and keep average luminance constant. The minimum interval RGB value of bright and dark strips was 0.25.

2.4 Measurement Subjects

Six people were chosen for the measurements, who were all 20-30 years old males with normal colour vision. Observers viewed the display binocularly in four viewing condition. Six subjects taking part in the experiments were all master students majored in colour vision, colour science and technology. They were all tested for normal colour vision using Ishihara plate and normal or corrected-to-normal spatial acuity before the experiment. Prior to the actual test all of them achieve some experience of threshold test and were trained with the actual tested grating and procedure for twice or third.

3 Results

Experimental results was described as Fig.1 by lots of measurements, which reflected how contrast sensitivity (the reciprocal of contrast threshold values) under the lightings and dark room viewing conditions changed with spatial frequencies, and compared the contrast sensitivity under the lightings viewing conditions with one under the dark room viewing conditions. It could be found that observers were the most sensitive to patterns under the lighting viewing condition with luminance of 312cd/m^2 in three kinds of lightings when viewing patterns with average luminance of 60 cd/m^2, and when viewing the patterns with average luminance of 90 cd/m^2, contrast sensitivity was reduced with luminance of lighting increasing, and all contrast sensitivity under lightings condition was much lower than one under dark condition from the Fig.1.

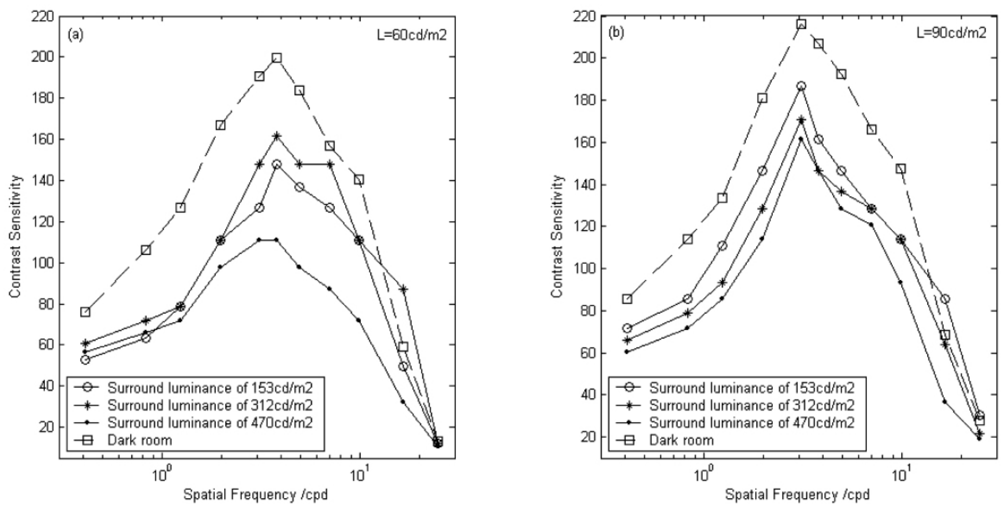

Fig.1 Contrast sensitivity under three kinds of lightings and dark room viewing condition.

4 Discussion and Conclusions

The reason could be obtained that observers were more sensitive to view patterns under the dark room condition than did under the lightings viewing condition by analyzing the experimental results. When viewing the patterns under the lightings condition, the screen of display reflected the light that made observers feel pattern lighter, but the difference value between Ldark and Lbright kept constant in same pattern, while the sum of them increased, that's to say, actual contrast sensitivity of pattern was smaller than one computed. While actual contrast sensitivity couldn't be obtain, only got computed one. What's more, it was reflected that the bigger viewing ambient luminance was, the bigger contrast detection threshold was. Increased contrast threshold viewed under the lightings condition compensated the threshold affected by ambient luminance. But by far it haven't been known why observers felt the most sensitive to patterns under the lighting viewing condition with luminance of 312 cd/m^2 in three kinds of lightings when viewing images with average luminance of 60 cd/m^2 from Fig.1, which still needed go on researching by more experiments.

Part of the study about the contrast sensitivity of human vision system under different viewing ambient conditions was carried on abroad[4-12]. In the study of Youn Jin Kim, M. Ronnier Luo and Peter Rhodes,et al, eight neutral patches displayed on a mobile display were visually assessed under a dark and an outdoor ambient viewing condition. Those data were used to establish the contrast sensitivity function (CSF) under the outdoor condition, and it was verified by the results measured using the contrast threshold detection method. The results was described as figure 2[4]. Cox, Webster and Norman, et al had done much research on it [5], who adopted the photograph of the apparatus to use for measuring the contrast sensitivity to Pelli-Robson letter targets, as a function of surround luminance of 5.6, 9, 30, 90, 300, 900 cd/m^2, in order to study how contrast sensitivity changed with the surround luminance when tested at a viewing distance of 4m and 1m (Fig.3) by the statistical significant method. But their results only showed difference and change

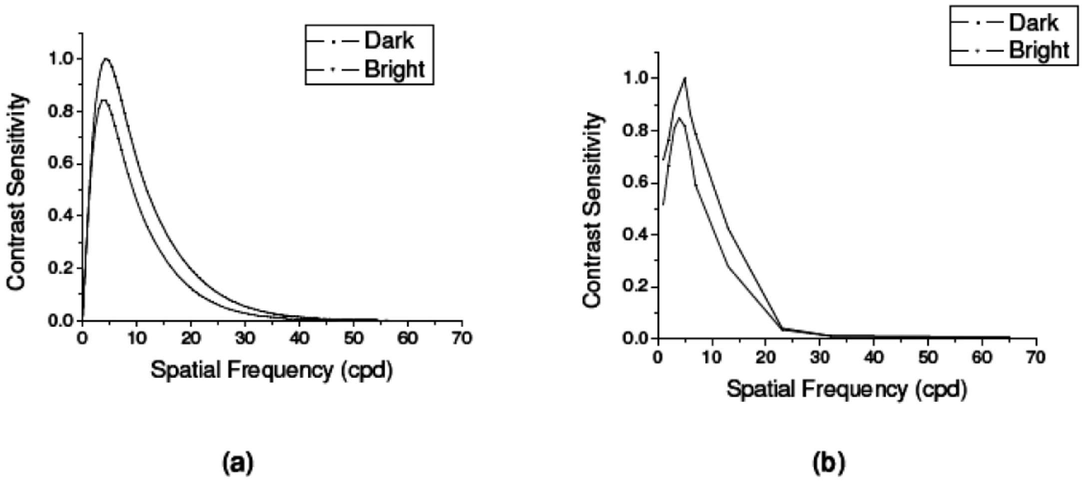

Fig.2 The CSFs experimental results, (a)the CSFs obtained using the perceived brightness magnitude estimation, (b) the contrast threshold detection measured under dark viewing condition (the upper curves) and outdoor viewing condition (the lower curves)

trend. And Fig.3 showed also that the higher ambient luminance was, the lower the levels of contrast sensitivity produced. It was similar to the result of Fig.1. They resulted in the experiment that the effect of the ambient luminance was greater when measuring contrast sensitivity to sine-wave gratings using a method of constant stimulation, optimum performance was found using a ambient luminance of 9 cd/m² (20% of the mean target luminance), and that a wide range of ambient luminance (3-30 cd/m² or 7-67% mean target luminance) gave similar levels of visual performance, but higher luminance surrounds led to contrast sensitivity reduced, statistically. Analyzing the results of Fig.1, Fig.3 and Fig.3, they was much similar, but had also difference. Possible reasons for the difference between Fig.1 and Fig.3 might be different on the experimental parameters and experiment instrument. But possible reasons for the difference in the effect of surround depending upon the test were discussed further.

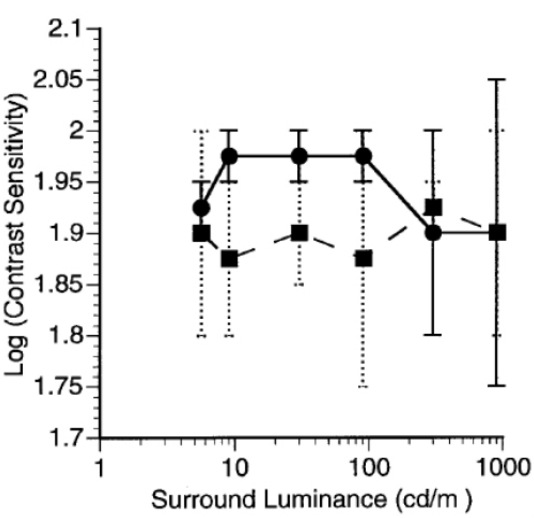

Fig.3 The mean of the log(contrast sensitivity) measurements for the two subjects when tested on the Pelli-Robson chart as a function of the surround luminance. ● and solid line-testing at 4 m. ■ and the dashed line-testing at 1 m. Error bars show ± one standard error.

Acknowledgements

This work is funded by grants from the National Science Foundation of China(grant number:10447005), and also funded by grants from the scientific research plan projects of Shanxi Province Education Department, China(grant number: 2010JK464). The authors would like to thank Huang XQ, Shuai C J, Shen J, et al., who participated in many experiments.

References

[1] Yury Petrov. Luminance correlations define human sensitivity to contrast resolution in natural images [J]. J. Opt. Soc. Am. A., 2005, 22(4): 587-592

[2] Mullen K T. The contrast sensitivity of human colour vision to red-green and yellow- blue chromatic gratings[J]. J. Physiol, 1985, 359:381-400

[3] Straw A D, Rainsford T, David C and Carroll O. Contrast sensitivity of insect motion detectors to natural images[J]. Journal of Vision, 2008, 8 (3):1-9

[4] Kim Y J, Luo M R, Rhodes P A, et al. Measurement of perceived brightness and contrast sensitivity for outdoor condition [C]. Proceedings of the 26th session of the Commission International de L'Eclairage, 3A-48-3A-51, Beijing, China, 2007

[5] Cox, M J, Norman J H, Norman P. The effect of ambient luminance on measurements of contrast sensitivity[J]. Ophthal. Physiol,Opt.1999, 19 (5):401-414

[6] Wester M A. Contrast sensitivity under natural states of adaptation[C]. SPIE, California, 1999, 3644:58-69

[7] Yao Jun-cai. Measurements of human vision contrast sensitivity to opposite colors using a cathode ray tube display [J]. Chinese Science Bulletin, 2011, 56(23):2425-2432

[8] Eva M V, Juan L N, Jose A G. Changes in contrast thresholds with mean Luminance for chromatic and luminance gratings: A re-examination of the transition from the DeVries-Rose to Weber regions [J]. Colour research and application, 2004, 29(3):177-182

[9] Sarah L. Elliott, Stacey S. Choi, Nathan Doble, et al. Role of high-order aberrations in senescent changes in spatial vision[J]. Journal of Vision, 2009, 9(2):1-16

[10] M Nadenau. Integration of human colour vision models into high quality image compression[D]. PhD thesis, école Polytechnique Fédérale de Lausanne, Switzerland, 2000
[11] Wenzel K, K Ladunga and K Samu. Measurement of color defective and nomal color vision subjects' color and luminance contrast threshold functions on CRT [J]. Periodica Polytechnica Ser. Mech. Eng., 2001, 45(1):103-108
[12] 蒋丽珠, 黄菊芳, 曾乐平. 视觉电生理技术在青光眼早期诊断中的应用[J]. 现代生物医学进展, 2007, 7(2):287-289
Jiang Li-zhu, Huang Ju-fang, Zeng Le-peng. Application of Visual System Electrophysiology Technique in Diagnosis of Early Glaucoma [J]. Progress in modern biomedicine, 2007, 7(2):287-289
[13] 姚军财, 申静, 王剑华. CRT 显示器亮度范围内对人眼视觉特性的实验研究[J]. 物理学报, 2008, 57(7):4034-4041
Yao Jun-cai, Shen Jing, Wang Jian-hua. Experimental research of human vision characteristic in the range of luminance of cathode ray tube display[J]. Acta Physica Sinica, 2008, 57(7):4034-4041

用显示器测量办公亮度环境下的人眼对比度敏感视觉特性 *

姚军财
(陕西理工学院物理与电信工程学院 陕西 汉中 723000)

摘要：对比度敏感是描述人眼视觉系统空间特性的主要指标之一，对比度敏感函数是反映不同条件下的对比度敏感与空间频率之间的关系。人眼对比度敏感数据的测量受到环境亮度较大的影响，为了研究常用办公环境条件下的人眼对比度敏感情况，对 6 位青年在环境亮度分别为 153, 312, 470 cd/m² 和暗室条件下，在距离为 2 米处观测 11 种空间频率的矩形光栅进行测量，光栅用显示器进行显示，其平均亮度分别为 60 和 90 cd/m²。实验结果表明，对于相同频率的光栅，人眼对比度敏感程度随着环境亮度的增加而减小，而且人眼在暗室环境下比在办公环境条件下对亮度光栅更敏感；但是在观测平均亮度为 60cd/m² 的光栅时，人眼特殊地对在环境亮度为 312 cd/m² 的条件下更敏感。

关键词：人眼视觉系统；对比度敏感函数；亮度；阴极射线管显示器
中图分类号：Q632 文献标识码：A 文章编号：1673-6273(2012)14-2663-05

* 基金项目：国家自然科学基金项目(10447005)；陕西省教育厅专项科研基金项目(12JK0959)；陕西省自然科学基金项目(2011JE012)
作者简介：姚军财(1979-)，男，讲师，硕士，主要从事眼视觉光学和光电图像方面的研究
E-mail: yjc4782@126.com
(收稿日期：2011-10-11 接受日期：2011-11-05)