Optik 126 (2015) 4887–4889

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Study of healthy light-color parameters for LED lighting

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ARTICLE INFO

Article history:
Received 27 November 2014
Accepted 27 September 2015

Keywords:
LED
Lighting environment
Color temperature
Illumination

ABSTRACT

Twelve kinds of luminous environments were set up with white LED light source by changing the color temperature and illumination. Using feel discriminative index and the reaction time as the evaluation index, the effects of different luminous environments on human psychological feelings were researched, based on Signal Detection Theory and open windows. The results showed that lighting environment with 6000 K, 300 lx should be recommended in the indoor lighting.

1. Introduction

As one new lighting product, the optical and chromaticity characteristic of LED has a large difference with the other light sources. When applied to the indoor lighting, it cannot be evaluated and used by the standards of traditional light sources. So it has great significance to explore the healthy-lighting parameters of white LED when using in indoor lighting [1,2].

The research of the "healthy lighting" has become a hot topic after "citopic" was found in 2002 [3]. But most of the research mainly focused on traditional light sources, and even to the traditional light source, there are different conclusions. For example, Hao Luoxi showed that 6500 K is the best color temperature for reading and other learning activities [4]. However, Yan Yonghong showed that 4000 K is the better color temperature [5].

In this paper, the effects of different luminous environments of white LED on human psychological feelings were researched, based on Signal Detection Theory and open windows. Our results showed that color temperature is 6000 K, illuminance is 300 lx.

2. Theory and experiment

2.1. Signal detection theory

Signal detection theory (SDT) is a psychophysical method. It is about how to make a decision when people are in an uncertain situation. In SDT experiments, using feel discriminative index d to represent the induction ability. The changes of the external environment can cause the changes of psychological conditions, so feel discriminative index d can accurately reflect the impact of psychological being tested in different light situations.

The discrimination index d is given by:

$$d = Z_{\text{hit}} - Z_{\text{false alarm}} \quad (1)$$

where Z_{hit} and $Z_{\text{false alarm}}$ respectively represent the Z values of the hit probability and the false alarm probability. The larger the value of d indicate the better susceptibility, otherwise susceptibility is poor.

In our experiment, the material of SDT use C, P, S, T, V, X to make a 9 letters meaningless alphabetic string. The letter string's position of 3, 5, 7 is SCT means signal, others are noise. For example, CVSCCXTSX is signal; PCXXSSTXC is noise. At test phase, there are 60 strings, including 40 signals and 20 noises. Subjects were asked to make a choice reaction of signal and noise. The section headings are in boldface capital and lowercase letters.

2.2. Open windows

Open windows is a method to measure reaction time in psychology. From the reaction time, we can see three stages process: encoding phase, conversion phase, storage phase. Open windows can directly measure each experimental time of stage process, and can clearly present these phase process.

Luminous environments' variation can cause physical and psychological conditions' variation, and thus will affect the subjects' reaction time. So reaction time can be used as an important evaluating factor in psychophysics scale. The result of open windows is represented by the reaction time, the shorter the time, the more

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http://dx.doi.org/10.1016/j.ijleo.2015.09.212
0030-4026/

rapid the response, which means the psychological state is good at that lighting environment.

In the open windows experiment, subjects are presented 6 letters and a number which is behind the letters, such as "FORJCQ +3". Subject's task is to say the third position letter behind the each given letter. The six letters of the conversion must be speak out together. The speed of letters are controlled by the subjects, one after one. The complete time will be recorded.

2.3. Experiment

The experiment choose three color temperatures, 3000 K, 4000 K and 6000 K, the desktop illumination levels is adjusted to 300 lx, 500 lx, 750 lx, 1000 lx, uniformity of desktop illumination is greater than 0.7. The subjects selected 8 undergraduates, 4 boys and 4 girls, and binocular correction vision are above 5.0. The subjects were divided into 4 groups and the time of each experiment is 45 min. All experiments were carried out at night 18:00–21:00 in order to exclude natural light completely.

The subjects were trained to be familiar with experimental procedures and methods before each experiment. After subjects fully understand the experimental methods, do the formal experiments as follows: the subjects get into a particular lighting environment to adapt 5 min, and then start the SDT experiment and the open windows experiment. After one test is completed, the subjects have a rest time about 10 min, and then do the next round of testing in the same way.

3. Experimental results

3.1. SDT

Fig. 1 shows the feel discriminative index under the same color temperature but different illumination. It showed that the sensitivity of the subject's feelings change with different color temperature and no fixed rule to follow. When the color temperature is 3000 K, the discriminative index is maximum at 300 lx; when the color temperature is 4000 K, 1000 lx is the most sensitive value, but 300 lx is the worst sensitive; when the color temperature is 6000 K, 300 lx is the most sensitive, and susceptibility is worst at 1000 lx.

Fig. 2 shows the feel discriminative index under the same illumination but different color temperature. As we can see, the sensitivity of the subject's feelings change with the illumination and no fixed rule to follow. When the desktop illuminance is 300 lx, the discriminantive index is maximum at 3000 K, while the worst sensitivie value is at 4000 K; When illuminance is 500 lx, 3000 K is the best color temperatuer; when illuminance is 750 lx, 6000 K is the best color temperature; when illumination is 1000 lx, 4000 K is the best color temperature.

From the experimental results of SDT, the five luminous environments should be preferred which is 3000 K–300 lx, 3000 K–500 lx, 4000 K–1000 lx, 6000 K–300 lx, 6000 K–750 lx, while the 3000 K–750 lx, 4000 K–300 lx, 6000 K–1000 lx lighting environments should be avoided.

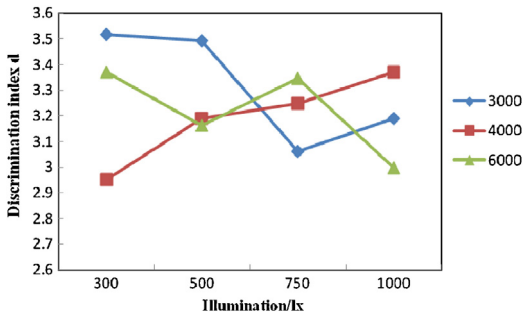

Fig. 1. The discrimination index under same color temperature but different illumination.

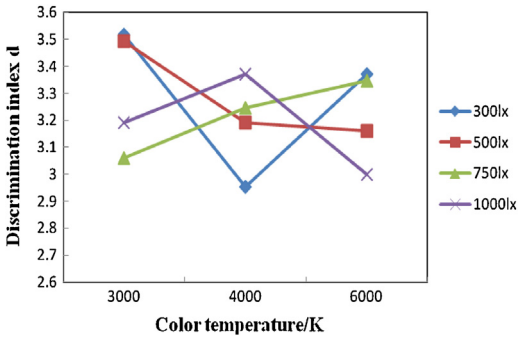

Fig. 2. Discrimination index under same illumination but different color temperature.

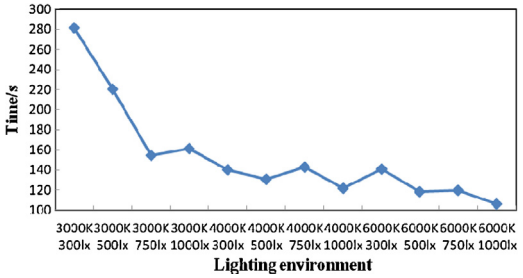

Fig. 3. The average response times under the 12 lighting environments.

3.2. Open windows

Fig. 3 shows the average response times under 12 lighting environments. The results showed that the reaction time has some regularity with color temperature and illumination. In the case of a fixed color temperature, reaction time increase with illumination value decreasing. In the case of a fixed illumination, the reaction time decrease with the color temperature increasing. From the experimental results of the open window, the two conditions of 3000 K–300 lx, 3000 K–500 lx, should be avoided, the other light environments can be selected.

4. Conclusion

The research was carried out the effects of different luminous environment on human psychological feelings based on Signal Detection Theory and open windows. The experiment set up 12 kinds of luminous environment.

Using feel discriminative index and the reaction time as the evaluation index, the effects of different luminous environment on human psychological feelings were researched. The follow suggestions were proposed based our experimental results: (1) the 3000 K color temperature should be avoided; (2) For the color temperature of 4000 K, the best illumination recommended value is 1000 lx, but 300 lx should be avoided; (3) For the 6000 K color temperature, the best recommended illumination is 300 lx or 750 lx, but the 1000 lx should be avoided. Considering two kinds of experimental results, lighting environment with 6000 K, 300 lx should be recommended in the indoor lighting.

Acknowledgements

This work was financially supported by scientific research project of Liaoning Province (L2012184), Youth Fund of Dalian