EFFECT OF FLUORESCENT LIGHT SOURCES ON HUMAN CONTRAST SENSITIVITY

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Abstract

In our current research our aim was to analyze the human visual effect of commercially available fluorescent light sources with similar photometric parameter. Achromatic and chromatic contrast sensitivity tests were used in human subjects to evaluate the effect of the lamps. We have encountered differences using several spatial frequencies and stimulus types. This suggests that the perceived contrast can be significantly different with the observed object properties (color and spatial frequency) and with the spectral parameters of the light source used for illumination. As a conclusion we can state that based on our research results the contrast sensitivity tests are adequate for the evaluation of the effects of fluorescent light sources on human vision.

Keywords: Fluorescent illumination, human vision, contrast sensitivity, psychophysical tests

1 Introduction

The characterization of general and task illumination from the aspect of human vision is getting more and more important when designing lighting systems. As the knowledge on human visual functions is generally available in details in the scientific publications (Gegenfurtner, 1999; Kaiser, 1996; Mollon, 2003; Deeb, 2006, etc.) today there arouse a demand to apply them in lighting research and development. Several research groups (Ohno, 2009, Viénot, 2009; Fotios, 2009; Stockmann, 2009, etc.) deal with human psychophysical measurements to verify the classical parameters of lighting conditions and to generate new ones for their better characterization.

Our previous research activities targeted several aspects of this issue addressing visual clarity (Toth, 2009) and perceived brightness under different fluorescent illuminations along with testing the effect of lighting on the colour vision of colour deficient subjects (Nagy, 2010). To continue our preceding research work we applied human contrast sensitivity tests (Kachinsky, 2003) for the characterization of the ambient and task illumination. Until today few research groups have studied the effect of illumination on contrast sensitivity and they mainly focused on the surround illumination levels when carrying out human contrast tests (Cox, 1999; Vizmanos, 2004) or controlling pupil size with large differences in the surround spectrum (Berman, 1996).

Our intention was to start from the other end meaning the use of contrast sensitivity tests (Samu, 2001) in the evaluation of how different illuminations affect the human contrast sensitivity function (CSF). Moreover we targeted to understand better the effect of light sources having similar but not equal photometric parameters and spectral characteristics.

2 Methods

In our test setup we have used different light sources illuminating typical CSF patterns in illumination environments with similar luminance conditions.

2.1 Light sources

In order to set up reference values for our tests first we have ran preliminary measurements using halogen incandescent illumination compared to a fluorescent type of 3000K.

In the second test series we have applied three fluorescent lamp types from different manufacturers with similar correlated colour temperatures (3918K for the ‘o’, 4141K for the ‘p’ and 4305K for the ‘l’ lamp respectively). The spectral characteristics of the sources were measured by means of a Konica-Minolta CS-10000 spectroradiometer. According to the specific spectral emission peaks we can state the all three types had generally similar phosphor coatings while the ratios of the various phosphor materials have been responsible for the spectral differences. The ‘p’ and ‘l’ type sources seem to be more similar while the ‘o’ type has shown relatively larger spectral differences. Table 1. shows the basic colorimetric parameters of the light sources determined from their SPDs.

Table 1. Colorimetric parameters of the three fluorescent light sources

	x	y	CCT	CRI	CQS
o	0.3854	0.3834	3918	80	79
p	0.3741	0.3716	4141	77	76
l	0.3714	0.3852	4305	78	78

2.2 Test setup

In the measurement setup we applied printed test patches using computerized (ICC) color management protocols to generate achromatic (black/white) and chromatic (red/green and blue/yellow) sinusoidal gratings (Fig. 1) while maintaining saturation and brightness for the latter ones. Applying five different spatial frequencies and twenty-six contrast levels ranging from 1 to 100% we aligned the light sources to achieve uniform illumination on the test patches. Photometric parameters were measured by means of standard instruments. The positioning of each light source type was carried out to reach similar luminance levels (135 ± 5 cd/m^2 as measured on the white background).

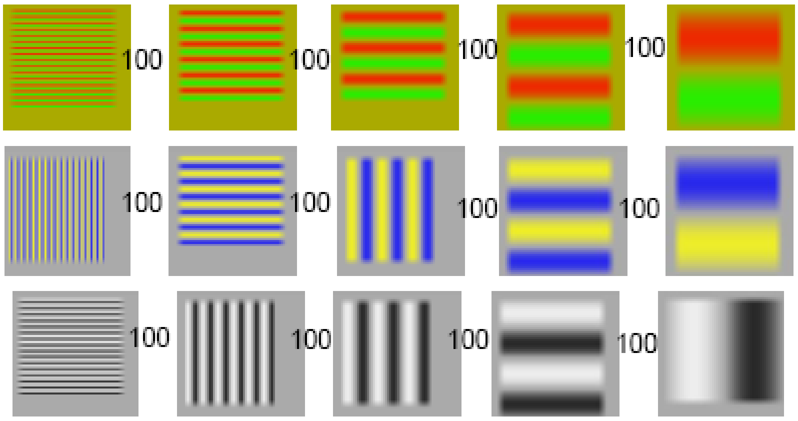

Figure 1. Achromatic and colour test conditions at all five spatial frequencies at 100% contrast level

The test subjects sat 3 m distant from the test patches and were adapted to the specific illumination for at least 8 minutes observing the white background of the test. The task for the observer was to consecutively look at a given spatial frequency and name the last distinguishable contrast level. For this each contrast pattern was labelled with a number. This way we could determine the threshold for each test condition. The threshold detection test was repeated for each lamp type separately. 15 human subjects with visual acuity at least 20/20 were tested and their thresholds were recorded.

3 Results

3.1 Reference test

Our preliminary study comparing contrast sensitivity under illumination of an incandescent and a 3000K fluorescent light source has indicated that there are differences in the CSF in both colour contrast tests (Fig. 2). The differences were statistically significant in some cases for the red-green and the blue-yellow conditions at 95% significance level, while no significance has been found for the achromatic conditions.

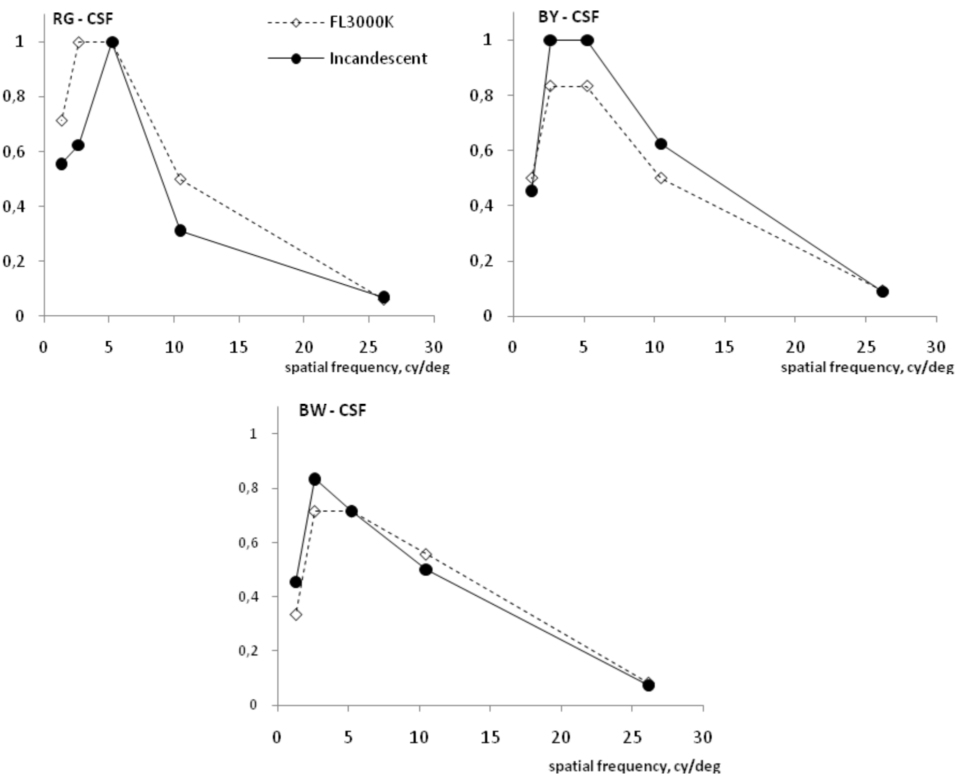

Figure 2. Contrast sensitivity functions for the Red-Green, Blue-Yellow and Achromatic (Black-White) experimental conditions comparing incandescent lamp with a 3000K fluorescent lamp

3.2 Testing fluorescent sources with similar CCT

Figure 3 shows the results of the contrast sensitivity tests of for the red-green, blue-yellow and achromatic gratings with three fluorescent light sources of 3918K for the 'o', 4141K for the 'p' and 4305K for the 'l' respectively.

In general the measured contrast sensitivities show slight differences between the three fluorescent illuminations. The highest tendencies of differences appear in the red-green contrast sensitivity mostly at the lower spatial frequencies where they are statistically different at spatial frequencies of 1 and 2 cy/deg for 'p' compared to 'l'.

The blue-yellow and achromatic tests show significantly less deviations among the fluorescent illuminations, however statistically significant differences can be observed in the peak sensitivity region at some spatial frequencies.

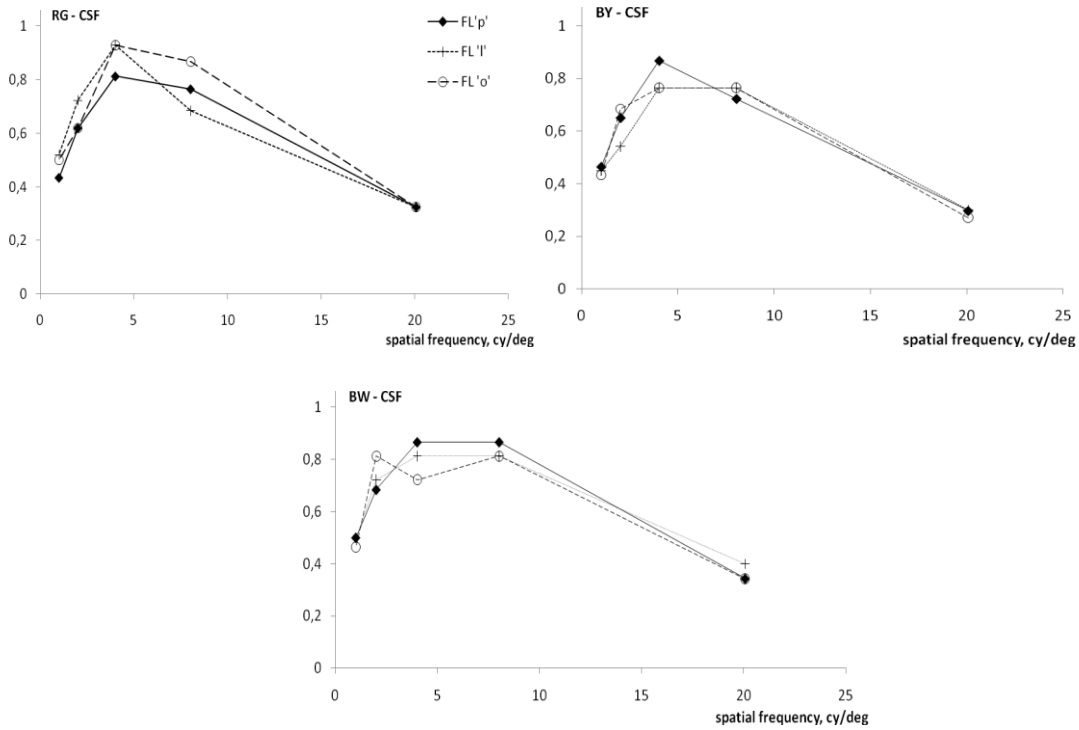

Figure 3. Contrast sensitivity functions for the Red-Green, Blue-Yellow and Achromatic (Black-White) experimental conditions comparing three different fluorescent lamp types of similar correlated colour temperatures

4. Discussion

Although the results have relatively large standard deviations as expected in human psychophysical measurements, some tendencies in differences can be observed. The incandescent illumination clearly affects colour contrast sensitivity in a different way when compared to fluorescent illumination showing that spectral emission shall affect colour contrast perception.

The differences between fluorescent illuminations differing slightly in their spectral power distributions appeared mainly in the red-green colour contrast test at the lower spatial frequencies. The colorimetric parameters (Table 1.) such as the CCT and the differences in spectral power distribution do not seem to directly correlate with contrast perception as the largest CSF differences were detected between the two lamps having smaller differences in their colorimetric parameters.

However if we calculate the red-green opponent signals based on the difference between the 'L' and 'M' human photoreceptors spectral sensitivities (Gegenfürtner, 1999) weighted with the specific illuminant (Toth, 2009) and look at their ratios for the red and the green stimuli we get ratios of 2.51, 2.37 and 2.90 for the 'o', 'p' and 'l' lamp types respectively. This result seem to support the findings of the statistically significant RG CSF differences at the lower spatial frequencies between lamps 'p' and 'l', however it doesn't explain the smaller differences at higher spatial frequencies. By all means there seems to be a need for further investigations and search for new parameters to describe our findings.

In summary our study's main goal, namely to use contrast sensitivity tests in light source evaluation can be considered successful. The achievements of this work shall inspire further measurement series using more developed CSF test setups and involving different light sources in order to understand human colour vision better and to apply the test results in practical solutions following today's increasing demand to optimize lighting ambience for human perception.

Acknowledgment

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