The experience of ambient light from common light sources with different spectral power distribution – Light emitting diodes (LED) vs. 3-phosphorus fluorescent tubes (T5)

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Abstract

It is now shown that light influences different hormones in the brain where the pineal gland plays an important role in controlling the sleep hormone melatonin which is provided to the blood in the body at low light levels or in darkness particularly when the eye is dark adapted. At high light levels the stress hormone cortisol is produced by the adrenal cortex which contributes to alertness.

During the last years a lot of studies have been carried out on how the spectrum of the light (daylight and artificial) affects humans in the hormone suppression and light distribution in the visual field brings emotional effects to the human being.

New legislations on the use of energy and findings in research will and have already created new more efficient lighting systems which are optimal for vision as well as for the human health.

The new light source LED shows a different spectral distribution in comparison to fluorescent tubes. The most widely used LED has an increase high irradiance in the short-wave area compared to other common light sources used in indoor lighting applications.

This may have an impact on the experience of the brightness of the ambient light in indoor lighting in the photopic vision where colour vision is possible because we have red, green, and blue sensitive cones and maximally active with adaptation luminances larger than about 3 to 10 cd/m². The spectral sensitivity of photopic vision is characterized by the Vλ (lambda) curve.

Further more for outdoor lighting a Technical committee (TC 1-58 “Visual performance in the mesopic range”) of the International Lighting commission and CIE, both parties are working to define a unified system of photometry for mesopic vision. In a Technical report CIE191-2010 CIE shows a recommended system for mesopic photometry based on visual performance at adaptation levels between approximately 10 and 0.0003 cd/m² both the cones and rods are active.

A table for common light sources with different spectrum power distribution of the light shows a difference between mesopic and photopic luminances (%) calculated with the recommended mesopic system.

This abstract shows a comparison of the subjective experience between indirect light from LED and T5-fluorescent tubes at different ambient light levels in an indoor office environment. The test was conducted as a laboratory study containing 50 subjects, ranging from 18 to 68 years of age.

The experience of the environment was measured by using semantic scales. Furthermore the experience of the lighting situation was conducted by means of semantic scales.

The results show no difference in the perception of the room. However, the results show that the LED light is perceived as brighter as and also better to see in than in the situation with fluorescent tubes. The results indicate that lower light levels may be recommended when using LED as light source.

The aim of the present study was to investigate whether ambient light in the normal field of view was experienced as brighter at luminance levels of 100 and 300cd/m² on the walls comparing Solid State
Two hypotheses were stated:

- Ambient light from the LED may be experienced as more bright than the light from the fluorescent tubes.
- Ambient luminance levels up to 300\(\text{cd/m}^2\) may not be experienced as glaring from neither light source.

Results were investigated in terms of:

- Room appearance
- Experienced brightness
- Experienced lighting quality
- Biological aspects – hormone analyses on cortisol

**Experimental design and methods**

The experimental sites were arranged as two equally equipped office rooms with the following dimensions; width=4900 mm, length=2700 mm and room height=2700 mm.

Each room was equipped with a desk and a chair and the desk was provided with flat display screen equipment (LCD) and some magazines for reading. A clock was positioned in the corner at the upper the side of the front wall. There were no other decorations in the room.

![Design of test room 1 and 2](image1)

The ceiling consisted of diffuse white panels with a reflectance of 82\% and the walls were painted with diffuse light broken white (NCS 0502-Y) with a reflectance of 84\%. The rooms were windowless and had no penetration of daylight. The glass doors were equipped with a non translucent curtain to avoid any spill light from the outside.

Two equal rooms were used for the study and the lighting was distributed indirectly from the room surfaces in the subject’s normal field of view.

Test room 1 was equipped with 3-phosphorous fluorescent tubes (T5) with CCT 4000 K a recessed dimmable luminaire was mounted above the workplace in line with the front of the desk in order to provide task lighting and to avoid reflections. The luminaire was equipped with two 54W T5 tubes (2x54W).

The ambient light from the front wall of the subjects was achieved by three wall washers with asymmetric light distribution. In test room 1 with \(\approx 100 \text{ cd/m}^2\) the wall washers were equipped with 3x(1x28W) T5 tubes and at \(\approx 300 \text{ cd/m}^2\) all wall washers were equipped with 3x(2x54W).

Test room 2 was equipped with Solid State Lighting (LED) with CCT 4000 K as follows:

Five recessed dimmable LED luminaires were mounted above the workplace in line with the front of the desk with symmetrical light distribution equipped with a LED module of type Philips Fortimo 1100 lm, 4000K.

The ambient light of \(\approx 100 \text{ and } 300 \text{ cd/m}^2\) in front of the subjects was achieved by nine dimmable recessed LED wall washers with asymmetrical light distribution equipped with a LED module of type Philips Fortimo of 2000 lm, 4000K.

![Picture of test room 2 equipped with Solid State Lighting (LED) 4000 K](image2)
Before any tests were carried out light sources had burned in for at least 100 h and before each test session the lamps were on for at least one hour.

The spectral irradiance from the different light sources as well as from the indirect perceived light was measured and evaluated using a spectroradiometer Avaspec 2048, Avantes.

![Fig 2: The spectral irradiance from T5 4000 K](image1)

![Fig 3: The spectral irradiance from LED 4000 K](image2)

![Fig 4: The spectral irradiance from direct light from LED vs indirect light from room surfaces](image3)

Subjects

50 subjects were selected to participate in the study based on the screening criteria and partly in order to obtain a suitable distribution of age and gender. However eight subjects had to be discarded due to different reasons, such as illness or severe headache. The remaining group consisted of 19 women and 23 men between 18 and 68 years of age (m=43, SD=18). The group represented a variety of occupations both blue-collar workers and white-collar workers. 31 subjects wore glasses and 5 used contact lenses.

Statistics

The statistical treatment of data was mainly conducted by means of analysis of variance SPSS: MANOVA, either with a simple factorial design or with a design including repeated measures and both within-group and between-group variance. Both these designs allow for analysis of covariance. Tests were carried out for all main effects and interactions. Statistical level of significance were set to p<.05, and with a tendency at p<.10. In a few cases missing values were replaced with individual means. This will not influence group differences but, for the repeated measures may tend to reduce the variations.

Results

Room appearance

The two test rooms in the two different ambient lighting conditions were perceived quite neutral. The rooms were perceived neither pleasant nor unpleasant, neither complex nor much unified. There were no significant differences between the perceptions of the two kinds of light sources.

Experienced brightness

In general the results show that the experienced brightness from LED was significant higher in both ambient light levels than from T5 tubes. Differences in experienced light intensity between T5 4000K vs. LED 4000K at different ambient light levels, p=.034. Furthermore, the difference in brightness increased at the highest ambient light level.
Experienced lighting quality

There was a tendency to experience the light from LED as better than from the T5 tubes (p=.07) at 100cd/m². However, the lighting quality was reduced for LED at the higher ambient light level, although not significant.

Biological aspects - Hormone analyses

The cortisol levels showed a significant increase when the ambient light from the different room surfaces was increased from 100 cd/m² to 300 cd/m² at all three times measured over the whole day. Differences in cortisol levels during the day and between the two ambient light levels (p=.000, p=.044 N=42). No significant differences were found between T5 4000 K and LED 4000 K.

Discussion

Lighting quality and energy efficiency will be an essential part in future lighting design. In order to provide lighting quality, ambient lighting plays an important part. Several studies have shown that ambient lighting affects people positively and is also a necessary part in energy efficient lighting design (Loe, 2003, Govén et al, 2011). This study shows that ambient lighting provided by LED may be more efficient without decreasing lighting quality.

The results indicate that there are differences in the experience of brightness from reflected light from interior surfaces between LED used in this study and T5 tubes. This is due to the differences in the spectral distribution in the shorter wavelengths. This must be considered while evaluating measured photometric data.

Regarding effects on lighting quality, LED was experienced as most positive at 100cd/m², then at 300cd/m². LED and the T5 tubes was experienced equal in lighting quality. This imply that levels around 100cd/m² seems to be the most appropriate ambient light level using LED with a horizontal task illuminance of 500lux (130 cd/m²). However, at higher luminance levels on ambient lighting above 300cd/m² there is a risk that LED may be experienced as more glaring than light from T5 tubes.

Our results show an increased positive experience of T5 tubes from 100cd/m² to 300cd/m² but the experienced quality of LED lighting declined at 300cd/m².

Using ambient light in indoor lighting application there may be a possibility to reduce lighting levels in the same way as in outdoor applications using an experienced brightness correction factor between LED another common used light sources. This has to be further investigated in future studies.

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