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ASPECTS AND IMPAIRMENT OF VISUAL FUNCTIONS AS A RESULT OF TEMPORARY BLINDING FROM HIGH BRIGHTNESS LEDs

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INTRODUCTION

In addition to the compliance with the specified exposure limit values indirect effects like temporary blinding have to be included in a risk assessment when utilizing or working with sources of optical radiation. Since modern high brightness LEDs (HB-LEDs) are capable to produce remarkable glare and dazzling effects in the human eye it is essential to determine the various effects and to identify functional dependencies between the applied light intensity and the various visual functions.

METHOD

Different test procedures have been developed and applied in laboratory tests in order to improve the current knowledge on temporary blinding from bright optical sources. In detail the main investigations given in table 1 have been performed in order to determine the quantitative effects associated with blinding from HB-LEDs in the working environment or in lighting applications.

Table 1. Various tests in order to determine temporary blinding from HB-LEDs

Size of an after-image as a function of time
Determination of visual acuity and inability to read after irradiation
Determination of the time dependence of colored after-images
Color and contrast sensitivity as a result of colored after-images due to glare

As optical sources mainly HB-LEDs Luxeon Star Hex or III Star (Red (625 nm or 638 nm), Amber (590 nm), Green (530 nm) and Royal Blue (455 nm)) and a Luxeon Star Batwing DS23 (white LED) have been used. The optical power ranged between 0.0045 mW and 3.96 mW, measured in a 7 mm aperture, and the exposure durations were between 1 s and 20 s, depending on the respective sub-study.

The test persons viewed into a reasonably collimated beam from the LED device and the respective task was performed immediately following the exposure. For this either the volunteers had to find the correct after-image diameter as a function of time by means of comparison with a fixed circle on a monitor or the duration of annoyance, i.e. the inability to read, after an irradiation with a white high-brightness LED was determined. In this case the subject had to read an unknown text from a distance, which was appropriate to read without difficulties, after the irradiation. Visual acuity was determined with colored HB-LEDs too.

In order to identify the flight of colors after an irradiation with a HB-LED a discrete color circle, consisting of 10 radial steps with a brightness decrease of 7 % and 24 azimuthally steps was developed and the after-image color trace according to the respective RGB-values was recorded with a computer and displayed in a chromaticity diagram.

The color and contrast sensitivity was determined with specially designed test charts based on the Pelli-Robson contrast sensitivity chart, but instead of Sloan letters colored Landolt C-rings were used as optotypes with 8 steps in contrast sensitivity between 11 % and 1 %. In addition 4 different Ishihara plates (Pseudoiso-chromatic plates) were chosen in order to find functional connections between the irradiating light and the respective color plate and to determine the temporary color deficiencies due to glare.

RESULTS

A total of 90 subjects have been tested concerning the impairment of different visual functions after altogether 935 irradiations involving temporary blinding. First preliminary results have been reported in [1]. In the meantime the research project has been finished.

The size of an after-image on the human retina as a function of time was found in 13 subjects in 23 irradiations to remain nearly constant with a slight decrease over a time duration of about 12 minutes, whereas the initial visual acuity is recovered within 30 up to 60 seconds.

Visual acuity recovery time was found to obey a dose-relationship as shown in fig. 1.

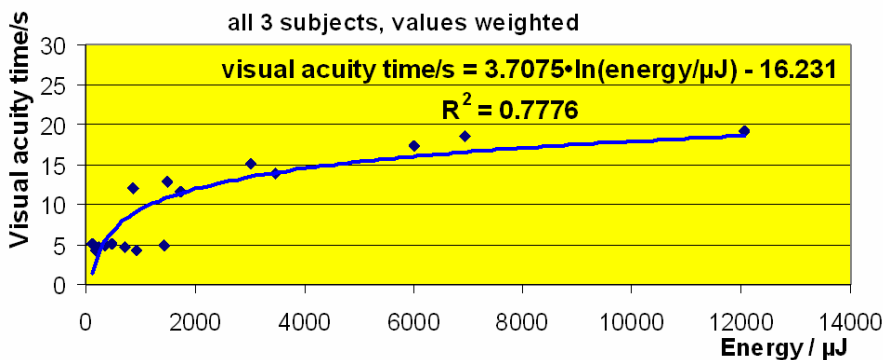


Fig. 1. Visual acuity time after irradiation with a green HB-LED as a function of optical energy; diamonds: 48 single measurement values

The results of the reading test showed that the annoyance duration does not depend very much on the applied optical power in the investigated power range up to a few milliwatts, but was found to be inter-individually different for the 7 tested subjects (249 irradiations). The disability to read increased slightly as a function of exposure duration between 1 s up to 20 s.

The well-known phenomenon of the flight-of-colors was investigated with 13 subjects in 223 trials with optical powers of 0.05 mW and 0.5 mW after an irradiation of 0.5 s or 5 s. Fig. 2 shows a representative progression of colors after an irradiation with a green HB-LED.

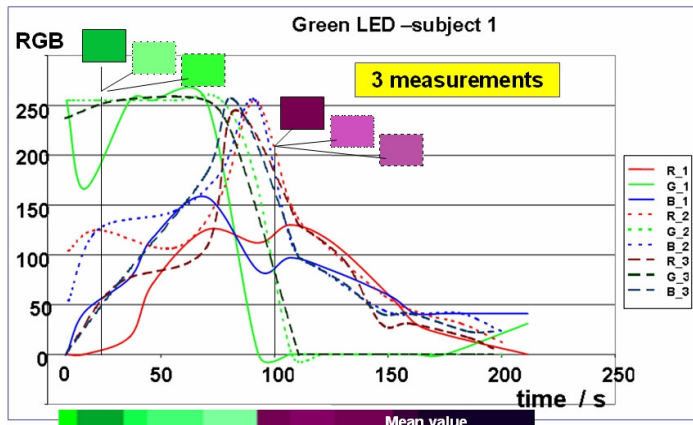


Fig. 2. Perceived colors after irradiation with a green HB-LED, 3 successive measurements

It was found that a clear dependence on LED color exists and that different subjects perceive colors differently. In addition the perception starts with variable delay and the duration of afterimage/flight of colors is different.

Color and color contrast tests have been performed with 43 subjects with 248 irradiations. The time delay to be able to identify the test chart was measured to be 12 s – 17 s due to glare and differences in contrast sensitivity became significant at lower contrast values. Green is most disturbing. Vision impairment times in Ishihara-tests were in a range between 27 s up to 186 s and blue LEDs resulted in strongest influence.

DISCUSSION

Glare might impair visual functions strongly and with a lasting effect via temporarily blinding, due to the fact that the adaptation system is overstrained and an afterimage is formed. The visual impairment lasts about 10 up to 30 % of the total afterimage duration.

Temporary blinding from current available high-brightness LEDs may cause more or less serious impairment of color vision up to about 3 minutes. Color vision impairment should be incorporated in a risk assessment if irradiation from high brightness light sources might be expected. The determined quantitative relations should be a helpful contribution in carrying out the assessment of risks arising from indirect effects like temporary blinding.

REFERENCE

- [1] Reidenbach, H.-D.: Proc. SPIE Vol. 6426 Ophthalmic Technologies XVII, Manns, F.; Söderberg, P. G.; Ho, A.; Stuck, B. E.; Belkin, M. (eds.), 2007, 642629-1 – 642629-10.