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Quantifying irradiance for eye-mediated non-image-forming effects of light in humans

Quantification de l'éclairement énergétique pour les effets non formateurs d'image de la lumière transmise par le biais des yeux chez l'homme

Bewertung von Strahlung für nichtvisuelle Wirkungen von Licht bei Aufnahme über die Augen

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Contents

Page

European foreword ... 3
Introduction ... 4
1 Scope ... 5
2 Normative references ... 5
3 Terms and definitions ... 5
4 Non-visual effects of light ... 10
4.1 General ... 10
4.2 Characterization of light regarding non-image-forming effects ... 11
4.2.1 Measurement of spectral power distribution ... 11
4.2.2 Determination of each of the photoreceptor inputs ... 12
4.3 Pre-receptoral filtering considerations ... 15
4.3.1 General ... 15
4.3.2 Definitions for age-corrected quantities ... 16
Annex A (informative) **Examples of use** ... 19
A.1 Quantifying stimulus to photoreceptors by illuminants ... 19
A.2 Discussion on cumulated photoreceptor input for non-image-forming effects ... 22
Bibliography ... 23

European foreword

This document (CEN/TR 16791:2017) has been prepared by Technical Committee CEN/TC 169 “Light and lighting”, the secretariat of which is held by DIN.

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Introduction

There is strong scientific evidence that light is not only essential for vision but also elicits important biological, non-image-forming effects that are highly relevant for human performance and well-being.

The non-image-forming effects can be either eye or skin mediated (e.g. vitamin D production, skin cancer or solar dermatitis). This document focuses on the eye-mediated non-image-forming effects. Depending on time of light exposure, spectral power distribution, duration of exposure, and individual parameters like circadian phase, light history, and others, light can cause suppression of the nocturnal release of melatonin, increase heart rate as well as alertness and affect thermoregulation [17], or the electroencephalogram spectrum. Light is the main synchroniser of the human biological clock. It can shift the phase of the circadian system and determines the timing of sleep/wake cycle. In a proportion of patients, light exposure can alleviate seasonal and non-seasonal depression and improve quality of life [1]. Upon light exposure, fast responses in the range of seconds were seen in the pupillary reflex or in brain activity.

The current lighting practice and the tendency for energy saving, e.g. European Regulations 244/2009 and 859/2009 as well as 245/2009 and 347/2010 tend to reduce indoor illumination levels. This can create lighting conditions that are sub-optimal for human well-being, health and functioning.

The above mentioned biological effects of light are elicited by stimulation of ocular photoreceptors. The receptors for vision, the rods and cones, are relatively well understood and characterized by standards such as CIE S 017. Although melanopsin containing retinal ganglion cells (intrinsically photosensitive Retinal Ganglion Cells, ipRGCs) play an important role in the non-image-forming effects of light, this photoreceptor is not yet included in existing lighting standards and recommendations. Therefore, a description of optical radiation solely according to the photopic action spectrum is not sufficient. The actual biological effect to ocular exposure to light will depend on the relative response of all photoreceptors and there is good evidence for synergistic responses between the receptors. For a deeper understanding of how a stimulation of the photoreceptors leads to a desirable or undesirable biological effect, light will be characterized in a way to quantify the input to each of the five known photoreceptors.

It is also important to recognize the importance of darkness, and the daily pattern of light and dark, particularly around and during periods of sleep. Additionally, certain changes to the balance of the spectrum of light at different times of day might be helpful in promoting circadian rhythms [18], but further evidence would be needed to support this as a general principle. Analysing the involvement of different photoreceptors would be crucial to understand how such outcomes with impact on human health are provoked.

The biological non-visual effects of light have a direct impact on human performance and well-being with large implications for architecture, indoor design, and lighting as well as for social- and work-schedules. The integration of these effects in lighting applications and designs requires new metrics to quantify light.

This report contains input of experts that, at the time of writing, also have contributed to the Draft International Standard in preparation by CIE JTC 9 "CIE system for metrology of ipRGC influenced light response". This Technical Report is entirely informative in nature and, unlike CIE JTC 9, does not address field of view aspects. Consequently, insights, terminology, tables (on spectral sensitivity and age correction) and symbols used in this report may be outdated after publication of the new CIE standard.

1 Scope

This Technical Report proposes metrics that can be used to evaluate and compare lighting conditions with respect to their potential to achieve non-image-forming, eye-mediated effects of light in human beings. This document applies to visible optic radiation in the wavelength range from 380 nm to 780 nm.

This Technical Report does not give information for particular lighting applications.

This Technical Report does not address health safety issues such as resulting from flicker, photobiological safety or the effects of non-visible optical radiation (ultraviolet and infrared radiation).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12665, *Light and lighting - Basic terms and criteria for specifying lighting requirements*

CIE S 017/E:2011, ILV: International Lighting Vocabulary

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CIE S 017/E:2011, EN 12665 and the following apply.

NOTE The differences for definitions of spectrally-weighted quantities that follow the SI convention are given where applicable.

3.1
α-opic
relating to the characteristics in non-visual photometry of the specified human photoreceptor and its opsin-based photopigment, denoted by α

Note 1 to entry: The symbol α represents one of the five photopigments. α can take one of five values, set out in Table 1. See 3.1.1 to 3.1.5.

Note 2 to entry: Based on [13].

3.1.1
S-photopic
relating to S-photopsin, the human S-cone photopigment (α = “sp”)

Note 1 to entry: S-photopsin is sometimes denoted as cyanopsin. In this report the term S-photopic is used to differ from other publications that are using slightly different sensitivity functions and denoting this sensitivity by the word cyanopic.

Note 2 to entry: The maximum of S-cone sensitivity is in the blue spectral region at 445 nm. S denotes maximum sensitivity at short wavelengths.

Note 3 to entry: The function for S-photopic sensitivity is based on the 10° cone fundamentals in CIE 170–1:2006.