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International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

International Standard

CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light

Système CIE de métrologie des rayonnements optiques dédié à la réponse à la lumière des cellules ganglionnaires photosensibles de la rétine (ipRGC)

CIE-System für die Metrologie optischer Strahlung für ipRGC-beeinflusste Antworten auf Licht

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Foreword

International Standards produced by the Commission Internationale de l'Eclairage are concise documents on aspects of light and lighting that require a unique definition. They are a primary source of internationally accepted and agreed data which can be taken, essentially unaltered, into universal standard systems.

This CIE International Standard has been prepared by Joint Technical Committee (JTC) 9 "CIE system for metrology of ipRGC influenced light response" of Division 1 "Vision and Colour", Division 2 "Physical Measurement of Light and Radiation", Division 3 "Interior Environment and Lighting Design", and Division 6 "Photobiology and Photochemistry" of the Commission Internationale de l'Eclairage, under lead of Division 6.

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Introduction

There is strong scientific evidence that light is not only essential for vision but also achieves important biological effects relevant for human health, performance and well-being that are not dependent on visual images. Many of these “non-image-forming” (NIF) effects of light (also sometimes denoted as “non-visual”) originate in the eye and therefore are distinct from skin-mediated responses to optical radiation (e.g. vitamin D production, skin cancer or solar dermatitis). This document focuses on the eye-mediated non-image-forming effects of light. These effects depend on the spectral power distribution, the spatial distribution, the timing and the duration of the light exposure. They also depend on person-specific parameters such as an individual’s circadian phase and history of light exposure. In the vision sciences and in photobiology it is often helpful to define standard physical quantities based on action spectra (that describe an average sensitivity to light). The connection between these quantities and actual physiological responses to light can then be studied using common light measurement concepts, which are not themselves dependent on observing any individual’s subjective responses.

Light is the main synchronizer of the human biological clock. It can shift the phase of the circadian rhythm and determines the timing of the sleep/wake cycle. Light can cause acute suppression of the nocturnal release of melatonin. There are also reports that light can increase heart rate, improve alertness, alleviate seasonal and non-seasonal depression, influence thermoregulation, and it can affect the electroencephalogram (EEG) spectrum. Exposure to light elicits fast responses (i.e. in the range of milliseconds and seconds) in the pupillary reflex or in brain activity.

Lighting standards, regulations and practice often focus on visual and energy efficiency aspects of light and do not address non-image-forming responses to light. This can result in lighting conditions that compromise human well-being, health and functioning.

The above-mentioned biological effects of light are elicited by stimulation of ocular photoreceptors. The classical receptors for vision, the rods and cones, are relatively well understood and characterized by existing CIE publications. Pioneering work over the past 25 years revealed that the eye has another kind of photoreceptor. This photoreceptor plays an important role in non-visual effects of light and has a peak sensitivity in the shorter wavelength part of the visible spectrum. Such photoreceptors are known as intrinsically-photosensitive retinal ganglion cells (ipRGCs), and their intrinsic photosensitivity is based on the photopigment melanopsin that is contained within them.

For non-image-forming effects of light, a description of optical radiation solely according to the photopic action spectrum is not sufficient. Moreover, there is no single action spectrum for non-visual responses. The actual NIF effects due to ocular exposure to light depend on the combined responses of all photoreceptors and there is good evidence for the potential for all receptor types to contribute to these responses.

The scientific literature contains examples of variation in the parts played by each photoreceptor type for eliciting several non-visual effects according to (retinal) irradiance and other light exposure properties like context (subjective time, prior light history, light adaptation, sleep pressure), duration, spectrum and variability over time. Other features such as spatial distribution of light, field of view and time of day may also be shown to influence non-visual effects. If uncertainty regarding the relative photoreceptor inputs to any response under defined conditions could be resolved it would be possible to predict the magnitude of evoked responses from the combination of the effective light intensity for each of the individual photoreceptors. For example, comparison of evoked responses to light with measures of effective light intensity under a variety of conditions could be used to reveal which photoreceptors dominate response amplitude. This requires a method of characterizing light that quantifies the input to each of the five known photoreceptor types. However, the spectral sensitivity function and new quantities and metrics to describe melanopsin-based photoreception are not yet defined. This standard provides these definitions so that the inputs of the five photoreceptor types that contribute to ipRGC-influenced responses can be characterized and used in relation to light, lighting and its effects on people, including its effects on health and well-being.

1 Scope

This International Standard defines spectral sensitivity functions, quantities and metrics to describe the ability of optical radiation to stimulate each of the five photoreceptor types that can contribute, via the melanopsin-containing intrinsically-photosensitive retinal ganglion cells (ipRGCs), to retina-mediated non-visual effects of light in humans. This International Standard is applicable to visible optical radiation in the wavelength range from 380 nm to 780 nm. In addition, this standard includes information concerning the effects of age and field of view (FOV) when quantifying retinal photoreceptor stimulation for ipRGC-influenced responses to light (IIL responses).

This International Standard does not give complete information for particular lighting applications, or for the quantitative prediction of IIL responses.

This International Standard is not intended for colorimetric contexts, nor does it address health or safety issues such as those resulting from light treatment, flicker or photobiological safety and only relates to retinal photoreception.

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.

ISO 23539/CIE S 010 *Photometry - The CIE system of physical photometry*.

CIE S 017 *ILV: International Lighting Vocabulary*.
[also accessible electronically as eILV at www.cie.co.at].

3 Terms and definitions

For the purposes of this document, in addition to the terms and definitions given in CIE S 017, the following terms and definitions apply.

3.1
α-opic
relating to the specified human photoreceptor response due to its opsin-based photopigment, denoted by the symbol α, and its characteristics in the context of ipRGC-influenced responses to light

Note 1 to entry: The prefix α in the term indicates one of five different photoreceptor responses, as set out in 3.1.1 to 3.1.5. The symbol α is also used to denote an index for quantity symbols related to these responses. Both these usages are summarized in Table 1.

3.1.1
S-cone-opic
relating to the human S-cone response due to its photopigment and its characteristics in the context of ipRGC-influenced responses to light

Note 1 to entry: In this standard, S-cone-opic is based on the cone fundamental $\bar{s}_{10}(\lambda)$, as defined in (CIE, 2006). This differs from the approach where the human S-cone response is denoted by the term “cyanopic” and its spectral sensitivity function is based on an opsin template (Lucas et al., 2014).

Note 2 to entry: The index “sc” is used for S-cone-opic quantities.

3.1.2
M-cone-opic
relating to the human M-cone response due to its photopigment and its characteristics in the context of ipRGC-influenced responses to light

