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

CIE Position Statement on Non-Visual Effects of Light

RECOMMENDING PROPER LIGHT AT THE PROPER TIME

2nd Edition[1]

October 3, 2019

Background

Light is defined as any electromagnetic radiation that can create a visual sensation by directly stimulating the retinal photoreceptors of the visual system. In addition to enabling vision, these photoreceptors also drive biological effects that powerfully regulate human health, performance and well-being. Light is the main synchronizer of the human biological clock. It can shift the phase of the circadian rhythm and can regulate the timing and quality of our sleep. Light in the evening and at night can disrupt sleep and can cause acute suppression of the nocturnal release of the hormone melatonin. There are also reports that light can increase heart rate, improve alertness, alleviate seasonal and non-seasonal depression, influence thermoregulation, and affect brain activity as measured with the electroencephalogram (EEG). Exposure to light elicits fast responses (in the range of milliseconds and seconds) in the pupillary reflex or in brain activity. To reflect their distinction from perceptual vision, these effects are often referred to as non-image-forming (NIF) or non-visual (NV) responses to light. In recent years various marketing terms, such as "human-centric lighting" (HCL), "circadian lighting", and "biodynamic lighting", have come to describe lighting solutions that target such effects. In the upcoming 2nd edition of the CIE International Lighting Vocabulary, currently available as DIS (CIE 2016), "integrative lighting" is the official term for lighting that is specifically intended to integrate visual and non-visual effects, producing physiological and psychological effects on humans that are reflected in scientific evidence.

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 last 25 years revealed that the eye has another kind of photoreceptor. These photoreceptors play an important role in non-visual effects of light and have 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.

Based on the outcome of an independent workshop of leading scientists in the field of quantifying light for non-visual effects in Manchester in 2013 (see CIE TN 003:2015 (CIE 2015)), the CIE issued an international standard, CIE S 026:2018 (CIE 2018), that defines a system for metrology of optical radiation for light-induced responses that can be elicited by ipRGCs (ipRGC-influenced light (IIL) responses).

[1] This edition replaces the 2015 CIE Position Statement on the same subject.

Lighting regulations and practice often still focus on visual and energy efficiency aspects of light, with little or no attention being paid to IIL responses. Conversely, there are many lighting products entering the market that are intended primarily to influence IIL without careful consideration of other lighting quality aspects. An improper balance between these two approaches can result in lighting conditions that compromise human well-being, health and functioning and that fail in terms of overall lighting quality. Since the first edition of this Position Statement in 2015, the CIE has issued relevant publications and engaged in collaborative activities to advance this exciting aspect of lighting fundamentals, technology and applications.

1. *How to characterize light with respect to its non-visual effects: CIE S 026:2018 "CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light"*

The International Standard CIE S 026:2018 (CIE 2018) defines spectral sensitivity functions, quantities and metrics to describe the ability of optical radiation to stimulate each of the five (α-opic[2]) 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[3]. The units of these α-opic quantities are in compliance with the International System of Units (SI) (BIPM 2019a, BIPM 2019b), which is essential to enable traceable measurements and international guidelines.

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 or proxy that can describe all eye-mediated non-visual responses to light. All five receptor types can contribute to these responses (Lucas et al. 2014). The relative contribution of each individual photoreceptor type can vary depending on the specific response and upon light exposure properties such as intensity, spectrum, duration, timing (external and internal/circadian), prior light history and sleep deprivation state of the individual. It is worth noting that in many cases light exposure for IIL responses is better represented by using the vertical measurement plane rather than the horizontal plane to determine α-opic irradiance (or α-opic equivalent daylight (D65) illuminance (α-opic EDI)).

2. *Identifying the proper light at the proper time*

This remains a key question for many people. As outlined in the 2015 position statement, the CIE is actively engaged with the international community in attempting to provide guidance that is based on solid scientific evidence and consensus. The CIE and ISO/TC 274 are developing the first international consensus-based technical report concerning integrative lighting (ISO/CIE TR 21783, in preparation), noting both its potential beneficial effects and its possible risks that are to be avoided. Furthermore, in August 2019, a second independent workshop of leading scientists in this field took place in Manchester to discuss how insights in this field can be translated into guidelines for a healthy daily pattern of light exposure. A consensus publication on the outcomes of the workshop is currently being prepared by the workshop participants and will be followed by a CIE Technical Note reporting on the workshop in detail.

The CIE recognizes that spending adequate time outdoors during the day is associated with better health and well-being, and that exposure to natural light is a significant causal

[2] The term α-opic represents S-cone-opic, M-cone-opic, L-cone-opic, rhodopic or melanopic.

[3] The CIE S 026 action spectra of the five human α-opic photoreceptor classes (S-cones, M-cones, L-cones, rods and ipRGCs), tabulated in steps of 1 nm, are available at http://files.cie.co.at/S026_Table2_Data.xlsx.

component in these effects. CIE also recommends not to unnecessarily restrict daylight within indoor settings.

For two important, well-studied human non-visual responses to light (melatonin suppression and pupil control), evidence is accumulating that the overall light sensitivity of these responses is largely controlled by melanopsin-based photoreception (Nowozin et al. 2017, Souman et al. 2018, Prayag et al. 2019, Spitschan 2019). In order to provide some initial guidance while waiting for the participants of the August 2019 workshop in Manchester to develop further insights and consensus in this field, the CIE recommends the manipulation of melanopsin-based photoreception as a useful strategy to manipulate overall light input into non-visual responses. This means that specifications in terms of melanopic EDI are a reasonable route to provide initial guidance on how to manipulate the human (polychromatic) lighting environment in typical everyday life for non-visual responses in people with a regular, day-active schedule (as long as these specifications are not compromising visual comfort and visual performance):

- *A high melanopic EDI during the day is usually supportive for alertness, the circadian rhythm and a good night's sleep.*
- *A low melanopic EDI in the evening and at night facilitates sleep initiation and consolidation.*

Suitable light patterns for night-shift workers are more complex, as they depend on the specific schedule.

Further CIE Strategy

Delivering proper light at the proper time will require integrative approaches that meet the needs of all the people within a space. Ongoing CIE projects in this field include the joint activity with ISO/TC 274 to revise the international standard for indoor workplace lighting, ISO 8995-1:2002/CIE S 008:2001 (ISO/CIE 2002).

The CIE is committed throughout all of its work, to providing scientifically-grounded recommendations and to advancing science that will support the next generation of standards. The development of proper evidence-based recommendations continues to demand concerted research efforts, and the CIE in its Research Strategy calls upon the research community to engage in developing this knowledge base. As a support to researchers and practitioners in this field, a toolbox to facilitate the application of CIE S 026:2018 will shortly be available on the CIE website. Researchers proposing to study topics relevant to the CIE Research Strategy may apply to the CIE for a letter of support for the proposal by emailing a request form to ciecb@cie.co.at.

References

BIPM (2019a) *The International System of Units (SI), 9th Edition*
Downloadable at https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9-EN.pdf

BIPM (2019b) *The International System of Units (SI), 9th Edition – Appendix 3: Units for photochemical and photobiological quantities*
Downloadable at https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9-App3-EN.pdf

CIE (2015) CIE TN 003:2015 *Report on the First International Workshop on Circadian and Neurophysiological Photometry, 2013*
Downloadable at http://files.cie.co.at/785_CIE_TN_003-2015.pdf

CIE (2016) CIE DIS 017:2016 *ILV: International Lighting Vocabulary, 2nd Edition*

CIE (2018) CIE S 026:2018 *CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light*

ISO/CIE (2002) ISO 8995-1:2002/CIE S 008:2001 *Lighting of Work Places - Part 1: Indoor*

ISO (in preparation) ISO/CIE TR 21783 *Light and lighting — Integrative lighting — Non-visual effects*

Lucas, R.J., Peirson, S.N., Berson, D.M., Brown, T.M., Cooper, H.M., Czeisler, C.A., Figueiro, M.G., Gamlin, P.D., Lockley, S.W., O'Hagan, J.B., Price, L.L., Provencio, I., Skene, D.J., Brainard, G.C. (2014) Measuring and using light in the melanopsin age. *Trends in Neuroscience* 37(1): 1-9.

Nowozin, C., Wahnschaffe, A., Rodenbeck, A., de Zeeuw, J., Hadel, S., Kozakov, R., Schopp, H., Munch, M., Kunz, D. (2017) Applying Melanopic Lux to Measure Biological Light Effects on Melatonin Suppression and Subjective Sleepiness. *Curr Alzheimer Res* **14**(10): 1042-1052.

Prayag, A.S., Najjar, R.P., Gronfier, C. (2019) Melatonin suppression is exquisitely sensitive to light and primarily driven by melanopsin in humans. *Journal of Pineal Research* **0**(ja): e12562.

Souman, J.L., Borra, T., de Goijer, I., Schlangen, L.J.M., Vlaskamp, B.N.S., Lucassen, M.P. (2018) Spectral Tuning of White Light Allows for Strong Reduction in Melatonin Suppression without Changing Illumination Level or Color Temperature. *Journal of Biological Rhythms* **33**(4): 420-431.

Spitschan, M. (2019) Photoreceptor inputs to pupil control. *Journal of Vision* **19**(9): 5-5

About the CIE and its Position Statements

The International Commission on Illumination – also known as the CIE from its French title, the Commission Internationale de l´Eclairage – is devoted to worldwide cooperation and the exchange of information on all matters relating to the science and art of light and lighting, colour and vision, photobiology and image technology.

With strong technical, scientific and cultural foundations, the CIE is an independent, non-profit organization that serves member countries on a voluntary basis. Since its inception in 1913, has been accepted as representing the best authority on the subject and as such is recognized by ISO as an international standardization body. As such the CIE is recognized by ISO as an international standardization body, publishing global standards on the fundamentals of light and lighting.

CIE position statements are approved by the CIE Board of Administration, which includes the Directors of all the CIE Divisions (the bodies that carry out the scientific work of the CIE), after first ensuring agreement with the relevant CIE Technical Committees.

For any further information please contact

CIE Central Bureau
Kathryn Nield, General Secretary
Babenbergerstraße 9/9A, A-1010 Vienna, Austria
Phone: +43 1 714 31 87
Email: kathryn.nield@cie.co.at
Website: http:/www.cie.co.at