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Light and lighting — Integrative lighting — Non-visual effects

Lumière et éclairage — Éclairage intégratif — Effets non visuels

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Foreword

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This document was prepared by ISO/TC 274, Light and lighting in cooperation with the International Commission on Illumination (CIE).

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The content of this document represents the state of the art at the date of publication and it is not necessarily complete.

At present ipRGC-influenced responses to light (IIL responses) are often referred to as non-image-forming (NIF) or non-visual (NV) responses to reflect their distinction from perceptual vision. This document reflects that interest while allowing for the possibility for the accepted range of light responses driven by ipRGCs to expand as we gain more knowledge.

The light patterns of exposure can be beneficial or non-beneficial for humans depending on the setting, relating to spectrum, intensity, duration, and timing of the resulting light exposure.

Light and lighting — Integrative lighting — Non-visual effects

1 Scope

This document provides an analysis and evaluation of the current state of the art with regard to ipRGC-influenced responses to light in applying this knowledge in the context of identified topics to be considered for use in lighting applications. This analysis has taken into consideration published scientific papers, use cases, reports, best-practice guidelines and recommendations, see Annex A. However, evaluation of the results will be based on scientifically validated findings.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CIE S 017:2020, *ILV: International Lighting Vocabulary*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

CIE maintains a terminology database for use in standardization at the following address:

— e-ILV: available at https://cie.co.at/e-ilv

3.1
integrative lighting
lighting integrating both visual and non-visual effects, and producing physiological and/or psychological benefits upon humans

Note 1 to entry: The term "integrative lighting" applies only to humans.

Note 2 to entry: Lighting primarily for therapeutic purposes (light therapy) is not included.

Note 3 to entry: The term "human centric lighting" is used with a similar meaning.

[SOURCE: CIE S 017:2020, entry 17-29-028]

3.2
ipRGCs
intrinsically-photosensitive retinal ganglion cells
retinal ganglion cells that are photosensitive by means of the photopigment melanopsin

[SOURCE: CIE S 026:2018, entry 3.11, modified — notes to entry omitted]

3.3
ipRGC-influenced responses to light
ipRGC-influenced light (IIL) responses
light-induced responses or effects that can be elicited by ipRGCs

Note 1 to entry: ipRGCs can play a role in both visual and non-visual responses to ocular light exposure. At present ipRGC-influenced responses to light are often referred to as non-image-forming (NIF) or non-visual (NV) responses to reflect their distinction from perceptual vision.

Note 2 to entry: ipRGC-influenced responses to light can be influenced by rod, cone and melanopsin inputs.

[SOURCE: CIE S 026:2018, entry 3.12, modified — notes 1 and 2 to entry revised]

3.4
spectrum
display or specification of the monochromatic components of the radiation considered

[SOURCE: CIE S 017:2020, entry 17-21-015, modified — notes to entry omitted]

3.5
illuminance
density of incident luminous flux with respect to area at a point on a real or imaginary surface

$$E_\mathrm{v} = \frac{\mathrm{d}\Phi_\mathrm{v}}{\mathrm{d}A}$$

where

Φ_v is luminous flux;

A is the area on which the luminous flux is incident.

Note 1 to entry: The illuminance is expressed in lux ($\mathrm{lx} = \mathrm{lm{\cdot}m^{-2}}$).

[SOURCE: CIE S 017:2020, entry 17-21-060, modified — notes 1 and 2 to entry omitted]

3.6
electric lighting
lighting by electric light sources

[SOURCE: CIE S 017:2020, entry 17-29-025, modified — notes to entry omitted]

3.7
daylighting
lighting for which daylight is the light source

[SOURCE: CIE S 017:2020, entry 17-29-031, modified — notes to entry omitted]

4 Practical implementation

4.1 General

Daylighting and electric lighting can affect psychological and biological functioning via image-forming and non-image-forming pathways.[1] Due to benefits and risks that relate to both pathways, experience has shown that both ought to be considered in the lighting design process. Knowledge about both image-forming and non-image-forming effects of lighting enables a better evaluation of the effects of daylighting and electric lighting on the human body.

In particular, the processing of information contained in the light beyond the forming of images plays a crucial role. Among other things, this additional information can influence the human internal clock and circadian rhythm. Besides the quantitative properties of light in the space as defined in CIE S 026:2018,[64] their temporal course is also of central importance. In practice, this means that a given lighting installation, which will always have non-image-forming effects (positive or negative), is managed in a suitable way in order to make positive use of the lighting.

All lighting installations will have effects on visual and physiological systems and can be intentionally designed for these effects. Best results will occur when the lighting designer works with a multidisciplinary team that includes occupational health experts, psychologists and others.

4.2 Beneficial aims

4.2.1 General

Considerations with regard to beneficial effects of light on humans focus on criteria for daylighting and electric lighting. These considerations can be identified in addition to the classic visual criteria as listed in ISO 8995-1 [65] and are not meant to affect the visibility and quality of vision. The considerations are grouped based on the strength of the scientific evidence at the time of writing. *Well-established* effects have a strong body of scientific literature to support them. *Moderate evidence* effects have a smaller scientific literature basis, but the evidence is consistent across studies. *Insufficient evidence* effects are emerging areas with less consistent effects and low consensus. This classification into levels of evidence only represents the status as at the end of 2019. Future research and publications might provide new insights resulting in a different level of evidence.

For the individual planning and implementation of integrative lighting, it is important to determine the desired outcomes and to prioritize their importance. This requires an understanding of the conditions to which users can be exposed over the entire day and night (e.g. during working hours, while at home or in transition). The effects of any light exposure also depend on the state of the individual, including their prior light history and their internal states (e.g. groups of individuals in an airport could have differing states of jet lag or circadian disruption).

Therefore, an informed design choice taking into account at least the following considerations is advisable:

— probability of achieving the desired outcome;

— net benefits of the desired outcome.

IMPORTANT — The beneficial results of integrative lighting can only be achieved if it is planned and applied correctly by qualified specialists. Equally important is the correct operation of the lighting system by the actors/users involved.

The scientific background to the conclusions below is presented in Annex A.

4.2.2 Well established

The following are well established:

Integrative lighting can synchronize and support the human circadian system. To achieve this goal, it is necessary to establish a strong daily light-dark pattern when planning and implementing daylighting and electric lighting.

Integrative lighting can be beneficial for both acute and long-term effects on well-being and mood states.

4.2.3 Moderate evidence

There is moderate evidence for the following:

Integrative lighting can have positive effects on sleep quality, sleep onset and performance on the subsequent days. This is partly based on avoiding a possible negative influence on the circadian system by the non-visual effects of the electric lighting.

Integrative lighting can activate, increase cognitive performance and reduce sleepiness during evening/night-time, which might be desirable for night work. These influences can also be sought in the short term, without taking into account a daily course.

Integrative lighting might benefit some individuals with medical conditions such as dementia[2,3].

4.2.4 Insufficient evidence

There is insufficient evidence for the following:

Integrative lighting can activate, increase cognitive performance and reduce sleepiness during daytime. These influences can also be sought in the short term, without taking into account a daily course.

Integrative lighting could increase academic performance and concentration. There is some evidence from animal models, but limited evidence in human populations and none published showing longer-term benefits.

4.3 Avoidance of risks

4.3.1 General

As already mentioned, the consideration of benefits and risks is an important task in the planning and commissioning of a lighting installation. In particular, risk prevention measures can be recommended for some specific applications and lighting situations.

4.3.2 Well established

The following are well established:

Light exposures below established exposure limits published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) will avoid any risk of injury to the visual system.

Exposure to light during night shifts can reduce melatonin secretion and affect the timing of sleep. This is one possible contributing factor in the aetiology of some adverse health effects of night shift work.

If night-shift work cannot be avoided, lighting patterns need to be planned to take into account the shift schedule, and users need to maintain 24-hour patterns of light and dark exposure to achieve the intended results. Darkness during sleeping hours would be good practice. The negative health impacts of most night-shift schedules cannot be fully mitigated by integrative lighting.

For many people insufficient levels of lighting during the daytime can have negative physiological effects. Too much light at the wrong time for the wrong activity and person can be detrimental to well-being. The challenge is to understand the user group and needs well in order to avoid mismatches.

4.3.3 Moderate evidence

There is moderate evidence for the following:

High light exposure in the evening hours can cause sleep disturbances.

Interactions between the circadian system and safety at work have to be taken into account (e.g. the need to maintain alertness in night-shift medical staff throughout the shift and on the travel home).

Different light exposures might be needed for different age groups to account for changes in short-wavelength transmission in the eye. Young children are more sensitive to short-wavelength optical radiation than adults, because of higher transmission of the lens of the eye at these wavelengths.

4.3.4 Insufficient evidence

There is insufficient evidence for the following:

If night-shift work cannot be avoided, filtering out short wavelengths during night work could maintain alertness with less circadian disruption.

Very high intensity "blue enriched light" can compete with natural light as a zeitgeber. This can counteract seasonal adaptation of the biological clock. Thus, dynamics of lighting aimed at biological effects have to consider seasonal changes in natural light exposure.

4.4 Implementation Considerations

In planning an integrative lighting installation, it is important that the aims above be achieved in concert with the established aims of a high-quality lighting installation, such as providing positive and avoiding negative physiological effects, supporting visual tasks, providing good colour rendering and spatial brightness. This requires a careful consideration of several factors, including:

— occupant profile (e.g. age distribution, visual conditions, state of health) of the expected users of the space;

— activity profile: predominantly transitory, predominantly sedentary, predominantly active but at a fixed position, etc.; and

— predominantly controlled (e.g. institutionalized) or predominantly uncontrolled population.

These factors can be reviewed to produce an assessment of:

— potential health conditions expected to be encountered;

— generalized expectations of sleep patterns (e.g. it can be reasonably expected that teenagers will generally have different sleep routines compared to elderly occupants);

— the quantity of light required at the eye to achieve a defined circadian stimulation, which will differ between individuals.

NOTE These lists are not exhaustive.

Achieving the aims will not depend on light sources and lighting installations alone, but requires consideration of control systems, training on their appropriate use, and user understanding and acceptance. Considerations include:

— Interindividual differences (e.g. chronotypes, sensitivity to light) cannot fully be considered in a fixed design, but could be managed using controls and local modifications.

— Conflicts of priorities between different needs (of the same or different users in one space) can occur. This has to be solved by the designer in a way that does not compromise lighting quality.

— Problems can occur when individuals have control over the lighting but inadequate instructions on how to use it in a beneficial way. Provision of detailed and easy to understand instructions is likely to mitigate this problem.

— The power of building operators (such as employers) to decide on the time and duration of activation can result in problems of acceptance of lighting. This needs to be properly addressed when a lighting installation is introduced, see last point above. This problem could be mitigated by clearly informing occupants about the functioning and objectives of this lighting installation.

4.5 Conclusion

Besides visual and psychological effects, every form of lighting affects the human body via the ipRGC-influenced pathway. The light patterns of exposure can be beneficial or non-beneficial for humans depending on the setting relating to spectrum, intensity, duration, and timing of the resulting light