European Standard for Visual Environment

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Keywords: Visual comfort, visual tasks, visual performance, integrative lighting, lighting requirements, lighting design criteria, visual environments visual environments.

Introduction

Among other aspects, indoor environmental quality (IEQ) includes visual comfort and wellbeing determined by proper lighting. Indoor lighting, due to daylight, electric light or a combination of both, has an impact not only on occupants' visual performance and comfort, but also on their mood, alertness and health. These latter are defined as "non imaging forming effects" or "non-visual effects" of lighting. Some years ago, the term "human centric lighting" (HCL) was spread, even with commercial purposes, for generically considering these effects, and more recently the CIE coined the term "integrative lighting" for defining "lighting integrating both visual and non-visual effects and producing physiological and/or psychological benefits upon humans". Despite HCL is still used (and sometimes abused), *integrative lighting* is to be preferred. Today, for non-visual effects linked to the impact of light on circadian rhythms, a metric has been proposed by CIE [1], and some requirements have already been proposed in Standards [2], in agreement with findings from the scientific community [3].

The EN 12464-1 Standard

The European Standard that specifies lighting requirements for humans in indoor environments is the EN 12464-1 [4], which is referred to indoor work places, but it can also be adopted in those parts of private or residential places, where visual tasks are the same or can be assumed similar to those reported in the standard. In the Annex B, which is informative, several additional information on visual and non-visual effects of light are reported and it is expected that they will be more detailed and presented as "recommendations" in future revisions and in the namesake ISO-CIE 8995 Standard project: "Light and lighting — Lighting of work places — Part 1: Indoor".

The main aim of the EN 12464-1 Standard is to provide requirements for lighting systems in indoor environments where work activities are performed, considering the several different visual tasks. Requirements and recommendations for good lighting practice are reported, involving both quantitative and qualitative aspects. It must be noticed that this standard does not consider neither outdoor work places [5] nor emergency lighting [6].

Lighting requirements for a good environmental quality are based on three main goals to achieve: visual comfort (including wellbeing), visual performance, and safety. Today, as previously mentioned, also non-visual effects (mainly effects on circadian rhythms) should be considered. The main criteria adopted for describing the luminous environment with electric lighting and daylighting are reported in **Table 1**.

Table 1. *Criteria for characterizing the luminous environment.*

Criterium	Comment
Luminance distribution	Affects both visual comfort and performance. Depends on illuminance on surfaces (walls and furniture) and materials' reflectance.
Average maintained illuminance and uniformity on surfaces	Illuminances on task areas, vertical walls and other relevant surfaces.
Glare	Discomfort glare produced by light sources must be avoided.
Directionality of light, lighting in the interior space	Spatial and three-dimensional perception of space and objects. Cylindrical or semi cylindrical illuminances for visual communication are quantitative useful parameters.
Colour rendering and colour appearance of the light	For objects: colours' naturalness, colour fidelity, colour discrimination. For light sources: colour tone, expressed as correlated colour temperature.
Flicker	Electric light is characterized by time modulation that can affect health or produce stroboscopic effects.
Variability of light	Proper light at proper time for a good circadian rhythm entrainment. Human beings are adapted to variable light scenarios (daylight). This can be achieved even through electric light. Light scenes can be varied as well, according to different uses of the same environment.

Use of daylighting, when possible, is highly recommended for its numerous beneficial effects. Luminance distribution gives the sense of brightness of the environment, and it is somehow linked to visual perception and comfort. It depends on the point of view of the observer, so it's important to evaluate it in correspondence of the working positions. For each point of view, the luminance distribution determines the "average adaptation luminance" for the visual system. If, in the visual field luminance gradients are excessive, they can produce eye fatigue and glare, whereas if the variations are too low, the working environment will be perceived as dull and non-stimulating. A properly balanced luminance distribution can enhance both visual performance and comfort, by increasing visual acuity, contrast sensitivity and efficiency of the ocular functions. In **Figure 1** an example of luminance distribution in an office is shown.

Luminance distributions are very complex to assess, due to the need of accurate knowledge of materials' optical characteristics and their dependence on the point of view. By the way, assuming a diffusing behaviour and neglecting spectral selective characteristics for surfaces, luminance depends on illuminance and reflectance, see **Figure 2**, so the Standard provides a guidance in terms of range of reflectance and minimum illuminance values for room surfaces.

Generally, it is recommended to obtain bright interior surfaces. Besides the approach based on illuminance and reflectance, in Annex B information about other methods for assessing room brightness are reported, as the mean ambient illuminance [7], the mean room surface luminous exitance [8] and the visual lightness and interest [9]. All of them are aimed to create a link between qualitative and quantitative aspects in lighting design.

Regarding Illuminance on surfaces, besides room surfaces related to the luminance assessment, the Standard is focused on the so-called task areas, that are horizontal, vertical or inclined areas where the work activities are performed. The Standard provides minimum maintained average illuminance values ($\bar{E}_m$ [lx]) in task areas for each type of activity, for example

Figure 2. Luminance depends on illuminance and reflectance. For diffusing surfaces $L = E{\cdot}\rho/\pi$.

Figure 1. Task area and immediate surrounding area according to EN 12464-1.

in an office, for reading, this value is 500 lx, **Table 2**. The adjective "maintained" means that it is necessary to multiply the illuminance obtained when the lighting system is in its initial conditions by a reduction factor that considers the decrease of illuminance due to several causes linked to lamps' aging, luminaires' typology and cleaning frequency of luminaires and room.

The maintenance factor is calculated according to the ISO/CIE TS 22012 [10]. The adjective "average" means that illuminance is measured or calculated in points individuated by a rectangular grid and the average value is considered. The dimensions of grid cells, at the center point of which illuminances are calculated or measured, depend on the dimensions of the considered area, following the indications reported in the standard. In order to obtain adequate uniformity on the task area, the ratio between the minimum and the average value on the grid, named uniformity ratio U_0, is evaluated and it must be higher than the prescribed limit value. For the example reported in **Table 2**, the limit value is 0,60. It is possible that illuminances in the immediate surrounding area (band with a width of at least 0,5 m around the task area in the visual field, see **Figure 3**) are equal or lower than those on the task area, within a limit value depending on the illuminance. It is individuated also a background area (band with a width of at least 3 m adjacent to the immediate surrounding area or up to the limits of the space for smaller rooms) on the floor level, in which the illuminance can be lower than the one on the immediate surrounding area, but not lower than1/3 of it.

The maintained average illuminances on task areas are prescribed considering, for each activity, the following aspects: psycho-physiological factors as visual comfort and well-being, requirements for visual tasks, visual ergonomics, practical experience, contribution to functional safety and economy.

Despite these are minimum levels, it is recommended not to significantly exceed them, for energy efficiency purposes. On the other side, it is possible to increase them if at least two of the following conditions are present: visual work is critical; errors are costly to rectify; accuracy, higher productivity or increased concentration is of great importance; task details are of unusually small size or low contrast; the task is undertaken for an unusually long time; the task area or activity area has a low daylight provision; the visual capacity of the worker is below normal. This demonstrates that, when necessary, visual performance and comfort are more important than energy issues. Unfortunately, the Standard does not provide an indication on what is considered, for example an unusually long time or unusually low contrast: no threshold or reference values are provided. In **Table 2**, the proposed modified value of illuminance is 1 000 lx.

As for glare, in indoor environments discomfort glare is considered, i.e. the one that causes discomfort without necessarily impairing the vision of objects.

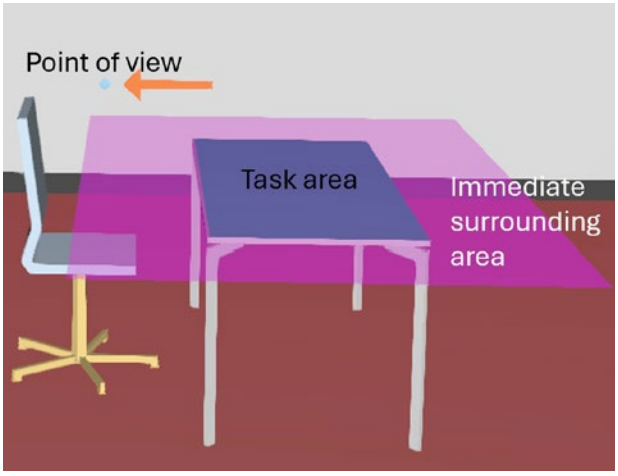

Figure 3. Task area and immediate surrounding area according to EN 12464-1.

Table 2. *Lighting requirements for activity of writing, typing, reading, data processing in offices. From [4].*

Task area or activity area design For example: Office				Room or space design requirements			
Task or activity related requirements For example: Writing, typing, reading, data processing					For visual communication and recognition of objects	Brightness appearance of rooms	
E_m [lx]		U_0	R_a	R_{UGL}	$E_{m,z}$ [lx]	$E_{m,wall}$ [lx]	$E_{m,ceiling}$ [lx]
required	modified				$U_0 \geq 0{,}10$		
500	1 000	0,60	80	19	150	150	100

Special requirements: DSE-work, Room brightness, Lighting should be controllable. For smaller cellular offices, the wall requirement applies to the front wall. For other walls, a lower requirement of minimum 75 lx could be accepted.

In the Standard, only discomfort glare from electric light is dealt with, referring to the EN 17037 [11] for daylight. Discomfort glare from electric light is quantified by means of the UGR (unified glare rating), an index that is a function of the light source's luminance, its dimension and position in the observer's visual field, and the background luminance. It can be evaluated through a tabular method, by using tables provided by the luminaires manufacturers or can be calculated. UGRs are calculated in correspondence of each point of view and for each of them, values depend on the direction of view. The standard prescribes that UGR must be lower than a limit value R_{UGL}, as a function of the specific task (19, for the case of **Table 2**). Furthermore, glare due to veiling effects should be prevented or minimized, by adopting some strategies, such as proper positioning of workstations with respect to luminaires and daylight openings and use of matte surface finishes.

Indoor environments and objects contained in it are three-dimensional and all the space where people move or work must be correctly perceived. For this reason, the standard prescribes adequate average cylindrical illuminance, $\bar{E}_{m,z}$ [lx], in the space. This is the mean value of illuminance on the outer curved surface of a very small (real or imaginary) cylinder that is oriented vertically at a point in space. It can be approximately assessed as the average value of four vertical illuminances orthogonal to one another. It must be calculated on points on horizontal planes at 1,20 m from the floor for seated people and 1,60 m from the floor for standing people.

Light directionality is of outmost importance, generally lighting should not be too directional for avoiding harsh shadows, but at the same time it should not be too diffuse, otherwise a correct perception of three-dimensional objects will be lost, producing a very dull luminous environment.

Chromatic characteristics of lighting must be carefully chosen, they are described by two parameters. The former is Colour Rendering (Ra), which defines the capacity of the light source's spectrum in rendering and discriminating colours, providing a sense of naturalness. It should be higher than 80 for most indoor activities and higher than 90 when colour recognition and fidelity are fundamental (for example hair-dressing, dyeing, etc.). The latter one is the correlated colour temperature (CCT [K]), corresponding to the "colour appearance" of light: warm (below 3 300 K), neutral (3 300 K – 5 300 K), cool (above 5 300 K). Both are provided by manufacturers. CCT value is not a required parameter: its choice depends on several factors, including the colours of walls and surfaces and illuminance levels. Some lamps are white tuning, i.e. the CCT can be changed, according to different conditions.

All electric light sources don't emit time-constant light flux, in most cases this effect (flicker) is not detectable by the human visual system, but sometimes it can induce undesired effects (as stroboscopic effects), can reduce visual comfort and task performance, with consequences as fatigue or headaches. Lighting systems should be designed in order to avoid undesirable effects from flicker.

As for the variability of light during the day for a good entrainment of circadian rhythms, the CIE has introduced the melanopic equivalent daylight illuminance m-EDI [lux], measured or calculated at the eye's level. Just because the non-visual effects depend, among other parameters, on the spectrum of radiation at the eye, the m-EDI due to a specific spectrum represents the illuminance from standard daylight that produces the same "circadian" stimulus of this spectrum. It is desirable that what today is only in form of recommendation or is simply reported in the Annex of current standard [4] as informative material will be developed and integrated into a common practice for designing high quality visual indoor environments.

References

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