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INTERNATIONAL ASSOCIATION OF LIGHTING DESIGNERS | IALD

Brussels, 15 July 2022

How to create Better Lighting?

No renovation in Europe without an upgrade of the lighting installations

The World Health Organisation reports that people are spending on average 90% of their time indoors, and the Covid-19 pandemic has highlighted the importance of indoor comfort and wellbeing. High quality, energy efficient lighting products and technologies are already available and ready to install. By leveraging the impact of these products and technologies to create both energy efficient buildings and buildings with high indoor environmental quality (IEQ) – so-called Healthy Buildings - we can also improve the well-being and productivity of building occupants.

Although traditional electric lighting does wonders in terms of the visual, it simply lacks the non-visual benefits of natural light, created by dynamics in intensity and colour of the light throughout the day. This is where Human Centric Lighting (HCL) comes in. Using daylight as the baseline for quality lighting, HCL brings the benefits of natural light inside. More specifically, HCL supports the well-being and performance of humans by combining the visual, biological and emotional benefits of light.

HCL provides the right light, at the right place and the right time for the various activities we carry out every day. A wide range of users can benefit from HCL, including patients, residents, and staff in hospitals and nursing homes; students and teachers in schools; employees in offices; workers in manufacturing sites; and residents in their private homes.

The European Union announced with the EU Renovation Wave Initiative its intention to at least double the renovation rates across Europe in the next ten years. This represents a unique opportunity to achieve the needed energy efficiency of buildings and to address the well-being of occupants through a better indoor environmental quality, both of which lighting contributes to. Specifiers, such as lighting designers, installers or architects, will play a central role in making the EU Renovation Wave a success and making a difference in the life of EU citizens.

To grasp the full benefits of better lighting, we strongly recommend specifiers to ensure that the following characteristics, requirements and design tips are considered as part of the Lighting Design Process.

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The main characteristics of better lighting

Within the IEQ design process, lighting should address the core issues of safety, task requirements and occupant needs in a coherent and integrated manner.

Better Lighting is adjustable in light levels

Traditional lighting design within a space involves metrics such as lux levels on a task plane, surrounding area, ceilings and walls, uniformity and discomfort glare. While these metrics are important in adequately lighting a space for people to work or perform their everyday visual tasks safely, they will not necessarily help to promote well-being or the biological and emotional performance of an individual. To do this, other factors must be considered.

A range of lighting levels required by occupants with a range of visual capabilities (e.g. age related) are most commonly considered on a horizontal surface at floor level or on a nominal working plane but the vertical illuminance within a space is also important, as this is the plane eyes are generally looking in. The variation in illuminance is important, ceiling to wall, to accents of light. Glare should be considered. Techniques such as washing the walls or ceiling with light may reduce discomfort glare caused by large contrasts in lighting levels. Areas of relative darkness are as important as brighter areas to provide visual interest and a more natural lit appearance. In the natural world shadows are cast from the sun, they help reveal an object's solid form and define a space. With that in mind, daylight is an important factor to consider and not just the spectrum it produces but also the quantity, directionality and its ever-changing nature. In general, more light during the day is better, although when wrongly implemented, higher light levels can cause discomfort due to glare or contrast issues. It is also important to consider the usage of the space, for example display screen equipment requires special consideration. The ratio between screen brightness and the background will affect glare and visual comfort to the user, poor application of this can cause headaches and fatigue. Lighting controls can be used to provide a dynamic lit appearance which can increase visual interest and specific lighting levels for a particular user. To provide a truly Human Centric lighting scheme we must consider that individuals have preferences, in lighting this may be illuminance levels and personal controls to dim or boost the illuminance levels should be used.

Considerations – Light levels

- Use a lighting system that enables you to change the light levels: dimming (=reducing the light level) and boosting (=increasing the light level)
- Provide horizontal and vertical light levels that ensure adequate visual performance and comfort, while simultaneously providing non-visual (biological and psychological) benefits
- For task illuminance and illuminance of surrounding area, background area, wall, ceiling, and cylindrical illuminance levels, see the minimum required levels for each of these areas and surfaces in EN 12464-1:2021. Please note the new column "modified", which recommends using 1 or 2 light levels higher than the minimum required level with common context modifiers such as the presence of a part of the workforce over 50 years old. When increasing the task lighting, also light levels on the surrounding, background, wall and ceiling will need to change accordingly to avoid problems with contrast. It is important to read the full text in this new edition of the standard and not only use the tables.

Considerations - Distribution of light in the room

- Design[1] for maximum daylight entry into the room via windows and skylights.
- The light level from daylight decreases rapidly when you are two of more metres from the window. Additional electric lighting may be needed to provide adequate light levels in the inner areas of the building during daytime.
- Some advanced lighting systems can also change the distribution of light across the space (dynamic distribution) which is very powerful in changing the ambience in the room.
- As daylight itself varies during the day (in direction, intensity, colour, shadows, weather etc), such variations in the electric lighting system will be appreciated by the occupants and support creation of a natural environment.

Considerations - Glare

- Disability glare in buildings will most likely come from direct sun on the occupant's eye or on the computer screen. Installing blinds will be an effective tool against direct sunlight. These blinds should open again when no direct sunlight is directed on the window anymore (e.g. due to clouds, sunset or movement of the sun throughout the day). Occupants will appreciate the view outside. Note that additional indoor electrical lighting will be needed when blinds are closed.
- To avoid discomfort glare from luminaires in the room, ensure to use luminaires with the appropriate UGR according to EN 12464-1. The UGR shall be calculated via the tabular method to ensure an overall and average visual comfort everywhere in the room.

Better Lighting uses quality light sources

The quality of the light generated by the light source(s) and the luminaire in which the light source(s) are installed will impact the quality of light output from an electric lighting installation.
The development of LED lighting has revolutionised the lighting sector and opened the door to many new HCL-related opportunities not possible with previous technologies. Intelligent Lighting Systems make indoor environments more attractive and functional, allowing users to control light and dynamically adapt it to their specific needs, for instance by dimming. Several different distributions of light output are possible, and the spectral output from LEDs can be varied across a very wide range of colour temperatures. Adjustment of the colour temperature of the light output from LED light fixtures between 2700K and 6500K to suit occupant needs are common today, whereas traditional light sources are much more limited in these aspects.

Colour rendering index (CRI) is a measure of colour fidelity, i.e. how similar the colours of objects appear when illuminated by the light source as compared to illumination by a reference light source of the same colour appearance. CRI is not a measure for consumer preference. CRI can be derived from the spectral power distribution. Alternative metrics recently developed for colour quality include a colour fidelity metric, as well as a colour Gamut calculation. Recently, a new measure for non-visual performance is also derived from the spectrum: Melanopic Equivalent Daylight Illuminance (melanopic EDI). This melanopic EDI, described in the international standard CIE S 026/E:2018, combines illuminance levels and spectral composition, indicating the effect that the light source may have on human circadian rhythms. As this is still an area of research, application of these metrics are still indicative rather than absolute. Care should be taken in application design and performance claims based on these metrics.

[1] John E. Flynn et al.; 'Interim Study of Procedures for Investigating the Effect of Light on Impression and Behaviour', *Journal of the Illuminating Engineering Society 3(1)*, 1973, 87- 94. and John E. Flynn et al.; 'A Guide to Methodology Procedures for Measuring Subjective Impressions in Lighting', *Journal of the Illuminating Engineering Society 8(2)*, 1979, 95-110.

The absence of annoying factors such as flicker or stroboscopic effect are also seen as part of light source quality.

Better Lighting is created by professional lighting designers

Good lighting doesn't just happen, it's designed. Architectural lighting designers provide aesthetic, innovative and economically viable lighting solutions. Lighting design is both inherently functional and innately aesthetic. Professional lighting designers are uniquely qualified to bridge the gap between technical regulations and aesthetic considerations. They understand the role of lighting in architecture and interior design and rely on their extensive knowledge of lighting equipment and systems to ensure high quality design in the built environment.

A professional lighting designer:

- Strengthens and enhances any space through creative and practical lighting solutions, meeting the needs of the people who use the space.
- Specifies cost-effective and energy-efficient products most appropriate for the project.
- Creates an innovative lighting scheme that achieves the perfect balance of function and aesthetics.
- Solves the unique lighting challenges posed by a wide range of interior and exterior environments.

Considerations - Melanopic EDI

- A group of 18 scientists have recently published the recommendation[2] for healthy daytime active people for melanopic EDI ≥ 250 lux during daytime. This must be measured at the eye, generally vertically at sitting or standing height.
- Such high melanopic EDI can be achieved by increasing vertical illuminance in the room, by spectral engineering of the light, (Spectral Power Distribution (SPD)), or a combination of both.
- The recommended levels in the evening (melanopic EDI ≤ 10 lux) and at night (melanopic EDI ≤ 1 lux) are much lower as healthy daytime active people are recommended to (prepare for) sleep at these times.

Considerations - Colour

- Use light sources with both proper colour fidelity and colour saturation. Just using a higher CRI does not always lead to the most preferred solution in the application.
- Check for colour consistency of the various light sources in the room, also when replacing light sources during maintenance.
- Which Correlated Colour Temperature (warm, neutral, cool white) to use is a matter of personal and cultural preference. Please note that CCT is only a proxy for spectrum. The spectral content (SPD) determines the potential of the more advanced benefits with tuned spectra. Tunable light sources are becoming more common in the market. (See section 3.)

[2] Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults (plos.org)

Considerations - Temporal Light Artefacts

- Flicker can be easily avoided by selecting proper quality LED light sources and drivers with low P_{st}^{LM} values. Before specification and installation, it should be confirmed that dimmers are suitable for use with LED lighting without visible flicker. If confirmation is not available, it is recommended that testing is done before installation.
- A low stroboscopic visibility measure (SVM) can be easily achieved by selecting proper quality LED sources and drivers with low SVM values. SVM is not designed for application in workshops with fast moving or rotating machines. In such a case, please contact the lighting manufacturer or the lighting designer.

Better lighting is tunable or tuned for the application

Better lighting has a tunable spectrum or is tuned to support a specific activity in the application space. It is also possible to control simultaneously and automatically both the spectrum and light intensity of a lighting installation. This functionality may be valuable for aesthetic reasons, by introducing dynamism and drama to the space, or it may be used to improve visual acuity for certain tasks benefitting from different light levels or spectral composition. Tunable and dynamic lighting also allows the intensity and colour temperature of the electric light inside a space to be aligned with those of the daylight or sunlight outside, helping create the effect of 'bringing the outside in'. If correctly applied, it can support specific activities and a healthy sleep/wake cycle.

Given that we typically spend more than 90% of our time indoors nowadays, many of us have become starved of nature including natural daylight. The growing awareness of the concept of biophilia (a human's desire to be connected with nature) has driven lighting designers to increasingly incorporate daylight-mimicking aspects into their designs. A key aspect of daylight is its dynamic nature. Unlike traditional indoor lighting, daylight changes its brightness and colour appearance frequently according to multiple key factors like the time of day and time of year.

Considerations - Tuning Lighting to Mimic Daylight

- Choose luminaires and a lighting controls system that allow the brightness as well as the colour appearance to be separately adjusted to mimic time of year, time of day, and potentially compensate for weather conditions:
  It is possible to use sensors outdoors that allow the system to follow the actual daylight conditions prevailing very closely at the time, but those actual outdoor conditions are not always pleasant. It would be unusual if the occupants in a space on a cold rainy day in November wanted to mimic those actual conditions indoors. Instead, it is generally recommended instead to use a time-clock in the controls system that adjusts the luminaire brightness and colour temperature according to a program simulating dynamic, but pleasant, outdoor conditions.

Considerations - Tuning Lighting to Accommodate Different Visual Tasks

- Lighting that can have its colour appearance and brightness changed also allows the lighting to be tuned to the specific needs of an occupant in a space and the activities being carried out at any time. For example, think about specific lighting scenes for different activity types such as concentrate, relax, present, socialize. Also consider specific task lighting controllable by the user for tasks requiring higher level of concentration or detail.

Better lighting is personalised through controls

Several factors, such as the personal preferences, visual acuity of a person, the type of activities carried out in a certain space at a certain time or prevailing weather conditions, can affect the quantities, distributions and spectral qualities of light that are required. Lighting design tends to implement a scenario as described in the Application Standard (e.g. EN 12464-1 for indoor workplaces). The misinterpretation of the Standard frequently led to visually uninteresting lighting designs, limited visual comfort and, for a significant number of individuals, too low or too high lighting levels. For this reason, the 2021 revision of EN 12464-1 includes for the first time the concept of *Modified* light levels, which allows adjusting illuminances upwards for situations where higher levels may be required.

The personalisation and optimisation that is achieved by using lighting controls will both save energy and help ensure that the occupants of a building are provided with the right light, at the right time, in the right place for the various tasks they carry out every day. Pre-programmed settings can allow for light levels to be automatically changed. The current daylight conditions or a manual override by the inhabitants of the building based on their preferences or needs at that particular time can also activate certain settings.

It has been demonstrated that providing personal control of lights and shades can improve satisfaction at work. Being able to achieve one's preferred lighting conditions increases satisfaction with the environment.

Considerations - Facilitate Personal Control

- Choose luminaires and a lighting controls system that allow the illumination level as well as the colour appearance to be separately adjusted.
- Discuss with project stakeholders what level of control and which controls interface type (e.g., keypad, mobile app) are appropriate for different user types. For example, occupants might be provided with the option to override the programmed brightness to suit their own needs and preferences at any moment, but the colour temperature might be fixed according to the programmed algorithm (perhaps to maintain a design aesthetic across the whole space).

Daylight

Daylight in indoor workspaces has been shown to improve worker satisfaction and productivity. Furthermore, high levels of daylight during the day are reported to improve sleep quality during the night with consequent additional productivity improvements. In addition to the occupant benefits achievable by optimising daylight utilisation in a space, the 'harvesting' of daylight allows the electric lighting installation to be 'dialled-down', greatly reducing its daytime energy consumption.

Daylight is a high-quality light source. However, impacts such as disability glare from the sun, overheating due to excessive solar thermal gains and subsequent increased cooling energy costs may need to be addressed, for example by using automated solar shading[3].

[3] Nicholas Dodd et al.; 'JRC Technical Reports: Level(s) indicator 4.3: Lighting and Visual Comfort - user manual, overview, instructions and guidance, 2020. Available at 20201211 New Level(s) documentation_Indicator 4.3_Publication v1.0.pdf (europa.eu).

Managing daylight in a way that optimises it is a balancing act between maximising the benefits of 'free' light in the space, natural dynamics in intensity and colour appearance, views out and (wanted) solar thermal gain against the drawbacks of glare and (unwanted) solar thermal gain.

Considerations - Maximise Beneficial Daylight in a Space (and remove daylight discomfort)

- In commercial installations it is known that manually operated shades are very often kept closed all of the time[4]. To maximise daylight availability and views out whilst minimising glare and overheating effects from direct sunlight, use an automated shading system that works in tandem with the automated lighting controls to ensure that the system is constantly performing that balancing act in a way that provides the optimal result for the building and its occupants.

Each application requires its own lighting design

There is no one-size-fits-all solution for providing better lighting. It is recommended to have this realized by a professional lighting designer. The appropriate design solution depends on the application, which means that better lighting in an office, for example, differs from better lighting in a school:

- **At the office**: During the working day, lighting supports employees in their work. The visual, biological and emotional effects of lighting should be considered. Modern lighting concepts make working easier: Human Centric Lighting increases concentration, reduces fatigue and is bright enough for all visual tasks, including tasks performed by aging employees. The minimum value for illumination at eye level should be met by a sufficient vertical lighting level of the required spectrum. Higher lighting levels and the right spectral composition help to maintain the performance for a longer period of time. Furthermore, personalization through controls is of utmost importance. The right amount and spectral distribution of light vary according to each individual's personal needs and the needs of the task they are performing as well as according to the time of day and prevailing weather conditions. A study by CBRE[5] in offices showed an improvement of 12% in task performance with Human Centric Lighting.

- **At school**: The beginning of classes, during both summer and winter, can be supported by high light levels. For well-being and performance, the lighting spectrum should respect the seasonal daylight conditions. Vertical illuminance at eye level deserves additional attention in the lighting design. The right light supports students in their learning: concentration is increased, studying together is easier and fun. Compared to adults, a teenage girl's internal clock is generally delayed by one hour, and a boy's is generally delayed by up to two. That is why students, especially during winter, need extra amounts of short wavelength light early in the morning to wake them up and better synchronize their rhythms with the working day.

[4] Vorpat Inkarojrit; 'Balancing Comfort: Occupants' Control of Window Blinds in Private Offices', Dissertation University of California, Berkely, 2005. Available at Balancing comfort: occupants' control of window blinds in private offices (escholarship.org).

For visual tasks, lighting must comply with all the requirements defined in the European standard EN 12464-1 but these only constitute a minimum. Standards are based on established good-practice, but inherently lag behind latest knowledge and developments – often by many years. We therefore recommend going beyond the minimum requirements set in these standards.

Contact

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About IALD

Founded in 1969, the International Association of Lighting Designers (IALD) is an internationally recognised organisation dedicated solely to the concerns of architectural lighting designers operating independently from lighting manufacturers. The IALD strives to set the global standard for lighting design excellence by promoting lighting quality, the advancement and recognition of architectural lighting designers and the architectural lighting design profession. IALD members are located in 54 countries and practice globally. The IALD has a European office based in Brussels. More information about IALD is available at www.iald.org.

About LightingEurope

LightingEurope is the voice of the lighting industry, based in Brussels and representing 30 companies and national associations. Together these members account for over 1,000 European companies, a majority of which are small or medium-sized. They represent a total European workforce of over 100,000 people and an annual turnover exceeding 20 billion euro. LightingEurope is committed to promoting efficient lighting that benefits human comfort, safety and well-being, and the environment. LightingEurope advocates a positive business and regulatory environment to foster fair competition and growth for the European lighting industry. More information is available at www.lightingeurope.org.