theLIA

HUMAN CENTRIC LIGHTING

OBJECTIVES OF THE GUIDE

This LIA document is not a structured design guide, but rather is intended to assist in the understanding of the concept of Human Centric Lighting (HCL) to support human requirements from lighting, leading to enhanced well-being for occupants of indoor spaces. Controls and connectivity play a major part in providing an HCL solution especially where sensing and personal lighting is concerned.

This document attempts to consolidate some of the claims that are gaining credibility in the market, but it is important to point out that the concept of HCL is closely linked to science and particularly to wellbeing and health. The LIA is not expert in these matters and this document must not be interpreted as providing expert guidance in matters related to wellbeing or health.

The creation of this guide would not have been possible without the valuable help provided by members of the LIA Human Centric Lighting Task Force (HCL TF).

You can rely on a number of reputable suppliers to provide the details to suit your application. Just explain how, and when, your business works and they will design the best strategy and system for your needs.

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INTRODUCTION

Good lighting has an ongoing impact on our lives and facilitates all our activities. The converse, which is more noticeable, can have many detrimental effects such as on our ability to concentrate and even on our health and wellbeing. However, we are all individuals, and we all have different lighting requirements depending on our age, activity, preference, eyesight, where we are and the time of day.

Good lighting should focus on the individuals and their needs, and we need to look at the totality of the lighting requirements including biological, visual, non-visual and emotional responses. We have evolved over millions of years under daylight, and it is a vital element of our needs which should be incorporated as much as practically feasible but often it will need to be supplemented by electric lighting.

In the past, we have been limited by the electric light that we have been able to create, but modern LED light sources have given us the possibility to reproduce many aspects of daylight, with variations in colour temperature and intensity now being relatively simple to achieve. We are no longer constrained by what daylight can achieve and with current technologies, it is possible to create lighting effects that enhance the appearance of objects, people and spaces in a way that is not possible even with daylight.

Previously, we concentrated on supplying sufficient light to perform a visual task or view an object without considering other aspects of a space. When we consider lighting for people, (true Human Centric Lighting [HCL]), we should add all the other aspects that we instinctively appreciate, for instance, a bright ceiling replicates the natural direction of light, whereas a dark ceiling can feel oppressive and gloomy.

Using the balance of light correctly within a space can create a comfortable environment but also one that can stimulate and work with all our senses. Therefore, light levels in the vertical, horizontal, and cylindrical plane should be considered. Accent light can add visual interest and variation which is something we enjoy. Using varying colour temperatures of lighting throughout the day is one of the cornerstones of HCL where the colour rendition of the light should be of high quality.

Of course, the lighting must work technically; this means aspects such as flicker, glare and distribution have to be well controlled, and it must work on a level to ensure safety. Additionally, we can design lighting to increase the wellbeing of building occupants which is becoming an important factor within many commercial buildings.

The winter months can have a very depressing effect on some people; rainy and stormy weather is not something we would normally want to replicate inside, so we can choose which aspects of natural daylight we want to reproduce. A 24-hour society pushes us beyond the natural environment, and we need to find the balance between the conditions that we have evolved under and the modern-day requirements.

What is now commonly known as Human Centric lighting (HCL) has been used to cover many aspects of light and is increasingly being used in many different ways. Within this document we have used the CIE approved terms and the definitions are quoted here.

Adaptive Lighting – lighting responding to circumstances or according to predefined conditions, while maintaining the lighting quality within the specified requirements for these circumstances or conditions.

Integrative Lighting - lighting integrating both visual and non-visual effects, and producing physiological and/or psychological benefits upon humans.

ASPECTS OF HCL

The light output quality from an electric lighting installation fundamentally depends on the light sources themselves. The lamp and/or luminaire in which the light source(s) are installed will also have some influence on the quality and quantity of the light output.

The development of LED technology has revolutionised the lighting sector and LED lighting is highly amenable to spectrum and dimming control. There are now many different distributions of light output possible due to the flexibility in assembling the light-emitting diodes in various configurations to create LED modules. Furthermore, the spectral output from LED light sources can be varied across a very wide range of correlated colour temperatures (CCT). Adjustment of light fixtures between 2000K and 7500K to suit occupant needs are not uncommon today, whereas traditional light sources are much more limited in these aspects.

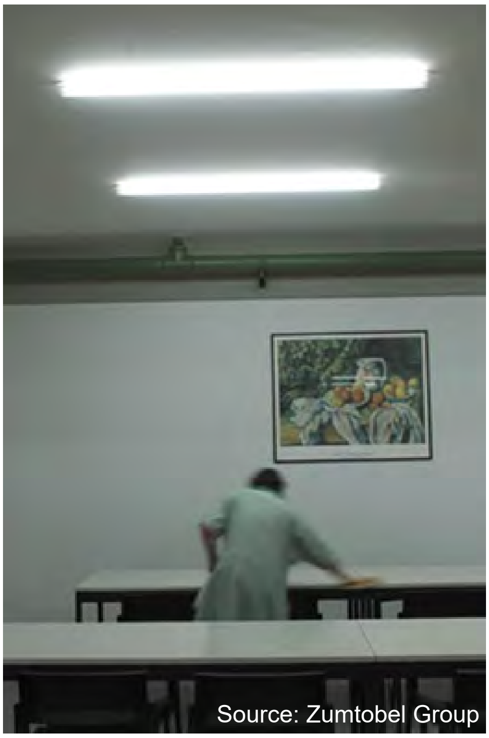
The limitations of traditional colour metrics such as colour rendering index and colour temperature to fully describe how an object or space will be rendered has led to those metrics being supplemented with new ones that allow better specification of object rendition as affected by a greater number of light colour parameters.

Suitable provision should also be made for light sources that are adequately free of so-called temporal light artefacts (flicker and stroboscopic effects) and that is tuneable in their spectral output and intensity according to the needs of the occupants in the space. There is also growing interest in the output of light sources in terms of their contribution to non-visual performance and particularly the effects that may have on human circadian rhythms.

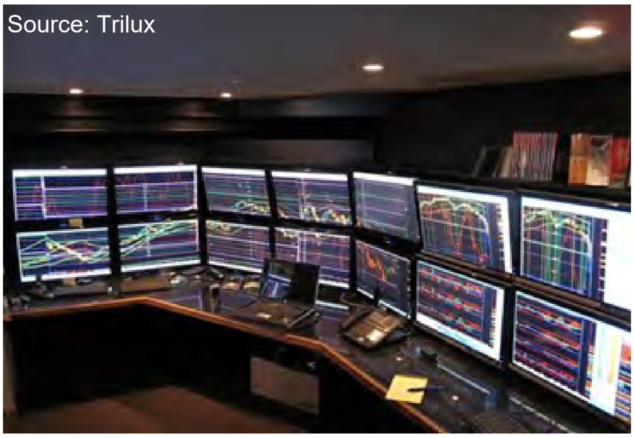
Lighting quality within the lit space

Traditional lighting design of a space as we know it, involves metrics such as lux levels on a horizontal plane, uniformity, and unified glare ratings. While these metrics are important in adequately lighting a space for people to work or perform their everyday tasks safely, they will not necessarily help to promote wellbeing or performance of an individual. In order to do this, other factors must be considered.

Lighting levels are traditionally measured on a horizontal plane at working height to achieve compliance against standards. However, the vertical illuminance within a space is also important, after all your eyes are generally looking in this plane. The variation in illuminance is also important, ceiling to wall, to highlighting points of interests. Techniques such as wall or ceiling washing should be considered to reduce glare levels. Darkness is as important as light to providing interest and a natural lit appearance. In the natural world shadows are cast from the sun, with the sun being perpendicular to the earth for only a short period of the day. With that in mind, daylight is an important factor to consider and not just the spectrum it produces but also the quantity. More is not always better and could cause issues with glare and increased contrast leading to user discomfort. 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 other illnesses [1].



Example of a poor glare effect



Example of a poor contrast ratio between screen and background

Integrative Lighting

Lighting that goes beyond a purely visual impact is integrative lighting. Creating a lit space that lets us relax and de-stress can be classed as integrative lighting, in that it has a psychological impact, giving us a heightened sense of wellbeing. Lighting of a landmark or artefact that makes us stop and appreciate the beauty of the object can have a similar impact beyond the pure visual ability to see it.

The human body's daily sleep/wake cycle patterns, referred to as circadian rhythms, are to a great extent dictated by biochemical reactions triggered by our exposure to light. As humans have evolved, daylight has been the primary regulator of this cycle, however as we have moved to the point that we typically spend around 90% of our time indoors [2], we can become starved of this natural light. The spectral properties, intensity, distribution and time of light provision are factors that are believed to play significant roles in stimulating or indeed suppressing the body's natural circadian system. Lighting designs that incorporate this are known by several popular names including Circadian Lighting design and Integrative Lighting design and these are elements of human centric lighting.

Multiple new possible metrics for this have been developed and are gaining attention, including Equivalent Melanopic Lux, Equivalent Daylight Illuminance, Circadian Light and Circadian Stimulus. It should be understood though that whilst knowledge of circadian rhythms has a fundamental grounding in the science, the application to electric lighting design is still ongoing and consensus has not yet been reached. Nonetheless, it seems prudent that some awareness of the concept and likely contributory factors is obtained and considered when conceptualising a lighting installation today.

Adaptive Lighting

Adaptive lighting refers to the simultaneous and automated dynamic control of both colour temperature 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 to improve visual acuity for certain tasks benefitting from different light levels or colour temperatures. Adaptive 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. This could be as part of an indoor biophilic design concept, or in the context of circadian lighting, it may be in an attempt to align the electric light indoors with human circadian rhythms.

Example of white tuneable light effect

Control Strategies

Lighting controls can be used to provide an individualised lighting level for a particular user whilst also providing a dynamically lit appearance to increase visual interest. In order to provide a truly Human Centric derived lighting scheme then we must acknowledge that individuals have preferences, which may be lighting levels, colour, controllability, and the absence of glare and flicker, etc.

The quantities, distributions and spectral qualities of light that are required from a lighting design/installation vary considerably according to multiple factors. These include the tasks that are being carried out at any point in time as well as the visual acuity and preferences of the individuals in the space at the time. Traditionally, lighting designs have attempted to accommodate this by providing for the worst-case scenario, inevitably leading to unnecessarily high light levels across the entire space and with limited visual comfort. Of course, this also has a material effect on increasing the power consumption of the lighting installation.

As well as saving energy, personalisation and optimisation via lighting controls can help ensure that only the right light, in the right quantity, at the right time and in the right place is provided. Light levels can be changed automatically through pre-programmed 'scenes' that can themselves be triggered by external factors like prevailing natural daylight conditions or by manual override by the occupants, depending on their particular needs or preferences at the time.

Innovation and the continued development of 'smart' control systems utilising mesh networks and intuitive 'app' based systems is further supporting the possibility of delivering control systems that can support human focused lighting solutions and future upgradability.

Daylight

Natural light in office spaces has been shown to improve worker satisfaction and productivity [3][4][5]. In addition to the occupant benefits achievable by optimising daylight utilisation in a space, the 'harvesting' of natural light allows the electric lighting installation to be 'dialled-down', greatly reducing its daytime energy consumption.

Although daylight is a high-quality light source which must be optimised during the lighting design of the building, there are some potential negative impacts that may need to be mitigated, for example, through the use of automated solar shading. These negatives include glare, overheating due to excessive solar thermal gains and subsequent increased cooling energy costs.

Source: Trilux

Example of daylight in offices

CASE STUDIES

All lighting designs/installations are unique to their particular applications and specific requirements which challenge designers to think beyond simply horizontal illuminance. For example, in healthcare, it may be to create an environment where medical professionals can provide the best care and patients can recover resulting in free bed spaces for future patients. The lighting designer needs to support these objectives by providing the right light for the medical professionals to do their tasks, but by also creating an aesthetically pleasing and comfortable space in which the patients spend their time recovering. Within commercial spaces, this may be linked to an increase in productivity whilst in educational spaces this may be to align with beneficial Ofsted results.

Therefore, whilst the general principles of lighting remain reasonably constant across the board, the specific requirements of outcome can differ both in the various market sectors and in individual application.

The initial aims for lighting designs are to provide a solution which makes the building affordable within budget constraints and meets the relevant European and national legislative requirements and that of best practice and guidance. Additionally, a well-designed lighting solution can help in reducing the environmental impact by using a low carbon solution and low energy consumption in addition to a reduced maintenance schedule.

When designing the lighting of the space, a number of factors should be considered in the design to produce spaces that are comfortable for the occupants. Factors that should be considered include:

- Occupant profile of the expected users of the space;
- Predominantly transitory, predominantly sedentary, predominantly active but at a fixed position, etc;
- Expected physical and visual capability;
- Age distribution.

Whilst the lighting for the task is well covered in standards the size and complexity of the task, including contrast(s) in luminance and/or colour, should also be considered to ensure ease of viewing for the user.

Commercial

In September 2014, the World Green Building Council published 'Health, Wellbeing & Productivity in Offices: The next chapter for green building' [6]. In this report, they reported that 1% of the cost for a business is energy, with 90% being people. The influence of light (daylight and electric light) is one factor considered within the report for businesses to consider delivering welcoming, comfortable, productive, health focused and inspirational environments for us, the employees.

Illustration of business costs

Over the last decade, in many cases the adoption of LED technology has often been driven exclusively for energy benefits with little thought for the lit effect beyond delivering a horizontal illumination level at 0.75m above floor level. However, and as already highlighted in this document, a lighting designer must consider many more metrics within their design to deliver spaces that go beyond just simply the task performance but the health and wellbeing of those employees.

Commercial (continued)

Some of the additional considerations are highlighted below:

- Age of user – aging working population – do levels go far enough?
- Task location – is it necessary to uniformly light the whole floor plan?
- Correct level of illumination for task to be performed.
- Importance of Communication – Cylindrical Illuminance & Modelling.
- Visual comfort & Glare control, i.e., UGR.
- Removal of veiling reflections to avoid disability glare, <3,000cd/m2@65 degrees and above.
- Use of indirect light & visual interest.
- Surface finishes & surface illumination.
- Simple, intuitive lighting control systems.
- Colour rendition.
- Research around benefits of ‘integrative’ & ‘adaptive’ systems – e.g., EML, Circadian Stimulus etc.


Source: Whitecroft lighting

Example of a lighting installation in a commercial environment

Education

A major feature in the initial learning process is in providing a qualitative educational environment and one that recognises the benefits of motivation & sense of well-being without distraction hindering the process. Improving the learning environment can be achieved by providing functionality, visual stimulus, a comforting ambiance, and sustainability.

Providing access to a well illuminated environment has an impact on learning and improved productivity [7][8].

When undertaking lighting designs for applications within the education sector, it is suggested that lighting designers provide a solution which considers the following:

- High levels of wall illumination – Teaching, Visual Contrast.
- Indirect Light to support visual comfort & lighting of ceiling space.
- Appropriate lux levels for task and age of students.
- Importance of vertical illumination to support learning, communication & safety for occupier.
- Intuitive controls to harness effective learning spaces & optimise energy savings.
- Use of Colour Temperature & Intensity to support different activities.
- Flicker


Source: Whitecroft lighting

Example of a lighting installation in an educational environment

Healthcare

The primary healthcare objective is providing lighting for the staff and patients who will each have different lighting requirements. A well-illuminated environment is known to improve recovery times & patient comfort [9][10]. In addition, patients should have some control over their own environments.

Good quality lighting can boost staff morale, efficiency, and well-being [9] whilst specialised procedures may need a specifically lit environment.

Example of a lighting installation in a healthcare environment

When undertaking lighting designs for applications within the healthcare sector, it is suggested that lighting designers provide a solution which considers the following:

- Position lighting at task not the whole room.
- Create domestic feel where we can – do not get too concerned about small variations in levels and uniformity particularly away from medical tasks as this will support more relaxed lighting solution. E.g., if not getting perfect uniformity on the task then do not worry.
- Importance in CRI for key medical areas The Cyanosis Observation Index (COI) is also frequently used in these areas.
- Material use and protection against cleaning chemicals.
- Using light and colour to create visual interest in stressful areas.
- Appropriate products for application e.g., MRI no ferrous metals, remote gear & emergency system.
- Simple logical controls.
- Importance of daylight in the health benefits [11]
- Careful consideration and appropriate colour temperature to support patient wellbeing, & clinical needs [10][11][12].
- Ongoing studies into the importance of integrative lighting in mental health and potential health benefits.

How to make it happen from a technical point of view

Current standards are based upon two principle factors, safety and visibility. Firstly, a space must be safe to be in. There must be enough illumination to move and exist within the space with minimal risk of harm. (It should be noted that good lighting cannot in itself create safe spaces, it can only decrease the risk factors within a space. It is still possible to be injured in a space with good lighting as many other aspects of the space may come into play that can result in harm).

However, sufficient illumination to aid occupation of a space does not necessarily provide sufficient illumination to perform activities or tasks within the space and vice versa. (i.e., a focused light to perform a task on an industrial machine does not necessarily provide adequate levels of light to move within the space). Therefore, additional illumination may be required to allow people to perform other tasks within the space.

Standards such as BS EN 12464-1 and BS EN 12464-2 generally address these two issues well, providing advice for the lighting of tasks and spaces. However human-centric lighting adds a third dimension. Lighting practices need to change and evolve to create layered solutions, addressing the existing core issues of safety and task requirements but also considering the occupant needs in a coherent and integrated manner.

This is a difficult and complex requirement although standards do already consider this issue in a relatively simplistic way. For example, BS EN 12464-1 considers the wider lit environment by specifying illuminance values for walls and ceilings within a room and cylindrical illuminance to light faces and objects within the space as well as UGR and Ra values.

General criteria as mentioned above but applied (light levels and distribution/ light source/tuned and tunable/control/daylight).

Perceived room brightness (mean ambient illuminance, visual lightness, adaptation luminance)

The perceived brightness of a space is important for the occupants' wellbeing and alertness [13]. In the field of vision, the perceived brightness (luminance pattern) is a result of the interaction between illumination and the reflectance properties of objects and room surfaces. However, illuminances are more practical to evaluate than luminance since no detailed information is usually available on interior decor or occupant seating and primary viewing directions at the design stage.

By using the values for average illuminance on the walls and ceiling and also cylindrical illuminance, an adequately perceived room brightness and illumination of people and objects can be ensured. The exact values are application specific and as such need to be adapted to the activity and/or task characteristics. These include visual communication (e.g., in classrooms, meeting rooms and offices) and visual comfort for areas where the specified task or activity is performed for extended periods of time.

How to make it happen from a technical point of view (continued)

Whilst the wall, ceiling and cylindrical illuminances are indicators of room brightness and the recognition of objects and people alternative methods have been proposed and three of these are briefly described below.

Mean ambient illuminance, Ēamb (Govén et al) [14]

This method calculates an approximation of the apparent brightness within a space by evaluating the total amount of light reaching the walls and ceiling of the space. The average illuminances on these surfaces are calculated and these values are then averaged to calculate the mean ambient illuminance for the room.

Mean room surface luminous exitance, Mrs (Cuttle) [15]

This approach considers that the visual appearance of a space is based upon the brightness of the room surfaces. That is the luminous flux leaving a surface as opposed to the luminous flux falling onto the surface. It proposes the use of mean room surface luminous exitance, which serves as a measure of average illuminance for all points within the space due to reflected light from the room surfaces, (direct light from either luminaires or windows is excluded) and is expressed in lm m-2.

Visual lightness and interest - 40 degree band luminance (Loe et al) [16]

This considers that the key factors in the perception of a space are the two subjective parameters of 'visual lightness' and 'visual interest' related to the brightness of a horizontal band, 40° high and centered at normal eye height. In relatively small rooms this 40° band relates closely to the area of the walls, but in larger rooms it includes the ceiling and the floor.

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Further reading

– IES (TM-18)

– IES (TM-30)

– WELL Building Standard

– World Green Building Council

– Fitwel

– BCO Lighting Guide