BURO HAPPOLD

NDTi
National Development Team for Inclusion

Technical Note: Sensory Friendly LED Lighting for Healthcare Environments

30 August 2022

1 Executive Summary

1.1 Understanding of the scope

Responding to the climate emergency and crisis, the report '*Delivering a Net Zero National Health Service*' for NHS England (NHSE) published in October 2020 delivers a clear commitment towards improving NHSE's carbon footprint and reducing the environmental impact of the services. As part of this combined effort, one of the targeted early steps to decarbonise is by upgrading the lighting to LED technology expanding across the entire NHSE and improving patient comfort, whilst providing operational cost and carbon savings over the coming three decades.

LED lighting is now the dominant light source that has gradually led to phasing out of conventional light sources. The rapidly advancing LED technology and lighting controls offer great benefits in terms of energy optimisation. However, caution needs to be taken where aspects related to the sensorial stimulation and visual comfort of all users, with particular attention to people who are hypersensitive to light. This is often the case with many people with sensory processing differences, autism and other neurodivergent and neurodegenerative conditions.

1.2 Document audience

This technical note is relevant to the following parties:

- National Development Team for Inclusion (NDTi) teams
- Consultants, designers and procurement teams, involved in lighting for healthcare facilities, including contractors who have been awarded procurement and implementation of the project
- Facilities/asset management or operators of premises
- Electrical Engineers and Sustainability Assessors
- The document may also be informative for regulatory bodies such as Building Control officers.

1.3 National Development Team for Inclusion (NDTi) role

Over the past year, the NDTi Autism Team have supported the development of NHSE Sensory Friendly Ward Principles. There has been a longstanding understanding that fluorescent lighting can cause strobe-like flickering and/or humming which is distressing for many autistic people and others who experience visual hypersensitivity.

The popular alternative light source is LED lighting, particularly following the recent 'Net Zero' drive within the NHS and its associated recommendations to move towards LED lighting for energy efficiency purposes. However, LED lighting can also be extremely problematic for autistic individuals or other light sensitive users. As part of our work supporting the Sensory Friendly Ward Principles, NDTi sought specific, technical lighting guidance to share with hospitals to ensure that the upgrading schemes will cater for appropriate luminaires to the setting that do not impact those using the space negatively. It was found that there was not any existing clear or comprehensive guidance to ensure a best practice and autism-informed approach. As a result, NDTi have sought partnership with specialist teams from Buro Happold, NHSE and UCL to begin this work.

1.4 Buro Happold role

Through interdisciplinary collaboration, Buro Happold Lighting and Inclusive design teams were put in contact with the National Development Team for Inclusion (NDTi) to compile a technical note addressing lighting performance guidance for creating balanced sensory environments for autistic and neurodivergent people.

1.5 Reason for issue

The purpose of this document is to:

- Raise awareness of the additional impact that lighting can have on those with sensory sensitivity – in particular autistic and neurodivergent individuals.
- Raise awareness on the psychological impact of lighting, particularly in healthcare environments.
- Provide guidance when designing, procuring, or installing lighting systems, during the refurbishment of lighting in existing healthcare facilities or planning the lighting design for new healthcare buildings.
- Safeguard the performance of the lighting installations over time.

1.6 Key objectives

- Support patient and staff well-being by offering a dynamic experience and intuitive user control, where appropriate.

- Optimisation of energy use to satisfy sustainability targets.
- To share current understanding of how to ensure that LED lighting installations can be adjusted to reduce the negative impact on autistic/ light sensitive people accessing the space.

1.7 Benefit - The importance of lighting and daylighting in healthcare environments

The quality and appearance of the environments where we spend the majority of our days have a direct effect on our physiological state and well-being. For many people, staying or even visiting healthcare facilities can be stressful. Particularly where longer in-patient stay is required, creating a soothing, caring, and engaging environment is of key importance.

Autistic individuals often experience heightened sensory sensitivity which can lead to high levels of physical and psychological distress. Current lighting provision within NHSE healthcare settings rarely matches the needs of photosensitive or photophobic individuals and, as such, can create a sensory environment that runs counter to the wellbeing of autistic patients (and staff): potentially hindering and slowing down recovery times.

It is also important that staff working on shifts and being present around the clock can feel supported to enable them to provide their maximum efforts for patients care. Well considered lighting installations utilising high quality LED lighting equipment and intelligent controls improve working conditions as well as patient experience and are responsive to the demanding operational requirements of healthcare facilities.

1.8 Methodology

This technical note addresses key principles related to daylight and artificial lighting. Where deemed appropriate, area specific criteria are outlined for consideration. Current regulations and technical guidance documents are summarised to enable easy review by readers and encouraging opportunities for discussion on the need for further research on the impact of lighting on people who experience hypersensitivity to lighting.

The baseline was built upon good practice guidance including specific and wider considerations that affect spatial experience and our behavioural reaction to our environment. Further, the methodology employed for the composition of this technical note is collection of qualitative observational data through a series of meetings with NDTi members, consisting of people with mixed levels of light sensitivity. We held monthly meetings aimed to pass real user feedback gathered through conversation with inpatients in hospitals such as a medium secure CAMHS inpatient facility and useful insights on spatial experience in varying factors including but not limited to lighting conditions.

An explanatory note on the direct impact of the discussed technical parameters is added for reference under each paragraph within Section 4 of this document.

1.9 Status of the document

This technical note provides advice and practical guidance on design aspects and lighting characteristics applicable to healthcare premises, with a particular focus on inpatient environments for individuals with neurodivergent conditions or experiencing visual hypersensitivity. It needs to be clarified that the document has not gone through public consultation. However, it is referencing up-to-date established best practice including standards and topic specific memorandums. The guidance is applicable to new and existing sites and is intended to be used at various stages during the design and operation of the building.

1.10 Use of this document and presentational conventions

This document takes the form of guidance and recommendations. It should not be cited as if it were a specification or a code of practice.

It has been assumed that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Any recommendations are expressed in sentences in which the principal auxiliary verb is "should" and in an upright font. Commentary or explanation presented in italics is informative only. Where quotes are expressed in sections of this document, these are indented and teal bold text used.

1.11 Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by Buro Happold and NDTi in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

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2 Technical References

The daylight and artificial lighting design should be in accordance with the following but not limited to the regulations and standards noted below:

- BS 8300-2, 2018 Design of an accessible and inclusive built environment - Buildings. Code of practice;
- BS EN 12464-1, 2021 Light and lighting, Lighting for Work Places, Part 1 Indoor working places;
- BS EN 17037:2018, Daylight in buildings;
- BS 8493:2008+A1:2010, Light reflectance value (LRV) of a surface;
- CIBSE Guide A, 2021 Environmental Design;
- CIBSE SLL LG02, 2019 Lighting for Healthcare premises;
- CIBSE SLL LG10, 2014 Daylighting;
- CIBSE SLL LG11, 2001 Surface Reflectance and Colour;
- IEEE P1789-2015, Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers;
- PAS 6463, Design for the mind – Neurodiversity and the built environment (refer to section 11 for lighting related content) – due for publication spring 2022;
- CIE 97-2005, Guide on the maintenance of indoor electric lighting systems.

Note: Bibliography and research documentation are provided at the back of the document.

3 The WHY - The autism sensory context

3.1 Autism as a sensory difference

Autistic people have long been known to experience 'a typical sensory reactivity' (Hannant, Tavassoli and Cassidy, 2016: 2). However, it is only very recently that we have come to understand these sensory difference as an essential component of what it means to be autistic. The recent inclusion of sensory processing difference in the diagnostic criteria for autism (DSM-5, American Psychiatric Association, 2013; ICD-11, World Health Organization, 2018) is based on persuasive modern research recognising the neurological basis of autistic differences in sensory processing across all sensory domains (see Proff et al., 2021, for recent systematic review). While modern diagnostic criteria have only caught up, autistic people have been talking about their sensory differences for a long time.

> **"Our five senses are how each of us understands everything that isn't us. Sight, sound, smell, taste, and touch are the five ways – the only five ways – that the universe can communicate with us. In this way, our senses define reality for each of us… What if you're receiving the same sensory information as everyone else, but your brain is working differently? Then your experience of the world around you will be radically different from everyone else's, maybe even painfully so. In that case, you would literally be living in an alternate reality – an alternate sensory reality."**
>
> **Temple Grandin and Richard Panek (2014:70)**

Understanding that the sensing and perceptual world of autistic people differs from the neurotypical sensory world is central to providing supportive and nurturing environments for autistic individuals. NDTi and the associated Sensory Friendly Wards Principles advice, recommend that the sensory environments of inpatient hospital settings are always assessed by or alongside autistic people who are knowledgeable and experienced in sensory environments, as autistic people are the best placed to identify potential sensory challenges. However, this document can provide specific technical guidance around lighting equipment and lighting methodologies employed within premises that can support autonomy and wellbeing.

3.2 Autistic experience of lighting

Due to visual sensitivity, many autistic people experience a given light intensity as brighter than neurotypical people. Parmar and colleagues (2021) found that autistic people experience a 'range of visual hypersensitivities, including light, motion, patterns and particular colours, which contribute to distraction and are frequently part of a wider multisensory issue. Such experiences have significant negative impacts on personal wellbeing and daily life with participants describing fatigue, stress and hindrances on day-to-day activities (e.g., travel and social activities).'

Not only is it good practice to make adjustments that will support positive outcomes for autistic people, but it is also a legal requirement under the Equality Act 2010 to make such reasonable adjustments where the level of impairment meets the definition of disability. All healthcare providers therefore have a duty to make reasonable adjustments, including adjustments to the lighting conditions that affect spatial perception of the environment.

3.3 Autistic people in hospital settings

Hospital settings are places where people are often already under a degree of mental and/or physical stress and multi-sensory processing of the environment can significantly add to this. However, the sensory hypersensitivity experienced by many autistic and neurodivergent individuals is often overlooked or not properly understood, leading to potential additional anxiety and distress. This has been acknowledged in the Care Quality Commission (CQC – 2020) report into restraint, seclusion, and segregation, which found that patients were not having their needs met.

> **'Environments they were living in were not adapted to their sensory needs and they were not being offered support to communicate. Some providers were not making reasonable adjustments legally required under the Equality Act 2010'. (CQC, 2020: 12)**

With regard to the specific, harmful impact of the sensory environment on the wellbeing of inpatients, the report goes on to say that:

> **'being placed in an inappropriate environment can be damaging and creates a pattern of distress, restraint and seclusion, which often cannot be broken. In many cases, we found that the impact of the environment on people, such as the noise, heating and lights of the wards, had not been considered. In many cases staff did not understand people's individual needs and the distress that being in the wrong environment could cause, particularly for people with sensory needs. This could lead to people expressing their distress in a way that others find challenging, leading to staff resorting to using restrictive practices.' (CQC 2020: 13)**

We hope that this guidance will support providers, ward staff and facilities teams in inpatient settings to adapt the lighting to ensure an autism-informed approach is taken to reduce harm to patients and support better outcomes for individuals.

It is also important to remember that not all autistic people in healthcare settings will be patients. Current estimates suggest that between 1 in 100 (The NHS Information Centre, Brugha et al., 2012) and 1 in 59 (Baio et al., 2018) people are autistic. Many healthcare and facilities staff members will also be autistic and would benefit from these adaptations.

4 The HOW - Technical guidelines for balanced lighting in healthcare environments

4.1 Daylight design and integration

Note: Daylight is easier for most people to process and is less likely to cause negative impacts such as buzzing or flickering, that artificial lighting is more prone to.

Daylight has a positive contribution to patients' recovery and well-being. Access to daylight and exterior views not only helps with stimulation and alignment of patients' and staff members' biological clocks but also can offer measurable energy savings in line with power density requirements and responding to the sustainability targets on reduction of carbon emissions.

Daylight can be further categorised as direct sunlight, ambient skylight and reflected daylight:

- Direct sunlight can pose challenges in balancing visual contrast. Sunlight penetration over extended periods of time may also result in high cooling requirements for thermal management of the interior environments. Therefore, direct sunlight needs to be managed and controlled to prevent negatively affecting the building's performance in terms of energy demand and user comfort. Despite the aforementioned challenges, exposure to sunlight has a positive psychological and biological effect that is particularly applicable to patients and staff in healthcare environments. Direct sunlight is most likely admitted via vertical openings and glazed surfaces. Orientation and size of apertures are key considerations. However, the level of control of these features will vary depending upon the degree of intervention possible in existing buildings and user engagement in new developments.
- Ambient skylight (daylight excluding direct sunlight) and reflected daylight are indirect forms of daylight. Skylight is mostly admitted via horizontal openings and reflected daylight via vertical openings on buildings at close proximity. Provided suitable glazing and shading devices are in place, these forms of daylight have a softer effect, with a reduction in defined shadows. For example, using glazing with a degree of diffusion or other treatment (e.g. fritting) can help filter the direct daylight, leaving a diffused quality of daylight to enter the interior of the building. Similarly, a range of internal and/or external shading devices that are mechanically or manually operated can provide additional control of the daylight entering the building.

Appropriate daylight design reduces the need for artificial lighting at high intensity at all times during daytime. In addition to the LED technology becoming increasingly more efficient year by year, the integration of daylight lowers energy demand, reducing operating costs/ operational carbon emissions, increasing the longevity of the lighting installation, and requires less regular maintenance.

The above benefits require the introduction of dimming for artificial lighting. Lighting equipment should be linked to data devices such as photosensors that trigger gradient transitions (fade in/out time of 5-10 seconds) of light intensity based on the occurring daylight levels. Where daylight presence is significant, shading strategies need to be considered and put in place ensuring visual contrast is managed. Automatic mechanical control of shading components is beneficial as an additional consideration in shared or common areas of the building.

In areas for regular occupancy over an extended time (e.g. residents/ patients' rooms, meeting rooms, offices etc.), providing a level of individual control further benefits the spatial experience and allows adjustability of internal ambient conditions to comfortable levels.

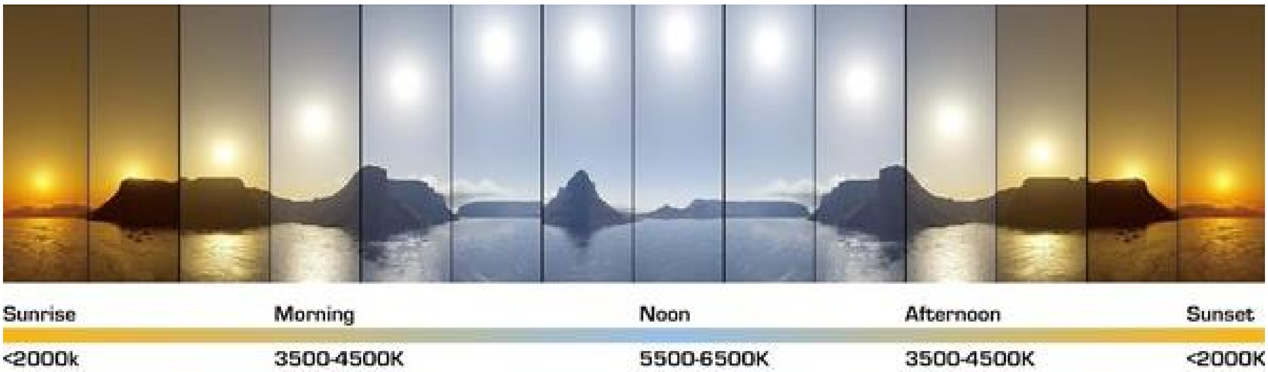


Figure 4—1 Range of daylight colours throughout daylight hours

4.2 Light intensity and uniformity

Depending on the use of the space, lighting intensity and uniformity requirements may vary. Refer to BS EN 12464-1, 2021 Light and lighting, Lighting for Work Places, Part 1 Indoor working places and SLL LG02, 2019 Lighting for Healthcare premises for light intensity guidance for key areas in healthcare facilities. However, as these aim to address the everyday needs of people who do not experience hypersensitivity to light, it is recommended that light intensity can be adjusted based on the feedback from user experience (patients with sensory processing differences affecting the sensitivity to light, visitors and staff). Based on current research and surveys on spatial experience, it is understood that some people have a lower threshold of comfort under high illuminance levels and may also be sensitive to contrast colours, patterns and other variances in the perceived environment. Wider implications of design are set out in 'PAS 6463 Design for the Mind – Neurodiversity and the Built Environment'.

In general, areas where visual tasks are performed, transitional areas and spaces where a higher accumulation of people is expected, high uniformity is recommended (>0.6) with low contrast levels. Lower uniformity is likely to be acceptable and often beneficial in patients' private rooms or dwelling areas on the basis that sufficient light coverage is provided at localised level enabling the performance of more demanding tasks (e.g. reading) for that individual or group of users.

4.3 Light quality

Note: Autistic people, particularly those with photophobia, are more likely to be sensitive to the quality of lighting and to be adversely impacted by poor quality lighting equipment.

Light quality encompasses a set of attributes that are associated to the emitted light. These attributes are often associated with cost implications and therefore need to be addressed as part of the targeted performance specification to allow accurate costing. In addition, setting the threshold to a high standard is a way to ensure the delivery of a high quality environment whilst safeguarding the lighting installation over time.

4.3.1 Colour temperature (CCT)

Note: Some autistic people have reported finding cool white / blue light difficult to process. In some instances, this causes significant sensory processing delays and can lead to sensory overload.

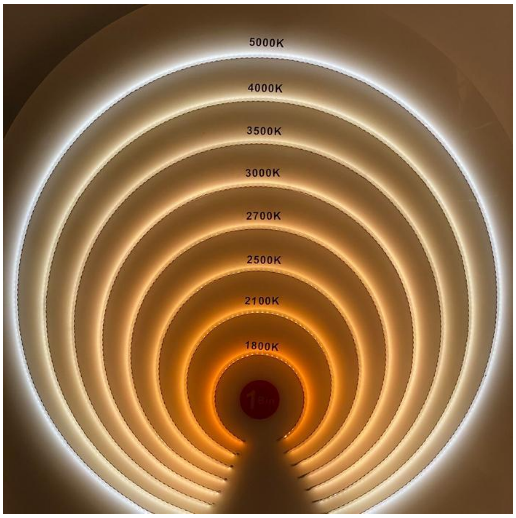


Figure 4—2 Colour temperature range

The term CCT - Correlated Colour Temperature - is assigned to a light source to identify the chromaticity of the emitted light. The colour characteristics of the light source are measured in degrees Kelvin. The warmer the appearance of the light source, the lower the degrees of Kelvin. It is a quality to which people are subconsciously susceptible as our circadian rhythms are tuned to respond to natural light encompassing the full range of light colours throughout the day. As each spectrum of CCT is proven to have an impact on human psychology, suitability is judged by the area usage, activities, time of the day etc. Warmer light evokes feelings of relaxation and creates an inviting ambience. From a human centric lighting point of view, warmer colour temperatures imitate natural light at times of sunset and dawn, whilst cooler white light resembles natural light at the brightest time of the day. Cooler light increases alertness, concentration and is linked to higher pace of activity.

Table 4—1 Colour temperature recommendation by area (key areas addressed)

Area	Recommended colour temperature	Additional considerations
Admissions, receptions, lobby	3000-3500K	Tuneable white lighting (2700K-4000K) where significant daylight contributions apply
Treatment areas, examination rooms, procedure rooms	4000K	n/a

Circulation areas, corridors	3000-3500K	Consider using layers of light with different colour temperatures to aid building navigation and orientation
Relaxation rooms, recovery rooms, lounges, food & beverage facilities	2700-3000K	n/a
Supporting facilities (e.g. toilets, utility etc)	3000-3500K	n/a
Patient rooms	2200-3500K	Consider using layers of light with different colour temperatures to aid in room examination and personal activities. Refrain from cooler colour temperatures during the evening to improve sleep quality.
Offices, meeting rooms, labs, consulting rooms, administration	4000K	Tuneable white lighting (2700K-4000K) where significant daylight contributions apply
Back of house spaces	4000K	n/a
Exterior areas and building facades	2700-3000K	Addition of coloured lighting for feature applications
Note: Through collected feedback from individuals, it appears that there is a tendency for warmer colour temperatures as these are perceived as more comfortable compared to cool colour temperatures. However, specific research studies are needed to deduct further verifiable results.		

4.3.2 Tuneable white lighting

Tuneable white lighting aids in tuning patients and staff with their inner circadian clock, normalise sleep patterns, regulate stress levels and prevent agitation. The control of the colour temperature within one luminaire assembly is also known as tuneable white lighting. Given daylight's dynamic nature, such LED technologies are recommended to be adopted in areas where significant daylight contributions apply. In addition, areas where extended duration of stay/ activity is expected (e.g. patient rooms and staff offices) could also benefit from tuneable white lighting.

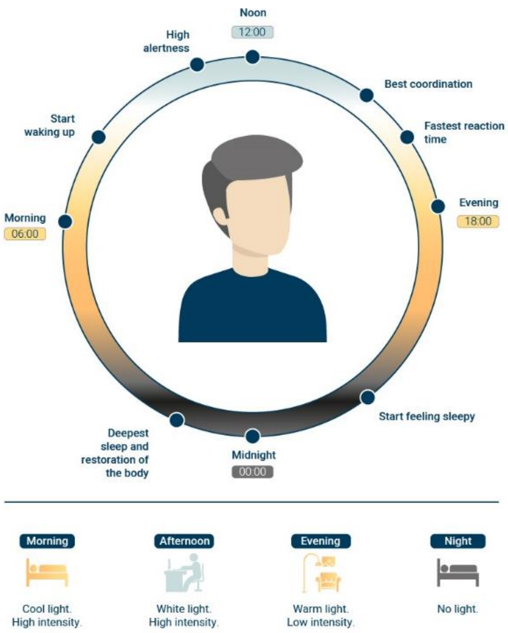


Figure 4—3 Human centric lighting

4.3.3 Colour rendering (CRI)

Colour rendering measures an objective indication of the ability of a light source to illuminate objects faithfully so they appear natural. The general colour rendering index Ra has been introduced to specify the colour rendering properties of a light source. The maximum value of the metric (Ra) is 100, and it is assigned to daylight. Daylight is also used as a reference measure when evaluating artificial light sources. Higher figures represent good/excellent colour rendering properties, whilst lower figures (<70) indicate inferior colour rendition. It is important for visual performance and the feeling of comfort and well-being that colours of objects and human skin are rendered naturally, correctly and in a way that makes people look attractive and healthy. A minimum requirement for CRI 80 is applicable to all areas. However, particular areas where demanding visual tasks are performed (i.e. examinations) present demands for higher colour rendering (CRI 85-90).

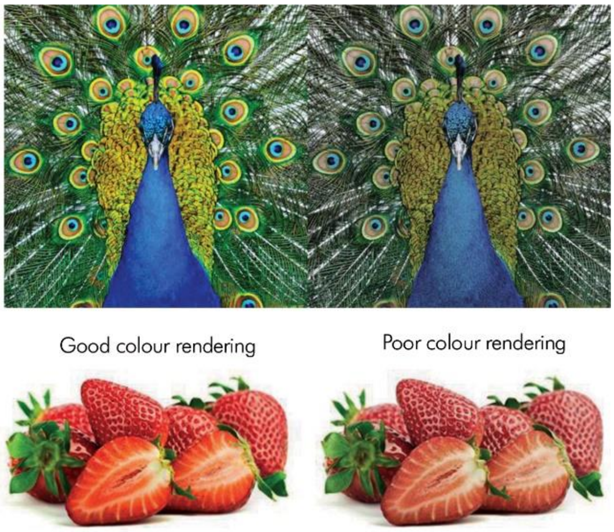


Figure 4—4 Colour rendering qualities

4.3.4 Colour consistency

Ensuring reliable colour consistency over time is critical for phased installations, where fixtures are purchased and installed at different times, for expansion and multi-site installations. Both initial and maintained colour consistency should be considered, as a luminaire may perform and look acceptable when first installed, but the light quality of the individual LEDs may degrade over time to an unacceptable level. Lighting manufacturers devise methods of selecting bins of LEDs in such a way as to minimise differences in colour that might be visible among luminaires or through different production batches.

The threshold at which a colour difference becomes perceptible is defined by the metric of steps on McAdam ellipse. The benchmark for acceptable colour consistency between lighting equipment of the same type should be set but not limited to 3 "steps" on the McAdam ellipse, tested for initial and maintained colour consistency over time (min. 5 years warranty). The above restriction ensures that the variations in chromaticity produced by the emitted white light source (CCT) are barely discernible by a trained eye when comparing the colour temperature of the same type of luminaires.

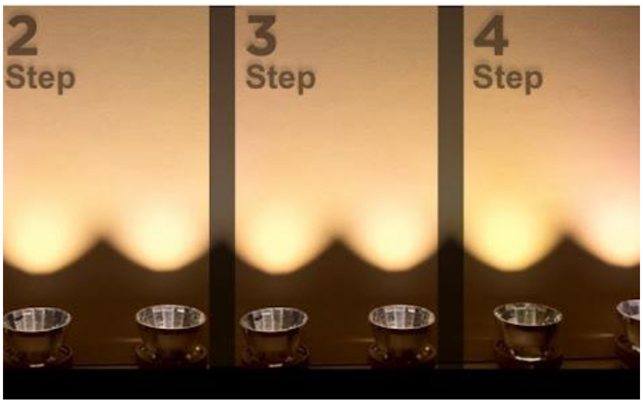


Figure 4—5 Variance in colour consistency

4.4 Lighting methodology and luminaire selection

Commonly, in order to achieve a cost effective lighting scheme and installation, lighting equipment is placed at high level in a grid/ linear arrangement with direct downward emission. Direct emission means that light is directly aimed towards the surface to be illuminated (e.g. floor), with the minimum quantity of equipment and minimum losses of light. This results in an energy efficient solution which is often adopted due to the national sustainability targets. However, beyond its functional use, light has a significant impact on people's perception of the space and their emotional response to it. An unshielded view of the light source is the trade-off from direct emission luminaires. Where uncontrolled optics occur, there is a high likelihood of causing glare or visual discomfort. Glare is a very subjective experience and is dependent on periphery contrast levels. Regardless of the neurocognitive profile of users, extensive use of direct luminaires increases the chance of experiencing glare which may lead to unpleasant spatial perception and stress.

The use of diffusing materials covering the LED light source mitigates the risk for glare but, depending on the scale of the lit surface, hypersensitive users might still perceive the contrast levels as high. It should also be noted that the addition of diffusing materials has a direct effect on the efficacy of the luminaire system as a portion of the light is absorbed by the diffused cover. Diffused luminaires are less likely to cast sharp/ defined shadows that may result in a confusing image of the perceived environment for people who are hypersensitive to visual stimulation and light.

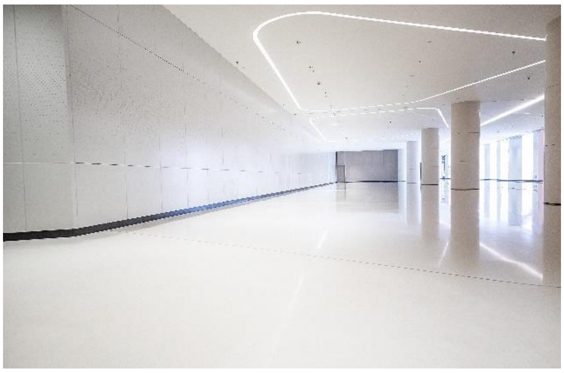


Figure 4—6 Good precedent application of indirect concealed lighting in hospital corridor (Source: Marienkrankenhaus Hospital, Germany), Figure 4—7 Good precedent application of lighting layers providing vertical and horizontal illumination (Source: Adobe Stock)

4.4.1 Recommended lighting methodologies

- Use multiple layers of lighting that can be controlled separately.
- Complement the lighting scheme using indirect light sources or light sources that are well integrated in the architectural/ interior design of the space. This may be in the form of ceiling/ wall coves, recesses or utilising a drop ceiling system (e.g. baffles) to conceal lighting equipment and minimise direct view of the light source from majority of sightlines.
- Make use of surrounding surfaces to bounce light indirectly towards the surface to be illuminated. For example, grazing or washing a wall in a corridor can reflect light towards the walking surface and sufficiently illuminated if planned correctly. Vertical illumination also has the added benefit of facilitating navigation and orientation, which are qualities of significant importance for users with high sensitivity who benefit from environments of calmness and comfort. Other alternatives to this method include uplighting the ceiling from luminaires mounted on the vertical surfaces and above eye level or use of backlighting.
- Use focused, glare-free lighting near the bed or seating area to provide better acuity for detailed visual tasks.
- Provide night light of a warmer colour temperature (<2700K) for ward/ patients' rooms through low level/ indirect source to allow comfortable navigation at night without high light intensity exposure.

Figure 4—8 Good precedent application of lighting above bedhead with direct and indirect light emission (Source: Adobe Stock)

4.4.2 Lighting equipment recommendations

- Where directly visible, use luminaires with deep set light sources (UGR <19);
- Where adjustable luminaires are used, light sources should be aimed at angles no greater than 25 degrees from the vertical axis;
- Consider parabolic "dark-light" louvres, special lenses, honeycomb inserts, cowls or full/half-moon snoot accessories on light fittings to shield luminaire and minimise visual discomfort;
- Avoid highly specular surface finishes which may reflect bright light sources;
- As a preference, use luminaires that prevent a direct view of the light source, either due to diffusing covers, deep set LEDs or via their concealed integration in architectural details;
- For overhead wall lighting in patients' rooms, use dual direct/ indirect emission to provide both a reading mode and/ or an ambient mode, maintaining individual user control of upward/ downward emission;
- Unless placed at low level to enable individual adjustment, lighting equipment should be installed away from public reach to reduce the probability of safety issues arising from close contact with electronic components. In addition, patient safeguarding considerations need to be taken into account in the luminaire selection.

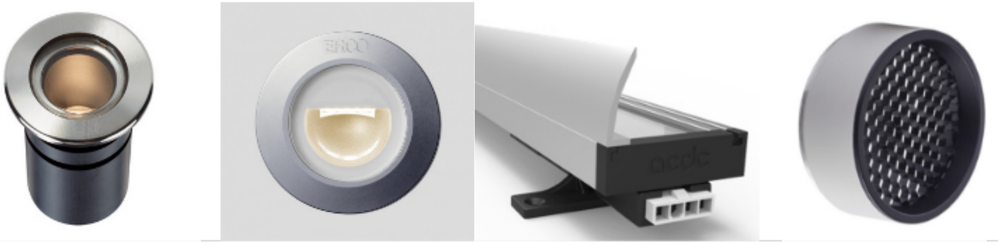


Figure 4—9 Indicative luminaire typologies aiming to conceal/ minimise direct view of light source

4.5 Lighting control

Note: People have different lighting sensitivities and individual needs. Any given space may be used flexibly and by multiple occupants. To support personalisation of the space and to meet individual need, it is important for users to have the ability to control and adjust the lighting. This is particularly important where people are affected by photophobia or have visual hypersensitivity.

4.5.1 General recommendations

- User control over lighting elements enables personalisation of the environment that ultimately leads to an enhanced user experience.
- Dimming is a prerequisite in achieving a dynamic ambience that follows the use and day/ night cycle. Going beyond the default approach of dimming levels (25/50/75/100%) for all lighting in an area, assessing and approaching the various layers of light within a space separately is recommended. Therefore, allowance for separate lighting control groups for each lighting typology in a space is advisable.
- Data devices: The addition of occupancy detection devices and sensors with long fade-in times coupled with an intelligent control system (DALI addressable or DALI Broadcast) operated by user-friendly interfaces, can result in an efficient scheme with optimised energy consumption. Five second fade in/out time with gradual smooth dimming is considered good practice to avoid abrupt changes in light levels. As these changes result from input fed to the dimming system by sensors, their location, calibration, sensitivity, and proper function is important.

- Interfaces and user training: Legibility and intuitive use are key consideration for lighting control panels and interfaces. Available functions and pre-set lighting scene settings need to be explicitly articulated. This can be achieved either by user training or clear tagging of lighting components adjusted via user control. Even though, architecturally, the aspiration is likely to be to achieve a close match on the finish of the hosting walls to the lighting control panel, adequate visual contrast from the wall surface needs to be considered to allow quick identification of lighting control panel locations. Reflectance is the proportion of light that a surface reflects compared to the amount of light that falls on the surface. An LRV (Light Reflectance Value) is a value given to a surface to denote the amount of light reflected. LRVs are marked on a scale of 1 to 100 depending on the percentage of light reflected. 50-60 points LRV difference is recommended for lighting control panels (reference document: BS 8493:2008+A1:2010), with 70 points LRV difference recommended for people with sight impairments (BS8300).

4.5.2 Flicker considerations

Note: Many autistic people are more sensitive to flickering lights that might not be perceptible to other users of the space.

Flicker can be defined as the variations in luminous output from a luminaire in time. Regardless of the light source type and it being visible or invisible to the human eye, flicker is an effect present in most artificial lighting luminaires. Flicker can be visible or invisible. Both types can have health effects on users when exposed for a duration of time. Especially when adding lighting controls to LED luminaires, the choice of the dimming method and the LED driver can directly impact the flicker performance of a luminaire as the main contributing factors. As the impact of flicker and its subsequent health effects remain highly subjective to the individual's perception, research groups and professional bodies are investing time and efforts in developing metrics that quantify flicker to define acceptable thresholds for different applications.

Health Impact of Flicker

Reducing the likelihood for users to experience flicker is particularly important in healthcare facilities and environments where users have a long duration of exposure to and reliance upon artificial lighting. The power supply and suitability of the control components need to be carefully considered to ensure that users are not adversely affected by flicker effects, particularly when lighting is dimmed. Flicker visibility is closely related to flicker frequency. In principle, the higher the flicker frequency, the least likely to be visible or result to health effects. Flicker frequencies up to 70 Hz are easily perceivable by humans, regardless of their neurocognitive profile. Flicker frequencies up to 160Hz may not be visible to the naked eye but may still affect people with light sensitivity and may result to headaches, visual disturbance and difficulty in spatial processing.

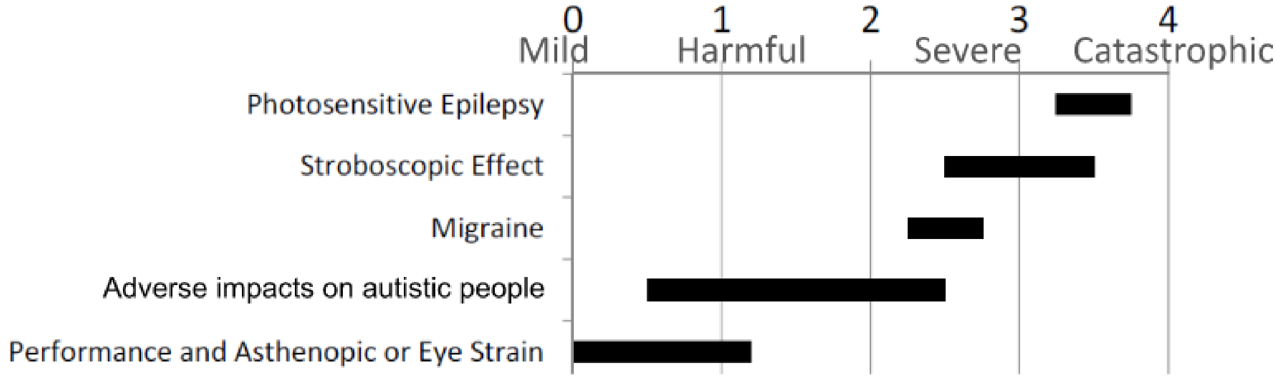


Figure 4—10 Key health effects caused by flicker in severity scale (Source: Lightfair International, 2016 and IEEE Risk Assessment Matrix)

Flicker percentage describes the metric used to measure flicker at a given frequency. Conformance with IEEE P1789 standard is a recommended performance criterion to be considered when specifying / procuring lighting for healthcare premises (Reference to 'IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers - IEEE P1789').

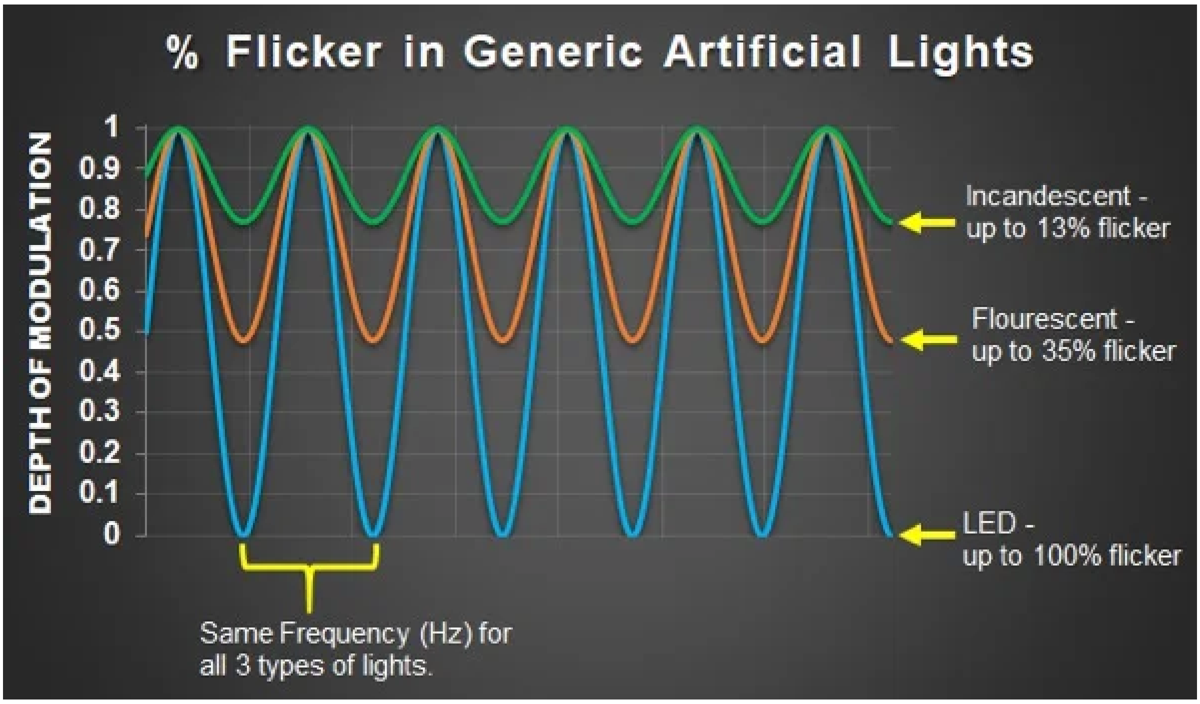
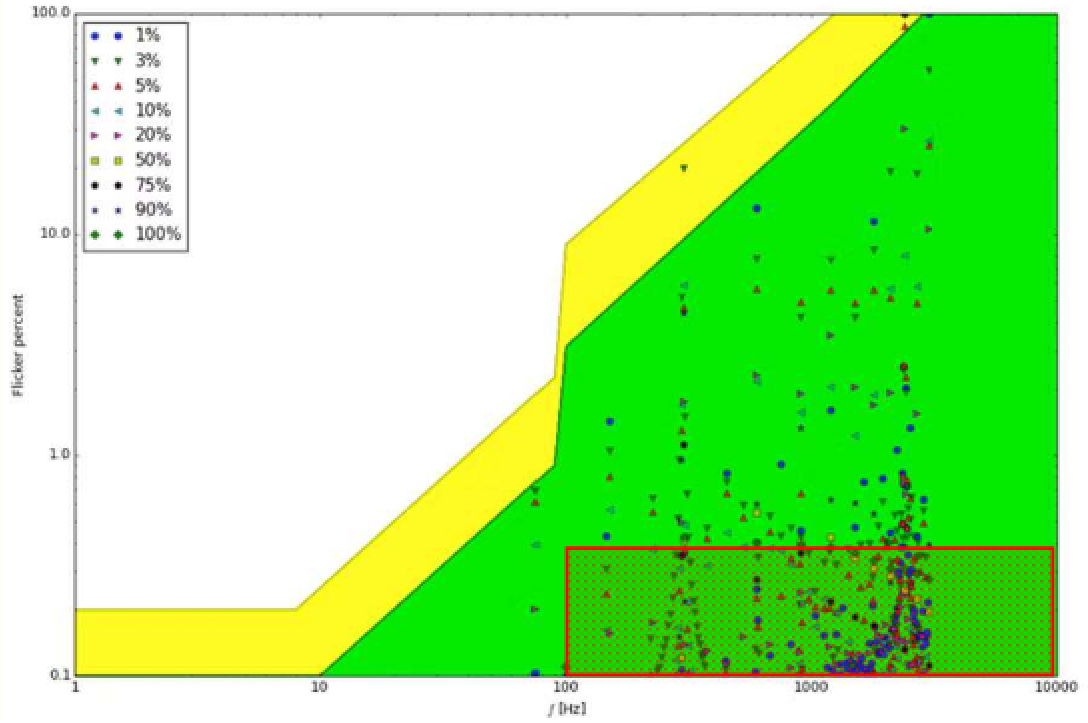
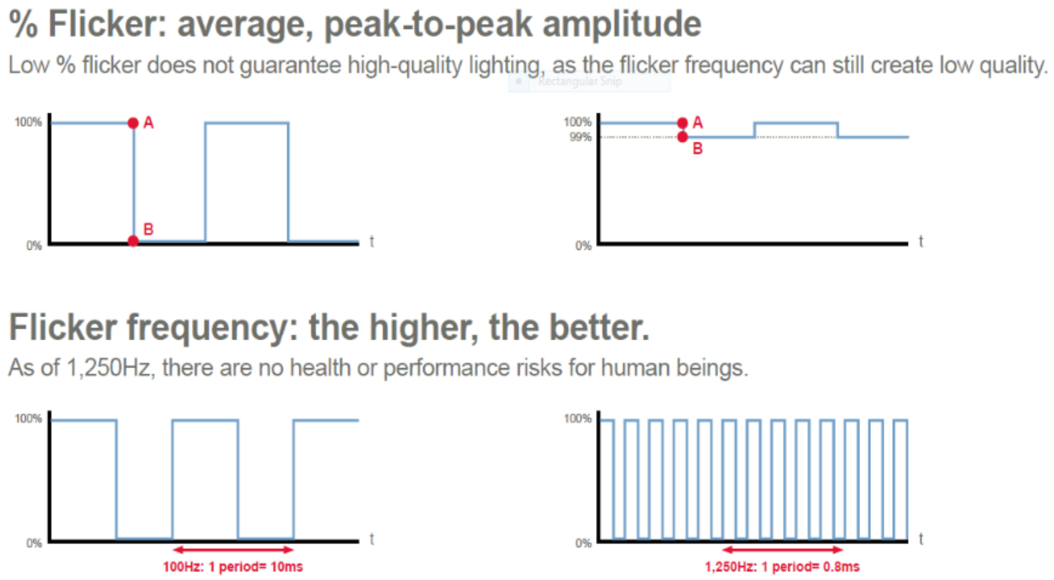


Figure 4—11 Percentage of flicker in generic artificial light source types

Table 4—2 Practical guidance on flicker produced by LED lighting

At Design Stage
• Request and review LED driver manufacturer's information on flicker metric calculations and verify conformance with IEEE P1789 standard. Refer to example result table for compliant LED driver – in principle, all recorded data need to fall within the green (acceptable) or yellow (low risk) zones. However, this is based on neurotypical users and the sensitivity for many neurodivergent people is very different. Please see explanatory note below.  **Explanatory note on added red hatched area on graph:** As previously stated, there is an awareness that many neurodivergent people have a heightened sensitivity to levels of flicker that might not be perceptible to other users of a space. While the IEEE P1789 standard has become the recommended performance criterion for specifying control devices with low levels of flicker, the standard was developed, and mainly supports people with a neurotypical response to frequency flicker. At the time of writing this guidance document, a lot more research needs to be carried out to fully understand how the above graph relates to people with autism or others who experience light hypersensitivity. While it is known that control devices which produce frequency flicker rates of around 1% provide positive benefits on neurotypical people, we cannot be certain that even at the relatively low level of 1% it will be equally comfortable to people with light/ flicker sensitivity. Therefore, it is recommended that when purchasing or specifying control devices, these should have a maximum frequency flicker level of 0.5% at control frequency ranges of 100Hz and above. This recommendation is based more on commercial considerations than technical evidence due to the lack of reliable research findings. This area of control is identifiable on the red hatched area to the bottom right of the graph. Control devices within this range will obviously carry a cost premium, but they will help produce the most comfortable visual environments for people with neurodivergent and neurotypical profiles.

- Include flicker criteria and conformance requirements in design documentation (i.e. specification documents) to safeguard the scheme's implementation. LED driver specification should consider the following criteria:
  - Flicker frequency is greater than 1250 Hz
  - Percentage Flicker (%) is ≤ Flicker frequency x 0.0333 (applicable to light sensitive user groups)



- Request samples of luminaires with dimmable drivers and dimmer control as (intended to be) specified to review and assess. Flicker is not dependent on one component only. It interrelates among the components of a lighting system assembly.

- Obtain a high quality flicker meter to enable accurate testing of luminaire samples at design stage.
- Add information on types of dimming and intended strategy.

PWM dimming
pulse width modulation

- Switching LED on/off in fixed frequency
- ✓ Good dimming regulations at low levels
- X Potential noise generation
- X Potentially undesirable flicker, depending on frequency

CCR dimming
constant current reduction

- Varying LED current, LED always on
- ✓ No flicker
- ✓ No noise generation
- ✓ Higher LED efficacy at lower dimming levels
- X Poor dimming regulation at deep dimming (low current) levels

Hybrid Hydra Drive dimming
"improved" modulation

- LED are not switched off (amplitude change)
- Modulation in *variable* frequency
- Less current when possible
- ✓ Best dimming regulations at deep dimming levels
- ✓ High duty cycle frequencies
  - ✓ No flicker
  - ✓ Dimming all the way to 0.1%
- ✓ Increasing LED efficacy at dimming
- ✓ Low noise generation

• Pulse Width Modulation (PWM) drivers are more likely to flicker and produce noise. The use of constant current drivers reduces considerably the likelihood of experiencing disturbing flicker effects. However, it prevents achieving very low dimming levels (3% or lower). Therefore, a hybrid approach now adopted by major LED driver and lighting controls manufacturers is recommended. See examples of such systems by LED driver manufacturers on the links below: - EldoLED: https://eldoled.com/technology/hybrid-hydradrive/ - Helvar: https://helvar.com/luminaire-components/dimming-with-led/ - Lutron: https://www.lutron.com/TechnicalDocumentLibrary/LED_Solutions_Brochure.pdf • Encourage implementation of case studies and user surveys which would be further interpreted and incorporated into a design framework.
At Procurement/ Construction Stage
• Request and review technical submittals of drivers as part of Contractor's submittals. • Ensure dimmer switches and interfaces are not overloaded/ underloaded. • Implement on-site testing of installed lighting at dimmed levels using flicker meter during commissioning visits. • Ensure dimming system is based on open source protocol and fully interoperable. • Check for electromagnetic compatibility (EMC) compliance.
At Operation
• Request, gather and analyse feedback from frequent users of the spaces and their perception of flicker. • Ensure that appropriate drivers meeting specified criteria are procured during maintenance cycles over the lifetime of the installation. • Check if a power surge is occurring from high energy demanding appliances connected to mains power that may be affecting the stability of electrical supply to the lighting circuits. • Check for loose wiring by authorised electrician. • Maintenance/ operation teams to take a proactive approach on taking flicker readings of lighting equipment at different dimming levels using a flicker meter to inform and further adjust the scheme.

4.6 Other considerations

4.6.1 Materiality

As the perception of light and its behaviour is closely interrelated to the materials from which it reflects, consideration of finishes (hue, reflectance, specularity etc.) is of paramount importance when using direct/ indirect ways to illuminate a space. The finish of the surface has a direct impact to the efficiency of the lighting installation as darker finishes absorb more of the emitted light than they reflect. A higher percentage of gloss (>25%) could also lead to uncomfortable visual effects and high incident contrast from certain viewing angles. Close coordination of material finishes with the Architect/ Interior Designer can lead to a balanced visual experience. Direct illumination strategies (high level lighting facing downwards) are less reliant on the surface materiality.

4.6.2 Noise generated from lighting equipment

Note: Many autistic people have multi-sensory sensitivity – including auditory hypersensitivity. They may therefore be able to detect noise from lighting equipment and associated devices that is not within the range of other people's threshold using the space. Many autistic people also do not habituate, so they will continue hearing the noise from lighting and not be able to tune it out.

Noise, and its control, frequency and intensity, is an added factor impacting physiological and psychological state and wellbeing. People with neurodivergent conditions (such as autism) are very often sensitive to noise. Amongst various elements resulting in the noise levels of a space, a common observation is buzzing/ humming noise generated by the lighting typically when operated at a dimmed level of light intensity.

The cause of this common issue is linked to the dimmer switches and their compatibility with the LED lighting equipment and, more specifically, the driver/ power supply component. When transitioning from using conventional light sources (e.g. tungsten, fluorescent lights) to LED lighting, it is important to ensure that suitable dimmer switches are specified. Due to the low wattage and electronic nature of LED lighting, connecting it to traditional dimmer switches used for high wattage conventional light sources and resistive loads may not reach the minimum power required to allow dimming, resulting in unsettling noises. For example, if a dimmer switch with a range of 20W to 300W is connected to one 15W LED luminaire, the luminaire may start to flicker or buzz. Equally, exceeding the upper threshold of 300W is likely to cause short-circuiting and lead to LED failure.

To mitigate this issue, it is recommended to request and follow lighting manufacturers' recommendations for tested and compatible LED dimmer switches. The minimum and maximum power of the dimmer switch is commonly stated on the packaging or at the back of the component itself.

4.6.3 Design considerations for operation and maintenance

One of the notable benefits enabled by the transition from conventional light sources to LED lighting is the significant improvement on the rated life of the light source. The extension of the rated life of products has a positive impact on the longevity of the lighting installations which, in turn, reduces the frequency of maintenance intervals. In addition, as LED lighting technology continues to advance rapidly, and lighting equipment becomes more efficient (more useful light for the operating power consumption). Control systems also receive regular updates allowing live monitoring, reporting of issues and collection of data that further inform the facilities management strategies and preventative maintenance planning.

Key recommendations that have an impact on operational regime and maintenance can be found below. Please refer to *'CIE 97-2005, Guide on the maintenance of indoor electric lighting systems'* for extended guidance on the maintenance of electric lighting installations.

- Height of lighting installation and access requirements: typically, lighting or electrical components that are installed in areas with access restrictions (e.g. atriums, facades etc.) pose a maintenance challenge as they incur increased costs and added coordination for the facilities team of the premises. This could lead in delays in the replacement/ remedial works, temporarily creating light imbalance and in turn affecting user comfort. Therefore, ease of maintenance access to the lighting equipment and/ or control components (e.g. LED drivers) should be considered during the design stages.
- Ease of replacement/ re-lamping: Spot or group re-lamping are common strategies for the replacement of failed light sources. Spot replacement means that a single light source is replaced once failed within a short period of time. Group replacements mean that remedial works take place once a number of light sources have failed. Group replacements are usually favoured as they reduce labour costs. However, this entails that time can pass with a few light sources having failed prior to maintenance being carried out. With LED lighting having a notably longer lifespan than conventional light sources, group replacements may potentially lead to years going by with a percentage of luminaires remaining unserviced. This could potentially compromise light levels and uniformity, creating higher contrasts which will be more noticeable to those with some level of photosensitivity and could prove detrimental to many people with sight impairments who rely on even lighting to navigate spaces.

- Sustainability: Maintenance of spares used to be a common practice. However, with LED lighting equipment constantly developing in their design, retaining spares can be wasteful as they may be obsolete or incompatible with latest technologies by the time they are used. Instead, it is recommended that modular lighting equipment is utilised from manufacturers that offer long warranties (5+ years and/ or a long duty of care period). This enables ease of replacement with minimum intervention to the installed lighting equipment. Modularity and extended warranties also contribute towards the assurance of having a sustainable system that can stay updated perpetually and be disassembled, reused, re-purposed or recycled as appropriate, reducing the environmental footprint of the lighting installation throughout its lifecycle, from the materials for manufacturing, through to operation and reuse/ disposal.
- Cleaning intervals: As discussed above, admitting natural light can be of great value to users' well-being as well as reducing energy demands. Therefore, glazed apertures will need to be maintained in a clean condition to maximise daylight. Incorporating self-cleaning glass can reduce the operational demands for frequent cleaning, especially in areas with access restrictions. In addition, the regular cleaning of the lighting equipment (housing) ensures the targeted/ designed light levels are maintained on the reference plane to be illuminated (i.e. floor, working plane, wall etc).

4.6.4 Monitoring

Continued collection of user feedback to inform/ further improve the installation is essential. In addition, pursuit of research on the lighting focused impact on both patient and staff experience is encouraged in collaboration with academic bodies (e.g. UCL).

We welcome your comments on this document through the feedback form that can be found here. The short anonymous survey will take approximately 5 minutes to complete.

5 Conclusions/ Next Steps / Actions

As a result of the issue of the first version of this document in November 2021, we are now in close correspondence with the NHS National Autism Team and planning on ways to take this guidance on board in their internal processes associated to lighting.

The next steps will be to continue engaging with health organisations, the lighting industry and academic bodies and to reach out to more people and gather further feedback on the above guidance. Another key step of the process is related to securing funding for carrying out research projects to strengthen/ support the guidance noted in this document or further adjust it. We also hope to engage with the target reader groups of this document to seek feedback on ways to ensure the above guidance is considered when carrying out regenerative works for existing facilities or designing new premises.

Ultimately, the intention is that these guidelines will be applied in broader healthcare facilities with the view of providing more inclusive, equitable and engaging environments for all those visiting, working or residing in healthcare facilities.

6 Glossary

Term	Definition
Colour Rendering (Ra)	An indicator of how accurately colours can be distinguished under different light sources. The colour rendering index (measured in Ra) compares the ability of different light sources to render colours accurately. This measures the ability of a light source to render colours naturally, without distorting the hues seen under a full spectrum radiator (like daylight). The colour rendering index (CRI) ranges from 0 to 100. Colour rendering index CRI
Correlated Colour Temperature (CRI)	The colour temperature provides an indication of the light colour and is expressed in Kelvin (K). Lamps are generally rated between 2700K (warm), 4000K (neutral) and 6500K (cool). Unit: kelvin, K.
Control Gear/ Driver	A 'package' of electrical or electronic components including ballast, power factor correction capacitor and starter. High frequency electronic control gear may include other components to allow dimming, etc.
Chromaticity	Term is used when addressing colour consistency to describe the colour of the emitted light gradually shifting away from its initial value.
Dimmer switch	A device for varying the brightness of an electric light.
Dimming	Dimming means changing the output of a luminaire (lower/ higher). The output of a luminaire is measured in lumens (lm) and is known as its "luminous flux". As a luminaire is dimmed its lumen output decreases or increases accordingly.
Glare	The uncomfortable brightness of a light source against a darker background which results in dazzling the observer or may cause nuisance. Condition of vision in which there is discomfort or a reduction in the ability to see significant objects, or both, due to an unsuitable distribution or range of luminance.
Unified Glare Rating (UGR)	UGR stands for Unified Glare Rating. It is an objective measure of glare that is used by lighting designers to help control the risk that occupants of a building will experience glare from the artificial lighting. International standards such as EN12464 recommend maximum UGRs for different situations.
Illuminance/ light intensity	The amount of light falling on a surface of unit area. The unit of illuminance is the lux, equal to one lumen per square metre. Unit: lux (lx) = lm/m^2
LED	Light Emitting Diode used as a light source. Solid-state semiconductor device that converts electrical energy directly into light of a specific colour or even white light.
Lumen	Unit of luminous flux, used to describe the amount of light produced by a lamp or falling on a surface.
Lumen Depreciation	The decline in the light output of a light source during its lifetime.
Luminaire	The correct term for a light fitting. An apparatus which controls the light from a lamp and includes all components for fixing and protecting the lamps or light source, as well as connecting them to an electrical supply.
Pulse width modulation (PWM) dimming	Pulse-width modulation is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage fed to the load is controlled by turning the switch between supply and load on and off at a fast rate.
Uniformity	Ratio of the minimum over the average illuminance for a specified area (Emin/Eave). When defined as such, the uniformity ratio is also the ratio of the minimum over the maximum illuminance for a specified surface area (Emin/Emax).
Vertical Illuminance	Illuminance incident on the vertical surface. Unit: lux (lx) = lm/m^2

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