The Society of Light and Lighting

Position Statement

Circadian Lighting

July 2020

Whilst the overall title of this statement still refers to 'circadian lighting,' following the publication of the CIE *Position Statement on non-visual Effects of Lighting – Recommended Proper Light at the Proper Time 2nd Edition* in October 2019, the Society of Light and Lighting has made the decision to amend the terminology used in this statement, referring to 'integrative lighting,' as opposed to 'circadian lighting.'

"In the upcoming 2nd edition of the CIE International Lighting Vocabulary, currently available as DIS (CIE 2016), "integrative lighting" is the official term for lighting that is specifically intended to integrate visual and non-visual effects, producing physiological and psychological effects on humans that are reflected in scientific evidence."

With ongoing research and increasing publicity focused on integrative lighting, the Society of Light and Lighting would like to outline its position on this topic, with a view to providing some much needed clarity. The SLL works on behalf of all who are interested in light and lighting, promoting the importance of these topics and disseminating guidance. This document will define the Society's understanding of the term integrative lighting. It will look to highlight areas of established and ongoing research that relate to the topic, providing an overview of what is commonly accepted, as a result of sufficiently robust research and evidence. Additionally, this document will seek to identify areas where further research is required. The intention is not to reach a decisive conclusion but to raise awareness of the areas where more information may be required.

As stated within the first edition of this statement, the Society recognises the need for additional properly designed and monitored field studies, along with further laboratory research in order to recommend or advise the use of integrative lighting. Additionally, whilst research is ongoing, certain questions should be asked regarding the validity of products or services claiming to offer the suggested benefits of integrative lighting. The SLL will continue to monitor the work of lighting researchers around the world, both in Lighting Research & Technology Journal and more generally, with a view to updating this document as new evidence is made available.

Whilst this paper uses the term integrative lighting, the previous edition referred to circadian lighting and there are several terms which are used interchangeably. For example, the term human centric lighting, which is arguably problematic in that lighting design and the use of artificial light generally centres on human beings. It refers to the creation of a lighting system which adapts to the changing needs of an individual throughout the day to allow them to receive the varied spectrum and quantity of light in relation to their natural circadian rhythm. This paper focuses on artificial lighting that is described or marketed as integrative, circadian or human centric lighting. However, it is recognised that, for stimulation of the circadian system and support of human health, there is no substitute for daylight.

In his editorial piece for Volume 48, Issue 2 of Lighting Research & Technology, Professor Peter Boyce wrote that human centric lighting;

'…considers both the visual and non-visual effects of light and that widens the range of possible visual effects from visual performance and comfort to sleep quality, alertness, mood and behaviour with consequences for human health...'

In this sense, integrative lighting implies a transition from traditional approaches to lighting design and application, referring to the creation of a lighting system, dynamic in both intensity and spectrum, which can be controlled to stimulate the human circadian system.

In gaining a better understanding of the effect that light has on an individual's health and well-being, elements including timing and duration of exposure to light; quantity and spectrum of light; and the spatial distribution also need to be considered.

Dr Mariana Figueiro highlights developments in our understanding of non-visual responses to light since the discovery of the intrinsically photosensitive Retinal Ganglion Cells (ipRGCs) in 2001 in her research paper, *Non-visual effect of light: How to use light to promote circadian entrainment and elicit alertness,* published in Vol. 50, Issue 1 of Lighting Research & Technology. It is understood that the light-dark cycle informs our biological clock, with the level of light signalling the appropriate responses within the human sleep-wake cycle. The body will release or supress hormones, depending on the need to be alert or to rest in relation to the time of day and incidence of light on the retina. As a result, integrative lighting has the potential to support biological rhythms where they may otherwise be disrupted.

In recognising that a high intensity, shorter wavelength of light acts to supress the release of melatonin, helping us to wake up in the morning and a less intense, warmer white light assists in the release of melatonin, helping us relax in the evening, these elements can be incorporated within an integrative lighting scheme in an attempt to support circadian rhythms. The potential benefits of this are increased alertness during the day, with improved sleep at night, resulting in a positive effect on well-being. Obviously, this leaves out myriad other factors which also have an impact on an individual's well-being.

The final report from the CIBSE and BRE jointly funded study, *Circadian Lighting effects on Health and Wellbeing,* is now available to read online via the SLL website. This study involved researchers monitoring both the objective measures, including the light levels within the test space and the light exposure of 23 participants in an office environment, along with the subjective measures such as questionnaires at the end of each lighting condition and regular computer based tests to monitor participant's reaction time.

The study was carried out in an open plan office with very little daylight. It was carried out in two phases, with four lighting conditions which are outlined in the report. Valuable findings from the study include the following;

"Even though the new LED lighting appeared more uniform and all lamps were working, there were still big differences in the amount of light reaching different people's eyes."

As highlighted in the report, this has significant implication in relation to understanding the impact of integrative lighting as it is very challenging to supply each occupant with a 'standard dose of light.'

The aim of the study was to ascertain the best time of day to provide different intensity and spectra of light to improve alertness, how long it should be provided for and when it should transition to warmer colour temperatures. Whilst useful in affirming prior understandings of integrative lighting, the results of the study were not statistically conclusive. The conclusions in the final report supports the fact that lighting requirements differ between individuals, with a large variation depending on age and lifestyle. Additionally, it highlights the need to consider different chronotypes, with the optimum timing for dynamic lighting varying between individuals. As a result, the final report states;

"For all these reasons it is very difficult to give particular recommendations for the amount of light needed to synchronize circadian rhythms. The existing recommendations in the WELL Building Standard and DIN SPEC 67600 should be treated with caution."

Responses to the final report have raised questions relating to the Hawthorne or Observer Effect, which relates to participants altering their behaviour in response to their awareness of being observed and/or novelty effects created by a change in their usual working environment.

Additionally, whilst it may seem obvious, it is critical to highlight that the lighting introduced should have been designed for the people working in the space, taking the tasks they perform and the way in which they will be performed into consideration. On this basis, there should have been additional input from a Lighting Designer. This would have helped to ensure that the lighting solution responded to the furniture layout, the type of space, any light obstructions and the reflectance values of surfaces in the room. It is unlikely that a CAT A, grid of lights would support the individual needs of occupants which are thought to be central to integrative lighting.

As a point of comparison, *Light, entrainment and alertness: A case study in offices,* an article featured in Lighting Research & Technology outlines a field study conducted by the Lighting Research Centre at Rensselaer Polytechnic Institute. LRC has developed two metrics, Circadian Light (CL_A) and Circadian Stimulus (CS), 'to characterise light as a stimulus to the biological clock.' The field study in question involved 19 participants working from three different facilities. The interventions used relied on previous studies that have shown that exposure to long wavelength (red) light in the afternoon can promote alertness without affecting the circadian phase.

The study sought to address three primary hypotheses; that blue light $(CS \geq 0.4)$ from the hours of 06:00 – 12:00 would help circadian entrainment and also advance the circadian phase, with sleeping and waking also advanced as a result; the morning intervention will aid participant alertness, reducing subjective sleepiness and increasing subjective energy; and finally, that red light between the hours of 13:30 – 17:00 would continue to support alertness, reduce subjective sleepiness and increase subjective energy without disrupting the circadian phase.

Participants were monitored using a Daysimeter, a light measuring device developed by the LRC, worn on a lanyard throughout the day and an Actiwatch at night to monitor their rest periods. Their sleep was assessed using the Pittsburgh Sleep Quality Index and the Karolinska Sleepiness Scale.

The outcome of the research appears to support the hypotheses. The morning intervention appeared to advance the participant's circadian phase.

Participant's sleep start and end times were also advanced, which could suggest that their entrainment improved, relative to the local 24 hour light dark cycle. However, participants may have already been entrained and, their evening light exposure, which may have impacted the morning's intervention, was not monitored. The article states;

"Importantly, these findings are consistent with our basic understanding of light's impact on circadian phase and were observed in the present field study.'

Whilst the findings of this study do not support the development of an SLL guide to integrative lighting, it does, along with the BRE research, stand alongside a growing number of studies that suggest that by introducing integrative lighting to a work environment, there is the potential to mitigate some of the negative side effects of circadian misalignment or de-synchronisation. This is generally accepted as a positive application of integrative lighting, with the intention of reducing disruption to occupant sleep-wake cycles by actively manipulating the suppression and release of melatonin. However, as highlighted by Deborah Burnett, Principal and Partner at Benya Burnett Consulting in her article for LED Magazine, *First do no Harm;*

"…with the link between light and health, there are no time honoured rules, an established body of rules or proven best practices that can be used to redefine this paradigm of lighting design with health benefits."

In this sense, Burnett compares the installation of circadian lighting to projects, based on unsupported claims, to 'a poor man's version of practicing medicine without a license.'

Introducing an element of individual control also plays a part in the application of integrative lighting. Several studies have shown a positive occupant response, when given control over certain elements of their surrounding environment, including lighting, temperature and the amount of natural light entering the space. This in turn has led to a feeling of increased well-being whilst in the space. However, it is important that there is a balance between areas with individual control according to preference and any centrally controlled colour and timing schedules that may be in place for a space or building.

It is essential for the lighting industry to recognise the current limitations in our knowledge of the implications of introducing integrative lighting. Under no circumstances should commercial sales be prioritised, when there is a lack of factual or proven evidence for the claims being made. Referring back to Professor Peter Boyce's editorial, he states, 'The further the outcome is from the direct effects of lighting on human physiology, the more likely it is that factors other than lighting will intervene.'

There have been various attempts to quantify integrative light and its impacts, with a view to creating a metric for practical application. For example, the WELL Building Standard. Version 1 of the WELL Standard introduced the concept of melanopic Lux, which focuses on luminous efficiency function, peaking at 480 nanometres and based on the action spectrum of melanopsin. As opposed to the more traditional photopic luminous efficiency function, peaking at around 555 nm, based on the foveal cone photoreceptors.

Within WELL v2, there is an emphasis on the importance of daylight. L01 Light Exposure and Education of Users in a precondition, meaning the requirements must be met for a WELL v2 project. However, if it is not possible to meet L01 using daylight alone, you will need to compensate by meeting the requirements outlined in L03 Circadian Lighting, which otherwise is an optimisation as opposed to a mandatory requirement of WELL v2. L03 requires the provision of equivalent 150 – 240 melanopic lux at the vertical or cylindrical plane at 1.4m (for cat A or general space) or 450mm above the work station for 4 hours per day (typically from 09:00 – 13:00).

Within their article, *Quantifying Circadian Light and its Impact,* Dr Mariana Figueiro and Dr Mark Rea state the following in reference to WELL and melanopic lux;

"Photometric units have not yet been established for the circadian luminous efficiency function; consequently, quantifying light in terms of melanopic lux has yet to be defined."

They go on to explain that as the impact of melanopic lux on the suprachiasmatic nuclei is unknown, it is impossible to use the action spectrum for the suppression of melanopsin to describe how affective artificial light or daylight are for stimulating the human circadian system. Within this article, Dr Figueiro and Dr Rea conclude:

"…a metric based on melanopsin alone will be fundamentally inaccurate and incomplete as a representation of the spectral and absolute sensitivities of the human circadian systems."

In their work at the Lighting Research Center at Rensselaer Polytechnic Institute, Dr Figueiro and Dr Rae have been developing alternative metrics and tools to assist designers and specifiers in the practical application of circadian light in the built environment, including the aforementioned circadian stimulus (CS). As outlined in the LD+A article, *Designing with Circadian Stimulus,* by determining the spectral irradiance distribution of light incidence at the cornea, you can then calculate circadian light (CL_A);

"…which is irradiance at the cornea weighted to reflect the spectral sensitivity of the human circadian system as measured by acute melatonin suppression after a one-hour exposure, and CS, which is the effectiveness of the spectrally weighted irradiance at the cornea from threshold (CS = 0.1) to saturation (CS = 0.7)."

Whilst efforts to produce a metric for circadian lighting are a step in the right direction, with regard to providing a quality lit environment that does not have a detrimental effect on the health and well-being, it is premature in relation to our understanding of the elements that affect the human circadian system.

It is these other intervening factors that we need to understand before we can provide a useful evaluation of the benefits of integrative lighting. At present, we understand, and multiple studies have shown that individual lighting requirements will differ on basis of age, chronotype and duration of exposure, amongst other factors. A light history or context is required in order to provide a circadian lighting solution that will cater to individual requirements. The factors which contribute to good circadian health are cumulative and will vary from person to person.

There needs to be further clarification on the other parts of our brain which are influenced by light. The majority of studies so far being carried out in laboratory conditions or, have simply been reports by manufacturers containing enthusiastic and anecdotal responses from occupiers of a space where new lighting has been installed. Often people will have a positive response if a new, high quality lighting system is introduced, especially when replacing something which may have become outdated. Therefore, there is a need for more field studies, with enough participants to produce representative data sets, whilst also taking certain human factors, such as responses to change, into account.

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