Influence of Varying Electric Light Distribution on Melanopic Equivalent Daylight Illuminance and Lighting Energy Use

Popular Abstract

Winters in southern Sweden are characterized by overcast skies and the absence of thick snow cover which would reflect daylight. Indoor spaces are dark and, to see, electric lighting is often needed in addition to daylight. But allowing to see (visual effects) is only a small part of what light does. The variation of daylight in level and spectral composition throughout the day, and its absence during the night, influence the production of a hormone called melatonin and eventually regulates our sleep-wake cycles. The daily variation of melatonin concentration is one of our (many) circadian rhythms. Lack of daylight and prolonged exposure to artificial illumination disrupts the circadian rhythm and can impact people's health, quality of life, and reduce task performance. And so, light (and daylight) has also non-visual effects, which is of concern as humans spend more than 90% of their time indoors.

Interests in circadian controls over lighting– officially named 'integrative lighting'– have been booming in recent years. These controls are intended to deliver the right amount of light vertically at the eye. This is measured with a new unit called melanopic equivalent daylight illuminance (mEDI), and target mEDI values have been recently introduced. But what is an integrative lighting system? Integrative lighting generally refers to a LED electric lighting system with variable spectrum and intensity of electric lighting, trying to mimic daylight. Only few daylighting designs do exist where the focus is explicitly on integrative lighting. This poses a challenge with regards to building energy use, among other issues. For example, the luminous power output of integrative lighting can be three times higher than standard lighting design criteria, which are generally based on horizontal illumination on the desk for fulfilling "visual" requirements.

As daylight is the ideal time-giver, this study examined (1) whether daylight alone can fulfil the visual and non-visual requirements during most of the working hours and (2) when not, whether different distributions of electric lighting could help fulfil the requirements in an energy-efficient way.

This study investigated direct (spotlight) and direct-indirect (pendant) distributions of electric light combined with daylight in two office-like test rooms at the Energy and Building Design Laboratory located in Lund, Sweden. Field tests with subjects were carried out to understand whether different lighting scenarios could ensure similar visual perception, task performance, and alertness. Further lighting scenarios of the two light distributions with different correlated colour temperatures (CCTs) and view directions were tested using point-in-time simulations in Grasshopper (with LARK 2.0 plug-in) to determine which of the scenarios could reach the visual and non-visual requirements in the most energy-efficient way.

The subjective results indicated that the two light distributions perform similarly in terms of visual perception, task performance, and alertness. The simulation results indicated that the visual requirement on the desk was achieved for all lighting scenarios, with higher values in the room with pendants. It was shown that non-visual requirements are challenging to meet and were never achieved with only electric light. Only after including daylight from a clear sky was the non-visual requirement achieved for most of the year as circadian illumination on the vertical is largely provided by daylight. Overall, it was shown that simulated results for spotlights showed slightly higher mEDI for all lighting scenarios. Without daylight-linked control, spotlights have a lower energy consumption than pendants. With dimming controls, there is a higher energy saving potential for pendants.

The information presented in this study will hopefully encourage the design of energy-efficient integrative lighting systems while including the role of daylight in reaching the non-visual requirements.