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Editorial

The Future of Interior Lighting Is Here

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1. Introduction

One word that characterizes the situation in the lighting industry during recent years is "change". This change is based on the symbiotic relationship between technological development, lighting design improvement, and, of course, the adoption of sustainable principles [1–3]. The term of sustainability is used more and more in the field of lighting. It is obviously related to the effort to reduce energy consumption in the built environment but includes the impact of the lighting system on human health/wellbeing and the environment. Indeed, energy savings are an important priority in the design of a lighting system and are approached by the use of efficient equipment and/or the adoption of better design methodology. Lamps with increased luminous efficacy, efficient luminaires, and the use of control systems are now widely available, while the use of the Internet of Things-enabled smart lighting to expand, offering interoperability and thus the integration of lighting systems into buildings' existing infrastructure. Lighting digitization together with the widespread use of LED lamps has led to an increased device connectivity, which in turn offers a wide range of possibilities. LiFi, the Internet of Things, Power over Ethernet, and wireless sensors have transformed the traditional luminaires into smart devices capable of connecting to a network transmitting information [4]. As the light is enriched now with information, it is therefore possible not only to increase energy savings through controls [5–11] but also to include additional functions such as the ability to adjust the lighting system's operation according to the users' expectations and needs [12–14]. The aforementioned developments allowed not only the control of luminaire's emitted luminous flux but also the color temperature of the light source, thereby mimicking the daily change of daylight. This is the core concept of the Human Centric Lighting approach, one that affects health, wellbeing, and productivity, providing proper lighting when and where it is needed [15–18]. Furthermore, in recent years, zero-energy buildings received increased attention though proper legislative pressure, and this can potentially sideline the human factor from the epicenter of the build environment [19,20]. Fortunately, it seems that the focus of lighting and daylight design has just moved from spaces to humans [21–23]. Better design can also be used, in an effort to create a pleasant environment but also to save energy by providing lighting where, when, and as much as needed. BIM software can consider alternatives to improve energy efficiency in artificial lighting. It is therefore urgently important that the new and often contradictory lighting trends be examined, and that was exactly the scope of this special issue. Case studies of exceptional lighting projects were welcomed. Ten research papers and one review paper were published.

2. Materials and Methods

The Special Issue, entitled "The Future of Interior Lighting Is Here", addressed several subjects on interior lighting such as architectural lighting, daylighting, Human Centric Lighting (HCL), the impact on human health, lighting design, sustainability, and social impact and wellbeing. A total number of eleven articles, ten research papers [24–33] and one review paper [34], were published. In terms of the geographical distribution of the affiliations of the 34 contributing authors, contributions originated from ten countries, including Austria, Denmark, France, Germany, Korea, Slovakia, Spain, Sweden, Tunisia, and UK.

3. Discussion

3.1. Daylight

Ravn et al. [25] performed various simulations in order to identify how daylight can affect lighting levels on the horizontal working plane, comparing these levels with the Melanopic Equivalent Daylight Illuminance (MEDI) on a vertical plane as a measure of physiological effects. MEDI values were calculated in ALFA software for an office environment. Parameters such as orientation, spatial orientation, time, and sky conditions were taken into account. The daylight design in office buildings, concerning their results, contributed to the physiological effects of dynamic light. Daylight was a sufficient light source, and in the majority of the examined cases, the recommended values of MEDI met the Danish Standards and provided the appropriate horizontal illuminance. Some guidelines in the design process were also provided for future smart building systems.

Dolnikova et al. [30] examined the impact of daylight when renovating a range of balconies, from a façade to a loggia. The article compared the façade before reconstruction and after to loggias. They evaluated the daylighting conditions prevailing in residential building with the use of the Daylight Factor (DF) for overcast sky, and they used DIALux EVO. The use of loggias reduced the DF by half compared to façade before reconstruction. However, the reconstruction of the balconies to make them loggias improved the thermal behavior of the building.

Sibley and Pena-Garcia [33] presented a comparative study concerning the performance of light pipes with two different types of apertures. A bohemian crystal dome was compared to a flat glass. Measurements of daylight were taken over a year in two newly built identical houses located in Manchester, UK. The analysis of the data showed that the crystal-domed case was consistently outperformed the flat glass one. Furthermore, the crystal dome had better performance during winter while at the same time its transmittance degradation due to the pollution was smaller than that of the flat glass.

3.2. Lighting Design in Educational Buildings

Lighting is an active element of the educational buildings, influencing students' performance and affecting the realization of all educational activities. An educational building constitutes a unique type of building, and the lighting parameters affecting students' performance are the illuminance, uniformity, visual comfort, glare, and light sources-correlated color temperature. Angelaki et al. [24] described the general lighting design strategies for kindergarten students. Their objective was to identify environments that support each pupil's spatial perception. Moreover, they examined how the proper lighting design can affect shape and object recognition. The interrelations of light, perception of scale, space, and human physiology were investigated through the use of audits in kindergartens in an effort to analyze existing lighting schemes. Furthermore, simulations were used to test various lighting-design scenarios. The outcome was a strategy on how to take into account children's vantage points when designing lighting in kindergartens.

Liinares et al. [27] analyzed the impact of Correlated Color Temperature (CCT) and illuminance levels in university classrooms on the attention and memory of the students. Ninety participants were evaluated using memory and attention tasks. Nine virtual classroom configurations were used with three different lighting design levels (100 lx, 300 lx, and 500 lx) and three different CCT values (3000 K, 4000 K, and 6500 K). It seems that memory and attention tasks required different lighting levels. Memory improved with lower lighting levels while attention with higher ones. Both attention and memory tasks improved with higher CCT values. The connection of lighting and students' cognitive responses were highlighted in these results. The authors state that the proposed methodology can be useful for architects and researchers as they establish lighting design guidelines.

3.3. Human Centric Lighting

Ngarambe et al. [28] assessed the potential influence of Spectral Power Distribution (SPD) on work performance, visual comfort, circadian energy, work performance, and mood. They used two different light sources, LED, and organic light-emitting diode (OLED). These two sources have different spectral content and different dominant and peak wavelengths. LED had 455 nm and OLED 618 nm. Through a circadian-phototransduction model, the melatonin suppression, the circadian light, and circadian efficacy were calculated for both lighting conditions. Furthermore, 26 subjects evaluated these conditions in terms of work performance and visual comfort. LED induced higher biological actions regarding circadian lighting with relatively less energy consumption. Concerning visual comfort, the participants preferred the OLED while the LED source was selected for better work performance and mood.

Concerning HCL, the technical guides DIN SPEC 5031-100 and CIE S 026:2018 comprise the regulatory framework for achieving health-preserving indoor lighting. However, these standards are largely congruent, while their inconsistencies will be harmonized with the DIN/TS 5031-100. Neberich and Opferkuch [34] provided the background information for this standard and a review with a detailed technical and medical overview. The authors did a literature review of projects over the past 20 years related to the ecological lighting design, presenting ordinances, standards, and applicable laws for a number of countries.

3.4. Light Distribution and Spectrum

Light distribution can affect both the perception of spatial size and shape. Lindh and Billger [26] investigated how light patterns can affect the perceived spaciousness and revealed the relationships between light patterns and perceived size. The authors used systematic visual observations of scale models and performed pair-wise comparisons. They confirmed through observations that illuminated walls increase the spaciousness of a space. Composite and separate lighting zones can extend the depth, height, or width of a space. Moreover, the position of the lighting zones, with placements at the edge or in the center, can additionally affect the perceived size.

Bachouch et al. [29] reported a methodological approach for simulating luminaires' spectrum for greenhouse plants. That was achieved by mixing LED chips in an effort to match the absorption spectrum of any plant. A multi-Gaussian model used with various recorded narrow-band LED spectrums. The particle-swarm optimization method was applied in order to optimize the weighting of the relevant parameters and minimize the discrepancy between the reference target curve and the combined spectrum. The resulting relative standard deviation was 3.4% with only five colored LED sources.

3.5. Sustainability

Luengo [31] states that a definition of the original lighting conditions is required for a sustainable conservation, ultimate interpretation, and perception of artworks. For this reason, 17th and 18th century churches from Americas, Asia, and Europe were selected and examined with modern conservation frameworks for artworks. The results showed that chosen materials and light exposure are connected. This allows the spaces to be effective at reducing electricity consumption.

BIM 6D is a methodology of using a digital information model, which allows the simulation of the energy behavior of a building and can help to improve the performance of its lighting system. Montiel-Santiago et al. [32], using the aforementioned BIM 6D methodology, analyzed a hospital building and studied the possible alternatives to improve energy efficiency in artificial lighting, achieving 50% energy savings at the building level and up to 13% for lighting.

4. Conclusions

The papers included in the present Special Issue, cover a wide research field in lighting. The majority (27%) of the papers concern daylighting. Daylighting affects both energy consumption and wellbeing in the building environment. Proper daylight design can have a beneficial effect on both physiological and psychological levels, since the complex interrelationship between daylight and biological parameters, such as the Melanopic Melanopic Equivalent Daylight Illuminance, need to be balanced carefully. Human Centric Lighting (HCL) is another issue that accounts for 18% of all papers published. Today, we spend about 80% of our time indoors and in many cases the workplace is located in a dense urban environment, resulting in the biological effect of natural light being limited. It is obvious that an integrated design with a combination of day-artificial lighting is needed to optimize biological functions. The easiness with which LEDs with different spectral composition can be combined is not only used for HCL design but also to generate suitable spectra for plant growth. Surprisingly, there were not many articles in this Special Issue that focused on lighting energy savings. Existing technology has greatly reduced the installed power for lighting, and so the research focus seems to be on the creation of a suitable visual environment. Finally, the mature LED market is reaching the sustainability milestones and is focusing on a more human-friendly interior environment.

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