Discussions Around Implementing Better Lighting in the Workplace

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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At first glance, lighting seems trivial, yet lighting has become a prodigious part of our daily experiences. Lighting has the ability to affect an individual's visibility, safety, mental health, and productivity (An, Colarelli, O'Brien, and Boyajian, 2016). Despite the aforementioned benefits of better lighting, different groups have discussed separate aspects of lighting: new research on the effects of lighting, strategies to improve lighting, methods of determining appropriate lighting, and standards/metrics of what constitutes good lighting. For example, in Bijker's (1992) analysis of fluorescent lighting, the article documents the evolution of lighting as a conflict emerging between stakeholders, new technologies, and the production of new knowledge. Initially, incandescent lighting was the main instrument for electric lighting and utility companies thrived as they sold energy and advertised for maximum levels of illuminance for greater energy usage which yielded greater energy costs. The invention of fluorescent lighting was much more energy efficient compared to incandescent lighting which would lower the profits of the utility companies. Thus, these companies retaliated by persuading institutions to convince the public that fluorescent lighting was unhealthy. Through a process of negotiation, fluorescent lighting became widely available at the cost of conforming to brighter lighting standards and thus becoming less energy efficient. I will use a similar Social Construction of Technology approach to rethink lighting as new research has started to examine various features of lighting.

For example, one stakeholder group known as the Building Research Establishment (BRE) Group notes ambiguity in what good lighting means for workers. Similar studies have indicated that there is still an ongoing debate on what is proper lighting. Therefore, this paper

will document emerging discussions around implementing better lighting in the workplace and capture how different stakeholder groups define good lighting.

Emerging Understanding of the Effects of Light on Work and Health

Experts are bringing attention to a previously ignored topic and that new knowledge can be disregarded, integrated, or modified. There are existing standards that identify the proper amount of lighting for specific locations revealing that standards are a form of problem framing and closure around the issue of determining good lighting. If a standard is approved and accepted by architects and office workers, then the standardization organization proposing the standard is considered a winner. Standards also have the ability to evolve if they are initially rejected or new information is introduced, and recent studies have opened up space for conversations about lighting in the workplace.

Recent research has illuminated the crucial role sunlight exposure has for employees. For example, Dumont and Beaulieu (2007) from the University of Montreal found a direct correlation between light exposure and mental health for office workers. Specifically, Dumont and Beaulieu (2007) noted an analysis regarding the natural light exposure for day workers:

> For people working at least 8 h a day, about half of the time awake is spent at work. Light exposure is, therefore, largely determined by light levels in the work environment . . . Many indoor workers having little access to natural light complain of . . . sleep disorders, fatigue, lack of concentration and depressed mood. (p. 560)

Even without scientific knowledge on the importance of lighting, office workers note inadequate lighting in a survey published by the Harvard Business Review,

> Over a third of employees feel that they don't get enough natural light in their workspace. 47% of employees admit they feel tired or very tired from the absence of natural light or a window at their office, and 43% report feeling gloomy because of the lack of light. (Meister, 2018, para. 3)

This topic is further explored as another study done by Tefft (2012) from the Department of Economics at Bates College examines how the index of darkness, which is the daily hours of

no sunlight, is correlated to seasonal affective disorder (SAD) and health-related quality of life (HRQOL) as "adverse mental health outcomes . . . [are] associated with (a) more hours of darkness and (b) worsening employment status" (p. 253). An et al. (2016) inspected the effects of sunlight on employees and found that "Sunlight exposure was positively related to job satisfaction and organizational commitment" and "Exposure to natural elements is associated with decreased levels of diastolic blood pressure, depression, and anxiety . . . and increased attentional capacity" (p. 2-12). Thus, the amount of natural light exposure holds a significant role in the productivity, retention, and health of employees.

The purpose of advocating for better lighting can also be related to visibility, safety, aesthetics, and energy efficiency. While lighting's primary role is to enable general visibility, visual comfort should also be considered as one study investigated how lighting affects visual performance. In the *Institute of Electrical and Electronics Engineers (IEEE) Industry Applications Magazine*, Duffy, Jayawardena, and Manahan (2017) examined lighting in industrial environments in order to create a framework to link workplace safety and lighting-quality metrics. Through vision science, Duffy et al. (2017) discovered that poor lighting "could influence fatigue by degrading the sleep quality of night-shift workers, causing visual discomfort" (p. 54). Moreover, Duffy et al. (2017) noted the disregard of the relationship between safety and lighting:

> Safety is the primary reason for industries to invest in lighting in their facilities. However, the specific attributes of lighting that have a real impact on safety are often not considered in many product developments and are often overlooked during the facility planning process . . . Lighting-quality improvements would lead to enhanced target detection, reduction in reaction time, higher visual performance, better color discrimination, better visual comfort, and less fatigue induced by lighting. (p. 55)

Additionally, architects can implement lighting to improve the overall atmosphere as the *Architectural Record*, a monthly magazine on architectural history, describes how "designers

employed distinct lighting solutions on each [floor] to create a dialogue of contrasts-both aesthetic and pragmatic" (Cohn, 2009, p. 216). Finally, by introducing sustainable methods such as biophilic design that favors daylight over artificial light, energy meant for electric lighting can be conserved (Heerwagen, Kellert, and Mador, 2008). Therefore, lighting within the workplace should be reexamined to ensure employees are exposed to the necessary illuminance levels in order to receive the previously mentioned benefits.

Improving Lighting in the Workplace Environment

Before inspecting existing literature on writing, the relevant stakeholders should be revealed. The first group of actors are the organizations that create the lighting standards as they determine what is the proper level of illuminance in areas such as offices. The second group are the architects and civil engineers that decide to adhere to the aforementioned standards and construct the lighting systems. The third group consists of employees within the workplace environment who are essentially the users of the lighting. The last group comprises researchers who introduce new knowledge to the public on lighting.

With the significance of lighting being highlighted by researchers, questions regarding public awareness and reaction to new knowledge should be considered. Already implemented as well as recommended approaches on upgrading modern lighting conditions will be discussed initially. Afterwards, the documentation of existing literature and the prominent stakeholders involved will be explored.

There are several practices that have been researched to ensure better lighting. One popular example is the implementation of high-performance green buildings (HPGBs) which uses biophilic design. One study concluded that the "benefits of nature-based experiences can extend to real-life indoor environmental features of green buildings" and "employees'

satisfaction with their indoor environmental features is a crucial factor that may impact their wellbeing" (Dreyer, Coulombe, Whitney, Riemer, and Labbé, 2018, p. 13). The restorative effects of sunlight are partly responsible, but the distinction between direct sunlight and indirect sunlight as well as their associated effects should be distinguished. Direct sunlight is defined as "sunlight exposure while outside without any interference" which "stimulates vitamin D synthesis" and indirect sunlight is defined as "refracted sunlight, which could be, for example, sunlight exposure through windows" which is "negatively associated with depressed mood" (An et al., 2016, p. 3-12). Therefore, by maximizing the usage of daylighting over artificial light, regardless of whether the office infrastructure incorporates biophilic design or not, the result of such efforts will still be advantageous for employees.

Another option to upgrade lighting in the workplace environment is to refine the current lighting standards. Besides increasing the level of illuminance required for office lighting, careful wording of the standards can be crucial when designing the lighting systems for buildings as European Standards (EN) for lighting states a *minimum* of 300 lumens per square meter (lux) for general illumination (National Institutes of Health, 2019). However, the United States (US) General Services Administration (GSA, n.d.) has a general illumination of *about* 300 lux which could lead to consequences such as light architects being able to get away with lower lighting. Additionally, the Occupational Safety and Health Administration (OSHA, n.d.), a regulatory agency that is part of the US Department of Labor, recommends that lighting in the office should be 30 foot-candles (about 322 lux) which exposes contradictory requirements with the GSA. Finally, too much lighting could cause potential issues with glare and energy efficiency. Overall, there are various areas regarding lighting that have room for improvement.

Professional Appreciation of Lighting over Time

There is much to explore regarding the reason why lighting has been thoroughly analyzed in the last thirty years. Starting from 1990, in *Interiors* which is an interior design magazine, there were discussions on visual display terminals (VDTs). Specifically, "what constitutes optimal VDT lighting" to create "high levels of ambient light and yet reducing the glare of exposed high brightness sources reflected in the video screen" (Barna and Henderson, 1990, p. 56). The architects were concerned with having to balance proper lighting and glare reduction as the solution to one is the adversary to the other. Later, Miller and Rodgers (1997) reviewed in the *Architectural Record* how "Lighting design was hired to devise a cost-effective lighting scheme that optimizes energy savings, while providing balanced brightnesses" (p. 154). Similar to the previous article, brightness was balanced within the office to "reduce the brightness of images on a VDT screen and to improve the workers' visual comfort" (p. 154). Despite architects working toward an energy-efficient solution, this method of balancing could be used by architects to justify lower light levels as a means to solve the glare problem. A potential factor in this decision of lower lighting could be linked to beliefs in 1995 that lighting would not affect the productivity of employees. Specifically, a revolutionary study by Enmarker and Knez (1998) in the peer-reviewed journal, *Environment and Behavior*, stated "No effect of the lighting on cognitive performance was obtained, as was hypothesized by Knez [in 1995] . . . The results supported, however, one important assumption from Knez [in 1995] . . . namely, that the artificial light can alter mood" (p. 562). This research marked the beginning of the correlation between lighting and mood as well as caring for the health of employees.

Despite the awareness of sunlight's effects, daylight was not always a popular option for architects. In the Royal Institute of British Architects (RIBA) Journal, Meyrick (2006) noted that

while “Few dispute that natural light is critical to our ability to stay focused and alert, . . . Since the 1960s problems caused by direct sunlight glare, contrast ratio and particularly solar gain have led to daylight being designed out of buildings to a great extent” (p. 63). However, Meyrick proceeds to provide solutions to imitate daylight by improving artificial light, but concedes that “if you want to imitate the quality of daylight, the lighting solution will be more expensive and perhaps less energy efficient . . . For the moment, though, artificial lighting is unsatisfactory, too expensive and non sustainable. Architects must therefore try to maximise daylight penetration” (p. 66).

The desire for a sustainable and energy-efficient method led to the research and development of biophilic design (Heerwagen et al., 2008). While Novitski (2009) in *GreenSource*, a magazine on sustainable design, expresses that biophilic design “features are closely tied to familiar ideas of energy conservation and renewable materials,” Novitski also emphasizes that further benefits of biophilic design are “improved learning by students, greater productivity in workers, and faster healing by patients . . . [which] tends to motivate architects and their clients” (p. 103-104). The list of benefits is only one reason for the rise in popularity for biophilic design as Novitski notes

> Interest in biophilia has increased recently for several reasons, according to Elizabeth MacPherson, a principal of Seattle-based Mithun. One reason is the accumulation of documented benefits. A second is the growth in urban density, making nature less accessible and forcing designers to be more conscious of creating access. Third is a change of values. With the end of agricultural and industrial economies, she says, we now have an "experiential economy." (p. 105)

However, biophilic design is not the only lighting approach with these benefits.

Task-lighting is lighting for a specified area as opposed to biophilic design’s ambient lighting for general areas. In *Architectural Lighting*, Pfund (2010) accentuates “a survey of professionals in the building products and facilities industries identified tasklighting as the most

important type of lighting in the office environment" (p. 25). The rationale for this result could be attributed to "growing evidence that personal control over lighting is a key determinant of office-worker environmental satisfaction and productivity" and methods for task lighting "satisfy two important aspects of high-performance workspaces: They save energy and provide personal lighting control" (p. 25). Therefore, "to maximize user satisfaction, productivity, and energy conservation, it is best to satisfy the personal lighting requirements of the office first" as opposed to providing employees with an average ambient lighting solution (p. 26). Despite the new discoveries within biophilic design and task-lighting, architects have begun to divide on which characteristics of lighting to advocate for.

Energy efficiency versus visibility are the two main topics of contention among architects. In *Architects Journal*, Ravenscroft (2014) desired to design urban architecture that was "environmentally sustainable -- to be smart, to react and be energy-efficient . . . [by] reducing wastage of light" (p. 2). In order to accomplish this, Ravenscroft had to "subvert the obvious purpose of light -- to increase visibility" confirming the bias toward energy efficiency over visibility (p. 2). Alternatively, in *Architectural Lighting*, Liao (2015) proclaims "Reflected glare, or veiling reflection, caused by daylight or electric sources, is particularly problematic, as it severely reduces the visibility of the screen" and mentions "Fixtures that prevent glare or light indirectly are less energy-efficient" (p. 2-6). Moreover, Liao warns that "concern for visual performance in office lighting has taken a back seat to energy codes and energy performance . . . Until people decide that lighting quality is equally important to the energy used, then we'll not see a lot of movement" (p. 6-7). The clash among architects is clearly revealed through the arguments of both articles, yet new studies favor the implementation of daylighting.

Specifically, in the *Architectural Record*, Horwitz-Bennett (2020) states that "although biophilic design is not a new concept, companies and institutions are recognizing its positive impact on individuals' comfort, attitude, and health in their daily lives" and "biophilic design also offers sustainability benefits, such as reduced energy consumption by utilizing daylight and reducing artificial light" (p. 156-157). Horwitz-Bennett also quoted that

> Payroll is one of the biggest expenses of just about any U.S. business and biophilic design can increase employee satisfaction and productivity, and reduce employee absenteeism and turnover-which are all significant positive economic benefits. (p. 157)

This quotation solidifies the significance lighting has on office workers as a connection between profits and lighting is portrayed. Despite the various conversations about lighting, defining proper lighting is still an ongoing issue.

For example, one stakeholder group, the Building Research Establishment (BRE) Group conducted a study called the Biophilic Office that had employees work within a regular building which was the control group and a biophilic-designed building which was the test group. Through surveys given to the occupants, the BRE Group (2020) found that "the quality of the electric lighting was rated as fairly low in the test group" and "The electric lighting in the test building at desk surfaces is below standard recommendations, but does not appear to be a significant issue for the occupants" (p. 25-27). Therefore, the optimal level of lighting has not yet been determined. With new discussions and research on lighting continuously appearing, standards have adapted over time.

Evolution of Lighting Standards in the Office

In 2002, the International Organization for Standardization (ISO) and the International Commission of Illumination (CIE) declared that proper lighting in the workplace environment is when glare is limited and the levels of illuminance guarantee "safe, healthy and efficient work performance. The values can be achieved with practical energy efficient solutions" (para. 2).

While healthy work performance could allude to the findings of light's effect on mood, it is necessary to clarify that efficient work performance was referring to the visibility of tasks as "There are also visual ergonomic parameters . . . which determine the quality of the operator's visual skills, and hence performance levels" (para. 3). Lastly, this standard encourages the implementation of natural light as a sustainable option.

In 2011, EN 12464-1 was released as a new standard for lighting at the office. Despite no mention of biophilic design nor biophilia, there exists brief sections on energy efficiency and the benefits of daylight. Furthermore, there are various illumination levels presented for a prodigious number of tasks and scenarios. Three new additions have also been introduced: illuminance on surfaces, complementary backgrounds, and median cylindrical illuminance. These innovations ensure visual comfort, sufficient illumination, and visibility inside the workplace environment, respectively. Lighting standards can provide methods for improved levels of illuminance, but these solutions are useless if they are not acknowledged by architects.

DIAL, a lighting design firm, performed an analysis five years after the introduction of EN 12464-1 to determine if the standard is being upheld. According to DIAL (2016),

> In our daily work with lighting designers and luminaire manufacturers, with participants in seminars and through our own work as independent lighting designers it becomes clear that the new standard has not managed to establish itself. Many lighting designers have never had to provide evidence of or check values for room surfaces of cylindrical illuminance. (para. 12)

DIAL believes that architects "only apply parts of the norm. What is applied is mainly what has already been well-established" since "it is also possible to have a good lighting concept without these innovations" in the EN 12464-1 and concludes that the "standard does not seem to be regarded, on its fifth anniversary, as a recognized rule of technology" (para. 12-19). This situation raises concerns as the consequences of architects not upholding standards are unsatisfactory lighting systems, reduced lighting benefits, and increased issues related to

insufficient lighting for employees. The strict specifications of the standard and potential redundancy with current practices could be a possible cause for the lack of adoption, but a suitable revision became obvious to European Standardization Organizations (ESOs).

In 2019, EN 17037 was announced and included substantial information regarding daylighting. EN 17037 is the "the first European standard to provide requirements for daylight in buildings" which conveys standardization organizations working toward energy-efficient solutions and biophilic design (National Institutes of Health, 2019, para. 3). Besides the appropriate quality and quantity of illuminance for natural light, EN 17037 discusses the benefits of sunlight, knowledge about glare, and how access to daylight should be handled. At the end of the document, EN 17037 notes "with the increased awareness of healthy design in the US, similar requirements may be adopted" which suggests further adoption of daylighting and ESOs as leaders in lighting (National Institutes of Health, 2019 para. 9). Overall, there have been various discussions and stakeholders throughout the last thirty years that require further analysis.

Discussion: Lighting up a New Path

After examining existing literature on lighting in the last thirty years, there has been a definite shift in the advocacy for lighting. Architects, standardization organizations, and employees were concerned with the visibility and health aspects of lighting in the beginning because glare posed a problem for visual display terminals and low lighting caused fatigue. Although daylight was a main contributor to glare, the usage of sunlight over artificial light conserved energy and the benefits of natural light for office workers which was uncovered by researchers could not be ignored. Consequently, biophilic design began to gain popularity from all stakeholders as architects tried to include nature into infrastructure, standardization organizations started to cover daylight, employees were more productive and in better moods,

and researchers continued to study the effects of nature on humans. Thus, the characteristics of lighting that biophilic design is associated with are health and energy efficiency, which is essentially profits. Although personal task-lighting provided valid arguments, specific lighting for employees with distinct preferences while incorporating daylighting into lighting designs would discourage architects to prioritize lighting as a generic desk lamp could perform personal task-lighting. Additionally, one issue that affects one stakeholder group affects other groups; for example, redundant practices enforced in standards lead to architects disregarding lighting standards and potentially designing unsatisfactory lighting systems for employees. There is a dependent relationship of office workers trusting civil engineers to design appropriate lighting systems, yet this trust can easily be misplaced without accountability. Despite these problems, daylight's sustainability and restorative effects on employee productivity and mood became correlated to greater profits as employee retention was connected. By providing office workers with knowledge on daylighting, interest in lighting could influence public opinion which would propagate to improved standards and practices by standardization organizations and architects for better health and profits. Therefore, biophilic design has always been about health and profits while lighting has gradually changed from visibility and health to profits and health.

In the workplace environment, lighting's primary purpose was to provide greater visibility for employees as well as reduce their fatigue, but there has been a shift in how people see lighting. Through the introduction of biophilic design and daylighting, lighting began to be correlated to health and profits and this connection only became stronger over time. Admittingly, this document mainly covers the growth of European Standards on indoor office lighting due to accessibility, so further analysis on other countries, standardization organizations such as American National Standards Institute (ANSI), and outdoor lighting could be worthwhile to

explore. A final recommendation would be to either examine or develop regulations that ensure accountability for architects to design proper lighting systems in order to enable trust from office workers and accentuate that lighting is still an ongoing discussion.

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