

Lighting in the Workplace as the Visual Environment That Affect the Occupant's Mood: A Literature Review

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ABSTRACT

Lighting in the workplace is often assessed based on functionality. In line with scientific development, the research into lighting observes its effect on the occupant's health and psychology. This article discusses research publications related to the relationship between artificial lighting and mood, by reviewing relevant literature from journals, dissertations, theses, and books from the last 10 years. Some of the literature refers to the older sources; hence the study is expanded to cover, in certain cases, a publication period of more than 10 years ago. The first section of this review discusses the general definition of mood and its role in the workplace. The next section explains the visual requirements of a workplace environment, especially regarding the required standards and the lighting's effects on health. The third section of the paper discusses the relationship between the visual environment and mood, with particular reference to how lighting enters and affects mood. The final section of this discussion addresses previous research related to the visual environment and mood that can be categorized into three focal points: (i) illuminance level effects; (ii) correlated color temperature effect, and (iii) mixed influencing factors.

Keywords: *Artificial lighting, CCT, illuminance level, non-image forming, office*

1. INTRODUCTION

The design of a building is commonly intended for the performance of: a) functionality, b) physical comfort, as well as c) economic, d) symbolic, and e) aesthetic manifestations [1]. Comfort itself is influenced by several factors such as: i) lighting, ii) temperature, iii) humidity, iv) air movement, v) air quality, vi) noise, vii) culture, viii) habits, ix) personal preferences, x) ability to control environmental conditions, xi) clothing, and xii) activities [2]. Of these twelve factors there is evidence to suggest that lighting is the most influential factor shaping an occupant's perception of the comfort of a room [3], [4]. Research related to lighting and visual comfort was initially limited to: a) the level of brightness, b) lighting contrast levels, and c) prevention of glare [5].

In the workplace, lighting is one environmental component that must be considered [6] for its functionality purpose. The initial aim of lighting might be limited to create a design that offers visual comfort, achievable by adjusting the lighting to the needs of the activity being accommodated [7], particularly with reference to the illuminance level. To formulate optimal lighting during working hours, further research is needed which takes into account the illuminance level and CCT of the lighting [8], [9].

Lighting has an impact on recipients' physical and mental conditions [4] and so does visual comfort in the workplace

which, in turn, has a direct impact on mood [10], [11]. Gradually, it was realised that visual comfort was an important factor informing employees' health and productivity [12]. Potential productivity can be derived from a range of factors including: i) reducing pain due to breathing problems such as asthma and ii) the defeat of 'sick building syndrome' coupled with improved employee performance due to iii) changes in temperature and iv) visual conditions [13].

Little attention has been given to understand how lighting affects an individual's psychology and their physiological system, including the circadian function that regulates the sleep cycle and mood [14]. The discoveries in the field of neurological health and biology indicate the existence of non-visual processes due to lighting in terms of behaviour, psychology, and physiology [15]. Understanding the relationship between lighting and behaviour will lead to architectural designs that achieve and implement more effective lighting for the workplace, leading to improved mood and better working ability and performance of the occupants [16]. This article aims to discuss publications related to lighting, especially artificial lighting in the workplace, and its effects on recipients' moods.

2. RESEARCH METHOD

This paper addresses the research methods by carrying out a literature review informed by journals, dissertations, theses, and books from the last 10 years. The literature often refers to sources older than 10 years so the review will, at times, quote from sources that are outside that 10-year limit. The online literature used the keywords: i) lighting, ii) artificial, iii) visual comfort, iv) mood, v) office, and vi) workplace with site restrictions on edu. and ac. and the form of pdf files. The skimming method is used for initial source reduction to separate writing that addresses the issue of artificial lighting in general from research that investigates lighting that is relevant to an individual's mood and workplace. From the results of this reduction, skimming was again performed in order to separate the literature review's results from the results of the study. The scanning method is carried out to read in more detail about relevant research results to support the preparation of a theoretical framework regarding the effect of visuals on mood in the workplace.

3. FINDINGS

3.1. Lighting Standards in the Workplace

In the workplace, the sense of sight is considered the most important, compared to other senses [17]. Visual comfort is the most important thing in realising user satisfaction in office buildings [18] in terms of health and work productivity [12], [19]. Good lighting leads to better performance in terms of: i) speed, ii) fewer errors, iii) fewer accidents, and iv) less absenteeism [20]. When visual discomfort is resolved, the workplace becomes pleasant thereby optimising subjective responses and improving employees' performance [8], [17].

Even though its potential is realised in health, lighting at work is often designed only to meet visual needs [14]. In Indonesia, lighting in the workplace is recommended to be a Colour Rendering Index (CRI) level of 1 or 2 [21]. Suk (2019) recommends lighting in the workplace is limited to a light intensity of 2420 cd / m² [22]. In the case of the daylight factor (DF), the office is recommended to receive a minimum of 2% [23] and the ratio of walls to windows (WWR) is 20% - 50% [24]. The illuminance level in the workplace has the greatest impact on employees' visual comfort, followed by the correlated colour temperature (CCT) and the uniformity of the lighting [12].

3.1.1. Illuminance level

Illuminance level is associated with subjective alertness [25]. However, a high illumination level also brings slow response times, which was likely because the backlighting was so bright that it distracted an individual's attention during performance testing [26]. In Indonesia, a minimum

of 350 lx is recommended for work environments [21]. This level is in accordance with the opinion that the acceptable brightness level is above 300 lx [27], [28] or an average of 350 lx [29]. Other researchers say the vertical lighting should be 351.6lx at the user's eye position [22].

Some articles recommend workplace lighting of different illuminance level. Ambient lighting in the work area chosen by the occupants is 400 - 500 lx while the lighting for vertical surfaces such as partitions is 200 - 250 lx [30]. In other cases an illuminance level of 500 lx is preferred over 300 lx [31], [32]. More than 60% of participants chose a lighting of 800 lx or higher [33]. An ambient lighting of 700 lx or higher, i.e. at 1500 lx seems better for e-paper [34]. Ambient lighting of 1000 lx and 1500 lx supports visual performance better, while lighting of 500 lx and 1000 lx gives less fatigue than 200 lx lighting [35]. The recommended illumination level for optimal performance also differs, depending on the type of work. Another article recommends 500 lx for general office work and 750 lx for offices with designs that do not allow sunlight as well as drawing jobs that involve color sensitivity and proofreading that require precision [36].

The actual light received by the eye's pupil is lower than the recommendation and yet there were no complaints about the lower illumination [37]. The acceptance of lower illuminance is in accordance with the opinion that the illumination level can be lowered from the recommended standard because workers can still carry out their activities with lighting below 350 lx [38]. In the case of Japan, the acceptance range for illuminance level that still meets visual comfort in the workplace is wider due to the awareness of saving energy without reducing the satisfaction of lighting users [39].

3.1.2. Correlated Colour Temperature

Correlated Colour Temperature (CCT) is important to support worker productivity [40]. Lighting in the work environment is generally recommended at (CCT) warm white of 3300 K - 5300 K and cool daylight above 5300K [21]. Variation in CCT significantly impacts visual comfort and especially on CRI-related colour clarity [29]. Typical CCT for office lighting are between 2000 K and 4000 K [41]. Room users stated to preferred lighting between 4000 - 5000 K [33]. This preference is not different from the previous statement, that with illumination level of 500 lx 4000 K is more favourable than 6500 K [31], [32]. A CCT of 6000 K is less favourable than 3000 K and 4500 K. The average CCT chosen is 4150 K [42]. Cool white lighting of 4000 K and mimicking natural lighting (daylight 6200 K) are considered more suitable for computer-based workplace [43].

Lighting with CCT 6000 K can be used for activities with special needs, such as color adjustment and does not need to be applied in the work environment unless required for local lighting in a specific work area [41]. Other researchers recommend 6000 K [28] for e-paper as it will be better [34].

Participants felt more comfortable visually under 6500 K exposure [29]. High CCT lighting (17,000 K) can be a useful intervention to increase productivity in the work environment [44].

3.1.3. Light Distribution

Lighting must be installed appropriately to ensure an even distribution of lighting [45]. Light distribution is not discussed much because it is generally associated with designs handled by practitioners with limited resources. This condition is different from other lighting characteristics such as the light spectrum, which research develops because it is part of product development and is handled by large companies [46]. In Indonesia, the distribution of lighting for office buildings is not as clearly recommended as is the colour temperature, brightness or colour rendering. The distribution of localised and general lighting is stated in the procedures for artificial lighting design [21].

3.2. Review of Mood

Mood refers to feelings that are generally less intense than emotions. Mood is not always due to some cause [47] which initiates certain actions [48]. Mood refers to psychological conditions experienced by an individual, so that he or she may seem: i) calm, ii) disappointed, iii) excited, iv) reflective, v) unhappy or vi) neutral [49]. Mood is different from emotions where the latter are more intense and focused or related to someone or something [47].

Positive mood can be a state manifested in strength, friendliness and satisfaction [50]. The presence of plants in a room, or the arrangement of shelves and magazines, can improve the mood of the occupants of that room when compared to a room that has no greenery or magazine racks [51]. Listening to music also provides comfort and mood in a positive sense so that it can be used to eliminate boredom and maintain a positive mood [52], [53]. Improved sleep quality can have a significant impact on the moods of people; those with and those without mood disorders [54]. A negative mood is often resulting in stress, depression, nervousness, and fatigue [50]. Climate and weather can also affect a person's mood, although only slightly. The impact of these two factors varies in each individual, with their response depending on the duration of daily light exposure received by that person [55]. The difference in average duration of weekly light exposure has a different effect on mood on warm days when compared to cold days [56].

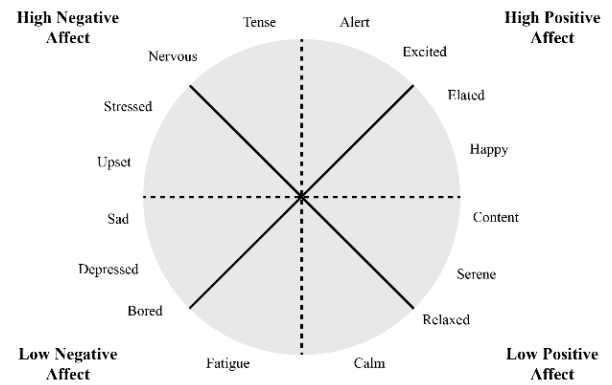


Figure 1 Structure of Mood [47]

3.2.1. Visual Comfort and Mood

Lighting is often seen as a simple thing that only causes visual effects. This view ignores the effects of lighting exposure to *neuroendochrines* and the associated psychology of that individual such as mood and depressive behaviour [11], [57]–[59]. Lack of exposure to light has a negative impact on mood; a condition also known as Seasonal Affective Disorder (SAD); which often results in sleep disturbance and a lack of alertness [59], [60]. Research into the relationship between exposure to bright light with mood concludes that bright light facilitates better mood; similar to the effects of tryptophan, a drug used to treat insomnia, anxiety, and depression [61]. Research with subjects from countries located far from the equator, reveals that there are significant variations in the mood of indoor workers throughout the year. The fluctuation of this mood can be related to the amount of lighting entering through the translucent opening in the walls or roofs [62]; variations which will not occur in areas close to the equator.

The non-visual effect forming process of light entering the eye begins with the reception of light by the photoreceptors. The receptors send a radiation energy response transmitted through nerve pathways or a combination of *neuroendochrines* to tissues or organs where several cyclical effects occur, effects including body temperature and secretion glands such as cortisol from the adrenal cortex and melatonin from the pineal [63]. In line with Bickford's explanation, Boyce explained that light reaching the retina of the eye is converted into an electrical signal transmitted by the optic nerve. Most of these signals end up in the brain's visual cortex and produce our sense of sight. However, some nerves separate from the optic nerve after leaving the eye and send signals to the suprachiasmatic nucleus (SCN), which is the part of the brain where the main clock of the human body is located [20], [64].

Regarding light and lighting's non-visual effect Benarroch (2011) explains in more detail that when light enters the eye in both natural and artificial lighting, the receiver of light integrates their response to the function of forming effects other than images: non-image forming (NIF) [65]. Another article mentions the importance of integrating information about lighting with cycles that regulate mood via the path known as the Photic Regulation of Arousal and Mood

(PRAM) pathway. This flow is a unique path in the regulation of mood in humans and other species [66].

The two hormones involved in the process above are: i) cortisol as a stress hormone and ii) melatonin as a sleep hormone. Both play an important role in regulating alertness and sleep. Cortisol levels increase in the morning and prepare the body for activity. These levels subsequently decrease gradually but remain at levels sufficient to provide blood sugar and energy throughout the day, to then reach their lowest levels at midnight. Instead melatonin levels drop dramatically in the morning thereby reducing the sleepiness. Under normal conditions, the levels will rise again when daylight turns to darkness, allowing for healthy sleep at the same time as cortisol is at the lowest levels in the individual's body / brain [20]. Another hormone that balances melatonin in the sleep process and also plays an important role in maintaining emotional feelings is serotonin. Serotonin is reactive to daylight and plays a role related to mood, balance control and movement, pain perception and peristalsis [67].

3.2.2. Mood in the Workplace

In the workplace, employees' moods are considered important to form positive perceptions that: a) are associated with improved work performance [68] and b) will affect levels of job satisfaction [69]. These benefits are manifested and evident in increasing productivity, improving welfare, and decreasing absenteeism rates so that a short return on investment is achieved [33]. Moods in the workplace (positive or negative) are also associated with influencing creativity [48], [70], [71]. Positive mood leads to creativity as it activates motivation and increases concentration [70]. Environmental pressure can disturb the mood of workers and indirectly cause a decrease in work performance [58] as negative mood can be influenced by inappropriate lighting or noise [72]. Conditioning mood in the workplace does not mean to change the existing mood but to maintain a mood that is positive [72] rather than creating hyperarousal which: a) can lead to discomfort that b) may decrease work performance [73].

3.3. Previous Research on Vision, Lighting and Mood

Research on the effect of light on mood has been carried out in a variety of ways for a variety of reasons. One study that focused on natural lighting found that such lighting affects mood levels [74]. Another study has shown that exposure to bright natural lighting at a level of more than 2000 lx for 30 minutes, when compared to lighting of less than 100 lx, is considered capable of improving one of the mood dimensions: pleasantness or comfort, as well as reducing drowsiness, even though this effect is only felt during

exposure to light [75]. Changes in the quality and quantity of natural lighting are considered to bring changes in: a) visual perception, b) alertness, and c) mood during the day [76]. That article states that subjects prefer natural lighting in terms of visual acceptability and glare. The statement is not in line with the conclusions from another study [77] which actually reveals a decrease in positive mood due to the amount of natural lighting that enters the workplace.

Other studies have focused on lighting arrangements which apparently also influence mood. Light distribution is an important element in creating an attractive atmosphere [46]. Not only can it improve the atmosphere, direct lighting distribution as well as general lighting is considered to be able to improve a positive mood. Increasing a positive mood due to the effect of direct lighting during the experiment is confirmed in real conditions [78]. The placement of general lighting has the potential to increase the level of a person's positive mood, while indirect or ambient lighting is better for reducing negative mood levels [50]. Ambient lighting significantly influences brain activity and is a requirement as a biological marker for environmental change [79]. Lighting can affect the mood of a room's occupants that arises because of various lighting arrangements with varied illuminance levels [80]. The space becomes brighter and more attractive with wall lighting [81] which with its uniformity, makes the users more interested in and at ease with their environment [82].

Articles on research into the effect of lighting on mood can be grouped into research that focuses on one or more of three categories: i) the CCT, ii) the illuminance level, and iii) a combination of both.

3.3.1. The effect of CCT on mood

Comparisons of the CCT have been carried out by several researchers in order to determine the effect of CCT on mood. Exposure to cool light (6000 K) and warm (2700 K) at 500 lx in mornings and evenings affects mood, thereby enabling the world to look more positive and less negative when bathed in 'warm lighting' [83]. Bluish white light (17000 K) is more effective than white lighting (6500 K) in suppressing melatonin. Exposure to bluish white light, rather than white light, significantly reduces drowsiness and increases an individual's alertness [84].

Individuals who are exposed to lighting from new technology models providing CCT 17000 K show decreased levels of fatigue as well as consistent improvements in levels of: a) concentration, b) memory, c) mood and d) energy compared to people in a room with lighting at 2900 K [44]. Compared to traditional fluorescent lamps with a low CCT of 3345 K, LEDs with a CCT of 4000 - 6000K are considered to be more conducive for: a) creating and maintaining positive mood, b) extending the duration of being in fit condition and c) accelerating performance in both visual and cognitive perception tasks [85]. When compared with white lights (4000 K), bluish white lights (17000 K) provide benefits for: i) alertness, ii)

performance, iii) mood and iv) eye fatigue reduction during the day. Such light also offers benefits outside working hours, particularly relating the quality and duration of a person's sleep [86].

The lighting research on CCT recommends suitable arrangement of CCT around 3000 K can be used to avoid melatonin suppression and changes in circadian rhythms, whereas lamps with a CCT 4000 K can be used to help an individual adapt to night work sessions [87]. Lighting with warm lamp temperatures of 2700 K, with the addition of 3000 K lamps, can create a calming environment; whereas a cold atmosphere of 6500 K, with an additional 4000 K, can provide an encouraging atmosphere for the elderly, through being stimulated emotionally [88]. Bluish white light (17000 K) can improve a person's alertness, performance, and mood both at work, as well as outside working hours. It was concluded that wakefulness, visual comfort, and sleep quality functions can be enhanced by enriching the spectral composition of the lighting source with short wavelengths of light [86]. Enhancing lighting with bluish white light (17000 K) can adjust the circadian rhythms of night session workers, reduce sleepiness levels, and improve their cognitive performance [84].

3.3.2. The effect of illuminance level on mood

The dynamism of illuminance levels is recognised as having potency in influencing subjective mood, although it is not accompanied by the benefit of circadian profile markers [89]. Exposure to light lamps with an intensity of 1000 lx (compared to 200 lx) in the eyes for 75 minutes succeeded in making participants feel more energised and believe that there is a bright lighting effect on their mood [90]. Exposure to bright light of more than 7000 lx for 21 minutes after and before undergoing a dark condition of 0.01 lx can help to eliminate the sleepiness that an individual is prone to develop in the dark. On the microscopic scale, the effect of such light on alertness appears as an increased activity in the brain that regulates cortisol's response to cognitive challenges [91].

Research to investigate the impact of bright lighting can also be done in the real environment. Research in the workplace with actual lighting conditions proves the lighting material and colour of the workplace have an influence on an individual's mood when he or she is working in that place [62]. A worker's mood will be at its lowest if the environmental lighting is too dark. The mood will improve and reach the highest level when the lighting is felt to be 'enough', to then decrease the level when it becomes too bright. However, there is no significant impact found on mood when the effect is assessed objectively. The research in the aerobic rooms with 400 – 600 lx and 2500 - 4000 lx concludes that positive mood effects are enhanced with exposure to bright light [92] rather than 'ordinary' less bright lighting. Regarding the moods of individuals exposed to repeated 2500 lx bright light during winter, one study clearly indicates that the intensity of depressive symptoms in healthy workers was reduced. The use of bright light is an option to improve the vitality and mood of workers in

their workplace context during the winter months, when daylight hours are most limited [93].

3.3.3. The effect of illuminance levels, CCT, and time of exposure on mood

A single factor of lighting might not affect a person's mood as mood change may well be the result of the interaction of the effects of other lighting or even non-lighting factors [50]. Therefore, below are presented studies which have examined the effect of lighting illuminance levels as well as the CCT and individuals' lighting exposure times.

Research tested lighting of 500 lx and 750 lx with CCT of 3000 K, 4000 K and 6500 K and concluded that the subject's mood was influenced by both CCT and illuminance level. Lighting with 3000 K produces a better mood with 500 lx compared to other colour temperatures. However, 3000 K is not recommended for office work related to visual performance, as it may not be sufficient while 4000 K results in a better mood at 750 lx. Therefore, 4000 K conditions are recommended for working environment lighting, with a target light level of more than 500 lx [11].

The other research, not only comparing light levels of 200 lx and 1200 lx with CCT 3000 K and 6500 K, includes time variables by testing light exposure in both the morning and evening [9]. The conclusion of the study stated that both the illuminance level and CCT of the light influenced the process of cognition, mood, and alertness whenever presented. Compared to the CCT, the illuminance level has been shown to improve alertness by reducing sleepiness, as well as facilitating mood improvement, so that the application of bright lighting is useful for improving employees' alertness levels and mood during working hours. When only testing during the day, it is found that light levels at 1000 lx and 100 lx affected subjects' performance and mood (but not alertness) better than did high (6500K) and low (3000K) CCT [8]. The CCT does not significantly benefit sleepiness and performance but affect the mood negatively. Therefore, such an arrangement can be applied to office lighting during the day to optimise the subject's response and performance.

Research including CCT and illuminance levels was developed by testing the dynamics in the form of changes in CCT and / or illuminance levels. Dynamic lighting is tested by exposing lighting that changes illuminance level and is tested on two CCTs as well as the dynamicization of both [94], [95]. Static lighting uses a high illuminance level of 2800 lx at 4050 K and a low light of 250 lx at 3900 K. The dynamics are in the form of lighting being gradually decreased from 2800 lx to 200 lx, with the CCT dropping from 4050K to 2800K. The lighting was also gradually increased from 200 lx to 2800 lx, with the CCT rising from 2800 K to 4050 K. The study concluded that the improved psychology and increase in body temperatures of workers on the midnight to morning shift occurred under: i) static lighting at 2800 lx with CCT of 4050 K or ii) gradually

decreasing illuminance level from 2800 lx to 200 lx and CCT from 4050 K to 2800 K.

Lighting effects, with a brightness level of 500 lx - 1800 lx, are found to give benefits to the office space related to subjective mood, although there is no significant difference in *sulphatoxymelatonin* (aMT6-s) levels when compared with ordinary lighting [89]. That findings can be interpreted as a positive effect of dynamic lighting being able to improve individuals' moods and perceptions, as well as possessing the potential to improve the employees' performance as a positive and beneficial effect of lighting variations. Artificial lighting dynamics research that imitates dawn lighting, with an intensity of 1.2 lx and which gradually reaches 250 lx, with colour temperature from 1090 K to 2750 K upon subject improves subjective perception, mood and performance after a lack of appropriate sleep time [96]. Since it does not have an effect on cortisol and melatonin, this exposure does not disrupt the individual's circadian rhythm.

4. CONCLUSION

The discovery and understanding of the light-receiving mechanism in a person's eye that is responsible for non-visual effects, can ensure that occupants of a room remain psychologically healthy even when they have to work in an environment that is lacking the appropriate or optimal levels of lighting. This condition can be achieved if the workers are given appropriate lighting when needed. Therefore, the workplace may need the research to evaluate links between health effects and artificial electric lighting. Research needed includes studies which evaluate the responses of human subjects as a result of being exposed to different qualities and quantities of lighting. Various lighting characteristics can be observed for the effect on mood, including: i) illuminance level, ii) CCT, iii) distribution, iv) timing, and v) duration.

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