International Journal of Design & Nature and Ecodynamics
Vol. 18, No. 2, April, 2023, pp. 395-405
Journal homepage: http://iieta.org/journals/ijdne

The Effects of Lighting on Mood in the Workplace: A Literature Review of the Research Method Applied

Silfia M. Aryani[1,2*], Arif Kusumawanto[1], Jatmika A. Suryabrata[1]

[1] Department of Architecture and Planning, Universitas Gadjah Mada, Jl. Grafika no. 2, Sleman 55281, Indonesia
[2] Department of Interior Design, Universitas Sebelas Maret, Jl. Ir. Sutami 36 A Kentingan, Surakarta 52176, Indonesia

Corresponding Author Email: silfia.aryani@staff.uns.ac.id

https://doi.org/10.18280/ijdne.180217

Received: 21 December 2022
Accepted: 28 March 2023

Keywords:
artificial lighting, correlated color temperature, illuminance level, PRISMA protocol, research object, research subject

ABSTRACT

Studies on the effect of lighting on mood have used different information-gathering methods and have presented a range of different conclusions. This paper aims to review the previous research relating to the applied method. This review method was conducted by selecting relevant articles through skimming and scanning, informed by the PRISMA protocol. The literature review discussed the subject, object, purpose, and applied research treatment, as well as the data collection methods of the selected papers. The result was 1) the subjects' terms and conditions that are required to be a research participant, 2) the object's description of the previous studies' test cell, 3) the treatment applied to achieve research purposes that focused on: a) illuminance levels, b) correlated colour temperature (CCT), or c) a combination of both, and 4) the data collection that listed information collected and the data/information gathering method for effective implementation. This literature review discussion could be beneficial for constructing a research plan about the effect of lighting on an individual's mood. However, further research might still be needed to ensure that the research design regarding the chosen subject, object, applied treatment, and data collection method can support achieving the research purpose.

1. INTRODUCTION

Research on lighting and visual comfort was initially limited to dealing with the issues of : i) brightness, ii) contrast, and iii) glare problems to achieve visual comfort [1] and then maintain it. Good lighting in the work environment led to better performance (in a speed context), fewer errors, accidents, and less absenteeism [2]. Bright lighting positively influenced workers' cognitive [3] and work performance levels [4]. During the solution's development, it was found that lighting is related to and positive mood [5].

Meanwhile, dynamic sunlighting is known for its role as a human physiological regulator [2] that affects psychological conditions, including alertness [6]. This role relates to circadian cycles [7] that are considered healthy [8, 9] and recommended to be applied [8, 10] in areas without natural lighting exposure. As most workers spend their working hours indoors while inducing natural lighting can be problematic for glare [11] and heat issues [12, 13], especially in the hot climate, artificial lighting can be an undeniable solution [14] and is recommended for energy saving [12]. Research on lighting is then developed on artificial lighting based on the morning daylighting character [11] for ensuring indoor workers benefit from lighting for their biological needs [2].

The importance of evaluating the effect of electrical-based artificial lighting on health leads to recommendations for studying the correlation between lighting exposure and a human being [15]. Previous studies about the impact of lighting on mood have used different information-gathering methods and have presented a range of different conclusions. This article reviewed previous research about the effect of lighting on employees' moods in their workplaces. This topic might be important to be studied as concern about lighting has shifted from energy saving to healthy prioritizing [16]. The review focused on the methods used to compile an appropriate research plan which can produce evidence of the research. The result could be beneficial to inform the construction of a research plan focused on the effect of lighting on a worker's mood. Therefore future research with a similar purpose can be designed in such standardized procedures to have comparable results and contributions to the knowledge.

2. RESEARCH METHOD

The review collected data from journal literature from the Scopus and Science Direct databases. The Scopus database was accessed on March 2, 2022. The literature collecting used a title+abstract+keywords option with advanced search in lighting AND workplace OR office AND mood OR alert OR relax AND NOT daylight. The literature was limited to research articles and conference papers published between the five years 2017 – 2021, with the full paper or extended abstract written in English. The Science Direct database was accessed on the same day with similar options in an advanced search for lighting AND office OR workplace AND mood OR alert OR relax AND NOT daylight. The result was limited to open access and open archive research articles from the journal 'Building and Environment' with environmental science subject areas published in 2018 - 2023. Most of the papers

included in this literature review can be accessed from the cited databases or the journal publishers. A small number of additional articles were downloaded from the Research Gate source.

The literature review employed two data-gathering methods that were 1) skimming and ii) scanning. The skimming method was used to implement the PRISMA systematic protocol to screen the literature to be reviewed. From the Scopus and Science Direct databases, 135 articles met the first evaluation criteria based on the title, abstract, and keywords. Five articles were excluded as they were in the form of literature review papers. Therefore, there is no research method to be reviewed from those five articles. From the keyword skimming, 33 papers discussed/involved *lighting* and *office* or *workplace*. Skimming was then conducted with abstracts, identifying 17 articles discussing / including *lighting*, *office* or *workplace,* and *mood* or *alert* or *relaxed*. From those 17 articles, two papers were excluded because they were the subjects of a request process, and one was excluded because it was written in Spanish. The scanning method was then carried out to read 13 articles in more detail regarding the method(s) employed in the research articles. The selection process can be seen in Figure 1. The selected articles reviewed for this research are listed in Table 1.

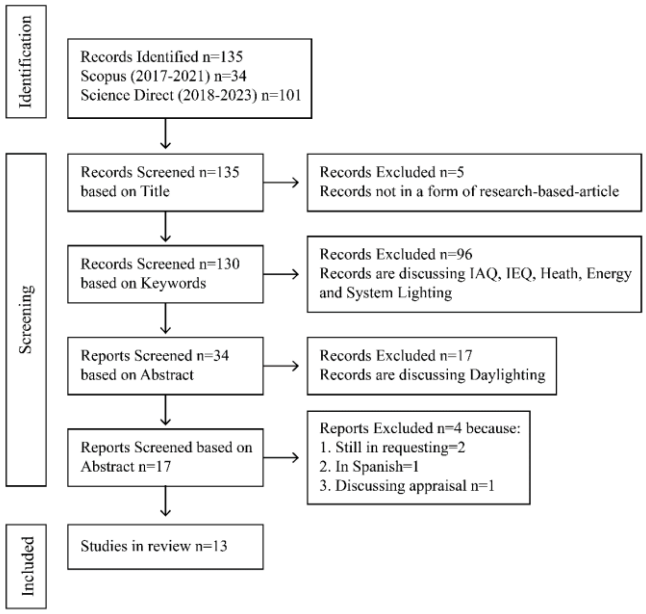

Figure 1. The selection process of reviewed papers

Table 1. The reviewed articles

Authors	Article Objective	Major Finding(s)
Aryani et al. [17]	Researched the effect of artificial lighting below standard on workers' mood and physiological condition	Artificial lighting that was below the standard affects the workers' physiological condition by drastically decreasing cortisol level
Askaripoor et al. [18]	Explaining the effect of correlated colour temperature (CCT) and illuminance level on alertness, mood, and cognitive performance during work hours	500 lx showed a positive impact. There is no different effect of CCT between 8000 K and 12000 K
de Vries et al. [19]	Studied the effect of lighting directed to the wall on the office appearance and subjects' affective level, alertness, and work performance	The wall lighting influenced the subjective alertness and maintained it if a high illuminance level
He et al. [20]	Studied the effect of dynamic illuminance level and CCT on alertness at different times of exposure	Dynamic lighting seems to create more alertness than static lighting
Hou et al. [21]	Researched the appropriate lighting to increase that work performance and reduce the negative effect of jetlag	Lighting can reduce jetlag's effect on alertness, short-time memory performance, and fatigue.
Mohammadi et al. [22]	Compared the effect of fluorescent and Light Emitting Diode (LED) lamps on alertness, cognitive work performance, and visual comfort level	LED lighting showed a significant effect on alertness, cognitive work performance, and visual comfort
Roslyakova et al. [23]	Researched the effect of CCT and illuminance level on mood, concentration, and work performance.	CCT and illuminance level affects the subjects' behavior, mood, and work performance.
Ru et al. [24]	Researched the effects of illuminance level and CCT that was exposed in the afternoon on subjective alertness and work performance	The arrangement of illuminance level and CCT showed an impact on subjective sleepiness, work performance test, and negative mood, even though not a significant result
Ru et al. [25]	Researched the task type and difficulty level that influenced the effect of lighting on cognitive performance	Illuminance level influenced the speed of subjects' cognitive performance, and this effect can be affected by the type and difficulty level of the task
Shahidi et al. [26]	Researched the effect of CCT on visual perception and mood in a room painted with various colors.	The combination of warm white lighting with a white wall or cool white with a blue wall was preferred for visual perception and mood in the workplace
Tonello et al. [27]	Compared two lighting arrangements with different CCT and illuminance levels in the workplace for increasing subjects' productivity and welfare	The bluish lighting (4000 K) contributed an effect that relevant to the psychobiological response
Zhang et al. [28]	Studied the effect of dynamic lighting on users' health, welfare, and experience	There was a change in partial positive mood under dynamic lighting compared to static lighting. There was not any effect on the negative mood
Zhu et al. [29]	Researched the effect of illuminance level and CCT on the cognitive performance and alertness of healthy adults while working	The combination of illuminance level and CCT affected cognitive performance, mood, and alertness during regular work hours. The effect depended on the exposure time

3. FINDINGS FROM PREVIOUS RESEARCH ON ARTIFICIAL LIGHTING AND MOOD

3.1 Research subjects

3.1.1 The requirements to be a participant in lighting effect research

In order to be a participant in research into the effect of lighting on mood, the main requirement is inseparable from eye health. Therefore, it is required that research subjects: a) do not have any vision damage [18, 21, 26]; or b) have damage that can be corrected, so the wearers of glasses or contact lenses are still included [19, 24, 29]. Another requirement is not to be colour-blind [18, 24], a condition confirmed by passing the Ishihara test [19, 26].

Not only is eye health a priority, but subjects must also be healthy in general [25, 26, 30], both physically and psychologically [18, 20, 29]. Potential participants should have no hearing disability [25] or disability regarding the language medium used in the research [19] for communication purposes. Further requirements relating to a participant's health criteria are that they should be free from chronic conditions; no neurological, cardiovascular, autoimmune, or pulmonary diseases [26]. Another article discussed the requirements for the participant's body mass index (BMI) to be 18 – 23.9 kg/m^2 [29]. Subjects have also been restricted to non-smokers [18, 20, 21, 24]. The subjects of research must not be extreme chronotypes [18, 25, 27] referred to in other articles as a moderate level of chronotype [19, 28]. The moderate chronotype does not apply to research on subjects exhibiting extreme early orate chronotypes [24].

In terms of age, some studies involved subjects with an average of 20s years old (yo) [17-19, 24, 25, 29]. Other research subjects' age ranges were 20 – 35 yo, 19 – 35 yo, and 21 – 35 yo. One study involved 38 yo average subjects [28]. This age consideration becomes essential as there are similar melatonin levels for a range of ages [20]. Besides age consideration, the occupation of subjects may need to be considered. Some research has workers as the subjects [17, 23, 28], whereas another research initiative involved students [19]. The requirements that need to be considered in subjects' selection are summarized in Figure 2.

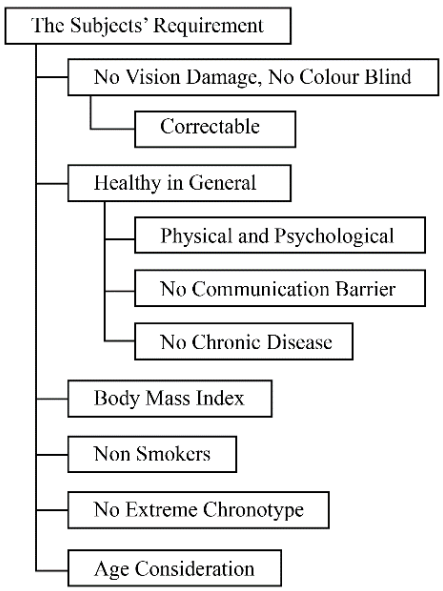

Figure 2. The subject requirement

3.1.2 Research subject's provision

The gender ratios of research subjects vary widely. Some studies included male and female subjects in almost equal proportions [21, 27], whereas other studies paid no attention to gender proportionality [19, 20, 23]. Some research only included male subjects [17, 18, 25, 26, 28], whereas one article focused solely on female subjects [24]. This gender variable is important because of different perceptions [29] between males and females.

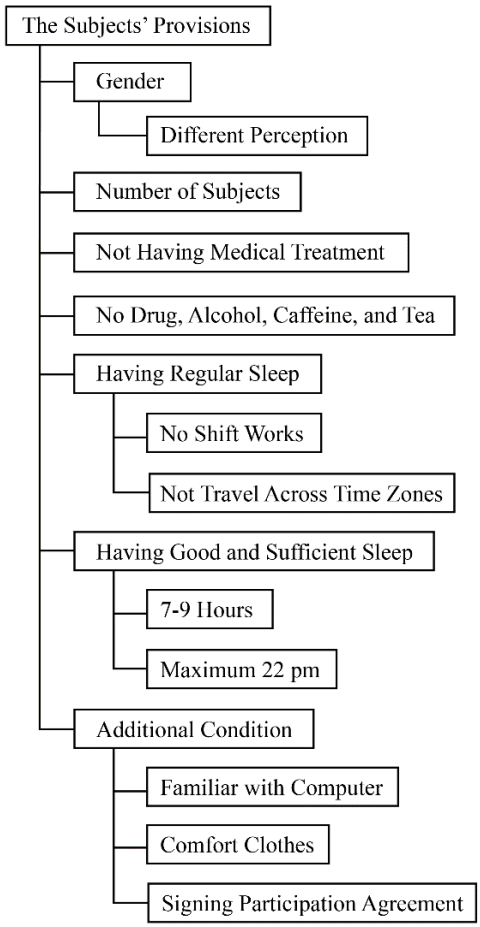

Figure 3. Subjects' provision

The number of subjects involved in a study varies. There was research involving more than fifty subjects [24, 29]. Other studies included subjects numbering in their 20s and 30s [18-23, 25, 26], and one study involved exactly 15 participants [28]. Two pieces of research involved fewer than ten subjects [17, 27].

Potential subjects involved in mood conditions research are rejected if they are receiving medical treatment [20, 24, 27, 29] for psychiatric, neurologic [22, 26], and/or sleep disorders [28, 29]. This restriction includes not consuming drugs during an ongoing research period [24, 26, 29]. In addition, subjects have been prohibited from drinking alcohol [21, 25-27, 29], caffeine [25, 29], and tea [21] for one week [26] before participating in the research.

Research subjects have been required to demonstrate regular rest [21]. Subjects should not experience activities that disturb their sleep time, such as running a night shift [20] or traveling across time zones during the previous three months [18, 24], two months [29], or one month [20, 25] before the lighting/mood research beginning. Subjects were asked to get

good quality [26] enough sleep, 7 – 9 hours [24], and not stay up later than 23:00 [20, 27] at night before the lighting/mood research.

Other provisions generally depended on research investigating issues such as participants being familiar with office work [28] and being required to wear natural colour clothes [27]. Before the research session, subjects must sign a written informed consent document agreeing to participate [18, 21, 23-28]. The participants are financially compensated after completing their duties as research subjects [29]. The provision that needs to be considered in subject's selection are summarized in Figure 3.

3.2 Research objects

Some research on lighting's effect was conducted in office environments [17, 28]. Other studies used artificial rooms set up in a laboratory [23, 29], simulating offices [19, 24-27, 29], or conference rooms [18, 20]. The colours used for the wall and ceilings are white [17, 19, 27] or different bold colour depending on the research purpose [26]. Two colours used on the floor or carpet were grey [27] and brown to avoid glare [26]. In order to prevent natural light from entering the research space, the experimental room was made without a window [22, 29]; any daylight coming in from outside [18, 26] was excluded by the placement of an opaque screen [19]. The condition of the experimental room was controlled in terms of temperature and humidity so that the main focus could be on lighting. However, such environmental control also has a weakness because it differs from the less controlled conditions encountered in the real world [29]. The consideration of the room where research may be conducted is summarized in Figure 4 below.

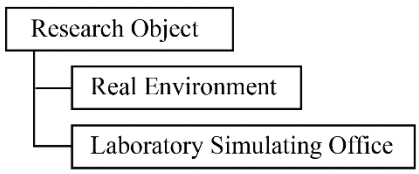

Figure 4. Research object

3.3 Research objectives and treatment applied

Research on the effect of lighting on mood can be done by several approaches that do not always produce the same conclusions.

The first research approach compares the impact of lighting different levels of brightness on an individual's affective state, alertness, and performance [18, 21, 23-28]. The second approach compares the effect of correlated colour temperature (CCT) in 3000 K warm white with 6000 K cool white for visual perception and mood [26]. In addition to studies that only focus on the illuminance level and CCT, some studies combine these variables to determine their effect on a person's mood. This third approach is made by comparing the effect of different levels of CCT and illuminance levels on a person's alertness, mood, and cognitive performance [18, 29]. The last potential approach is by comparing the effect of illuminance levels and CCT that exposure in different times, such as statically in a) morning and afternoon [29], b) summer and winter [27], and c) dynamically changing after lunch hour [28].

The carryover effect from the previous experiment treatment should be taken into account and avoided by imposing a gap between the testing that can last from a week [18, 20], three days [25], or just 20 minutes [27]. One research team identified that the weakness in their study was the duration of light exposure, which was considered insufficient [24]. There is also the potential influence of the Hawthorne effect and, at certain times of each year, fasting that may have influenced an individual's mood state [17]. The objectives and the observed variables of the research on lighting and mood are summarized in Figure 5 below.

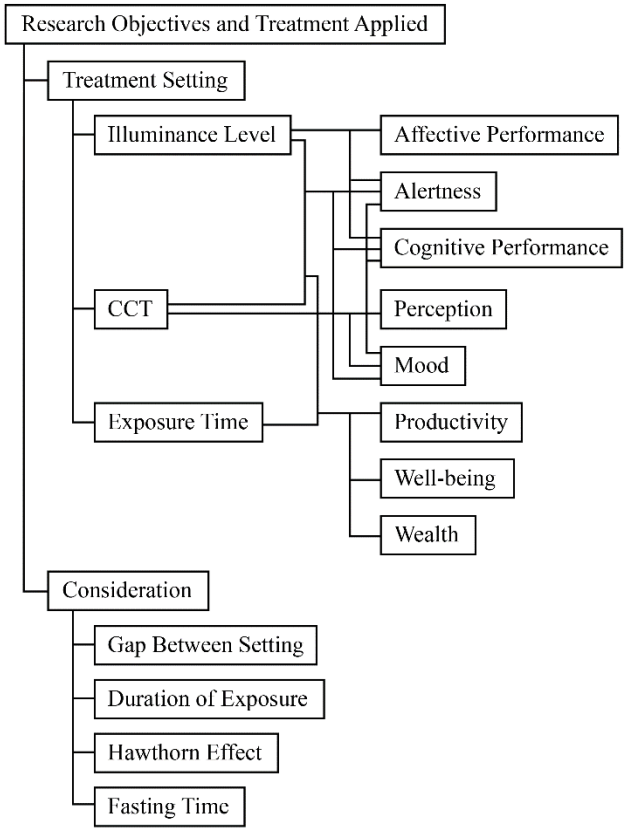

Figure 5. Research objective and applied treatment

3.4 Data collection methods and research findings

The data and collection methods were summarized in the Figure 6.

3.4.1 Subjective report and evaluation

Subjective data collection methods used concerning research on mood include various types of questionnaires, self-reporting, and assessment. A questionnaire can be used to collect basic data such as a) demographic profile [25, 28], b) general physical and mental health status [26], and c) sleep habit [25] such as Morningness – Eveningness Questionnaire [20, 21, 26, 28]. Questionnaires can also be designed to collect data relating to the room and or lighting assessment [22, 24, 25, 27, 29], and/or perceived stress, alertness, and mood [24, 28]. A sleep diary is another subjective data source reporting sleep quality [28]. Alternatively, some researchers employed the Pittsburgh Sleep Quality Index [24, 28].

Some subjective collecting instruments have been constructed in forms that can be used in research into lighting effect upon *mood*, such as i) the Positive and Negative Affect

Schedule (PANAS), ii) the Visual Analogue Scale (VAS), iii) Scale for Mood Assessment [27], iv) Brunel Mood Scale [26]. Research into *alertness* and *sleepiness* has involved the Karolinska Sleepiness Scale (KSS) [24, 25, 29], as well as the Epworth Sleepiness Scale [27] and Standford Sleepiness Scale [28].

PANAS has produced findings that confirm a person's mood is affected by lighting [24, 28, 29]. However, at least one initiative was unable to provide evidence to confirm the outcome of the direct impact of light on mood in a research initiative [24]. Similarly, KSS has proven the effect of lighting on mood in some research [19-21, 24] but failed in other ones [17, 18].

3.4.2 Performance observations

In studies related to light and mood, in addition to collecting data in the form of self-reports from research subjects, research is often accompanied by measured performances. The task assignment while being exposed to light is related to cognitive work and a participant's level of alertness. In terms of alertness, the research into the effect of lighting can employ the Psychomotor Vigilance Task (PVT) [18, 24]. For visual acuity, some research used paper-based tasks such as Landolt C [19], the Landolt Ring, or computer-based task: the Freiburg Visual Acuity and Contrast Test (FrACT) [22].

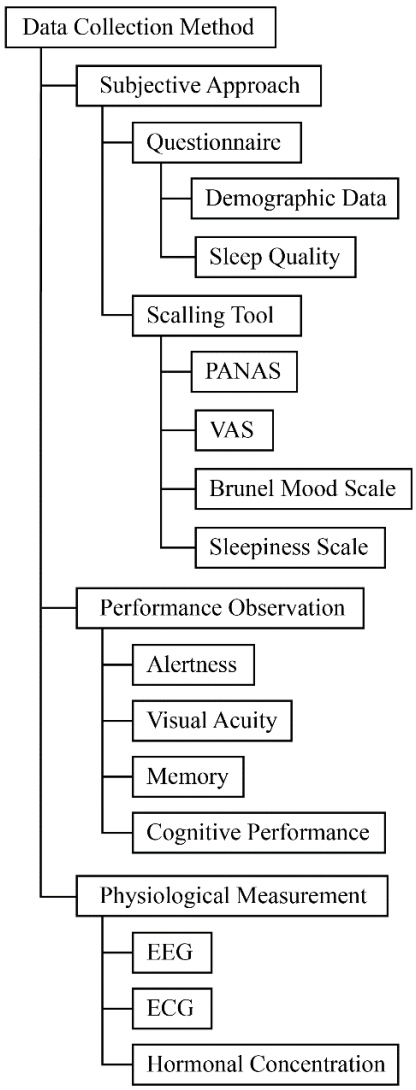

Figure 6. Data collecting method

Long-term memory performance has been tested [29], and use the Two-Back Test [18, 25, 29] have investigated short-term memory [30]. Another type of assignment for inhibitory capacity is the Go/no-go instrument [18, 25, 29]. Some other performance tasks used include the Continuous Performance Test [18], Remote Association Task (RAT) [19], the screen-based Stroop Task, or the combination-based Alternate Uses Task [19]. The D2 test can test attention levels in cognitive performance [21].

3.4.3 Physiological observations

Physiological measurements can be in various forms to observe the effect of lighting on mood. Electroencephalogram (EEG) tests have successfully shown the effect of lighting [21] or the effect of lighting type [22] on a person's alertness. In several studies, heart rate recorded with an electrocardiogram (ECG) showed a positive relationship between lighting and alleviating the recipient's negative mood [21]. Hormonal level or change measurement was successfully applied to research the effect of lighting on mood. Evidence was gathered by measuring the individual's saliva cortisol [17, 27], salivary [21], or urinary melatonin levels [27].

3.5 Summary of findings

Based on the results above, there are two crucial points for researching the effect of lighting on mood. The first point to be decided is the purpose(s) based on the research question(s). This decision will lead to what lighting variable will be observed and how it will be arranged in the room test, whether in a natural environment or a simulated laboratory. Meanwhile, suitable research subjects must be chosen to support the research purpose(s). Research needs to decide whether the research targets specific or general samples. Research might need to consider whether there are any treatments or requirements for the subjects before the observation.

The second attention might be on the research data that must be collected to answer the research question(s) and fulfilling the research purpose(s). The data can be in the form of subjective assessment, work performance observation, or physiological measurements. The data form will lead to the correct method for collecting and also analyzing them. Carefully considering and designing the research plan will achieve noticeable results that benefit lighting knowledge development. These findings are summarized in Figure 7.

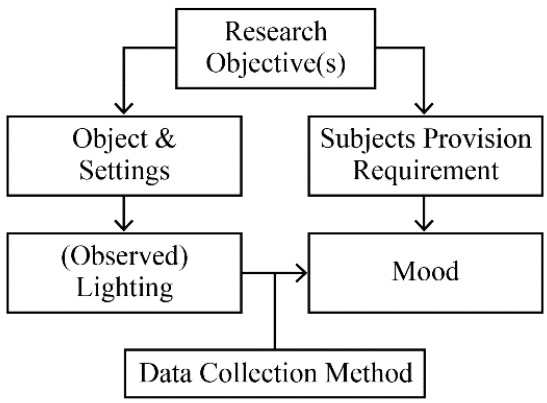

Figure 7. Summary of research method consideration

4. DISCUSSION

This part synthesized the result of the literature review with other relevant articles listed in Table 2 to support the statement of the result.

4.1 Consideration for research subjects

4.1.1 The requirements to be a participant in lighting effect research

For research that involves visual, in the matter of eye health, the subject must have healthy eyes and be free from retinal damage, glaucoma, and/or cataracts [30] except for specific research that involves subjects with vision damage to observe the effect of light on their moods [31]. A similar proviso applies to people with heart disease; they cannot be the subject of research on the effect of lighting on mood because their cortisol levels cannot be a stress marker [32]. Also, a potential research subject should not have to deal with performance/task deadlines or examinations to avoid stress or emotional burdens [33].

Related to sleep quality, known for its effect on mood [23], a high BMI score indicates the risk of an individual developing diabetes or obesity. These two conditions are closely related to sleep deprivation habits [34]. For the same reason, active smokers have been excluded from participating in a study as they are more prone to suffer from insomnia [35] than non-smokers. Before the sleep-related lighting research occurs, potential participants are asked to write down their daily sleeping and waking habits, which are classified as an individual's chronotype. This check is because those habits may include issues or conditions that could affect the research result [36].

Related to the age of the subject, some studies do not provide limits unless the research: a) aims to compare subjects with young and old ages [37], b) is focused on adolescents [38], or c) is focused on the elderly [39]. One major problem with lighting research involving young and old participants is that such studies will likely lead to extreme findings difference [37]. Researchers have set a minimum age of participants should be at least 18 years [40, 41] while another research limited their subjects to working age [42]. For a study designed to observe workplaces, students as participants might not be considered inappropriate because the results will differ [43]. This difference may relate to the incentives and performance produced by students (who do not have fixed incomes) and workers (who are already paid) [44].

4.1.2 Requirements to be a participant in lighting effect research

The choice of one gender is evident in a study with female subjects because it was difficult to find male participants who met the required criteria [45]. On the contrary, other studies limit the presence of male subjects so as not to confuse the menstrual cycle with the circadian cycle [6]. It is recognized because the former condition can influence a female's mood and assessment [46]. A person's gender may need to be considered as there are differences in working memory test results [47] between men and women, resulting from an observed effect of lighting. Women are considered more expressive [48] in perceiving space rather than men [49, 50] although other studies have found differences when comparing ages rather than genders [51].

Relating to the appropriate subject number for a particular study, some researchers underline that smaller numbers, such as 40 [52] or 52 [53], are perceived as insufficient; the merit of a sample size greater than 100 has been stressed [54]. However, it should be noted that a complex range of considerations dictates the optimal number of research participants.

The subject must sleep well and not be late to bed the night before the trial because it can weaken the research findings [30]. This proviso does not apply to studies that examine subjects with inappropriate sleep cycle conditions, such as sleeping for less than 7 hours or more than 9 hours [55].

4.2 Consideration for Research Test-cell

The use of real space as a research location in this field of interest is felt to be less than optimal since it will make it difficult to control incoming lighting, a problem that represents a research weakness [30]. The researcher should also consider any influence resulting from the Hawthorne effect. Initially, research subjects may show positive performance because they know they are being observed, creating an unusual or abnormal situation [56]. This qualifying observation is especially relevant when the study is conducted in the participants' working offices [17]. Therefore, the subject should be encouraged to be honest about their mood and assessment [47], a constant research challenge requiring subjective feedback. Research results from a tightly controlled environment could have a different effect when applied to real-world locations. In the experimental space, the colors used in the walls, ceilings, and floors were made to minimize color disturbance experienced by participants [44].

4.3 Consideration for research objectives and treatment applied

The duration and time of exposure, spectrum, and distribution [15] are important. Lighting is considered to have an impact after exposure for a certain period or exposure to a particular light source daily [57]. Another article suggested that the experiment time should be longer than 1-day and use actual office space [58].

4.4 Consideration for data collection methods and research findings

4.4.1 Subjective report and evaluation

The mood is generally measured based on personal reports submitted by research subjects [59], a subjective approach yielding results open to questions regarding their honesty/validity [60]. The questionnaire method is often used for data gathering, although it may miss more detailed information [61] and be influenced by the subjectivity of the respondent [60]. Although subjective, the questionnaire is an important tool used to reveal the health status of the subjects before the study takes place.

Another form of subjective data collecting is PANAS, an instrument containing 20 self-evaluation statements developed by Watson, Clark, and Tellegen that measure an individual's positive and negative emotions. The reliability and validity of the 20 statements have been empirically confirmed [62]. VAS is a measurement instrument for abstract things such as characteristics or behavior that cannot be measured directly [63]. Therefore, measurement is achieved by analogizing

quantities within a specific range from minimal to maximum conditions.

Research into the issue of mood generally also considers the quality of a person's sleep before and during the research period. Mood research is likely to involve sleepiness in the researchers' observations as evidence supports a clear relationship between mood and sleepiness [3]. The KSS measures sleepiness in 9 levels and can be used to assess changes as an environmental response [64].

4.4.2 The physiological observation

A deeper approach in research investigating lighting actually appeared in 1980. Before, lighting was still considered a 'not particularly complex issue,' so practitioners only study its effects visually, ignoring deliberately or by accident its neuroendocrine, psychological, and physiological effects, even though the effects are ongoing and perhaps evident [65]. Other researchers assessed the lack of a subject's attention to understand how light affects a room's occupants' physiological and psychological system, including the circadian function that regulates sleep and mood [66]. In their research into sleep quality, an issue indirectly related to mood conditions, psycho-physiological methods (EEG, ERP, and others) produced more valid and credible findings [52].

Electroencephalogram (EEG) tests demonstrate brain activities, some of which can be markers of stress levels. Related to skin condition, it was noted that electrodermal activity acts as a stress marker [4] based on the increased activity of a person's sweat glands [67]. Another stress marker is cortisol [68]; hence its changes in hormone levels can be physiological signs that correspond to psychological conditions.

Table 2. The relevancy of supported papers' research topic with selected reviewed articles

Author(s)	Relevancy
Abbas et al. [60]	Effect of lighting and colour on physiology and psychology
Asif et al. [69]	Effect of music on gender-based stress
Bonmati-Carrion et al. [3]	Effect of lighting and rhythmic change
Boubekri and Wang [54]	Effect of lighting on subjects' mood that correlated to performance
Boyce et al. [6]	Effect of lighting on enhancing the work performance of workers
Cajochen et al. [55]	Effect of LED with natural lighting spectrum on physiology, alertness, cognitive performance, and sleep quality
Crawford and Henry [62]	Evaluate PANAS as a research tool
Curcio et al. [52]	Effect of LED lighting on sleep, sleepiness, and mood
Deng et al. [48]	Differences between male and female subjects on experiencing and expressing emotional responses
Denk et al. [43]	Effect of the light source and CCT on mental and concentration state
Farshchi and Fisher [59]	Propose spatial modeling with a multidisciplinary approach of social, psychological, and aesthetics
Gabel et al. [37]	Effect of illuminance level and CCT on alertness, hormonal level, skin temperature with age-based subjects and sleep restriction
Gou et al. [53]	Effect of dynamic natural lighting on work performance and mood
Gould et al. [63]	Testing Visual Analogue Scale (VAS) as an assessment tool
Hadji et al. [33]	Effect of illuminance level and CCT on mood
Hoffman et al. [56]	Impact of illuminance level and CCT on a hormonal level and subjective mood
Kaida [45]	Effect of a short nap and bright light on mood
Kawasaki et al. [31]	Effect of scheduled bright light exposure on sleep, rest cycles, and subjective mood of patients with glaucoma
Knez [49]	Effect of CCT on subjective mood and cognitive performance
Knez and Kers [51]	Effect of lighting, age, and gender on cognitive performance and mood
Kuijsters et al. [61]	Effect of ambient lighting on elderlies' mood
Lan et al. [70]	Effect of illuminance level and CCT on mood and creativity
Leichtfried et al. [30]	Effect of intensive morning lighting on maintaining focus, mood, and melatonin concentration
Leppamaki et al. [42]	Effect of exercise with/out morning bright light on mood
McCloughan et al. [50]	Affect artificial lighting on mood and behavior
Newsham et al. [58]	Effect of individual's lighting control
Partonen and Lonnqvist [46]	Effect of bright light exposure on psychological distress
Rompas et al. [35]	Correlation between smoking habit and insomnia
Ryden et al. [32]	Correlation between coronary artery disease and stress
Smolders and de Kort [4]	Effect of illuminance level on mental fatigue
Smolders and de Kort [71]	Effect of 1-hour exposed morning and afternoon CCT on physiology and work performance
Sharma and Kavuru [34]	Association of partial sleep deprivation with obesity and diabetes
Sperlich et al. [68]	Heart rate and salivary cortisol as a psycho-physiological stress marker
Studer et al. [38]	Effect of red and blue-enriched lighting in the morning on attention-based performance
Veitch [44]	Effect of lighting on performance and mood
Veitch and Newsham [41]	Compared the quality of low and high lighting power density (LPD)
Wang et al. [39]	Effect of illuminance level and CCT on physiology, visual performance, and subjective mood of elderly
Yang et al. [36]	Effect of high illuminance level on work performance of two type chronotypes
Yang et al. [47]	Effect of illuminance level and CCT on brightness sensation, lighting perception, and cognitive performance
Zangronis et al. [67]	The device used for monitoring electrodermal activity as the stress marker

5. CONCLUSION

The invention in the mechanism of lighting effect on the human biological cycle and the relation to mood leads to an effort to provide the healthy benefit of natural lighting for users working in a room with insufficient lighting. This review shows that previous research articles have discussed many methods of examining the effect of lighting on mood. Discussed are the selected papers' subject, object, purpose, and treatment, as well as the data collection methods. The subject focus explains the terms and conditions required to participate in the reported research initiatives. The object section describes the test cells of previous studies. The purpose and treatment part categorised the applied approach to researching lighting, which focused on: a) illuminance levels, b) correlated colour temperature, or c) a combination of both. Also examined was how the lighting treatment that the subject is exposed to relates to their performance focus. The data collection part of this paper lists the information collected and the data/information gathering method that can be most effectively implemented.

However, it should be noted that a general agreement on this relationship is yet to be reached. Therefore, further research must consider such issues as:

- The selection and number of research subjects: consideration might be on the appropriate number, gender, and occupation of the subject, besides the basic requirement and provision of research subject for lighting research;
- the condition of the research object; consideration might be given to factors influencing decisions regarding the use of the real room or artificial test cells;
- the treatment applied; consideration might be devoted to the proper duration of the lighting exposure and interval time between the observed lighting settings for resulting significant effect;
- how to collect data might be considered when choosing the appropriate measuring instruments to achieve the research aim.

In sum, the result of how the research method for studying the effect of lighting on mood may still be debatable and a wide-open waiting to be researched. The discussion of this literature review might be needed as the current lighting concern seems to prioritize health rather than energy consideration. Unfortunately, this literature review has a limitation that is not currently conducted. Moreover, the reviewed papers have been limited from the last six years period of publication time with open access type. Therefore, future research needs to be carefully planned by considering the applied method from updated similar research articles to produce valid research conclusions that can contribute to this challenging area of science.

ACKNOWLEDGEMENT

Universitas Sebelas Maret supports this work through a doctoral program scholarship.

REFERENCES

[1] Fincher, W., Boduch, M. (2009). Standards of human comfort: Relative and absolute. Austin: The University of Texas at Austin.

[2] Van Bommel, W.J. (2006). Non-visual biological effect of lighting and the practical meaning for lighting for work. Applied Ergonomics, 37(4): 461-466. https://doi.org/10.1016/j.apergo.2006.04.009

[3] Bonmati-Carrion, M.A., Revell, V.L., Cook, T.J., Welch, T.R., Rol, M.A., Skene, D.J., Madrid, J.A. (2020). Living without temporal cues: A case study. Frontiers in Physiology, 11: 1-12. https://doi.org/10.3389/fphys.2020.00011

[4] Smolders, K.C., de Kort, Y.A. (2014). Bright light and mental fatigue: Effects on alertness, vitality, performance and physiological arousal. Journal of Environmental Psychology, 39: 77-91. https://doi.org/10.1016/j.jenvp.2013.12.010

[5] Katabaro, J.M., Yan, Y. (2019). Effects of lighting quality on working efficiency of workers in office building in Tanzania. Journal of Environmental and Public Health, 2019: 3476490. https://doi.org/10.1155/2019/3476490

[6] Boyce, P.R., Beckstead, J.W., Eklund, N.H., Strobel, R.W., Rea, M.S. (1997). Lighting the graveyard shift: The influence of a daylight-simulating skylight on the task performance and mood of night-shift workerst. International Journal of Lighting Research and Technology, 29(3): 105-134. https://doi.org/10.1177/14771535970290030501

[7] Dai, Q., Cai, W., Shi, W., Hao, L., Wei, M. (2017). A proposed lighting-design space: Circadian effect versus visual illuminance. Building and Environment, 122: 287-293. https://doi.org/10.1016/j.buildenv.2017.06.025

[8] Rea, M.S., Figueiro, M.G. (2018). Light as a circadian stimulus for architectural lighting. Lighting Research & Technology, 50(4): 497-510. https://doi.org/10.1177/1477153516682368

[9] Andersen, M., Gochenour, S.J., Lockley, S.W. (2013). Modelling 'non-visual' effects of daylighting in a residential environment. Building and Environment, 70: 138-149. https://doi.org/10.1016/j.buildenv.2013.08.018

[10] Lucas, R.J., Peirson, S.N., Berson, D.M., et al. (2014). Measuring and using light in the melanopsin age. Trends in Neurosciences, 37(1): 1-9. https://doi.org/10.1016/j.tins.2013.10.004

[11] Cheng, Y., Gao, M., Dong, J., Jia, J., Zhao, X., Li, G. (2018). Investigation on the daylight and overall energy performance of semi-transparent photovoltaic facades in cold climatic regions of China. Applied Energy, 232: 517-526. https://doi.org/10.1016/j.apenergy.2018.10.006

[12] Alawadhi, E.M. (2016). Effect of an incompletely closed window shutter on indoor illuminance level and heat gain. Energy and Buildings, 110: 112-119. https://doi.org/10.1016/j.enbuild.2015.10.040

[13] Goia, F. (2016). Search for the optimal window-to-wall ratio in office buildings in different European climates and the implications on total energy saving potential. Solar Energy, 132: 467-492. https://doi.org/10.1016/j.solener.2016.03.031

[14] Adamsson, M., Laike, T., Morita, T. (2018). Seasonal variation in bright daylight exposure, mood and behavior among a group of office workers in Sweden. Journal of Circadian Rhythms, 16: 1-17. https://doi.org/10.5334/jcr.153

[15] Lunn, R.M., Blask, D.E., Coogan, A.N., et al. (2017).

Health consequences of electric lighting practices in the modern world: A report on the National Toxicology Program's workshop on shift work at night, artificial light at night, and circadian disruption. Science of the Total Environment, 607-608: 1073-1084. https://doi.org/10.1016/j.scitotenv.2017.07.056

[16] Jarboe, C., Snyder, J., Figueiro, M.G. (2020). The effectiveness of light-emitting diode lighting for providing circadian stimulus in office spaces while minimizing energy use. Lighting Research & Technology, 52(2): 167-188. https://doi.org/10.1177/1477153519834604

[17] Aryani, S.M., Kusumawanto, A., Suryabrata, J.A., Airin, C.M. (2021). The effect of insufficient artificial lighting on workers' moods and physiology: preliminary research. In IOP Conference Series: Earth and Environmental Science, 738(1): 012028. https://doi.org/10.1088/1755-1315/738/1/012028

[18] Askaripoor, T., Motamedzade, M., Golmohammadi, R., Babamiri, M., Farhadian, M., Aghaei, H., Ghaffari, M.E., Kazemi, E., Samavati, M. (2021). The parallel effect of correlated color temperature and illumination level on alertness and cognitive performance: A multi-measure study. Journal of Health and Safety at Work, 11(4): 674-699.

[19] de Vries, A., Souman, J.L., de Ruyter, B., Heynderickx, I., de Kort, Y.A. (2018). Lighting up the office: The effect of wall luminance on room appraisal, office workers' performance, and subjective alertness. Building and Environment, 142: 534-543. https://doi.org/10.1016/j.buildenv.2018.06.046

[20] He, S., Chou, S., Chen, H., Lin, Y. (2020). Study on human alertness affected by dynamic trend of lighting. In 2020 17th China International Forum on Solid State Lighting & 2020 International Forum on Wide Bandgap Semiconductors China (SSLChina: IFWS), Shenzhen, China, pp. 192-195. https://doi.org/10.1109/SSLChinaIFWS51786.2020.9308709

[21] Hou, D., He, S., Dai, C., Chen, S., Chen, H., Lin, Y. (2021). Lighting scheme recommendation for interior workplace to adjust the phase-advance jet lag. Building and Environment, 198: 107913. https://doi.org/10.1016/j.buildenv.2021.107913

[22] Mohammadi, A., Rastin, A., Dehaghi, B.F., Gharagozlo, F., Angali, K.A. (2019). Survey effect of illuminance source on alertness in a laboratory design. Iran Occup Health, 16(5): 88-97.

[23] Roslyakova, S., Laushkina, A., Bragina, T., Zemlyanova, E., Basov, O. (2021). The influence of lighting system photometric characteristics on mental state of users. The case study of keyboard handwriting. In CEUR Workshop Proceedings, 3027: 826-836.

[24] Ru, T., de Kort, Y.A., Smolders, K.C., Chen, Q., Zhou, G. (2019). Non-image forming effects of illuminance and correlated color temperature of office light on alertness, mood, and performance across cognitive domains. Building and Environment, 149: 253-263. https://doi.org/10.1016/j.buildenv.2018.12.002

[25] Ru, T., Smolders, K.C., Chen, Q., Zhou, G., de Kort, Y.A. (2021). Diurnal effects of illuminance on performance: Exploring the moderating role of cognitive domain and task difficulty. Lighting Research & Technology, 53(8): 727-747. https://doi.org/10.1177/1477153521990645

[26] Shahidi, R., Golmohammadi, R., Babamiri, M., Faradmal, J., Aliabadi, M. (2021). Effect of warm/cool white lights on visual perception and mood in warm/cool color environments. EXCLI Journal, 20: 1379-1393. https://doi.org/10.17179/excli2021-3974

[27] Tonello, G., Hernández de Borsetti, N., Borsetti, H., Tereschuk, L., López Zigarán, S. (2019). Perceived well-being and light-reactive hormones: An exploratory study. Lighting Research & Technology, 51(2): 184-205. https://doi.org/10.1177/1477153517750714

[28] Zhang, R., Campanella, C., Aristizabal, S., Jamrozik, A., Zhao, J., Porter, P., Ly, S., Bauer, B.A. (2020). Impacts of dynamic LED lighting on the well-being and experience of office occupants. International Journal of Environmental Research and Public Health, 17(19): 7217. https://doi.org/10.3390/ijerph17197217

[29] Zhu, Y., Yang, M., Yao, Y., Xiong, X., Li, X., Zhou, G., Ma, N. (2019). Effects of illuminance and correlated color temperature on daytime cognitive performance, subjective mood, and alertness in healthy adults. Environment and Behavior, 51(2): 199-230. https://doi.org/10.1177/0013916517738077

[30] Leichtfried, V., Mair-Raggautz, M., Schaeffer, V., Hammerer-Lercher, A., Mair, G., Bartenbach, C., Canazei, M., Schobersberger, W. (2015). Intense illumination in the morning hours improved mood and alertness but not mental performance. Applied Ergonomics, 46: 54-59. https://doi.org/10.1016/j.apergo.2014.07.001

[31] Kawasaki, A., Udry, M., El Wardani, M., Münch, M. (2021). Can extra daytime light exposure improve well-being and sleep? A pilot study of patients with glaucoma. Frontiers in Neurology, 11: 584479. https://doi.org/10.3389/fneur.2020.584479

[32] Rydén, M., Hedbäck, B., Jonasson, L. (2009). Does stress reduction change the levels of cortisol secretion in patients with coronary artery disease? Journal of Cardiopulmonary Rehabilitation and Prevention, 29(5): 314-317. https://doi.org/10.1097/HCR.0b013e3181ac785f

[33] Hadji, S., Xia, L., Lan, L., Liu, R., Lian, Z. (2020). The effects of light correlated color temperature and illuminance level on mood states in offices. In: Wang, Z., Zhu, Y., Wang, F., Wang, P., Shen, C., Liu, J. (eds) Proceedings of the 11th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC 2019). ISHVAC 2019. Environmental Science and Engineering, Springer, Singapore. https://doi.org/10.1007/978-981-13-9520-8_136

[34] Sharma, S., Kavuru, M. (2010). Sleep and metabolism: An overview. International Journal of Endocrinology, 2010: 270832. https://doi.org/10.1155/2010/270832

[35] Rompas, G., Engka, N., Pangemanan, D. (2013). Dampak Merokok terhadap Pola Tidur. eBiomedik, 1(1): 276-282. https://doi.org/10.35790/ebm.v1i1.4359

[36] Yang, J., Ru, T., Chen, Q., Mao, T., Ji, Y., Zhou, G. (2019). The effects of ambient light on task switching depend on the chronotype. Lighting Research & Technology, 51(4): 544-556. https://doi.org/10.1177/1477153518777028

[37] Gabel, V., Reichert, C.F., Maire, M., Schmidt, C., Schlangen, L.J., Kolodyazhniy, V., Garbazza, C., Cajochen, C., Viola, A.U. (2017). Differential impact in young and older individuals of blue-enriched white light

on circadian physiology and alertness during sustained wakefulness. Scientific Reports, 7(1): 1-13. https://doi.org/10.1038/s41598-017-07060-8
[38] Studer, P., Brucker, J.M., Haag, C., Van Doren, J., Moll, G.H., Heinrich, H., Kratz, O. (2019). Effects of blue-and red-enriched light on attention and sleep in typically developing adolescents. Physiology & Behavior, 199: 11-19. https://doi.org/10.1016/j.physbeh.2018.10.015
[39] Wang, Y., Huang, H., Chen, G. (2020). Effects of lighting on ECG, visual performance and psychology of the elderly. Optik, 203: 164063. https://doi.org/10.1016/j.ijleo.2019.164063
[40] Boyce, P.R., Veitch, J.A., Newsham, G.R., Jones, C.C., Heerwagen, J., Myer, M., Hunter, C.M. (2006). Lighting quality and office work: Two field simulation experiments. Lighting Research & Technology, 38(3): 191-223. https://doi.org/10.1191/1365782806lrt161oa
[41] Veitch, J.A., Newsham, G.R. (1998). Lighting quality and energy-efficiency effects on task performance, mood, health, satisfaction, and comfort. Journal of the Illuminating Engineering Society, 27(1): 107-129. https://doi.org/10.1080/00994480.1998.10748216
[42] Leppämäki, S., Partonen, T., Lönnqvist, J. (2002). Bright-light exposure combined with physical exercise elevates mood. Journal of Affective Disorders, 72(2): 139-144. https://doi.org/10.1016/S0165-0327(01)00417-7
[43] Denk, E., Jimenez, P., Schulz, B. (2015). The impact of light source technology and colour temperature on the well-being, mental state and concentration of shop assistants. Lighting Research & Technology, 47(4): 419-433. https://doi.org/10.1177/1477153514532280
[44] Veitch, J.A. (1997). Revisiting the performance and mood effects of information about lighting and fluorescent lamp type. Journal of Environmental Psychology, 17(3): 253-262. https://doi.org/10.1006/jevp.1997.0059
[45] Kaida, K., Takahashi, M., Otsuka, Y. (2007). A short nap and natural bright light exposure improve positive mood status. Industrial Health, 45(2): 301-308. https://doi.org/10.2486/indhealth.45.301
[46] Partonen, T., Lönnqvist, J. (2000). Bright light improves vitality and alleviates distress in healthy people. Journal of Affective Disorders, 57(1-3): 55-61. https://doi.org/10.1016/S0165-0327(99)00063-4
[47] Yang, W., Jeon, J. Y. (2020). Effects of correlated colour temperature of LED light on visual sensation, perception, and cognitive performance in a classroom lighting environment. Sustainability, 12(10): 4051. https://doi.org/10.3390/su12104051
[48] Deng, Y., Chang, L., Yang, M., Huo, M., Zhou, R. (2016). Gender differences in emotional response: Inconsistency between experience and expressivity. PloS One, 11(6): e0158666. https://doi.org/10.1371/journal.pone.0158666
[49] Knez, I. (2001). Effects of colour of light on nonvisual psychological processes. Journal of Environmental Psychology, 21(2): 201-208. https://doi.org/10.1006/jevp.2000.0198
[50] McCloughan, C.L.B., Aspinall, P.A., Webb, R.S. (1999). The impact of lighting on mood. International Journal of Lighting Research and Technology, 31(3): 81-88. https://doi.org/10.1177/096032719903100302
[51] Knez, I., Kers, C. (2000). Effects of indoor lighting, gender, and age on mood and cognitive performance. Environment and Behavior, 32(6): 817-831. https://doi.org/10.1177/0013916500326005
[52] Curcio, G., Piccardi, L., Ferlazzo, F., Giannini, A.M., Burattini, C., Bisegna, F. (2016). LED lighting effect on sleep, sleepiness, mood and vigor. In 2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), Florence, Italy, pp. 1-5. https://doi.org/10.1109/EEEIC.2016.7555791
[53] Gou, Z., Lau, S.S.Y., Qian, F. (2015). Comparison of mood and task performance in naturally-lit and artificially-lit environments. Indoor and Built Environment, 24(1): 27-36. https://doi.org/10.1177/1420326X13507792
[54] Boubekri, M., Wang, N. (2012). Daylight's influence beyond our eyes: Investigating the mediating role of mood in cognitive performance in a sunlit workplace. Light & Engineering, 20(4): 37-50.
[55] Cajochen, C., Freyburger, M., Basishvili, T., et al. (2019). Effect of daylight LED on visual comfort, melatonin, mood, waking performance and sleep. Lighting Research & Technology, 51(7): 1044-1062. https://doi.org/10.1177/1477153519828419
[56] Hoffmann, G., Gufler, V., Griesmacher, A., Bartenbach, C., Canazei, M., Staggl, S., Schobersberger, W. (2008). Effects of variable lighting intensities and colour temperatures on sulphatoxymelatonin and subjective mood in an experimental office workplace. Applied Ergonomics, 39(6): 719-728. https://doi.org/10.1016/j.apergo.2007.11.005
[57] Huiberts, L.M., Smolders, K.C.H.J., De Kort, Y.A.W. (2015). Shining light on memory: Effects of bright light on working memory performance. Behavioural Brain Research, 294: 234-245. https://doi.org/10.1016/j.bbr.2015.07.045
[58] Newsham, G., Veitch, J., Arsenault, C., Duval, C. (2004). Effect of dimming control on office worker satisfaction and performance. In Proceedings of the IESNA Annual Conference, New York, NY, USA: IESNA, pp. 19-41.
[59] Farshchi, M., Fisher, N. (1997). The emotional content of the physical space. In RICS, COBRA 97 Conference, Portsmouth, pp. 10-12. https://doi.org/10.13140/2.1.3384.5446
[60] Abbas, N., Kumar, D., Mclachlan, N. (2006). The psychological and physiological effects of light and colour on space users. In 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference, Shanghai, China, pp. 1228-1231. https://doi.org/10.1109/IEMBS.2005.1616646
[61] Kuijsters, A., Redi, J., de Ruyter, B., Heynderickx, I. (2015). Lighting to make you feel better: Improving the mood of elderly people with affective ambiences. PloS One, 10(7): e0132732. https://doi.org/10.1371/journal.pone.0132732
[62] Crawford, J.R., Henry, J.D. (2004). The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. British Journal of Clinical Psychology, 43(3): 245-265. https://doi.org/10.1348/0144665031752934
[63] Gould, D., Kelly, D., Goldstone, L., Gammon, J. (2001). Examining the validity of pressure ulcer risk assessment scales: developing and using illustrated patient simulations to collect the data INFORMATION POINT: Visual Analogue Scale. Journal of Clinical Nursing,

10(5): 697-706. https://doi.org/10.1046/j.1365-2702.2001.00525.x
[64] Akerstedt, T. (2012). Karolinska Sleepiness Scale (KSS). in STOP, THAT and One Hundred Other Sleep Scales, A. Shahid, K. Wilkinson, S. Marcu, and C. M. Shapiro, Eds., 1st ed.New York: Springer-Verlag, 2012, pp. 209-210. https://doi.org/10.1007/978-1-4419-9893-4.
[65] Bickford, E.D. (1980). Biological effects of full-spectrum lighting. In Ocular Effects of Non-Ionizing Radiation, 229: 2-6. https://doi.org/10.1117/12.958780
[66] Figueiro, M.G., Rea, M.S. (2016). Office lighting and personal light exposures in two seasons: Impact on sleep and mood. Lighting Research & Technology, 48(3): 352-364. https://doi.org/10.1177/1477153514564098
[67] Zangróniz, R., Martínez-Rodrigo, A., Pastor, J.M., López, M.T., Fernández-Caballero, A. (2017). Electrodermal activity sensor for classification of calm/distress condition. Sensors, 17(10): 2324. https://doi.org/10.3390/s17102324
[68] Sperlich, B., Achtzehn, S., Buhr, M., Zinner, C., Zelle, S., Holmberg, H.C. (2012). Salivary cortisol, heart rate, and blood lactate responses during elite downhill mountain bike racing. International Journal of Sports Physiology and Performance, 7(1): 47-52. https://doi.org/10.1123/ijspp.7.1.47
[69] Asif, A., Majid, M., Anwar, S.M. (2019). Human stress classification using EEG signals in response to music tracks. Comput Biol Med, 107: 182-196. https://doi.org/10.1016/j.compbiomed.2019.02.015
[70] Lan, L., Hadji, S., Xia, L., Lian, Z. (2021). The effects of light illuminance and correlated color temperature on mood and creativity. Build Simul, 14(3): 463-475. https://doi.org/10.1007/s12273-020-0652-z
[71] Smolders, K.C., de Kort, Y.A. (2017). Investigating daytime effects of correlated colour temperature on experiences, performance, and arousal. Journal of Environmental Psychology, 50: 80-93. https://doi.org/10.1016/j.jenvp.2017.02.001

NOMENCLATURE

CCT	Correlated Colour Temperature (Kelvin)