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The correlation of lighting and mood in the workplace: digital image-based research

ABSTRACT

Mood affects an individual's performance, whether relaxed/tense or alert/fatigued. This article was based on research to study a correlation between the lighting setting with relaxed-tense and alert/fatigued moods in the workplace by observing the illuminance level, the correlated color temperature (CCT), and the overhead/peripheral placement of lighting. The research was conducted with two online image-based questionnaire evaluations of 7 different lighting settings specifying their illuminance level, CCT, and placement as overhead or peripheral lighting depicted in images from the DIALux simulation. In the first questionnaire, subjects were asked to rate the difference between the two lighting displays being compared and the combination of the seven lighting settings. In the second questionnaire, subjects were also asked to rate their relaxed-tense and alert-fatigued perceptions of the lighting diplayed in the image. The results of these two questionnaires were analyzed by multidimensional scaling and correlation analysis. This image-based research concluded that a relaxed/tense perceived mood correlated negatively with the CCT, and an alert/fatigued perceived mood correlated negatively with the illuminance level and the CCT.

KEY WORDS
Alert, correlated color temperature, fatigue, illuminance level, lighting placement, relaxed, tense

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Introduction

Lighting that provides visual comfort will positively impact the recipient's mood. The lighting relates to employees' work performance and positive mood (Katabaro and Yan, 2019). Attention should be carefully paid to the issue of mood conditioning, as a person being too activated might lead to an uncomfortable level of hyperarousal and pressure that disturbs that person's (a worker's) mood. Such a situation may indirectly lead to decreased work performance (Daurat et al., 1996; Lamb and Kwok, 2016). In such a case, relaxation mood conditioning, which reduces focus or activation levels, might be needed (Baas, de Dreu & Nijstad, 2008), notably to support an optimum night's sleep. Providing relaxation that suits and complements humans' circadian cycles is expected to improve an individual's sleep quality. The good quality of prior sleep seems to be essential in influencing a person's positive mood the following morning (Bower et al., 2010).

Workplace lighting that considers the correlated color temperature (CCT) and illuminance level can be a stimulus for both activating and relaxing, where both are needed. Such a stimulus can be created by artificial lighting (Kim, 2018). The activating function can be achieved by lighting; therefore, relaxation is also expected to be achievable via a lighting stimulus. This article aims to explain the results of research related to subjective perceptions of a room with different lighting settings, highlighting the variables of illuminance level, the CCT, and the placement of the lighting, to study a correlation between the lighting setting with relaxed/tense and alert/fatigued moods in the workplace.

Literature Study

According to the Coldwell Banker Richard Ellis (CBRE), by 2040, the office will be seen as 'a reward', and working will be a comfortable and luxurious experience, not merely a place to enable something to happen. The tendency and driver that may develop is increased concern over the mental health of employees/workers. This concern can be met by providing a system that cares for and implements their psychological and physical health, performance, and productivity. By improving the employees' commitment at work and ability to deal with organizational pressures, the expected result should lead to competitive benefits in productivity and staff wellbeing. At least half of the absenteeism numbers in an organization result from stress caused by work (CBRE, 2016). Work conditions deemed 'too hard' lead to decreased mental and physical quality, frequently culminating in what is referred to as 'burnout' (Philips, 2013). It has also been stated that emotional needs and absenteeism levels were closely related to the levels of individuals' workloads (van Woerkom, Bakker & Nishii, 2016).

A desired or optimal mood in the workplace needs to be maintained to activate the employees' motivation levels, as well as increase and support their work focus (Baas, de Dreu & Nijstad, 2008), perform improvement (Boubekri & Wang, 2012) and also positively influencing levels of work satisfaction (Judge & Ilies, 2004). Positive mood is indicated when employees are alert, enthusiastic, and active (Watson, Clark & Tellegen, 1988); factors depicting strength and satisfaction (Hsieh, 2015). A good mood will support cognitive ability and motivation (Liew & Tan, 2016), resulting in more creativity in some types of work activity (Davis, 2009) and in certain conditions (George & Zhou, 2007). Meanwhile, a negative mood is a condition where the subject feels uncomfortable and/or unmotivated (Watson, Clark & Tellegen, 1988); a situation where the appearance of pressure, tension, stress, nervousness, depression, and fatigue can be noted (Hsieh, 2015). A positive mood can often foster creativity, whereas a negative mood can be a sign or symptom of problems that hinder an employee from thinking creatively (George & Zhou, 2007).

Lighting may be seen as a simple system that only affects visuals. This argument does not pay attention to the impacts of lighting on *neuroendochrine* and psychological states (Bickford, 1980), such as mood and depressive behavior (Lamb & Kwok, 2016; Lee, Moon & Kim, 2014; Stephenson et al., 2012). Lack of lighting exposure can negatively affect the condition known as Seasonal Affective Disorder (SAD), which can negatively affect a person's sleep and reduce their alertness (Gomes & Preto, 2015; Stephenson et al., 2012). This impact will continuously occur, exacerbating the SAD syndrome as the lack of sleep will increase mood sensitivity (Dinges et al., 1997).

Two lighting parameters often related to lighting research regarding mood are illumination level and CCT. The illuminance level relates to the issue of subjective alertness (van Duijnhoven et al., 2018). It influences an employee's alertness level and the quantity and quality of their work errors, as seen through the decrease in work speed as a form of fatigue in low illuminance level environments (Boyce, 1970). However, a high illuminance level might lead to a slower response rate as the background lighting can be too bright, distracting the individual's attention during task performance (Min et al., 2013).

Meanwhile, CCT of the lighting is important to worker productivity (Zumtobel, 2014). The variety of CCT impacts visual comfort, especially for color clarity (Revantino et al., 2018). CCT relates to the perception of light brightness (Toftum et al., 2018) and significantly influences spatial lightness, visual comfort, satisfaction, and subjective productivity (Wei et al., 2014). Lighting with high CCT (17.000 K) can be an effective intervention for increasing productivity levels in a workplace (Mills, Tomkins & Schlangen, 2007).

Meanwhile, not only to condition alertness, providing relaxation in the workplace might be needed to reduce emotional fatigue and increase the pace of a person's physiological and psychological recovery as they respond to or are affected negatively by a stressor: for example, anxiety (Wilczyńska et al., 2019). Our body has an important role in coping with work stress and manifesting its ability to recover so that we can be motivated when waking up the following morning (Parker et al., 2020). If the need for resting cannot be fulfilled, the employee might become more stressed, resulting in reduced work performance and possibly physical or even mental sickness (Mednick, 2002). Time pressure and a heavy workload make it hard for workers to detach themselves from their work during their break time (Sonnentag & Fritz, 2007). Moreover, prolonged and/or heightened activation levels can often result in an individual finding it difficult to relax during their break time (Sonnentag & Fritz, 2007).

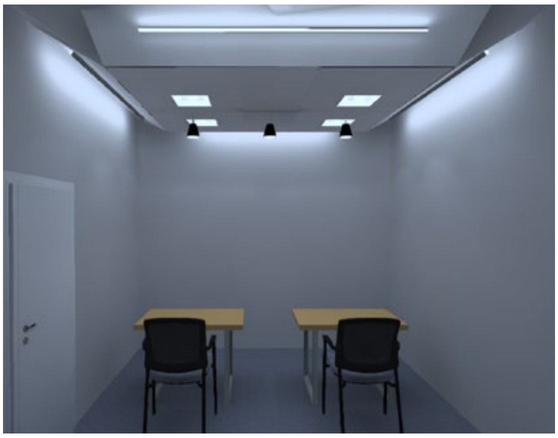
Relaxation can be provided by the lighting setting (Kim, 2018). Another article stated that the relaxation process could be speeded up using a blue lamp rather than a lamp giving off a white light (Minguillon et al., 2017). The rapid changing of the lighting hue to a higher chroma creates a lively atmosphere that can lead to activation; equally, the arrangement in reverse can be calming and supportive of relaxation (Li et al., 2019). Previous research on lighting and relaxed mood (Flynn et al., 1979) concluded that relaxed perception could be conditioned in a room with dim, peripheral, non-uniform lighting. In other literature, besides non-uniform and peripheral lighting, the issue of lighting color has been said to strengthen subjective relaxed impressions (Flynn, Segil & Steffy, 1988).

Methodology

This study observed the impression of subjective perceptions of a room with different lighting settings in: a) the illuminance level, b) the CCT, or c) the placement. Data collection was carried out by distributing online questionnaires since the researchers, in the context of data collection, avoided conducting face-to-face meetings in closed rooms during the Covid-19 pandemic.

This questionnaire displayed the appearance of a room with seven lighting settings taken from a DIALux simulation that was made as realistic as possible. The use of static visual media (Heft & Nasar, 2000; Jones & Reinhart, 2017; Manav, 2013; Totir, 2007) for the research related to perception (Huang, 2004) was considered able to represent the physical conditions of the room, particularly lighting (Eissa & Mahdavi, 2001; Mahdavi & Eissa, 2002); besides video and virtual reality (Chen, Cui & Hao, 2019). Image can be a tool for research to replace real settings that are more expensive (Newsham, Marchand & Veitch, 2004) as well as a simulation in lighting (Schielke, 2016).

The test cell of the simulation is a room of 3.3 m x 2.8 m x 3 m and equipped with two worktables and chair sets with wooden surfaces and 40% reflectance. The drop ceiling and wall color were white, with 85% and 57% reflectance, respectively. The floor carpet was a single-colored grey with 20% reflectance. The door material was plastic white 0.90 m x 0.13 m x 2 m with 76% reflectance. The test cell used the surface-mounted type Philips BN132C PSU L900 1 x LED9S/830 for the overhead lighting and Philips NA 1x Bulb 9W 2700K E27A60 929001150 NA for the peripheral lighting. The overhead lamp was 950 lm, 10 watt, with 95 lm/W efficacy and 100% light output ratio. The peripheral lamp was 807 lm, 9-watt, 98 lm/W efficacy and 100.2% light output ratio. Both overhead and peripheral lighting have a maintenance factor of 0,8. The lighting was arranged on 2700 K, 4000 K, and 6500 K of CCT.

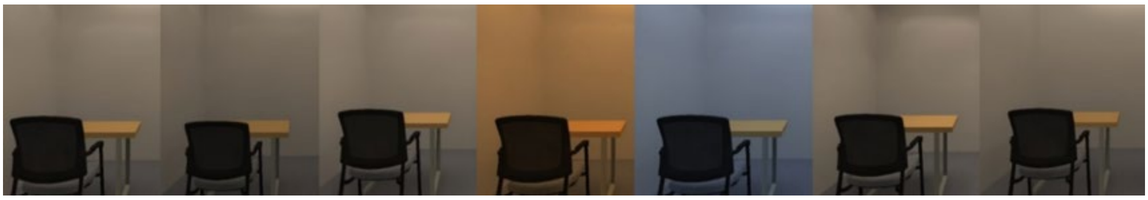


» **Figure 1:** *The DIALux-based image of the test-cell*

The seven lighting conditions were simulated and displayed in different terms of (1) illuminance levels, (2) CCT, and (3) lighting placement as the independent variables. The visualization results of the DIALux simulation were used to explore the effect of relaxed-tense and alert-fatigue perceptions as dependent variables. The images from the simulation result were displayed without showing the lighting setting so that such information would not affect the subjects' assessment responses. The following is the sequence of lighting settings:

1. The control condition that combined overhead peripheral lighting in 4000 K and created 258,5 lx in the workplane
2. The dim lighting that combined overhead peripheral lighting in 4000 K and created 124,8 lx in the workplane representation of dim lighting
3. The bright lighting that combined overhead peripheral lighting in 4000 K and created 390,3 lx in the workplane
4. The warm lighting that combined overhead peripheral lighting in 2700 K and created 255,0 lx in the workplane
5. The cool lighting that combined overhead peripheral lighting in 6500 K and created 254,3 lx in the workplane
6. The direct lighting distribution that only turned on the overhead lighting in 4000 K and created 254,3 lx in the workplane
7. The indirect lighting distribution that only turned on the peripheral lighting in 4000 K and created 254,3 lx in the workplane

The three illuminance levels were compared to study the effect of bright and dim lighting on viewers' relaxed – tense, or alert – fatigue mood. The chosen levels were based on the technical specification of the lamps



» **Figure 2:** *The appearance of seven lighting settings*

used in the simulation. When the test cell was exposed to only overhead or peripheral lighting to assess the placement variable, the 100% direct and bulb lighting, or 100% peripheral lighting, could only achieve 254 lx, hence adopted as the controlled setting standard at 260 lx. This value was then applied in other settings when observing the CCT variable. The bright lighting was set to a higher illumination level than the control condition. It can be achieved by turning on 76% of the bulb and 100% of the peripheral lighting. A lower illuminance level presented a dim setting by turning the lighting on 20% of the bulb and 35% of the peripheral lighting. The bright and dim lighting level was arranged to have the same 130 lx differences with the control condition.

This research compared two different 2700 K and 6500 K to observe the effect of CCT. Some studies compared the same level of CCT for researching the effect of lighting on mood (Hsieh, 2015; Smolders & de Kort, 2017) or alertness (te Kulve et al., 2018). Like this research, a study applied 4000 K beside 3000 K and 6500 K to observe the effect on mood and visual response (Lee, Moon & Kim, 2014). At the same time, the overhead and peripheral lighting placement was included as the variable to assess the differences between placements' effects. This method was applied by other researchers that studied the effects of lighting distribution on occupants' emotions (Fleischer, Krueger & Schierz, 2001; Shin et al., 2015) or mood (Hsieh, 2015), which were eventually affected by the placement of the lighting.

This research consisted of two questionnaires. In the first questionnaire, the seven lighting settings were compared to each other to assess their differences. The questionnaire was compiled by comparing two lighting settings presented in sequence. The test scale included in the questionnaire used a scale of 1 - 7. A value of 1 meant no difference, while 7 meant a massive difference between the two compared images. In this similarity-dissimilarity test, 42 setting pairs were compiled, a comparison combination of 7 lighting settings. The data from the first questionnaire was analyzed by multidimensional scaling (MDS) from SPSS. The MDS analysis could provide information about lighting variables needed to interpret the correlation analysis result of the second questionnaire.

In the second questionnaire, the research explored impression ratings with a bipolar rating scale. Bipolar scaling in the form of a semantic differential was used to express the subjective effect of various lighting settings on a room (Flynn et al., 1979). The impression rating of the selected evaluative scales was adjusted for the study, namely *relaxed–tense* and *alert-fatigue*. Subjects were asked to assess the room due to the influence of the seven lighting settings. The ratings were in the range of 1 – 7. In the relaxed-tense assessment, 1 means a 'relaxed impression,' and seven represents a 'tense'. In the alert-fatigue assessment, 1 indicates an 'alert impression' and seven as a 'fatigue impression'. The result was then analyzed with the SPSS Pearson Correlation test to see the correlation between the dependent and independent variables.

The subjects of this study were 42 students and alums (16 males, 26 females) from an interior design department of Universitas Sebelas Maret who were not colour blind, either totally or partially. Subjects were categorised as adults with an age limit of 18-40 years and had very similar social and professional backgrounds, ages, and education.

Results

This study observed subjective perceptions relating to relaxed-tense and alert-fatigued mood states in a room exposed to different types/levels of lighting. This study included the CCT variables in the 3D model not presented in Flynn's 3D model. The CCT variables replaced the uniform / non-uniform variables from the Flynn model that were not observed in this study. The MDS result was then used to interpret the correlation test result based on the subjective ratings in relaxed-tense or alert-fatigue mood assessment. In the range of 1 – 7, the lower level given means, the more relaxed or alert mood perceived by the subject. On the contrary, the higher level resulted means a more tense or fatigued mood perceived by the subject.

The perception of differences between lighting settings

The differences between lighting settings perceived by the subjects were analyzed with MDS. Table 1 presents the coordinate positions of the seven lighting settings resulting from the analysis for each of the three dimensions observed. The distance between 2 or more lights on the dimensional axis showed the lighting characteristics that distinguished them. The analysis results only showed the position of each lighting source; hence naming the dimensions was the researchers' interpretation (Flynn et al., 1979) after examining the seven lighting settings and was based on the characteristics that distinguished each of the seven settings.

Table 1

Coordinate of MDS result

Lighting Setting	Dimension 1	Dimension 2	Dimension 3
Setting 1	0.8023	0.0591	0.5217
Setting 2	0.7298	-0.0418	-1.0287
Setting 3	0.8868	0.0107	0.1591
Setting 4	-2.1425	1.8379	-0.0225
Setting 5	-1.9624	-1.9546	0.0703
Setting 6	0.7925	0.1080	0.6736
Setting 7	0.8935	-0.0193	-0.3734

This explanation could be seen from settings 4 and 5 that differed in the CCT. They had opposite coordinated positions on dimension two; dimension 2 was CCT axis with warm white on the positive coordinate and cool white on the negative coordinate. The same tendency also occurred in settings 6 and 7, which differed in the lighting placement. They had opposite coordinated positions on dimension three, so it can be interpreted that dimension 3 was the lighting placement axis with overhead representing positive values and peripheral representing negative values.

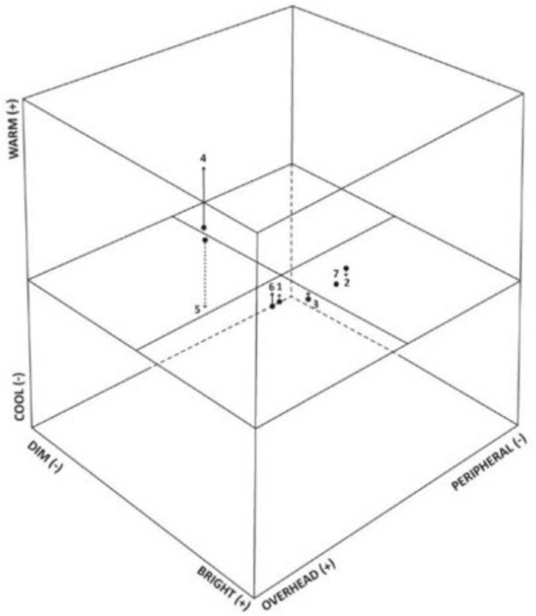
Although the other two axis had been named except for dimension one, and the rest variable was the illuminance level, the interpretation could not be made directly. It was because the dim–bright lighting conditions did not show opposite coordinates of difference perceived by the subject. This result might be because if the dark state were in the zero position, there would be no brightness level that a negative coordinate can represent. However, the result of dimension one can be arranged in order of lighting 3 (bright in 0,8868), 1 (control in 0,8023), and 2 (dim in 0,7298). So, the more positive coordinate can be interpreted as bright lighting. Meanwhile, the negative coordinate may represent dim lighting.

The dimension interpretation is summarized in Table 2. The interpretation and the MDS result coordinates can be modeled in Figure 3.

Table 2

The interpreted dimension for MDS analysis result

Lighting Setting	Dimension 1
1	Bright (+) / Dim (-)
2	Warm (+) / Cool (-)
3	Overhead (+) / Peripheral (-)



» **Figure 3:** *The position of seven different lighting in MDS analysis result with interpreted axis names*

The perception of relaxed-tense and alert-fatigued mood perceived between lighting settings

Subjective perceived relaxed-tense mood states showed a correlation with CCT (r stat = 0,172 > r table = 0,114, Sig (2-tailed) = 0,003 < 0,01) in negative coefficient.

Different results appear on the relaxed-tense mood states with illuminance level (r stat = 0,086 < r table = 0,114, Sig (2-tailed) = 0,140 > 0,01) and placement (r stat = 0,012 < r table = 0,114, Sig (2-tailed) = 0,834 < 0,01) as they did not show any correlation.

Subjective perceived alert-fatigue mood states showed a correlation with illuminance level (r stat = 0,172 > r table = 0,114, Sig (2-tailed) = 0,003 < 0,01) and CCT (r stat = 0,266 > r table = 0,114, Sig (2-tailed) = 0,000 < 0,01), both in negative coefficient.

Different results appear on the alert-fatigue mood states with placement (r stat = 0,074 < r table = 0,114, Sig (2-tailed) = 0,209 > 0,01) that they did not show any correlation.

Discussion

The correlation analysis results can be interpreted as the axis had been named. The Pearson analysis showed a correlation between relaxed-tense mood and CCT. This result was in line with the conclusion that CCT significantly affects the relaxed feeling (Chen, Tsai & Tsay, 2022). The negative coefficient on the result means that the warmer CCT, the subject will be more relaxed and the cooler the CCT will lead to a more tense mood. This finding is in line with another research finding that relaxation can be provided warm (Kim, 2018) or low CCT (Chao et al., 2020); hence it can be used for relaxation (Dugar & Agarwal, 2019) and resting (Yu & Akita, 2019). On the contrary, the cool white with high CCT was concluded to provide a tense feeling (Kim & Mansfield, 2021). However, this result was the opposite of some research statements that cool CCT had a relaxing effect on the subjects (Iwata, 2012).

The Pearson analysis showed a correlation between alert-fatigue mood with illuminance level and CCT. The negative coefficient on the result means that the brighter lighting (He et al., 2020; Leichtfried et al., 2015; Maierova et al., 2016) and warmer CCT, the subject will be more alert. In line with these findings, another research concluded that the bright CCT leads to alertness, so recommended to be applied in the office (Zhu et al., 2019). Meanwhile, the lower CCT makes the subject react faster (te Kulve et al., 2018). On the contrary, the dimmer lighting and the cooler CCT relate to fatigue mood. This result was the opposite of another research that concluded higher CCT (Askaripoor et al., 2021; Chou, Lu & Huang, 2016; He et al., 2020; Kazemi et al., 2018; Toftum et al., 2018) and low illuminance level lead to alertness (He et al., 2020).

Unfortunately, there is no sufficient proof to show the correlation between the relaxed-tense mood with illuminance level and both moods with lighting placement. The correlation found in this research also seemed questionable, as both relaxed and alert mood perceived by the subjects relates to the same high CCT. This result might be affected by the image as the research tool since another research found an inconsistency of CCT perception between simulation and actual size mock-up research (Schielke, 2016).

Moreover, the image is accessed from the subjects' devices. The researchers did not control the device's brightness, the time, and the lighting condition of the place (indoor or outdoor) where the subjects filled out the questionnaire. This missing point can be the weakness of this research, as there was research using an image-based approach. The previous study was conducted in a particular time and a room with the same lighting condition by using printout images (Totir, 2007), projecting the calibrated appearance images (Newsham et al., 2005), or displaying the images in a computer screen (Heft & Nasar, 2000; Prasetyaningsih, 2006). Therefore, future image-based research might need to consider the timing, device brightness, and room lighting used by the subject when filling out the questionnaires.

Conclusion

This image-based research observed subjective perceptions relating to relax-tense and alert-fatigue in a room exposed to different types/levels of lighting with the illuminance level, CCT, and lighting placement. The data were analyzed with MDS and Pearson correlation tests. The MDS analysis resulted in a 3D model with dimension one representing the bright (+) and dim (-) illuminance level axis, dimension 2 representing the warm (+) and cool (-) CCT axis, and dimension 3 representing the overhead (+) and peripheral (-) lighting placement. This dimension was used to interpret the correlation analysis result. The Pearson correlation analysis found:

1. Negative correlation between the relaxed-tense mood state with the CCT, which might mean the warmer lighting relates to a relaxing mood, and

2. The negative correlation between the alert mood state with the CCT and illuminance level, which may mean the warmer and brighter lighting relates to alert mood.

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