Original Article

Investigating the Effect of Luminosity and Color Temperature of Light Sources on the Extent of Mental and Visual Fatigue Under Experimental Conditions

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Abstract

Aim: Undesirable lighting can affect the visual system, as well as mental, neuropsychological, and physiological efficiency of staff. The present study was done to determine the effect of luminosity and nominal correlated color temperature (NCCT) on the extent of mental and visual fatigue under experimental conditions among students at Isfahan University of Medical Sciences. **Materials and Methods:** This experimental study was done in summer 2022 on 12 students at Isfahan University of Medical Sciences. To measure the mental fatigue, flicker fusion method, while for visual fatigue, Rajabi questionnaire was used. In this study, two lamps with NCCT 3000 K and 6000 K were used at three angles 15°, 30°, 45°. **Results:** The mean age of the subjects was 20.91 years. At both NCCT 6000 K and 3000 K, the maximum and minimum extent of visual fatigue occurred at angles 15° and 45°, while the maximum and minimum mental fatigue score happened at 45° and 15°, respectively. There was a statistically significant difference in the mean scores of mental fatigue ($P < 0.001$) and visual fatigue ($P < 0.001$) between 6000^{0}K and 3000^{00}K at 0.01 level. **Conclusion:** The NCCT and angle of the light source position can contribute to the development of mental and visual fatigue. Once the angle of radiation increased, the extent of mental and visual fatigue diminished. The extent of mental fatigue, as with visual fatigue, was greater at 3000 K compared to 6000 K.

Keywords: Asthenopia, color temperature, contrast sensitivity, flicker fusion, mental fatigue

Introduction

Light is part of electromagnetic spectrum, which is received upon hitting the human eye retinal receptor cells, and its quality and quantity are perceived after transmission to the brain.[1,2] Supplying suitable lighting is essential for performing tasks properly and preventing from fatigue as well as burnout. Insufficient lighting results in decreased speed, accuracy, as well as visual, physical, and other injuries.[1,3] Under conditions when human eye gets exposed to luminosity of a reflective surface with high luminosity, due to transient damage to the retina as well as nonirritability of part of it, it experiences glare for some time.[2,3] According to the international commission on illumination,[4] glare is defined as "visual conditions in which disturbance (disturbance glare) or diminished ability of vision of objects or both occur due to improper distribution or excessive luminosity or creation of extreme contrast at different places or times."[5,6] Glare, as one of the disturbing agents in lighting systems, causes constrained field of vision as well as development of fatigue in the eyes and minds of people. Glare is categorized into two types: Disability (paralyzing glare) and mild discomfort radiation.[7] The paralyzing glare is related to an underlying effect in the person, which lowers the visual acuity, and is often called "physiological glare." Meanwhile, discomfort glare causes development of

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discomfort or disturbance for the observers, and is often called "psychological glare."[8,9]

Although the discomfort glare does not necessarily impair the visual functioning or vision, it sometimes causes physiological and psychological symptoms such as stress and headache. It has been reported that some patients with migraines have had more sensitivity to discomfort glare compared to normal people.[8] Investigation of the relations between difficulty of visual tasks, time variables, and glaring responses at different times indicated that prolongation of the interval between the test sessions would lead to diminished sensitivity to fixed source luminosity along the day.[10] Meanwhile, when luminosity and contrast increase, the time of performing the reaction shortens systematically. Interestingly, the reaction time, when drawn inversely against contrast, grows linearly, and changes the slope of these lines to a parameter, which can be used for describing the rapid time changes of the reaction under special condition.[11,12] Meanwhile, the luminosity and color temperature are among different parameters of light sources that can cause various mental and psychological states in human.[13-15] Deficient or excessive luminosity can be one of the main causes of development of mental fatigue.[16-18]

Higher color temperatures (below 4000° Kelvin) are bluish-white and are commonly known as cooler colors, while lower color temperatures (below 3000° Kelvin) are more reddish and are known as warmer colors.[19] Recently, evidence on the nonvisual, psychological and biological effects of light has shown that different light conditions significantly affect many nonvisual functions such as physiological and psychological mechanisms and biological-cognitive processes such as circadian rhythm, alertness, core body temperature, hormone secretion. And sleep affects.[20] The review of various studies has shown that exposure to light with a high color temperature can be effective in improving the level of alertness, cognitive performance and psycho-physiological indicators.[21,22] It is necessary to explain that the lighting effects of lighting sources depend on various factors, including color temperature, lighting intensity, brightness, exposure time and duration of exposure.[23] In the study of Beheshti *et al*., with the increase in the temperature of the lighting color, the average number of errors decreased and the average number of correct answers increased, and the interference score, interference time, and nonresponse cases were significantly lower in men than in women.[24]

Over the past few years, measurement of the eye's ability in distinguishing succession (flicker fusion test) has been increasingly used as a graduated marker of fatigue. This test can be easily implemented, offer quantitative results, and its suitability has been confirmed in the literature.[24]

As stated, exposure to unfavorable lighting can cause disturbances in the visual system and mental performance of people. In past studies, the effect of various lighting factors such as lighting intensity, brightness of lighting sources, color temperature, etc., in causing eye fatigue or mental fatigue has been investigated, and in most of the studies, lighting sources with different intensity and brightness are used to create the test environment and determining their effect on one of the factors of mental or eye fatigue was used; But in this study, instead of using sources with different luminances, by placing the lamp at different angles of the visual range as one of the factors that cause glare, the effect of luminance and changing the placement of lighting sources in the field of vision on visual and mental performance It has been examined together. On the other hand, in addition to changing the angles to create different luminances, the simultaneous effect of the color temperature of the lighting source is also investigated. Due to the fact that specific studies of the simultaneous effect of changing the angle of lighting sources and their temperature in causing mental and eye fatigue have not been done, the present study was done to determine the effect of luminosity and nominal correlated color temperature (NCCT) on the extent of mental and visual fatigue under experimental conditions among students at Isfahan University of Medical Sciences.

Materials and Methods

Participants

This experimental study was done in summer 2022 among 12 students (six men and six women) at Isfahan University of Medical Sciences. The subjects were chosen through random sampling from among students of one only major, one contest acceptance quota, and one academic level. The inclusion criteria were: Male and female students at medical sciences university, lack of eyesight weakness and color blindness, no previous presence of subjects in the tests of interest, not taking medications (not using cardiac drugs, blood sugar lowering drugs, antidepressants and sedatives, antihistamines and antiparkinsonian drugs) and people with regular sleeping and waking patterns and without symptoms of sleepiness. The way the subjects needed to work with the devices was explained to each person, and consent form for participation in the study was studied by the subjects and confirmed.

Preparing the lighting room

To conduct this research, two light-emitting diodes (LED) lamps with power 20 W and with different color temperatures (NCCT 3000 K and 6000 K) were used, and by changing the place of source in relation to the subjects' visual axis, illumination with varying degrees of luminosity was established. In order to ensure the creation of standard and desired conditions in the test room, constant illumination levels (300 lux for all measurement modes) using a lux meter device in terms of lux, luminance using a TES glare meter device (made in Taiwan) according to intention (cd/m^2) was measured.

Study design and method

For data collection, a questionnaire was used for collecting the demographic information of the subjects, and flicker fusion method was used for measuring the mental fatigue. Zeinodini visual fatigue questionnaire was used for estimating the visual fatigue.[25] In this study, after completion of the demographic information form by the subjects, using Snellen's eye chart, the visual health of the subjects was ensured. Next, the subject entered the illumination chamber, which had no window and extra light. The subjects were exposed to different states of angle and NCCT of the light source for 15 min. At the baseline (time zero), 5 min, 10 min, and 15 min postexposure in the experimental environment, they were investigated in terms of mental and visual fatigue under exposure to each light source (with NCCT 3000 K and 6000 K) and at every angle (15, 30, and 45). The examination of visual fatigue was done at the baseline and before placement in the experimental environment as well as at the end of the experiment (15 min postexposure), while mental fatigue was checked at times of baseline, 5 min, 10 min, and 15 min postexposure. Each person was exposed six times to illumination conditions of angle 15 and NCCT 3000 K, angle 30 NCCT 3000 K, angle 45 NCCT 3000, angle 15 NCCT 6000 K, angle 30 NCCT 6000 K, and angle 45 NCCT 6000 K. To neglect the effect of fatigue, the order of establishing the experimental conditions was different for each person. Also, to simulate the experimental environment as the working environment, illumination conditions were in place also during the experiment.

Mental fatigue test

To measure the mental fatigue, flicker fusion method was used. The flicker fusion device is an instrument that creates flickering light with possibility of changing the frequency of the flickers. There is a red light source (LED lamp) in the center of this white plane. First, the flickering frequency of the lamp is 1 Hz. The device was adjusted such that one frequency would be added to the previous one once every 3 s. Thus, the flickering rate of the lamp would grow gradually. The subject was positioned in a comfortable state on the chain against the white plane of the device. The subject was asked to announce their perception of light as continuous with no flickering. At the same time, the tester would read the frequency on the device's liquid-crystal display (LCD) and recorded it in the form. Note that the subject was positioned such that he/she could not see the device LCD. At any stage of the implementation of the fatigue-inducing tasks, the extent of fatigue was measured three times through this measurement method, and its mean was used for statistical investigations. To establish standard and desired conditions in the experimental chamber, the illuminance was chosen as 300 lux (within the acceptable range of Iranian standard). Also, before entrance of the subjects to the experimental environment, the eyesight health status of the subjects was controlled, whereby it was found that all subjects had visual acuity of 10/10 and had healthy vision.

Visual fatigue test

Zeinodini visual fatigue questionnaire was used for estimating the visual fatigue, whose reliability coefficient has been reported 0.75.[25] the mentioned questionnaire has 15 questions in 4 main areas, including ocular strain, vision disorders, eye surface disorders, and extraocular disorders. The levels and areas of eye fatigue in the questionnaire are stated qualitatively and quantitatively. The maximum final score of the questionnaire is 10 points and includes areas without fatigue (≤0.65), low fatigue (2.36–0.66), moderate fatigue (3.88–2.37) and severe fatigue (≥3.89).

Data analysis

Ultimately, descriptive tests were used for measuring the mean, and one sample *t*-test, independent sample *t*-test and paired *t*-test for mean comparison of the mental and visual fatigue scores. Data analysis was done using Statistical Package for the Social Sciences, (IBM, Armonk, New York, USA) 26 with a $P < 0.05$ considered statistically significant.

Results

The mean age of the subjects was 20.91 years with standard deviation (SD) 1.24. The minimum and maximum age of the subjects was 19 and 23 years, respectively. In terms of gender, six were male and six were female.

The results related to each of the items of visual fatigue at different NCCT and angles at the beginning and end of the experiment are shown in Table 1. at the NCCT of 6000 K and at the angles of 15°, 30° and 45°, the highest score is related to the item "watery eyes during work" with an average score of 5.66, "eyelid heaviness" with an average score of 4.31 and "feeling sleepy" with an average score of 2.66. At the NCCT of 3000 K and at angles of 15°, 30° and 45°, the highest score is related to the item "need to rub and massage the eyes" with an average score of 4.58, "feeling of pressure around the eyes" with an average score of 3.33 and "feeling sleepy" with the average score was 1.58.

The visual fatigue in this study was examined at two times, once before the experiment and once at the end of the experiment and at 3000 K and 6000 K NCCT along with angles 15°, 30°, and 45° using visual fatigue questionnaire, with the results expressed in Table 2. The mean and SD of the eye fatigue score at the NCCT of 6000 K at the angles of 15°, 30° and 45° are 0.90 ± 2.81, 0.73 ± 1.93, and 0.61 ± 0.87, respectively, and at the NCCT of 3000 K and at the three angles, respectively, 3.88 ± 1.04, 2.51 ± 2. It was 0.91 and 1.36 ± 0.69. The results of the one sample *t*-test have shown that there is a significant difference between the average score of eye fatigue at different angles at the level of 0.01.

Also, based on the presented classification, according to the procedure for visual fatigue in four groups of no fatigue, low fatigue, average fatigue, and severe fatigue, the results are presented in Table 1. At a NCCT of 6000 K, at an angle of 15°, moderate eye fatigue with a frequency of 83.3%, at an angle of 30°, low eye fatigue with a frequency of 75%, and at an angle of 45° without eye fatigue with a frequency of 66.7% was the most frequent. Are also, at the NCCT of 3000 K in three angles, respectively, high eye fatigue with a frequency of 66.7%, moderate and low eye fatigue with a frequency of 50% and no eye fatigue with a frequency of 75% have the highest frequency.

The results of measuring mental fatigue using flicker fusion device at NCCT 3000 K and 6000 K as well as angles 15, 30, and

45° along with times 0, 5, 10, and 15 min are expressed in Table 3. Larger numbers are associated with a lower mental fatigue.

The average score of mental fatigue was 36.76, 40.75 and 44.97 at the NCCT of 6000 K at 15°, 30° and 45°, respectively, and 34.22, 38.04 and 42.47 at the NCCT of 3000 at three angles, respectively. The results of the independent sample *t*-test have shown that there is a significant difference between the average score of mental fatigue in different angles at the level of 0.01.

For comparing the extent of mental and visual fatigue at two different NCCT, paired *t*-test was used, with its results reported in Table 4. As it is known, there was a significant difference at the 0.001 level between the average score of visual and mental fatigue between two NCCT of 6000 and 3000 in all angles.

Discussion

Investigation of the extent of visual fatigue based on each of the visual fatigue questionnaire items [Table 1] at different states of conducting the experiment showed that at angle 15° of sunlight, the major complaint was related to the need to rubbing and massaging the eyes, while the minimum extent of fatigue was related to dizziness at the time of watching the monitor. At angle 30° of sunlight, the highest extent of fatigue was related to sense of eyelid heaviness, and the minimum extent of fatigue was linked to blurry vision of near objects. At angle 45° of sunlight, sense of drowsiness claimed the largest mean score, while blurry vision of objects showed the minimum score. At angle 15° of moonlight, the highest extent of fatigue was

Table 1: The results related to each of the mental fatigue items

Items	NCCT (K)						Zero time
	6000			3000			
	15°	30°	45°	15°	30°	45°	
Sense of pressure around the eyes	4.75	3.75	2.25	4.08	3.33	1.66	0.66
Dry sensation in the eyes	4.08	3.12	1.58	2.51	1.83	0.91	0.33
Burning sensation in the eyes	5.33	3.87	1.91	3.51	2.75	1.16	0.58
Sense of eyelid heaviness	5.33	4.31	1.91	4.08	2.66	1.41	0.41
Excessive flow of tears at the time of working	5.66	3.75	2.41	1.41	2.50	1.25	0.50
Dizziness at the time of watching the monitor	1.66	1.37	0.51	0.75	0.91	0.33	0.75
Extent of blurry vision of monitor	2.41	1.62	0.58	2.00	1.33	0.75	0.25
Double vision of words	2.75	1.5	0.66	2.00	0.66	0.25	0.08
Headache during work	2.33	1.93	0.58	1.41	1.41	0.58	0.08
Sense of drowsiness	4.50	4.25	2.66	3.51	2.83	1.58	66.0
Sense of eye pain	4.25	2.75	0.83	3.58	2.16	0.58	0.41
Blurry vision of near objects	2.41	1.18	0.33	0.91	0.41	0.41	0.08
Blurry vision of far objects	3.41	2.56	0.83	2.50	1.58	0.50	0.50
Need to rub and massage the eyes	6.16	3.87	2.58	4.58	3.00	1.08	0.16
Skipping words or rows	3.25	2.22	0.91	2.41	1.66	0.66	0.08

NCCT: Nominal correlated color temperature

Table 2: The descriptive results of visual fatigue

NCCT (K)		6000			3000		Zero time
Angel (degree)	15°	30°	45°	15°	30°	45°	
Mean±SD	2.81±0.90	1.93±0.73	0.87±0.61	3.88±1.04	2.51±0.91	1.36±0.69	0.36±0.31
Mean of angels		1.87			3.58		
P (between different angles)		0.001			0.001		
Without fatigue (≤0.65)							
Frequency	0	0	8	0	0	1	9
Percent	0.0	0.0	66.7	0.0	0.0	8.3	75.0
Low (0.66-2.36)							
Frequency	1	9	4	1	6	10	3
Percent	8.3	75.0	33.3	8.3	50.0	83.3	25.0
Moderate (2.37-3.88)							
Frequency	10	3	0	3	6	1	0
Percent	83.3	25.0	0.0	25.0	50.0	8.3	0
High (≥3.89)							
Frequency	1	0	0	8	0	0	0
Percent	8.3	0.0	0.0	66.7	0.0	0.0	0.0

NCCT: Nominal correlated color temperature

Table 3: Results of mental fatigue measurement

NCCT (K)		6000			3000		
Angel (°)	Time (min)	Repetition (frequency)	Mean of angels	*P*	Repetition (frequency)	Mean of angels	*P*
15	0	38.47	36.76	0.001	36.44	34.22	0.001
	5	37.58			34.44		
	10	35.94			33.63		
	15	35.5			32.38		
30	0	41.97	40.75		39.24	38.04	
	5	41.27			38.60		
	10	40.11			37.63		
	15	39.66			36.69		
45	0	46.13	44.97		44.05	42.47	
	5	44.52			42.85		
	10	44.86			42.02		
	15	44.38			40.94		

NCCT: Nominal correlated color temperature

Table 4: Comparison of the extent of visual fatigue and mental fatigue at two different nominal correlated color temperature (3000 K and 6000 K)

Variables	Angel (degree)	Time (min)	Paired differences				*t*	*P*
			Mean difference	SD	95% Confidence			
					Lower	Upper		
Visual fatigue between 3000 K and 6000 K	15		−1.07	0.65	−1.48	−0.65	−5.699	0.001
	30		−1.95	0.86	−2.49	−1.40	−7.82	0.001
	45		−0.49	0.36	−0.72	−0.26	−4.69	0.001
Mental fatigue between 3000 K and 6000 K	15	0	2.02	1.97	0.77	3.28	3.555	0.005
		5	3.13	1.69	2.06	4.21	6.421	0.000
		10	2.30	3.58	0.02	4.58	2.226	0.048
		15	2.66	3.62	0.36	4.97	2.547	0.027
	30	0	2.72	2.65	1.03	4.41	3.547	0.005
		5	2.66	2.49	1.08	4.25	3.702	0.003
		10	2.47	4.11	−0.142	5.08	2.081	0.062
		15	2.97	2.12	1.62	4.31	4.856	0.001
	45	0	2.08	1.36	1.21	2.95	5.287	0.000
		5	1.66	3.06	−0.27	3.61	1.885	0.086
		10	2.83	2.36	1.33	4.33	4.151	0.002
		15	3.41	2.47	1.84	4.98	4.786	0.001

SD: Standard deviation, NCCT: Nominal correlated color temperature

related to blurry vision of objects, and the lowest to sense of eye pain. At angle 30° of moonlight, sense of pressure around the eyes and blurry vision of objects claimed the highest and lowest extent of fatigue reported. At angle 45° of moonlight, again similar to angle 30° of moonlight, the highest extent of fatigue was in the form of sense of pressure around the eyes, and the lowest as word diplopia.

Based on the classification done according to the visual fatigue scores and classifications done as no fatigue, mild fatigue, moderate fatigue, and severe fatigue, as observed based on the mean scores of visual fatigue, upon elevation of the illumination angle at both NCCT 3000 K and 6000 K, the number of subjects with severe fatigue had diminished. At angle 15° and color temperature 6000 K, 8.3% of subjects reported severe fatigue. However, at this same color temperature and angle 45°, none of the subjects experienced moderate and severe visual fatigue. Also, at 3000 K NCCT and at angle 15°, 66.7% of the subjects reported severe fatigue. Based on the results of Table 2, it seems that the radiation of the source with temperature 3000 K and at radiation angle 15° has caused the highest level of visual fatigue. It claimed both the largest mean score of visual fatigue as well as the highest frequency of those with severe visual fatigue.

At NCCT 6000 K, the highest extent of visual fatigue occurred at angle 15° with the mean of 2.81, and the lowest level of fatigue at angle 45° with the mean 0.87. Further, at NCCT 3000 K, the highest degree of visual fatigue at angle 15° occurred with the mean 3.88 and the lowest at angle 45° with the mean 1.36. As can be seen, as the illumination angle increased, the extent of visual fatigue decreased. Meanwhile, the extent of visual fatigue was higher at NCCT 3000 K than at 6000 K [Table 1]. To explore the extent of mental fatigue, flicker fusion device was used. As seen in Table 3, as the angle increased at both 3000 K and 6000 K NCCT, the frequency at angle 15° with the mean of 35.49 times/min had the lowest value, and at angle 45° with 43.72 times/min showed the highest value. Since larger numbers of mental fatigue measured by the fusion flicker device are associated with lower fatigue, thus the extent of mental fatigue has been higher at angle 15° compared to 30 and 45°. Meanwhile, at all measured angles, the results of frequency had a descending trend over time; at the time of zero and before initiating the experiment, the minimum extent of mental fatigue, and at the time of 15 min and end of experiment, the highest extent of mental fatigue have been reported (given the inverse relationship between frequency and mental fatigue). Also, comparison of the results related to mental fatigue between the two NCCT indicated that at all angles and at the same time, the extent of mental fatigue has been greater at luminance 3000 K compared to 6000 K. Thus, it can be stated that with reduction of the radiation angle, prolongation of radiation, and reduction of NCCT, mental fatigue would increase.

Examination of the extent of visual fatigue at various NCCT using paired *t*-test indicated that there has been a significant difference at 0.01 level regarding mean score of visual fatigue between 6000 K and 3000 K temperatures. At all of the examined angles, the extent of visual fatigue has been greater at 3000 K compared to 6000 K. In the study by Zeinodini *et al*., the mean differences of scores of visual fatigue symptoms along two stages differed significantly.[25]

Ultimately, investigation and comparison of mental fatigue at two different NCCT [Table 4] showed that the mean score of mental fatigue differed significantly at 0.01 level between 6000 K and 3000 K NCCT at the same angles and times. The mean score of mental fatigue at 6000 K was higher at all angles as well as various times of experimentation compared to its value at 3000 K. Thus, these findings suggest that the NCCT of illumination sources can be effective in mental fatigue. In line with the results of the present study, in the study by Golmohammadi *et al*., it was found that illumination affects the human cognitive function in three areas including psychological (including visual comfort, visual perception, color recognition, recognition of symbols, attention, working memory, learning, reaction time, and brain function) biological (including vigilance, mood, joy and vitality, mentality, motivation, wellbeing, and sleep quality), and psychological burden (extent of working load, psychological stress, mental fatigue).[2]

In line with the results of our study, in the study of Luo *et al*.[26] and Askaripoor *et al*.,[27] it has been determined that higher color temperature has improved cognitive functions. It seems that the increase in cognitive functions in exposure to light with a higher NCCT is caused by increased arousal and alertness. However, unlike the results of our study, in the study of Smolders and de Kort[28] and Motamedzadeh *et al*.,[22] there was no significant difference in the results of functional cognitive tests between different color temperatures.

This study, like other studies, has limitations. One of the most important limitations of this study was the lack of monitoring and examination of people in terms of mental health status before entering the study; Since the aim of the current study was to determine the environmental factors influencing mental fatigue, it is recommended that in the next studies, preliminary screening should be done to remove the confounding factors affecting the mental and mental health status and to identify normal people to enter the study. Furthermore, the uncertainty of observing the regular sleep-wake pattern, which was based on the self-report of the subjects in the study, was another limitation of this study. It is recommended to use objective methods such as autography to confirm the sleep pattern in future studies.

One of the most important strengths of this study is the presence of people in the laboratory environment with low light intensity for half an hour before entering the testing process to create visual comfort, choosing different test modes randomly to prevent physical and mental fatigue of people. A 5-min rest between each of the different test modes and the use of an ergonomic chair and temperature control of the lighting room to control the environmental factors on the individual.

Since the experiments have been done along the day, the results of this study can be practical for day-working workers, and not the workers who work at the night shift. Thus, further studies are suggested to deal with both daylight and some of hours of night. Considering the youth of the people in the study and the potential changes that occur in the visual system due to aging, and considering the use of the results for work environments, it is suggested to select samples from workers in different jobs in the next studies. Considering use of results in occupational settings, it is suggested that further studies choose the subjects from among workers in different occupations.

Conclusion

The findings of the present study indicated that the NCCT of the illumination source as well as its angle of position can be effective in inducing visual fatigue. As the light illumination angle increased, the extent of visual fatigue decreased. Furthermore, visual fatigue has been greater at 3000 K compared to 6000 K. Meanwhile, investigation of extent of mental fatigue showed that as the illumination angle increased metal fatigue decreased. The extent of mental fatigue, similar to visual fatigue has been greater at 3000 K than at 6000 K. Based on the research findings, when using illumination sources in occupational settings, it is recommended that in working environments under lighting, necessary measures should be taken for resolving eye fatigue including observation of work-rest cycle, with doing exercises for resolving visual fatigue, etc., Further, to prevent mental fatigue, the illumination angle should be increased, and illumination sources with a higher NCCT should be used.

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Ethics code

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Conflicts of interest

There are no conflicts of interest.

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