

«Lighting Technologies»

The study on the effect of color temperature of LED luminaires on human performance and psychoemotional state.

September 2015

Background

A hypothesis exists that different color temperatures of the surrounding light sources can influence human performance and psychoemotional state. This is based on the fact that light can trigger a special type of photoreceptor cells responsible for regulating circadian (diurnal) rhythms in the human body. To confirm this hypothesis, a study was done on how different color temperatures of LED luminaires affect the human body.

Design of the study

Place: Kazan State Power Engineering University (KSPEU), department of lighting fixtures and medical electronics (LME).

Period: from April 27, 2015 until May 28, 2015.

Two neighboring classrooms of an identical size and interior design (see Diagram 1), where practice, labs, and lectures took place, were allocated for this study at the LBE department. The first classroom (A-212) had its entire lighting system replaced with Color Fusion series luminaires by Lighting Technologies, namely the LINER/S LED 1200 CF model with adjustable color temperature, and a lighting control system (controller and control panel) with pre-programmed lighting scenarios. In the second classroom (A-214), the lighting system was left as is, consisting of standard neutral-colored linear fluorescent luminaires without lighting control capability. The comparative assessment of the effect of color temperature on the human body was conducted in compliance with the regulatory requirements for lighting at educational institutions and with an identical luminaire light distribution in both cases. According to the design of the experiment, indicators of performance, well-being, and mood were measured during classes in both classrooms. The indicators were measured at 2800 K, 4000 K, and 5800 K in the classroom with LED lighting and at neutral color temperatures (3000 K to 3500 K) in the classroom with fluorescent lighting.

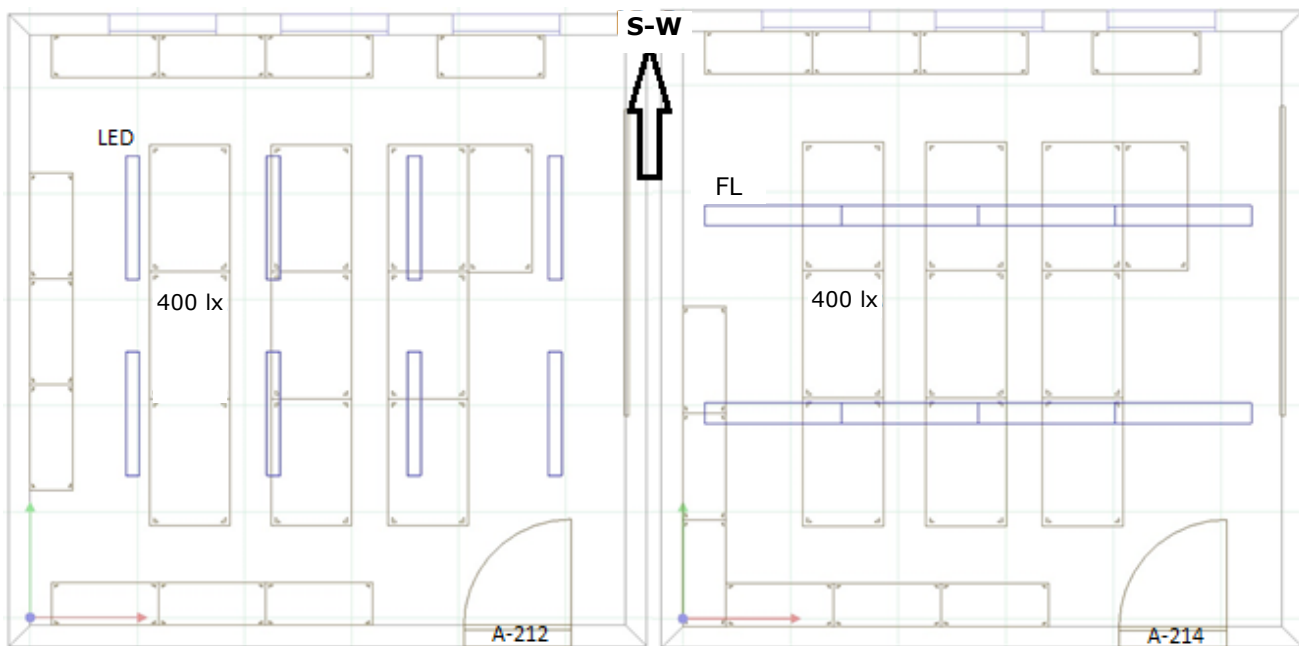


Diagram 1 – Classroom plans with LED-based and fluorescent luminaires

More than 100 people participated in the study, including male and female students from the 1st to 5th year aged 17 to 23. The total number of processed forms was 239. The research team consisted of teaching staff members from the LBE department, a practicing psychologist, and Lighting Technologies engineers.

Description of the study methodology

Form-based tests were performed in both classrooms at different color temperatures of the main lighting (see Table 1). To assess student attention span, performance, and fatigability, the Bourdon-Anfimov correction task method and tapping test were used. Psychoemotional state was assessed using the well-being, vigilance, and mood inventory. The results were evaluated using comparative analysis and statistical data analysis methods such as averaging, significance testing of sample mean differences using Student's t-test, and confidence interval estimation.

Method	Equipment	Time, min
Correction tasks	Bourdon-Anfimov tables	2
Tapping test	Ilyin method	0.5
Well-being, activity, and mood inventory	Well-being, activity, and mood inventory form	3

Table 1 – Research methods

Correction task method. In this method, visual performance is assessed based on the number of characters in the reviewed part of the correction table, productivity, error rate, and the accuracy of visual task performance in a specified time frame.

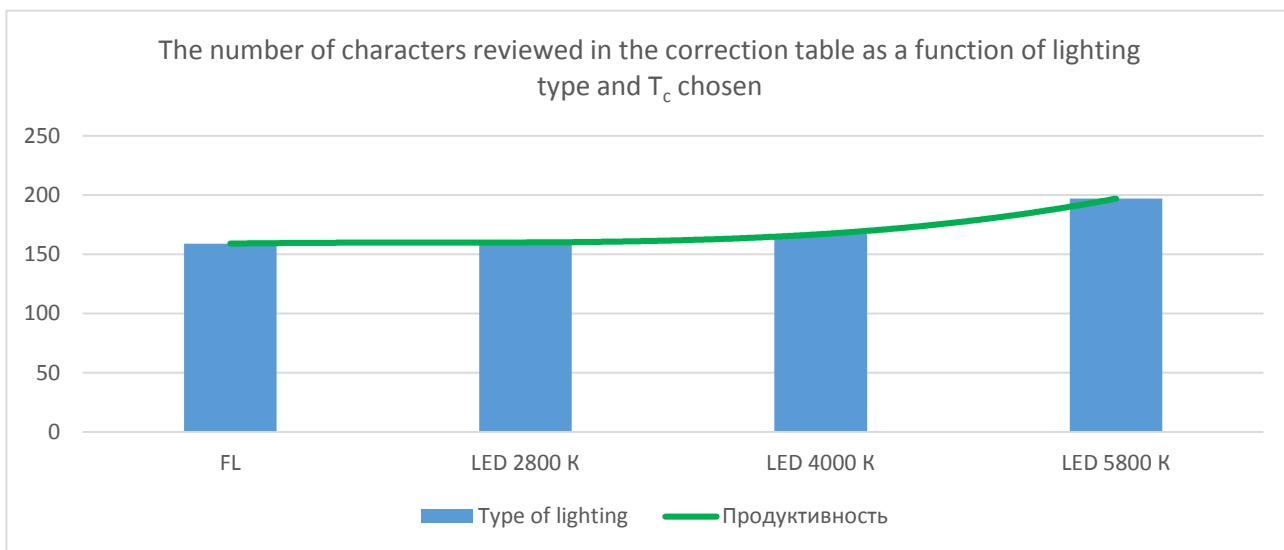
The tapping test is used to determine the state of the nervous system in humans using psychomotor measures. Here, the relative number of dots made on paper in a specified time interval is measured.

The well-being, activity, and mood inventory is a form-based test used to assess human psychoemotional state. The idea is that the subjects relate their own state to a number of attributes on a multi-level scale.

Statistics of the study

Results and conclusions for correction tasks

1. The hypothesis of visual performance being different depending on the lighting conditions was found statistically significant.
2. With LED lighting at $T_c = 5800$ K, performance was 20 % higher than with fluorescent lighting. Performance at $T_c = 5800$ K was 15 % higher than at $T_c = 4000$ K. At $T_c = 2800$ K, there were no differences in performance compared to fluorescent lighting (Graph 1).
3. With LED lighting at $T_c = 5800$ K, visual task performance was approximately 10 % higher than with fluorescent lighting.



Graph 1. Comparative analysis of average test scores for the entire set of corrective task tests performed

Results and conclusions for well-being, activity, and mood inventory

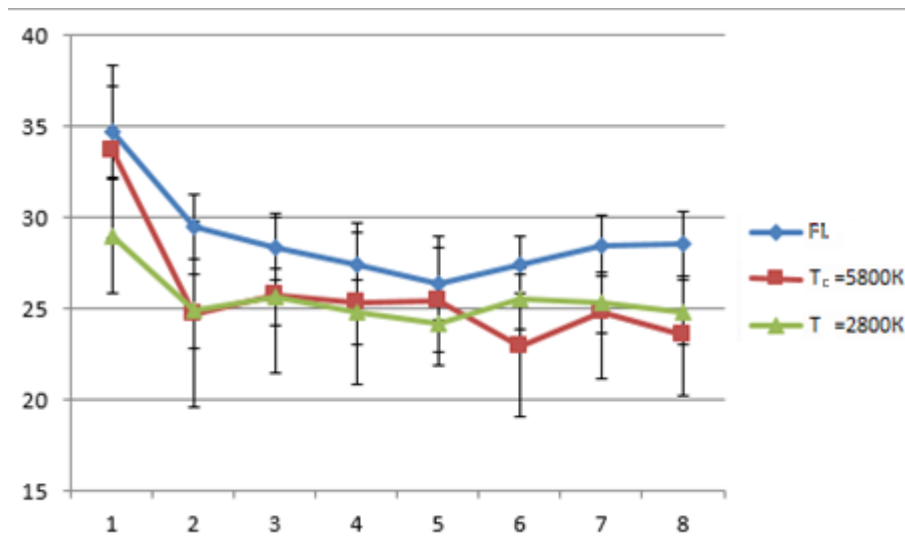
1. While the hypothesis of lighting conditions affecting well-being, activity, and mood was not found statistically significant, an analysis of the data collected suggests that individual response exists in humans to various external stimuli, including color temperature of the lighting, i.e. the spectral character of the light sources.
2. Some test results such as data comparison on individual subjects confirm the hypothesis that $T_c = 5800$ K causes increased vigilance in humans.
3. The average scores for the entire set of tests revealed a drop in performance. In this condition, a shift to lower activity and well-being was observed compared to the mood, which is demonstrated by LED-2 with $T_c = 2800$ K (see Table 2).

	FL	LED-1 (5800)	LED-4 (4000)	LED-2 (2800)
Well-being	5.2	5.4	5.4	4.9
Activity	4.5	4.9	4.7	4.5
Mood	5.4	5.4	5.6	5.2

Table 2. The average well-being, activity, and mood inventory scores for the entire set of tests

Results and conclusions for tapping test

1. While the hypothesis of the spectral character of light sources affecting psychomotor activity was not found statistically significant, a clearer descending trend of psychomotor activity due to fatigue was observed at $T_c = 5800\text{ K}$, and a flatter curve that could be indicative of a more stable psychomotor activity was observed at $T_c = 2800\text{ K}$ (see Graph 2).



Graph 2. The average tapping test scores for the entire set of tests

In addition to the form-based tests, the students gave their subjective assessments of the different lighting types. When asked "How do you feel right now?" at a warm (about 2800 K) color temperature of the lighting, most students reported being relaxed, drowsy, and unwilling to perform any activity. In response to the same question at a cold (about 5800 K) color temperature of the lighting, most students reported being alert, energetic, and willing to work. To prevent groupthink, the answers were given anonymously, in writing, with silence observed in the classroom.

Results

Despite the short duration of the study, preliminary conclusions can already be made regarding the effect of color temperature of lighting on the human body. The influence of different lighting types on visual performance was demonstrated in this study. An increase in performance compared to fluorescent lighting was observed during tests at $T_c = 5800$ K. The influence of different lighting conditions on the psychophysiological background was also observed, including the relaxing trend with LED lighting at $T_c = 2800$ K.

Because of the importance of the research, it was decided to carry out a second phase of this work that will commence at the beginning of the new academic period and run through the end of the year.

Research team members from KSPEU: M.F. Sadykov, Head of the LBE Department, Candidate of Engineering Sciences; R.R. Shiriev, Assistant Professor at the LBE department, Candidate of Engineering Sciences; I.S. Matveeva, practicing psychologist. Research team members from LLC "Lighting Technologies IGC": O.S. Vnukova, Senior Project Manager; A.V. Pavlova, Director for Business Development, Medical Lighting.

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