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Research Article

Research of Receptor Device Status for the Organ of Vision during Eyestrain Work Performance in Led Lighting Conditions

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ABSTRACT
The work is devoted to experimental studies of the visual organ peripheral unit functional state, in particular to its receptor system during the illumination by LEDs. The article used the methods of campimetry and anomaloscopy. The values of retinal fatigue were analyzed in LED and fluorescent lamp illumination terms when an intense visual work for an hour and a half - the dynamics of an optic nerve projection area and color differentiation thresholds. It was shown that during visual work under the illumination by fluorescent lamps and LEDs the functional condition of retina was not the same, and there was a significant change of the studied parameters. The bond of vibrations is noted concerning studied visual functions with a general psycho-physical fatigue and reversible changes in eye tissues. It was shown that LED lighting did not cause harmful effects on the receptor device of the vision organ.

Keywords: LED lighting, visual organ, receptor device state, visual strain, eye fatigue, campimetry method, color differentiation thresholds, experimental studies.

1. INTRODUCTION
In modern conditions the activity of a person is accompanied by a constant high stress on the organ of vision. Therefore, when you create an optimal light environment, it is important to control visual fatigue, which is related both to the nature of visual tasks, and lighting conditions.

It is known that a developing fatigue reduces visual functions. One of the earliest methods of visual fatigue detection may be the determination of a change presence in various kinds of receptor response, primarily a visual analyzer. The result of a visual fatigue, especially in the mechanisms of the initial analysis - the processes which occur in retina, leading to its activity decrease [1 - 4]. The purpose of this work is a series of experimental studies to assess the impact of lighting conditions by LEDs on the state of vision organ receptor device during intense visual work performance.

The study of sight [5 - 7] as the method of functional diagnostics, which allows to judge about the receptor device state is of great importance. For example, F M. Chernilovskaya [2] applied the perimeter determination of sight limits for the study of a light stream pulsation mechanism for discharge light sources. The performed observations showed the influence of light flux oscillation depth on the retina photoreceptor elements.

A number of authors [6] noted the descriptiveness of campimetry method at the evaluation of the visual organ retina functional state. Using this method, the shape and the size of a blind spot are examined. The works [7 - 9] devoted to the study of the physiological blind spot area are interesting ones. Another indicator of retina functional state is the color sensitivity, in particular, color thresholds. The studies [10 - 12] indicate that the sharpness of color differentiation is very responsive to the light conditions, in particular to the spectral composition of light sources. Taking into account the information stated above, in order to assess the state of visual organ device receptor we used in our study the dynamics of a blind spot projection area [13] and color differentiation thresholds into red, green and blue colors during intense visual work performance. Experimental research device, the conditions and the methods of experimental studies are thoroughly described in [14 -17].

2. RESEARCH OF VISION ORGAN RECEPTOR DEVICE ACCORDING TO CAPIMETRY METHOD

The analysis of a blind spot projection area results study of according to campimetry showed that the spread of data among an individual observer did not exceed 10%, and it did not exceed 15% between observers, which made it possible to carry out statistical analysis of the results for all observers together. The distribution of research results was checked according to the criterion x2, which showed that the distribution is subject to normal law.

Tables 1 and 2 show the dynamics study of a blind spot projection area after visual work within the conditions of illumination by LEDs and fluorescent lamps.

Table 1. Blind spot projection area change during the illumination by LEDs

Illumination, lux	Color temperature, K	Before work		After work		Correlation ratio	
		Blind spot area, cm^2, $\bar{x}$	Confident interval, $t \cdot \sigma_{\bar{x}}$	Blind spot area, cm^2, $\bar{x}$	Confident interval, $t \cdot \sigma_{\bar{x}}$	*r* (between prior and after work period)	*p*(*r*)
200	3000	80,10	12,10	85,10	7,39	0,77	*p*<0,05
400				83,20	6,21	0,80	*p*<0,05
1000				84,30	8,89	0,84	*p*<0,01
200	4000	80,30	7,97	85,70	8,02	0,72	*p*<0,05
400				83,60	7,62	0,91	*p*<0,001
1000				84,90	6,55	0,78	*p*<0,01
200	5000	81,70	8,45	90,50	8,46	0,73	*p*<0,05
400				89,20	11,02	0,81	*p*<0,01
1000				88,40	6,73	0,82	*p*<0,001

Table 2 Blind spot projection area change at the illumination byfluorescent lamps

Illumination, lux	Color temperature, K	Before work		After work		Коэффициент корреляции	
		Blind spot area, cm^2, $\bar{x}$	Confident interval, $t \cdot \sigma_{\bar{x}}$	Blind spot area, cm^2, $\bar{x}$	Confident interval, $t \cdot \sigma_{\bar{x}}$	*r* (between prior and after work period)	*p*(*r*)
200	3000	80,30	8,67	86,70	11,20	0,83	*p*<0,01
400				85,90	9,34	0,77	*p*<0,05
1000				86,30	7,87	0,70	*p*<0,05
200	4000	80,70	7,75	87,10	8,62	0,83	*p*<0,001
400				86,00	6,47	0,73	*p*<0,05
1000				86,30	8,58	0,83	*p*<0,05
200	5000	82,10	9,87	92,00	7,91	0,72	*p*<0,05
400				90,40	5,82	0,61	*p*<0,05
1000				89,60	7,40	0,58	*p*<0,05

The analysis of demonstrated data shows that a significant increase of the physiological blind spot area takes place after the visual load in all studied illumination versions ($p < 0,05$). In order to assess the impact of lighting conditions (illumination level, the spectral composition of light emission, color temperature) on the development of retinal fatigue the correlation ratio was calculated in each variant, which confirmed the uniformity of physiological blind spot area changes among observers prior and after visual load (table 1 - 2). The projection area range increase of an optic nerve in relation to the original for illumination by fluorescent lamps made 6.57 - 12.06%; the corresponding increase by LED illumination made 3.87 - 10.77%. The comparison of disk projection area dynamics for an optic nerve during visual load performance showed that the illumination by LEDs with the color temperature 3000 K decreases visual fatigue in comparison with the illumination by fluorescent lamps ($p < 0,05$). So after the visual load during the illumination by fluorescent lamps at the illumination value of 200 lux the projection area increases by 1.73%, for 400 lux this area increase by 3.1% and for 1000 lux this area increases by 2.23%. At that the validation of these differences is confirmed by t-Student criterion with a high level of significance ($p <0,01$). For the illumination with the color temperature of 5000 K the differences according to a studied parameter between compared options are reduced insignificantly ($p <0,05$).

It should be noted that at the beginning of the next day the physiological blind spot area among observers was restored to its original level. Similar findings were obtained in [20], which indicates a weak intensity of morphostructural changes in eye tissues under the influence of functional loading and the favorable conditions of the production process. Such fluctuations of visual function are explained by a general psychophysical fatigue and by reversible changes in eye tissues.

3. visual organ receptor device research according to anomaloscopy method

During the study of color differentiation sharpness an unequal nature of color differentiation thresholds at different illumination options was set. Tables 3 - 5 show the dynamics of color differentiation thresholds into red, green and blue ones at the illumination by fluorescent lamps and LEDs. It should be emphasized that the nature of observer visual load was not associated with the problems of object color differentiation.

Table3. The change of color differentiation thresholds into red color after the visual load at the illumination by fluorescent lamps and LEDs

Illumination, lux	Color temperature, K	The change of color differentiation thresholds into red color after visual load				
		Illumination by fluorescent lamps		Illumination by LEDs		Difference reliability between illumination options according to Student t-criterion
		Pore changeΔ.	Difference reliabilityaccording to Student*t*-criterion	Pore change Δ.	Difference reliability according to Student *t*-criterion	
200	3000	0,8	$p<0,05$	0,7	$p<0,05$	-
400		0,8	$p<0,05$	0,7	$p<0,05$	-
1000		0,7	$p<0,05$	0,6	$p<0,05$	-
200	4000	0,7	$p<0,05$	0,6	$p<0,05$	-
400		0,7	$p<0,05$	0,6	$p<0,05$	-
1000		0,6	$p<0,05$	0,6	$p<0,05$	-
200	5000	0,5	$p<0,05$	0,4	$p<0,05$	-
400		0,4	$p<0,05$	0,4	$p<0,05$	-
1000		0,3	-	0,3	-	-

Table4. The change of color differentiation thresholds into green light after the visual load during the illumination by fluorescent lamps and LEDs

Illumination, lux	Color temperature, K	The change of color differentiation thresholds into red color after visual load				
		Illumination by fluorescent lamps		Illumination by LEDs		Difference reliability between illumination options according to Student t-criterion
		Pore change Δ.	Difference reliability according to Student *t*-criterion	Pore change Δ.	Difference reliability according to Student *t*-criterion	
200	3000	0,9	*p*<0,05	0,8	*p*<0,05	-
400		0,8	*p*<0,05	0,8	*p*<0,05	-
1000		0,7	*p*<0,05	0,7	*p*<0,05	-
200	4000	0,8	*p*<0,05	0,7	*p*<0,05	-
400		0,7	*p*<0,05	0,7	*p*<0,05	-
1000		0,7	*p*<0,05	0,6	*p*<0,05	-
200	5000	0,4	*p*<0,05	0,4	*p*<0,05	-
400		0,4	*p*<0,05	0,3	-	-
1000		0,4	*p*<0,05	0,3	-	-

Table5 – The change of color differentiation thresholds into blue color after the visual load under the illumination by fluorescent lamps and LEDs

Illumination, lux	Color temperature, K	The change of color differentiation thresholds into red color after visual load				
		Illumination by fluorescent lamps		Illumination by LEDs		Difference reliability between illumination options according to Student t-criterion
		Pore change Δ.	Difference reliability according to Student *t*-criterion	Pore change Δ.	Difference reliability according to Student *t*-criterion	
200	3000	0,8	*p*<0,05	0,6	*p*<0,05	-
400		0,7	*p*<0,05	0,5	*p*<0,05	-
1000		0,7	*p*<0,05	0,5	*p*<0,05	-
200	4000	0,7	*p*<0,05	0,5	*p*<0,05	-
400		0,6	*p*<0,05	0,4	*p*<0,05	-
1000		0,7	*p*<0,05	0,4	*p*<0,05	*p*<0,05
200	5000	0,5	*p*<0,05	0,3	-	-
400		0,5	*p*<0,05	0,2	-	*p*<0,05
1000		0,5	*p*<0,05	0,2	-	*p*<0,05

All experiments demonstrate the trend to threshold increase, although the increase of thresholds is not always reliable (p> 0,05). This is true for the illumination option by fluorescent lamps and LEDs with the color temperature of 5000 K and the illumination of 1000 lux on a red color; the option for LED illumination with the color temperature of 5000 K and the illumination of 400 and 1000 lux on a green color; the illumination option by LED at the color temperature of 3000 K and the illumination of 200, 400 lux and 1,000 lux on a blue color.

The reduction of sensitivity on a red color is identified during the visual work at the illumination by fluorescent lamps and LEDs. So at the compared options with the color temperature of 5000 K and the illumination of 400 lux the decrease made 0.4 por. per day (p <0,05). At compared options with the color temperature of 4000 K and the illumination of 1000 lux the reduction of thresholds on a red color made 0.6 por. ($P < 0,05$). The comparison of experimental data for other variants showed that the change of thresholds is higher during the illumination by LEDs. This is the sign of a slight decrease concerning the retina receptor sensitivity.

Reduced sensitivity to a green color is identified during the visual work at the illumination with fluorescent lamps and LEDs. Thus, at the illumination of 200 lux and the color temperature of 5000 K the decrease made 0.4 por. per day ($p < 0,05$). The same character of threshold reduction to green color for comparable conditions is marked for the options with the color temperature of 4000 K and the illumination of 400 lux, where a relative decline made 0,7 ($p <0,05$); for the options with the color temperature of 3000 K and the illumination of 400 and 1000 lux, where the relative decline made 0,8 ($p < 0,05$) and 0,7 ($p < 0,05$) respectively. The obtained results suggest that the same mechanism of fluorescent lamps and light-emitting diodes action on retina receptor sensitivity reduction.

The maximum reduction of thresholds to a blue color is identified during visual work at the illumination by LEDs. Thus, at the illumination with the color temperature of 4000 K and the illumination value of 400 and 1000 lux the relative reduction of thresholds made 0,4 ($p < 0,05$). The comparison of experimental data for other illumination options showed that during the illumination by LEDs thresholds are reduced more intensively, indicating a slight decrease of retina c-receptor sensitivity.

According to the data of Tables 3 - 5, the influence of emission spectral composition is detected only at the study of retina c-receptor for the radiation with the color temperature of 4000 K (illumination rate makes 1000 lux) and 5000 K (illumination rate makes 400 and 1000 lux). For other studied conditions the effect of the spectral composition was insignificant. This can be explained by the nature of visual tasks - the operation with achromatic objects not related to the definition of color differences, as well as with the qualitative parameters of illumination - a favorable spectral composition of radiation, the absence of light flux pulsation.

4. CONCLUSIONS

Retinal fatigue study according to peripheral vision state made it possible to establish reliable increases of a blind spot physiological area after the performance of strenuous visual work. This is confirmed by the views of a number of authors, providing a leading role to the peripheral part of a visual analyzer in the mechanisms of adaptation after light effects [21].

The analysis of obtained experimental data shows that during the visual operation under the illumination by luminescent lamps and LEDs the functional condition of retina was not the same, which is obviously related with the photochemical reactions in retina. These reactions may be slowed down and amplified by the radiation action of visible spectrum various portions. These changes have an impact on a particularly sensitive retinal function - the color differentiation.

5. SUMMARY

The experimental study results suggest that LED lighting does not make harmful effects on eyesight, especially on its receptor device. The changes of studied functional parameters of a visual organ (the area of an optic nerve projection, color thresholds on red, green and blue color) which take place during visual work operations are included in the appropriate boundaries of physiological fluctuations and are reversible.

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