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THE AGE FEATURES OF VISUAL FATIGUE IN EMPLOYEES OF MODERN OFFICES WORKING WITH LED VISUAL DISPLAYS AND PREVENTION MEASURES

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Introduction. The problem of visual fatigue in professional users of personal computers (PC) and visual display devices (VDD) working in modern offices is quite relevant, especially with the introduction of new energy-saving technologies based on the use of LEDs and negative age-related changes in the demographic situation in EU countries and Ukraine. According to researches, from 40 to 70 % of professional PC users have manifestations of chronic visual fatigue (asthenopia) and other negative changes in the visual organ, the frequency of which increases with age and requires appropriate preventive measures.

The purpose of the study – to establish the age characteristics of the formation of visual fatigue in employees of modern offices when working with visual displays and to determine prevention measures.

Materials and methods of research. Sanitary and hygienic researches of working conditions and questionnaire survey of 121 professional users of computer equipments were carried out to determine visual fatigue and comfort of the light environment in office premises and visual stress in the age groups 20–29, 30–39, 40–49, 50–59 years. The studies of lighting levels, visible light spectrum and color temperature of light sources were performed using a spectrometer SECONIK 7000 (Japan). An original questionnaire on determination of degree of visual fatigue in professional PC users has been developed and tested. The evaluation of the results of the study was carried out according to the following gradation: no visual fatigue (0 points), light fatigue (< 4 points), moderate fatigue (4–10 points), severe fatigue (> 10 points). Additionally, KSS (Karolinska Sleepness Scale) and Samn-Perelli (SPS) tests of the seven-point fatigue scale were used.

Results. It is established that intense visual work is a leading factor in the labor process of office workers and monitoring of visual display devices (VDD) lasts for 3.5–6.0 hours. The non-production load on the organ of vision for 3–6 hours is also significant (laptops/PCs, smartphones, TV). The color temperature of information display devices in the workplace is (5905 ± 139) K and this parameter is close to «natural» light. The maximum radiation of the LED monitor falls on the «blue» part of the visible spectrum (430–450 nm), which has a negative impact on the functional state of the visual analyzer. According to the questionnaire, survey of office workers is determined on average, a moderate degree of visual fatigue [(4.89 ± 0.53) points]. The first signs of moderate visual fatigue in office workers of Naftogaz DT LLC appear 10 years earlier (age group 30–39 years) than general fatigue (age group 40–49 years), which requires the introduction of preventive measures.

Conclusions. The general assessment of working conditions of office workers belongs to class 3.1–3.2. (harmful) according to the criteria of the Hygienic Classification of Labor (2014) according to the leading factor of visual work intensity, which is due to the observation of VDDs for 3.5–6.0 hours a day. Taking into account the out-of-work viewing of VDDs, the total load on the vision organ during the day is 6.5–12 hours and exceeds sanitary norms in Ukraine (4 hours). To prevent visual fatigue, office workers are offered hygienic and technical measures: regulated breaks for rest every 1–2 hours for 10–15 minutes and organization of work in such a way as to minimize the duration of visual contact with VDD, the use of appropriate filters such as «ЖС-19» (Ukraine), which allow to shift the predominant wavelength of radiation from 430–450 nm (blue light) to 550–560 nm (green light).

Key words: visual fatigue, age features, employees of modern offices, means of visual display of information, prevention measures

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Introduction

Personal computers (PCs) and visual display devices (VDD) have become an integral part of modern workplaces in various industries and office work [1–4]. Today, out of 7443.0 full-time employees in Ukraine, 1238.3 people work in the areas of administrative and support services, public administration, social insurance, financial and insurance activities and others [5], which can be considered as office work [6]. At the workplaces of professional users of PC and VDD there is a set of physical factors of low intensity (electromagnetic fields, microclimate, noise) and intense visual work, which requires further research and hygiene regulations [7–10]. According to recent studies, from 40 to 70 % of professional PC users have manifestations of chronic visual fatigue (asthenopia) and other adverse changes in the visual organ, the frequency of which increases with age and requires appropriate preventive measures [1, 11–12].

Despite the introduction of new computer technologies using monitors with light emitted diodes (LED) or liquid crystal display (LCD) matrix, the problem of visual fatigue in professional users of this equipment remains quite relevant, and the presence in the radiation spectrum of «blue» light with a length of wave 380–480 nm requires further studies of the probable risks to the organ of vision [13–15]. In addition, Ukrainian sanitary norms and rules of work with video display terminals (VDT) of electronic computers DSanPiN 3.3.2.007-98 are apply only to VDT based on cathode ray tubes. Therefore, national hygienic requirements for electromagnetic safety, ergonomics and lighting environment in the workplace need to be refined and harmonized with international and European standards SWEDAC 1990: 8 (MPRII), ISO 9241-6: 2004, EN 12464-1: 2011. In this context, it is necessary to take into account the technical requirements of the standard DSTU ISO 9241-5-2004 «Ergonomic requirements for working with video terminals in the office» [16]. The working out and implementation of hygienic standards and recommendations must be taken into account scientific data on the development and prevention of visual fatigue in PC users and the parameters of the light environment that is created during the operation of VDD.

In Rajabi-Vardanjani et al. (2014) to assess visual fatigue in professional PC users, it is proposed to use a questionnaire that contains a number of diagnostic questions regarding the ophthalmic status of respondents [17]. The International Civil Aviation Organization ICAO (2012) also recommends the use of questionnaires to determine visual and general fatigue in air traffic controllers who work intensively with air defense systems [18].

The purpose of the study – to establish the age characteristics of the formation of visual fatigue in employees of modern offices when working with LED visual displays and to determine prevention measures.

Materials and methods of research

Sanitary and hygienic studies of working conditions and a questionnaire survey of 121 office workers, whose work is related to the use of computer equipment (heads of departments, project coordinators, IT specialists, economists, others) were carried out at Naftogaz DT LLC (Kyiv). The work stress and intensity of work was assessed according to the «Hygienic Labor Classification» No. 248 that adopted in Ukraine (2014). The study of lighting levels, visible light spectrum and color temperature of light sources was performed using a spectrometer Seconik 7000 (Japan).

In order to fulfill the set tasks for determining visual fatigue in professional PC users, we have developed and tested a questionnaire on 14

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questions on the presence and determination of the degree of visual fatigue. The evaluation of the results of the study was carried out according to the following gradation: no visual fatigue (0 points), slight fatigue (< 4 points), moderate fatigue (4–10 points), severe fatigue (> 10 points). Questionnaire survey on visual fatigue was conducted before the start of the working day. Given the psycho-emotional nature of human perception of light, the original questionnaire was used for a subjective 5-point assessment of the comfort of the light environment and visual stress.

Following the practical recommendations of ICAO (2012), the KSS (Karolinska Sleepiness Scale/ 0–9 points) and Samn-Perelli (SPS/0–7 points) tests were used for psycho-physiological assessment of fatigue [16]. Features of the impact of the production environment on workers and the development of visual fatigue were observed in the age groups 20–29, 30–39, 40–49, 50–59 years. Statistical data processing was performed using standard programs Microsoft Office Excel 2007, Statistica 6.0, which are installed as personal computer software. The reliability ($p < 0.05$) of the results was analyzed by Student's *t*-test.

Results of research and discussion

According to the data of hygienic research, labor intensity is a leading factor in the working process of office workers and is determined by the time of continuous monitoring of VDD from 3.5 hours (HR, development, etc.) to 6 hours (IT-specialists) a working day. Modes of work and rest of office workers when working with VDD at the workplace are not always respected. The parameters of electromagnetic fields and radiation, noise, microclimate meet sanitary norms.

Office workstations are equipped with video monitors and laptops such as HP, Sumsung, LG, Phillips with different types of matrices and LED screen backlight and mobile communication. The average corrected color temperature of LED light sources in the premises was (5209 ± 60) K. The levels of artificial lighting were (328,0 ± 23,6) lx, which corresponded to the normative values according to Standard DBN B.2,5-28:2018. The parameters of natural lighting met the requirements of DBN B.2,5-28: 2018 «Natural and artificial lighting» too. The average corrected color temperature of VDD information in the workplace was (5916 ± 223) K and by this parameter was close to «natural» light.

In general, the intensity of visual work is a leading factor in the labor process, and the overall assessment of working conditions refers to Class 3.1–3.2. (harmful condition) according to the criteria of the Hygienic Classification of Labor (2014).

The studies of radiation spectrum show that LED monitors and smartphones used by office workers have a dominated wavelength of 430–450 nm, which belongs to the range of «blue» light (400–480 nm), which may have biological risks to the retina due to high-energy photons (Figure 1, Figure 2).

As example, in LCD monitors with luminescent illumination of the screen matrix, the maximum radiation intensity falls on the «green» part of the spectrum (540–550 nm), which is the most comfortable for the human vision organ (Figure 3).

Thus, the artificial component of the lighting environment at the workplaces of the office premises was formed exclusively from visible radiation, which was of LED origin. This applied to both light sources and visual aids. Therefore, of particular interest was the study of the long-term impact of this factor in combination with intense visual work on the functional state of the visual analyzer working in the dynamics of their work.

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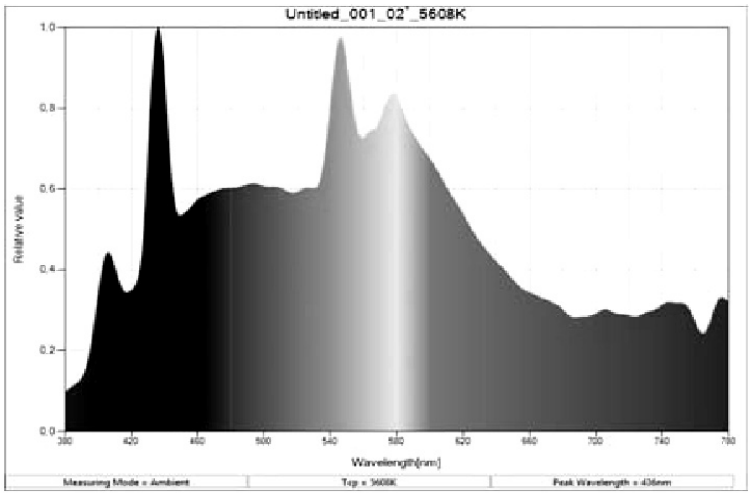

Figure 1. The radiation spectrum of the Phillips LED monitor

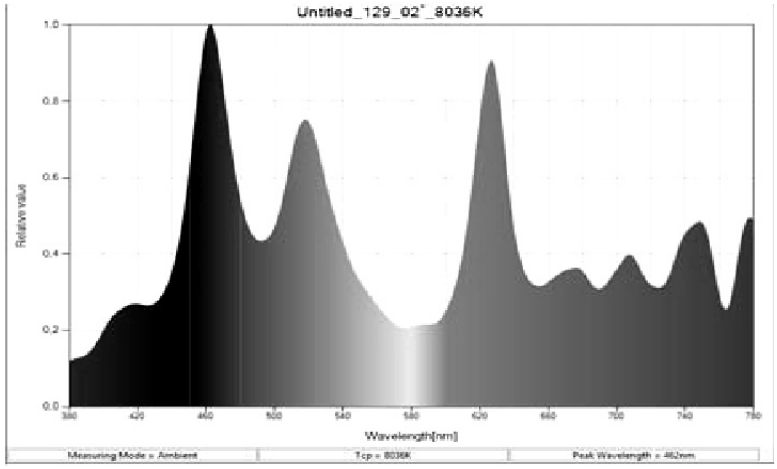

Figure 2. Spectrum of radiation of the Samsung J510H smartphone

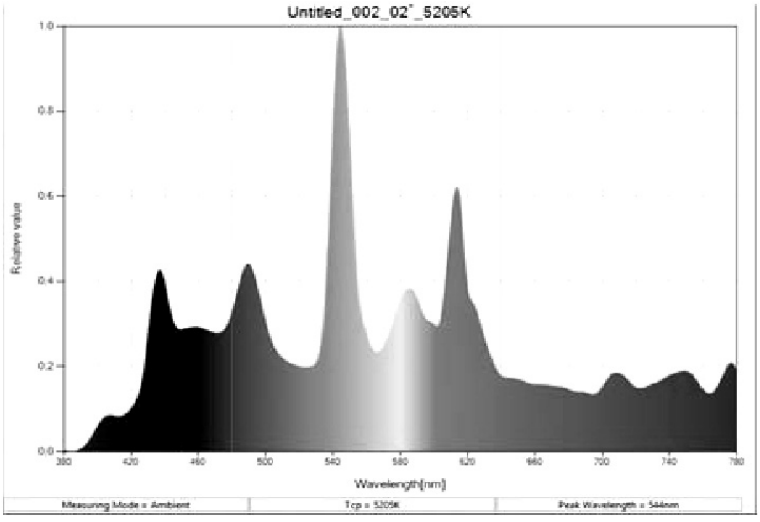

Figure 3. Spectrum of visible light of the LCD monitor ASUS VH 222D

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The age, work experience of office workers and the general assessment of their working conditions are presented in Table 1.

As can be seen from Table 1, working conditions met to class 3.1–3.2 (harmful of 1–2 degrees). Work experience of office workers ranges from (7.89 ± 0.57) years in the age group 20–29 years to (16.08 ± 1.45) years in the age group 50–59 years. The pair correlation coefficient between length of service and age of employees is: r = 0,724.

The angle at which the monitor screen is installed to the plane of the window is from (78.75 ± 5.51)° to (111.82 ± 8.15)°, which takes into account the risks of the presence of light reflected by the monitor screen from the source of natural light.

There should be noted a significant increase in the percentage of people wearing glasses for vision correction – 12.1 % in the age group 30–39 years to 22.0 % in the age group 40–49 years and in the age group 50–59 years – up to 76 %.

Subjective assessments of the quality of the lighting environment working with VDD on the original 5-point scale is presented in the Table 2.

As can be seen from Table 2, office workers evaluate the comfort of the lighting environment, mainly as «satisfactory» (3 points) and «good» (4 points), the intensity of visual work as «average» in the age groups 20–29, 30–39, 40–49 years and in the age group 50–59 years – as close to «difficult» (3.92 ± 0.14) points, and self-well-being was assessed as «mild fatigue»

Table 1

Age, seniority and working conditions of office workers

Age group, years	*N*, persons	Average age, years	Average work experience, years	Class of working conditions according to HLC (2014)	Angle monitor to the window area, °	Glasses for vision correction, % of people
20–29	28	26.56 ± 0.56	7.89 ± 0.57	3.1–3.2	95.0 ± 7.50	7.2
30–39	33	35.09 ± 0.51	10.84 ± 0.47	3.1–3.2	111.82 ± 8.15	12.1
40–49	35	43.63 ± 0.75	15.33 ± 1.48	3.1–3.2	95.29 ± 6.83	22.9
50–59	25	54.17 ± 0.48	16.08 ± 1.45	3.1–3.2	78.75 ± 5.51	76.0

Table 2

Assessment of the quality of the lighting environment by office workers (X ± m)

Age group, years	*N*, persons	Psychophysiological indicators, points				
		Assessment of the comfort of the lighting environment	Assessment of the degree of visual work intensity	Psychological perception of the light spectrum	Subjective attitude to the lighting spectrum	Assessment of self-well-being
20–29	28	3.89 ± 0.17	3.56 ± 0.12	3.89 ± 0.13	3.28 ± 0.13	2.83 ± 0.19
30–39	33	3.56 ± 0.09	3.47 ± 0.13	3.78 ± 0.07	3.06 ± 0.12	3.06 ± 0.15
40–49	35	3.56 ± 0.12	3.39 ± 0.17	3.44 ± 0.15	3.22 ± 0.09	2.92 ± 0.18
50–59	25	3.42 ± 0.22	3.92 ± 0.14*	3.75 ± 0.12	3.83 ± 0.14*	2.25 ± 0.13*

*Note. *p < 0.05.*

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(2.25 ± 0.13) points. While in other age groups, health was defined as «satisfactory» (3 points) or close to that.

Psychological perception of the lighting spectrum as «cold» (3.83 ± 0.14) points is more pronounced in the age group of 50–59 years, which coincides with the high color temperature (> 5000 K) of light sources and display devices screens in the workplace.

Table 3 presents a subjective assessment of visual and general fatigue according to the questionnaire in different age groups.

In Table 3 data show that the average score of visual fatigue in the age group 20–29 years is (3,72 ± 0,35) points (slight fatigue). While in the age groups 30–39, 40–49 and 50–59 years, the average score of visual fatigue increases from (5.30 ± 0.45) to (7.33 ± 0.25) points. Thus, it can be determined that in the age groups of 30–39, 40–49 and 50–59 years, moderate visual fatigue is formed with a tendency to its significant increase in the age group of 50–59 years.

According to Samn-Perelli test, general fatigue and negative changes in the functional state of the CNS according to the KSS test (vigor/sleepiness) indicate that signs of general fatigue in office workers statistically significantly ($p < 0.05$) begin to appear in age groups 40–49 years (Samn-Perelli test) and 50–59 years (KSS test and Samn-Perelli test). At the same time, at the end of the working day, general fatigue increases noticeably in all age groups ($p < 0.05$).

From the presented data it can be concluded that the appearance of moderate visual fatigue in office workers of Naftogaz DT LLC is manifested 10 years earlier than the development of general fatigue according to the questionnaire.

Table 4 presents the out-of-work vision load on the office workers in different age groups by visual display devices when used in domestic conditions.

As can be seen from Table 4, in addition to the work load on the organ of vision, it is very significant out-of-work load during 3–6 hours. a day (laptops and personal computers, TVs and smartphones). It should be taken into account when assessing the influence of working conditions on the functional state of the body of office workers. The maximum overtime load is observed in the age group 40–49 years – (5.17 ± 0.47) hours, minimum – in the age group of 50–59 years – (3.67 ± 0.14) hours a day. Out-of-work use of smartphones is most represented in the age groups of 30–39 years and 40–49 years for (3.06 ± 0.28) hours and (3.08 ± 0.31) hours a day, respectively. Smartphones as a means of displaying information are most used in the age group 30–39 years – 70.5 % of the total

Table 3

Subjective assessment of visual and general fatigue

Age group, years	*N*, persons	Psychophysiological indicators, evaluation points			
		Visual fatique, points	KSS test: vigor – sleepiness	Fatigue acc. to Samn-Perelli	
			Start of working day – End of working day, (the change in the assessment of functional state)	Start of working day	End of working day
20–29	28	3.72 ± 0.35	0.78 ± 0.28	1.80 ± 0.15	3.60 ± 0.32
30–39	33	5.30 ± 0.45*	1.09 ± 0.17	2.10 ± 0.18	4.40 ± 0.35
40–49	35	5.79 ± 0.47*	1.16 ± 0.12	3.10 ± 0.22*	5.60 ± 0.44*
50–59	25	7.33 ± 0.25*	2.25 ± 0.12*	3.40 ± 0.31*	6.20 ± 0.56*

*Note. *p < 0.05.*

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Table 4

Out-of-work vision load on the office workers

Age group, years	*N*, persons	In general (laptop + PC + TV + smartphones), hours a day	Smartphones, hours a day	Part of smartphones in general out-of-work load, %
20–29	28	3.94 ± 0.16	2.22 ± 0.18	56.3
30–39	33	4.34 ± 0.28	3.06 ± 0.28*	70.5
40–49	35	5.17 ± 0.47	3.08 ± 0.31*	59.6
50–59	25	3.67 ± 0.14	1.08 ± 0.08*	29.4

*Note. *p < 0.05.*

viewing time of screen devices, the least in the age group 50–59 years – (1.08 ± 0.08) hours a day or 29.4 % of the total time of their reviewing.

Thus, the total time of work with VDD, taking into account the production and out-of-work load on the organ of vision of office workers is 7–12 hours per day, which is a significant factor of influence on the body of modern man, which actively joins the existing information space.

Hygienic and technical measures should be offered as preventive measures. First of all, it is compliance with the requirements of Sanitary Norms No 3.3.2.007-1998 (p. 5.8) for regulated breaks for rest every 1–2 hours of work for 10–15 minutes and the organization of work in such a way as to minimize the duration of visual contact with VDD. The duration of viewing devices must meet health standards adopted in Ukraine – no more than 4 hours a working day.

As a technical measure to prevent the adverse effects of «blue» light from visual display devices (monitors, smartphones, tablets), it is recommended to use light filters such as ЖС-19 «Catalog of colored glass» (Ukraine) and similar «computer» goggles, which allow correction of the spectrum of LED VDD and shift the maximum wavelength of radiation from 440–460 nm (blue light) to 550–560 nm (green light), which will have a positive effect on the organ of vision during intense visual work.

Conclusions

1. The intensity of visual work is a leading factor in the labor process of office workers and observation of LED visual display devices lasts for 3.5–6.0 hours or more. The general assessment of working conditions belongs to class 3.1–3.2. (harmful) according to the criteria of Hygienic Labor Classification (2014).
2. The total time of work with VDD, taking into account the work and out-of-work load on the organ of vision of office workers is 6.5–12 hours a day and exceeds sanitary norms in Ukraine (4 hours). Out-of-work load for 3–6 hours (laptops/PC, smartphones, TV) needs to be taken into account when developing preventive measures.
3. The color temperature of LED visual display devices in the workplace is (5905 ± 139) K, and this parameter is close to «natural» light. The maximum radiation of the LED monitor falls on the «blue» part of the visible spectrum (430–450 nm), which has a negative impact on the functional state of the visual analyzer.
4. According to the questionnaire survey of office workers, on average, a moderate degree of visual fatigue (4,89 ± 0,53) points is determined. The first signs of moderate visual fatigue in the office workers appear 10 years earlier (age group 30–39 years) than general fatigue (age group 40–49 years).

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5. The introduction and control of work/rest regimes when working with VDD in the workplace of the office workers is a significant reserve for the prevention of visual fatigue, especially for people over 30 years. The use of light filter type ЖС-19 (Ukraine) allows to shift the predominant wavelength of radiation from 430–450 nm (blue light) to 550–560 nm (green light), which will have a positive effect on the visual organ during intense visual work.

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