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Research article

SUBSTANTIATION OF THE OPTIMUM SCREEN BRIGHTNESS PARAMETERS OF THE INTERACTIVE PANEL TO REDUCE THE RISK OF GENERAL AND VISUAL FATIGUE OF SCHOOLCHILDREN

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The digital transformation of modern education contributes to the active introduction of interactive panels (IP) into the educational process, replacing traditional chalkboards. Minimizing possible risk factors when using an IP also requires considering the visual characteristics of its screen. At present, there are no results of such studies in the scientific literature. The purpose of this work was to substantiate the optimal range of IP screen brightness when it is used in the classroom to prevent general and visual fatigue of schoolchildren. We analyzed research articles describing studies in visual hygiene, lighting engineering, display technologies, etc.

Our study involved measuring brightness and pulsation coefficient of a working IP screen. Ranges of IP screen brightness that could produce harmful effects on children's health have been empirically established. With the help of a specially designed questionnaire, complaints of students attending the 4th grade of secondary schools were studied to identify general and visual fatigue, as well as factors caused by the IP and negatively affecting the respondents' well-being. The relative risk values are calculated, namely a probability that these complaints would occur in schoolchildren, depending on parameters of IP screen brightness. The optimal range of IP screen brightness is justified for a working mode that significantly reduces the probability of students complaining about general and visual fatigue. Monitoring and correction of IP screen brightness mode during classes will reduce the risks of students' health disorders. It is necessary to continue research to substantiate the optimal visual characteristics of the IP screen based on investigating indicators describing the functional state of the child's body.

Keywords*: prevention, interactive panel, risk factors, screen brightness, fatigue.*

The digital transformation of modern education contributes to the active introduction of electronic devices in the educational process, starting from the elementary school. Traditional chalkboards are being replaced with digital models everywhere. The latest generation of electronic boards is an interactive panel (IP), which is an independent device: a touch display that runs on its own software.

The use of interactive panels in the classroom in the modern school is becoming a routine practice. Given that the panel is an electronic means of collective use (for the whole class team), an increasing number of schoolchildren come across it in the learning process.

The use of IP implies the presence of undeniable advantages in the visualization of information over traditional teaching aids. Along with this, modern scientific research shows the impact resulting from use of electronic technologies on the formation of visual

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impairment, the functioning of the nervous, cardiovascular systems, etc. [1–13]. The intensity of the educational process is increasing [14]. Electronic learning aids increase visual concentration, significantly prolonging a period during which the eyes have to work. In several scientific publications concerning ergonomics in connection with electronic devices, attention is mainly focused on the hygiene of visual work [15–18]. Previous studies have reported several complaints about health deterioration; general and visual fatigue of schoolchildren when using interactive panels in classes [19]. In addition, literature presents data indicating negative changes in the microclimate parameters in the dynamics of classes with the use of IP [20], unfavorable dynamics of the mental and visual performance of students during classes with unregulated use of IP [21]. With the accumulation of experience in the use of these electronic means in the educational process, research to study their effect on students' body remains relevant.

The issue of optimal IP screen visual characteristics is among the priority areas of research. The screen brightness and the pulsation of the panel screen brightness are significant parameters. The latter has no less negative impact on students' health than the pulsation of general illumination at a workplace because a student is forced to carefully peer at a panel and read information presented on it. The presence of brightness pulsations, as a rule, leads to rapid fatigue of the eyes and parts of the brain responsible for perception and analysis of visual information[1]. You can significantly reduce the panel display pulsation by increasing the brightness of the screen backlight. In its turn, too high brightness also has an adverse effect on a user's body [22].

Therefore, the use of IP in its optimal brightness mode is a significant component in preventing general and visual fatigue and reducing risks of overwork for schoolchildren. An advantage of the interactive panel is the adjustable screen brightness mode depending on lighting conditions. The IP screen brightness can be adjusted independently during classes, for example, by a teacher.

The timeliness of the study is evidenced by the results of scientific works addressing influence of digital means screens, including their brightness, on users' health, vision, etc. However, these data relate mainly to the monitor screen, i.e. working conditions are significantly different from those when using IP. In addition, all studies were conducted with adult subjects [23–28].

Given the above, it is extremely relevant to investigate optimal visual characteristics of the interactive panel screen when used in a class, especially brightness parameters that determine risks of health complaints.

The purpose of the study is to substantiate the optimal range of IP screen brightness when it is used in the classroom to prevent general and visual fatigue of schoolchildren.

To achieve this goal, the following tasks were solved:

• to substantiate the brightness ranges of the IP screen potentially causing various effects on schoolchildren's health;

• to determine the number of health complaints among students when working with IP in reasonable brightness ranges;

• assess risks of schoolchildren's complaints about general and visual fatigue depending on the different IP screen brightness.

Materials and methods. We measured the pulsation coefficient from the screen and the screen brightness of the operating IP.

The measurements were carried out in 30 school classrooms equipped with Irbis IP in accordance with the requirements of GOST 33393-2015, GOST 24940-2016, GOST 26824-2018. To exclude the influence

[1] Pul'satsii osveshchennosti i yarkosti [Pulsations of illumination and brightness]. *NOChU DPO 'EkoSfera'*. Available at: https://ekosf.ru/stati/pulsacii/ (September 12, 2022) (in Russian).

of natural light on the measurement results, they were carried out in the evening and the windows were equipped with thick shading devices (roller blinds). The measurement control points were located evenly on the entire working surface of the IP. The measurements were carried out simultaneously with two devices: the Combined Device, eLight, version 2, 63221-16 and the Combined Device, type TKA-PKM (09). Measuring range of devices was as follows: illumination (10…200 000) lx; pulsation factor (1…100) %; brightness (10…200000) cd/m^2; instrument error 8 %.

Measurement steps:

- sanitary and hygienic assessment of educational premises (in terms of creating an optimal light regime);
- measurement of artificial illumination levels from the general lighting system, measurement of background lighting from natural sources (windows);
- measurement of brightness and pulsation coefficient from the IP screen.

On each IP, measurements were taken at 13 control points at adjusted brightness values from 25 to 155 cd/m^2 with a step of 5 cd/m^2. In total, 10,350 measurements of brightness from the IP screen and 10,350 measurements of the pulsation coefficient from the IP screen were carried out.

We established relationships between values of the pulsation coefficient and the adjusted IP screen brightness. The brightness ranges of the IP screen are substantiated.

We studied children's complaints to assess adverse impacts exerted on their health by the use of IP with different screen brightness. Three hundred and thirty children attending the 4th grade in two secondary schools with standard educational programs underwent medical examination and participated in a social survey. This age group was selected because interactive panels are already actively used in elementary school where students are the most sensitive to the effects of risk factors. The use of interactive panels in the classroom was carried out as much as possible in accordance with the current sanitary legislation. At the end of use, the IP was turned off or put into 'sleep' mode. The survey was conducted in a face-to-face format. The questionnaire included questions related to a) identifying factors caused by the work of IP that negatively affect respondents' health; b) identifying students' complaints about general and visual fatigue. The criteria for including participants in the study were the following: they attended the 4th grade in secondary school; IPs were used in the educational process; availability of written informed consent to research from parents. Exclusion criteria were severe visual impairment; failure to meet the inclusion criteria.

We assessed the number of schoolchildren's complaints about general and visual fatigue that occurred when the IP was operating in different (previously justified) ranges of screen brightness. Nominal data were described in terms of absolute values, percentages, and boundaries of the 95 % confidence interval (CI) calculated by the Wilson method and corrected for continuity.

According to the principles of evidence-based medicine, relative risk values were established, namely likelihood of schoolchildren having complaints related to general and visual fatigue (outcomes) depending on the brightness parameters of the IP screen (risk factors)[2]. Differences between groups of indicators were assessed by calculating the relative risk using four-field contingency tables. After defining the boundaries of the 95 % confidence interval (not including one), the relative risk values were compared with one: values greater than 1 were chosen, if a factor increased frequency of outcomes. We calculated sensitivity and specificity of

[2] Biblioteka postov MEDSTATISTIC ob analize meditsinskikh dannykh. Slovar' statisticheskikh terminov [Library of MEDSTATISTIC posts about medical data analysis. Dictionary of Statistical Terms]. *Meditsinskaya statistika*. Available at: http://medstatistic.ru/theory/relative_risk.html (September 30, 2022) (in Russian).

the method. Significance of a contribution made by a risk factor to the increase in the frequency of the event was determined by calculating the etiologic fraction (EF) expressed as a percentage. To interpret the magnitude of the relative risk and the etiologic fraction, taking into account the continuous and long-term impact of education on the student's body, we used the 'Assessment of the degree of causal relationship of health disorders with work'[3].

Results and discussion. All classrooms equipped with Irbis IP had similar areas (49.0–52.0 m^2). Ceiling LED lamps were used as a source of general artificial lighting. The sanitary and hygienic assessment of the classrooms revealed the absence of burned-out lamps, the uniformity of the lamp arrangement, the absence of pollution on lighting devices, the uniformity of illumination of the IP working surface, the presence of shading devices on the windows.

The background natural lighting was determined to account for less than 10 % of the total artificial lighting. The pulsation coefficient from the general artificial lighting system in the examined premises equipped with LED lamps was 2.1 ± 0.8 %.

Screen brightness parameters were experimentally divided into three ranges.

The first range was obtained using a series of measurements of the pulsation coefficient from the MT depending on the increase in the brightness of the MT screen: a gradual increase in the brightness level of the panel screen was accompanied by an abrupt change in the pulsation coefficient (Figure).

According to the figure, at a brightness level of 115 cd/m^2, the pulsation coefficient reached its minimum values; it approached 20 %, and then, with increasing brightness, its value practically did not change. In addition, according to the reviews of teachers with long work records who have sufficient experience with IP, at an adjusted brightness of less than 115 cd/m^2, a fuzzy, pale image was observed. This made it possible to label a range of less than 115 cd/m^2 as 'potentially sub-optimal'.

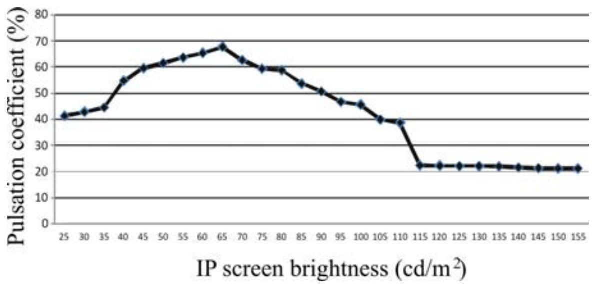

Figure. Change of the pulsation coefficient (%) from the IP screen depending on the adjusted brightness of the IP screen (cd/m^2)

According to the data available in the literature, the range of subjective brightness that the eye can perceive (brightness adaptation – the range of simultaneously distinguishable subjective brightness levels) is about 10–15 cd/m^2 [29, 30], i.e., the range from 115 cd/m^2, extended by the value of brightness adaptation, can hypothetically be considered 'potentially optimal', up to 125–130 cd/m^2. At the same time, according to the reviews of teachers who have significant experience in using IP, the adjusted brightness of its screen over 125 cd/m^2 was already 'uncomfortable' for the eye, so this figure was determined as the upper limit of the optimal brightness level.

Thus, the screen brightness parameters were divided into three ranges: less than 115 cd/m^2; 115–125 cd/m^2 and more than 125 cd/m^2.

To substantiate the optimal level of the IP screen brightness during classes, we studied students' complaints in the process of using it.

The schoolchildren were divided into three groups (90, 100 and 140 schoolchildren); the educational process was carried out for each of them using an IP operating in one (of the above) brightness ranges. The groups were similar in terms of age and sex and learning conditions.

[3] Professional'nyi risk dlya zdorov'ya rabotnikov: rukovodstvo [Occupational health risk for workers: guidelines]. In: N.F. Izmerov, E.I. Denisov eds. Moscow, Trovant Publ., 2003, 448 p.

The plan was to study students' complaints after working with the panel in each brightness mode for one academic week. However, a significant number of complaints was made by children during the operation of the IP in the adjusted brightness modes of less than 115 cd/m^2 and more than 125 cd/m^2 at the very beginning of the study. This led to earlier termination of any operation in these ranges and performing a survey.

Work with IP in the range of 115–125 cd/m^2 continued in the classroom for a school week; after that, students' complaints were also analyzed. The results are presented in Table 1. Analysis of the intensity of schoolchildren's complaints showed that such risk factors as a fuzzy image, in the vast majority of cases, are characteristic of low brightness; bright light from the screen and a rise in air temperature in the class are typical for high brightness. However, these factors, although to a much lesser extent, are also present during the operation of the IP with a screen brightness of 115–125 cd/m^2. This indicates the need to justify the hygienic requirements for the information supplied to the IP screen (contrast, clarity, color, font, etc.); as well as constant monitoring and optimization of the microclimate in classes with IP use taken in dynamics [20].

Complaints about general fatigue and eye fatigue among the respondents using IP in "non-optimal" brightness ranges are distributed approximately equally; headache, pain in the eyes, and lacrimation were significantly more often observed in the children exposed to IP brightness of more than 125 cd/m^2. When the panel was operating in the range of less than 115 cd/m^2, the schoolchildren, respectively, complained significantly more often about the blurring of the image and the feeling of flickering before their eyes.

Table 2 presents the significant relative risks of certain complaints during the operation of the IP in the brightness mode of less than 115 cd/m^2 and more than 125 cd/m^2 compared to the brightness of 115–125 cd/m^2.

Table 1

The number of students' complaints when working with IP in different brightness ranges

Survey Questions	Answer options	IP Screen Brightness Ranges								
		less than 115 cd/m^2			115–125 cd/m^2			over 125 cd/m^2		
		Abs.	%	CI	Abs.	%	CI	Abs.	%	CI
Factors that negatively affect health according to schoolchildren	Bright light from IP	–	–	–	28	28.0	20.14–37.49	138	98.6	93.91–99.69
	Small fuzzy image on the screen	90	100.0	95.1–100.8	17	17.0	10.89–25.55	2	1.4	0.31–6.09
	A temperature rise in the classroom	22	24.4	16.70–34.20	15	15.0	9.31–23.28	80	57.1	47.31–66.36
Students' complaints when working with IP	General fatigue	89	98.9	93.99–99.81	5	5.0	2.15–11.18	134	93.1	86.38–96.63
	Headache	2	2.22	0.60–7.71	2	2.0	0.55–7.0	26	18.6	12.19–27.34
	Pain in the eyes	12	13.3	7.77–21.84	3	3.0	1.03–8.45	71	50.7	41.06–60.29
	Image blur	43	47.8	37.78–58.00	3	3.0	1.03–8.45	2	1.4	0.31–6.09
	Lacrimation	11	12.2	6.95–20.55	3	3.0	1.03–8.45	70	50.0	40.38–59.62
	Feeling of flickering before the eyes	59	65.6	55.33–74.59	4	4.0	1.57–9.84	1	0.7	0.10–4.95
	Eye fatigue	68	75.6	65.80–83.30	5	1.0	0.18–5.45	124	88.6	80.89–93.45
The number of schoolchildren working with IP in each of the ranges, n		90			100			140		

Table 2

Relative risk of schoolchildren's complaints about general and visual fatigue at different screen backlight brightness of the interactive panel

Complaints	IP Screen Brightness	Relative risk	CI*	EF, %	Se	Sp
General fatigue	less than 115 cd/m^2 (compared to brightness 115–125 cd/m^2)	19.8	8.41–46.48	93.9	0.95	0.99
Eye fatigue		15.1	6.38–35.79	70.0	0.93	0.81
Image blur		15.9	5.12–49.56	44.8	0.94	0.67
Feeling of flickering before the eyes		16.4	6.2–43.3	61.6	0.94	0.76
Small fuzzy image		5.8	3.8–9.1	83.0	0.84	0.99
Lacrimation		4.07	1.17–14.14	9.2	0.79	0.55
Pain in the eyes		4.44	1.29–15.95	10.3	0.80	0.55
General fatigue	Over 125 cd/m^2 (compared to brightness 115–125 cd/m^2)	19.1	8.14–45.02	90.7	0.96	0.94
Headache		9.29	2.26–38.23	16.6	0.93	0.46
Eye fatigue		17.7	7.52–41.7	83.6	0.96	0.86
Lacrimation		16.6	5.40–51.43	47.0	0.96	0.58
Pain in the eyes		16.91	5.48–52.14	47.7	0.96	0.58
The bright light from the board interferes		3.52	2.6–4.8	70.6	0.83	0.97
Increasing classroom temperature (getting 'hot')		3.81	2.3–6.2	42.1	0.84	0.59

Note: *CI is a confidence interval ($p < 0.05$); EF, etiological component; Se, sensitivity; Sp, specificity.

The obtained data allow us to substantiate the brightness range of the interactive panel that is optimal for students in the classroom. When the brightness of the IP screen is between 115 and 125 cd/m^2, the risk of complaints about health disorders is detected significantly less frequently.

A decrease in complaints of visual fatigue with adequate adjustment of brightness levels, the use of screens with anti-reflective coating, maintaining an ideal visual distance was also noted in works evaluating the effect of a computer monitor screen in adult users [23–25]. A promising area of research is the assessment of the IP screen brightness at school depending on a viewing distance and field of view, as evidenced by the work carried out on large LED displays [25].

Conclusions. Thus, the use of an interactive panel with optimal visual screen parameters of 115–125 cd/m^2 in classes will reduce the risks of general and visual fatigue and the load on the visual analyzer.

The active development of digital technologies necessitates further research to substantiate the optimal visual characteristics of the screen of new electronic learning tools based on assessing indicators describing the functional state of the child's body.

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