

ANALYSIS OF THE DATA OBTAINED DURING THE EXPERIMENT, ASSESSMENT OF OBJECTIVE SYMPTOMS TO IDENTIFY CHRONIC VISUAL FATIGUE

**АНАЛІЗ ДАНИХ, ОТРИМАНИХ ПІД ЧАС ЕКСПЕРИМЕНТУ,
ОЦІНКА ОБ'ЄКТИВНИХ СИМПТОМІВ ДЛЯ ВИЯВЛЕННЯ
ХРОНІЧНОЇ ЗОРОВОЇ ВТОМИ**

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Summaries

There is a growing need to prevent visual fatigue of personal computer users due to the widespread use of computer technology. The purpose of the work is the analysis and development on the basis of the created software and hardware complex of the optimal mode of operation and removal of fatigue, conducting a series of experiments to test the effectiveness of the proposed mode of work and rest. Conclusions: The use of microcontroller technology with a wireless interface greatly simplifies the component base of the developed composite electronic components and expands the possibilities of diagnosing human fatigue. The proposed software makes this procedure accessible and easy for most diagnostic operators in the world.

Key words: visual fatigue, visual impairments, stimulus generation measurements, professional burnout.

Становлення сучасного суспільства характеризується стрімким розвитком інформаційно-комунікаційних технологій (ІКТ). Важливу роль в модернізації відіграє діяльність ІКТ: віртуалізація суспільних відносин в умовах глобалізації. Завдяки активному використанню інформаційно-комунікаційних технологій все суспільство інтегрується в єдину надсистему. У сучасному світі через пандемію зріс попит населення на кишенькові персональні комп'ютери, що спонукало розробників створити концепцію компонування мобільних пристроїв. Це стимулює швидке зростання технологій розробки мобільного програмного забезпечення. Хоча нові технології супроводжують людей на всіх етапах еволюції людини, вони порівняно недавно стали предметом спеціальних теоретичних досліджень. Конструктивне розуміння технології забезпечується активним комунікаційним підходом, орієнтованим на взаємодію людей і техніки. Зростає потреба у запобіганні зорової втоми користувачів персональних комп'ютерів, що пов'язано з широким використанням комп'ютерних технологій. Щоб скоротити поточне медичне забезпечення, зменшити потребу в спеціальному офтальмологічному обладнанні і спростити обслуговування користувачів персональних комп'ютерів (ПК), оцінку та зміну функціонального стану гостроти зору слід проводити безпосередньо на робочому місці за допомогою надійні та доступні методи. Метою роботи є аналіз та розробка на основі створеного програмно-апаратного комплексу оптимального режиму роботи та зняття втоми, проведення серії експериментів для перевірки ефективності запропонованого режиму праці та відпочинку. Висновки: використання мікроконтролерної технології з бездротовим інтерфейсом значно спрощує компонентну базу розроблених композитних електронних компонентів і розширює можливості діагностики втоми людини. Запропоноване програмне забезпечення робить процедуру доступною для більшості операторів діагностики у світі. Запропонований в роботі режим праці та відпочинку ефективний навіть при короткому терміні використання і може бути рекомендований для масового використання.

Ключові слова: зорова втома, порушення зору, вимірювання генерації стимулів, професійне вигорання.

В связи с широким распространением компьютерных технологий растет потребность в предотвращении зрительной усталости пользователей персональных компьютеров. Цель работы – ана-

лиз и разработка на основе созданного программно-аппаратного комплекса оптимального режима работы и снятия утомления, проведение серии экспериментов по проверке эффективности предложенного режима труда и отдыха. Выводы: использование микроконтроллерной техники с беспроводным интерфейсом значительно упрощает компонентную базу разрабатываемых композитных электронных компонентов и расширяет возможности диагностики утомления человека. Предлагаемое программное обеспечение делает эту процедуру доступной и простой для большинства диагностов в мире.

Ключевые слова: зрительная усталость, нарушение зрения, измерение генерации стимулов, профессиональное выгорание.

Introduction. Performing work in a state of fatigue, the number of erroneous actions, inadequate reactions to alarm signals and warning indications of devices naturally increases. Even a small degree of fatigue can manifest itself as a decrease in the accuracy of coordination of movements, visual acuity and field of vision, readiness and memory strength, the speed of thinking, the ability to perceive information, narrowing the amount of attention and difficulty in concentrating, increasing the time of sensorimotor reactions, and distorting the sense of time. Confidence in the correctness of the actions being performed disappears, the time for making decisions and performing control actions increases, an incorrect assessment of the situation and inadequate actions are possible, criticality to one's actions decreases, control over the actions performed, and the degree of automatism of previously developed skills [2; 3].

The tasks of determining the functional state were carried out by scientists L. Wang, X. Zhong, A. Martino Cinnera, L. Manzari, F. Tozzi, M. Tonotsuka, R. Horie, K. Hirata. The literature discusses a number of methods for determining the functional state and fatigue of a human being, but the process of adaptation to stress is not fully accessed in terms of individual characteristics of a particular human, there is no simple and obvious way of determining the onset of fatigue. Critical Flicker Fusion Frequency (CFFF) accurately assess the level of person's fatigue.

Studies of the processes occurring in the body of a person working at a computer have been carried out for a long time. The working group on the hygienic aspects of the use of computer technology of the World Health Organization (WHO) back in 1990,

summarizing the materials of international scientific conferences (Canada 1984, Sweden 1986, etc.), as well as scientific research concerning the impact of computer technology on human health, established 5 possible risks in violation of the health status of workers: eye diseases and visual impairments; disorders of the musculoskeletal system; stress-related disorders; skin diseases; adverse pregnancy outcomes [1; 6].

The detected disorders in the body were associated with the nature, intensity and mechanisms of the impact of environmental factors on the human body. Studies have shown that working at a computer is a model of mental work performed in a monotonous sitting posture, in conditions of limited general muscle activity with mobility of the hands, with significant eye strain against a background of high neuro-emotional stress under the influence of factors of various physical nature.

Data and Methods. Our research was carried out on the basis of a private enterprise "Workconsult". Several people over the age of 50 were selected as the target group, several people were between the ages of 30 and 50, and the rest were between the ages of 20 and 30. The measurements were carried out according to the working schedule of the experimental group.

The research presents the results of a study of the degree of visual fatigue of a person working at a computer monitor during a standard 8-hour day, which requires concentration of visual and mental attention, such as working at a PC. The study took into account the number of people that were functionally available for the experiment. A decrease in CFFF at the end of the working day by 31.9 ± 5.9 % was noted as a symptom of fatigue (Table 1).

This study was carried out using a special diagnostic module controlled by a mobile phone. In this module, stimuli of red, blue and green colors were set. The device generated colored light pulses of various frequencies and wavelengths. The frequency range is from 3 to 70 Hz (frequency adjustment is smooth), and the duration of one optical pulse is 5 ms or more. LEDs, which are non-inertial light sources, are used to generate light stimuli. Stimulus generation measurements are displayed on the phone screen. Light stimulation is controlled by the diagnostic module.

Test Results. Further studies were carried out in assessing CFFF, when only red stimuli were given with an increasing frequency, since the highest sensitivity to such stimuli was noted. Visual fatigue of the visual system was quantified according to the Visual Fatigue Index (VFI) criteria, which summarizes the frequency and severity of the following nine symptoms: 1) eye irritation, 2) itchy eyes, 3) gritty eyes, 4) hypersensitivity to light, 5) eye pain, 6) redness of the eyes, 7) excess secretion of the lacrimal glands, 8) dry eyes, 9) a feeling of blurred eyes on concentration.

The groups were divided using the principle of the presence of complaints of vision diseases

according to the indicators of visual discomfort. Group A concatenate persons with mild visual fatigue (n=16). Group B concatenate persons with severe visual fatigue (n=18). In these groups, not the age of the people was taken into account, but only the functional state of their vision. The groups were divided into subgroups to determine the most effective way to restore visual performance. The first subgroup rested every hour (10 minutes) during the work process to correct visual fatigue, the second subgroup worked as usual. Measurements were made during the working week.

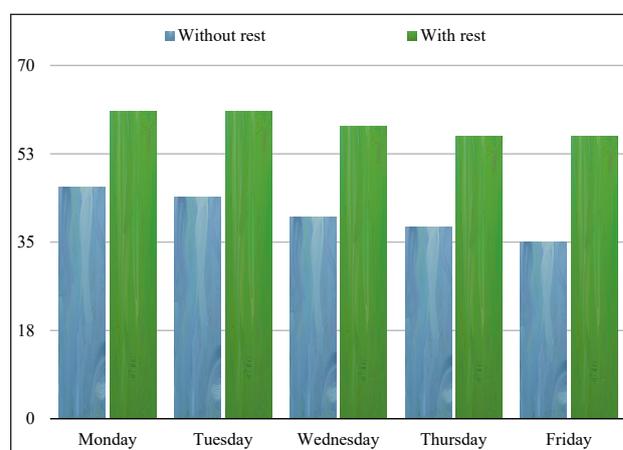


Fig. 1. CFFF indicators for all employees of the team, group A

Table 1

CFFF indicators for all employees of the team before the experiment at 9.00 (in the morning)

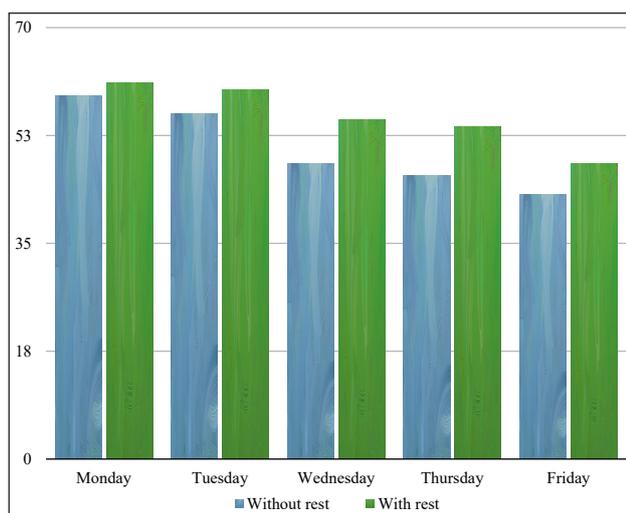
| Age | Number of eyes | CFFF data (Hz) | | | $ M_3 - M_K $ |
|------------------|----------------|----------------|-------------|-------------|---------------|
| | | green color | red color | blue colour | |
| $m \pm M$ | n | $m \pm M_3$ | $m \pm M_K$ | $M_c \pm m$ | Δ |
| 25,3±0,6 (20–30) | 20 | 62,0±0,7 | 61,1±0,6 | 58,8±0,6 | 0,9 |
| 35,5±0,5 (30–35) | 30 | 41,3±0,7 | 45,6±0,6 | 43,3±0,6 | 4,3 |
| 46,4±0,7 (35–45) | 12 | 42,0±0,6 | 46,0±0,4 | 44,8±0,5 | 4 |
| 59,2±5,0 (45–55) | 6 | 61,7±0,7 | 63,0±0,9 | 60,6±1,0 | 2 |
| Average rate | 68 | 62,2 | 54 | 51,8 | 2,8 |

Table 2

CFFF indicators for all employees of the team before the experiment at 18.00 (in the evening)

| Age | Number of eyes | CFFF data (Hz) | | | $ M_3 - M_K $ |
|-----------------|----------------|----------------|-------------|-------------|---------------|
| | | green color | red color | blue color | |
| $m \pm M$ | n | $m \pm M_3$ | $m \pm M_K$ | $M_c \pm m$ | Δ |
| 25,3±0,6(20–30) | 20 | 32,55±0,7 | 21,8±0,6 | 47±0,6 | 10,704 |
| 35,5±0,5(30–35) | 30 | 24,9±0,7 | 30±0,6 | 35±0,6 | 5,196 |
| 46,4±0,7(35–45) | 12 | 31,5±0,6 | 30,36±0,4 | 35,84±0,5 | 1,14 |
| 59,2±5,0(45–55) | 6 | 46,275±0,7 | 41,58±0,9 | 48,48±1,0 | 4,695 |
| Average rate | 68 | 33,80625 | 30,9705 | 41,5 | 2,84 |

In the group with less expressed complaints of visual fatigue, CFFF indicators had significant deviations from the generally accepted normal values – up to 21 %, as well as in the group with severe complaints of visual discomfort – 50 %. After 7 days of fixing the readings in group A, the following changes occurred: in the subgroup where short-term rest was used, this indicator changed to normal. In the subgroup where they worked in the regular mode, the CFFF indicators by the end of the working week decreased by 18.8 %, these indicators are in the lower range of normal values, initially the CFFF indicators in this group were significantly lower than in group B. The results of CFFF diagnostics in the group with severe complaints of visual fatigue, as can be seen from the figure, were in the lower range of normal values before regular short-term rest.



Index of Visual Fatigue (IVF) indices at the beginning of the study corresponded to the values reflecting the presence of severe visual fatigue – 23.9 ± 4.3 and 27.6 ± 4.8 points in groups A and B, respectively.

At the end of the experiment, the average IVF value for subjects whose short-term rest was used as rehabilitation was observed to statistically decrease to 16.3 ± 2.1 points, which indicates the absence of signs of visual fatigue at the workplace and can be direct evidence of work safety for the health of the company's employees.

To elucidate the mechanism of development of visual fatigue, the obtained data were analyzed

correlatively. In the course of the analysis, it was found that before the start of rehabilitation measures (10 minutes rest after 1 hour of work), the IVF indices depend on the CFFF. It should be noted that after rehabilitation measures this connection disappeared, most likely due to a decrease in the number of complaints of visual discomfort and an increase in the CFFF index to the level of generally accepted criteria.

As already mentioned, in the group with severe complaints of visual fatigue, the CFFF indices were initially close to normal values corresponding to 37–65 Hz.

An increase in the CFFF index after a short rest may be associated with an improvement in blood flow in the choroidal blood flow system and an increase in the energy and plastic metabolism of the central retinal artery basin, as well as the neuroreceptive system of the eyes.

Thus, it was found that a short visual rest led to an increase in the CFFF index, but since the experiment took a short period of time and an insufficient amount of human resources, the potential and direct dependence on the mental fatigue index from CFFF is not fully proven and is planned to be developed by the authors in subsequent research.

Establishing relationships between occupational, environmental and social stressors and the resulting consequences for humans – anthropoecological fatigue, stress diseases, accelerated biological aging, is necessary to determine an effective public health policy. The joint efforts of biologists, physicians, psychologists and sociologists are aimed at establishing the relationship between chronic stress reactions and chronic fatigue and biological aging and diseases [4; 7].

Thus, the publication describes the mechanisms common to fatigue and aging. The genetically programmed rate of biological wear (aging and resistance to stress) is fundamentally variable and modulated by environmental factors. When studying the ratio of the role of endogenous, genetic and exogenous factors on these processes, it was found that the latter determine about one third of age-related changes in physical and half of the age-related decrement of mental

performance, hypertension and hyperlipidemia. In the same work, it was shown that the dynamics of the population risk of functional limitations is significantly influenced by working conditions and visual fatigue. The lack of rest arising from physiologically inadequate modes of action of professional and non-professional stressors serves as a target diagnostic sign of a state of chronic fatigue, which is the root cause, initial stage and an accompanying component of almost all occupationally-related chronic diseases of workers.

Upon further research, it was found that 31 % of workers were more likely to fatigue at work on weekends, and only on vacation – 16 % of workers; moderate fatigue, respectively, in 18 and 2 % of employees; slight fatigue – 2 % of employees on weekends, among them there are no people with the accumulation of fatigue for vacations. Among workers who do not notice professionally conditioned fatigue on working days, only 5 % note a slight deterioration in health in the previous year. Among the “slightly tired”, 32 % of employees reported a slight deterioration in health, 1 % a significant deterioration. 35 % of moderately tired health worsened slightly over the year, and 8 % significantly. For “very tired” these values were 42 and 30 %.

The established regularity of the relationship between acute and chronic fatigue is based on the duration of the recovery period, which increases with an increase in the degree of daily fatigue. As shown in severe fatigue during an 8-hour day, the duration of being in a state of fatigue is 14.8 hours/day, 1/3 of these hours of fatigue is observed during working hours, 2/3 – outside working hours. Severely tired workers with an 8-hour working day and a 40-hour week, 70–75 hours a week are in a state of fatigue, a daily and monthly lack of rest occurs, which leads to the development of a state of chronic fatigue, which affects the nature of the annual change in the employee’s health. The risk of worsening health over the year, according to the testimony of workers, increases with an increase in the degree of their usual fatigue at work, with great fatigue it is 62 ± 6 %, which statistically

coincides with this value in people with CFS – 63 ± 5 %.

Discussion. Analysis of the problems that determine human digital visual fatigue has shown the existence of many methods. Most of them can only work with a certain time delay. As the physical form develops, the parameters that determine fatigue lose sensitivity and the amount of information, and data processing is primarily focused on the characteristics of its dynamics, comparing individual indicators with the average. Analysis of the involved processes, the nature of adaptation to stress, determination of the moment of onset of fatigue and overwork are not always immediately recorded by modern devices. The use of microcontroller technology with a wireless interface greatly simplifies the component base of the developed composite electronic components and expands the capabilities of human fatigue diagnostics [8].

The mobilization of intelligent tools facilitates the implementation of remotecontrol methods and smooth control of the main parameters of the diagnostic process. In comparison with the previous author’s model, the measurement accuracy is improved by 67 %. The proposed software makes this procedure simple and accessible to most diagnostic operators. But this model does not take into account the moment of training, which can distort the indicators, and the software does not provide the ability to save the indicators obtained during the study and build graphs for each color load. The research methodology did not take into account the distinctive criteria of fatigue, overwork and professional burnout. With further research and modernization, it became necessary for additional qualitative analyzes of the surveyed questionnaires, the preparation of additional test items and the development of a new survey methodology [9].

The lack of rest, arising under the modes of exposure to environmental, ergonomic and psychosocial factors that are inadequate to the regenerative capacity of the human body, is a target diagnostic sign of a state of chronic fatigue and fatigue. Chronic fatigue modulates the aging process and the growth of chronic

human diseases. To assess these processes, the values of age population trends in health indicators are required, observed in a favorable environment, without the harmful effects of professional and non-professional factors. With a high and very high level of physiological labor intensity, the annual increase in the risk of CFS increases by 2 and 4 times [3]. Programs for improving working conditions should include a section on minimizing the risks of a permanent lack of rest among workers, including regulation of the physiological intensity of work and options for “time protection” from harmful environmental factors [6].

Sociological surveys show that according to the population, the main causes of all diseases are work and stress. The share of the population employed in occupations in which psychogenic factors are the most frequent cause of stress and a source of health risk for workers is constantly increasing. When studying the impact of psychosocial factors on the health of the working population, the most commonly used models are demand-control-support (DCS) and “effort-reward-imbalance” (ERI). The main goal of the ERI model is to identify the relationship between employee health and the imbalance between his efforts at work and remuneration. In the last decade, more and more studies of organizational and psychosocial health factors of workers using DCS and ERI models are being integrated into a more general work-life balance system, in

which the root cause of chronic health disorders is the need for recovery from work, arising with occupational stress and workload inadequate to the recovery capabilities of the human body [5]. To assess the degree of harm of effort-reward imbalance, the chronobiological criterion “annual increase in risk” should be used, using modern diagnostic methods.

The authors plan to work on the relationship between digital visual fatigue and burnout, chronic fatigue in the future.

Conclusions. 1. The use of microcontroller technology with a wireless interface greatly simplifies the component base of the developed composite electronic components and expands the capabilities of human fatigue diagnostics.

2. The attractiveness of mobile intelligent tools contributes to the introduction of remotecontrol methods and smooth adjustment of the main parameters of the diagnostic process.

3. The offered software makes this procedure accessible and easy for most diagnostic operators in the world.

4. The mode of work and rest, proposed in the work, is effective even for a short period of use and can be recommended for mass use.

The practical significance of the work. The study can be used in the field of human life safety, industrial sanitation, in particular, in the system for determining the level of fatigue of programmers, personal computer operators, dispensary observations of the state of vision of schoolchildren and students.

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