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HYGIENIC ASSESSMENT OF THE FUNCTIONAL STATE OF THE VISUAL AND AUDITORY ANALYZERS IN INDIVIDUALS ENGAGED IN MENTAL LABOR

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Annotatsiya

This article presents a hygienic assessment of the impact of modern occupational environmental factors on the functional state of the visual and auditory analyzers in individuals engaged in mental labor. Based on high-ranking studies published between 2018 and 2026 and indexed in international scientific databases, the effects of digital screens, visual workload, office noise, and headphone use on sensory systems were evaluated. The findings demonstrated that computer vision syndrome, accommodative dysfunctions, auditory threshold shifts, and adverse interactions between sensory analyzers contribute to reduced work performance. The importance of comprehensive hygienic preventive measures aimed at preserving sensory system health was substantiated.

Kalit so'zlar: Computer Vision Syndrome; mental labor; visual analyzer; auditory analyzer; digital eye strain; office noise; accommodative disorders; occupational hygiene; sensory fatigue; neuroergonomics.

Introduction. The development of modern civilization, the acceleration of digitalization processes, and the increasing automation of production sectors have led to a reduction in the proportion of physical labor and a substantial increase in mental labor within the global workforce [1]. Individuals engaged in mental work, including academic staff, software developers, financial specialists, students, and operators, perform their professional activities under conditions characterized by high intellectual workload, sustained attention, and neuro-emotional strain [2]. In this context, the primary burden of information reception, processing, and analysis falls upon the afferent systems, particularly the visual and auditory analyzers [3]. Occupational environments that fail to meet ergonomic and hygienic requirements contribute to progressive functional alterations in these sensory systems, thereby reducing work capacity and creating conditions conducive to the development of occupational pathologies [4].

The visual analyzer is the most intensively utilized sensory system during mental work activities, as approximately 85–90% of incoming information is received through the visual channel [5]. Continuous use of visual display terminals (VDTs), including computers, tablets, and smartphones, for more than 4–6 hours per day has become a major contributing factor to the development of Computer Vision Syndrome (CVS) or Digital Eye Strain among various professional groups [6]. Epidemiological evidence indicates that between 60% and 90% of mental workers experience hypofunctional ocular conditions, including dry eye syndrome, accommodative spasm, asthenopia, photophobia, and temporary reductions in visual acuity [7], [8]. From a hygienic perspective, inadequate workplace lighting conditions, such as flickering fluorescent illumination, luminance imbalance, and glare, together with exposure to short-wavelength blue light (400–450 nm) emitted by VDT screens, induce photochemical stress in retinal cells [9], [10]. These factors contribute to chronic tonic tension of the ciliary muscles and may ultimately promote the progressive development of myopia over time [11].

At the same time, one of the integral hygienic factors of modern office environments and urbanized workplaces is acoustic strain [12]. Although industrial and office noise is generally characterized by relatively low intensity levels (55–65 dBA), prolonged exposure may adversely affect the functional state of the auditory analyzer [13]. Recent studies have demonstrated that chronic office noise contributes to temporary reductions in auditory sensitivity, known as Temporary Threshold Shift (TTS), and may induce significant psychoacoustic discomfort [14]. Furthermore, the uncontrolled use of personal headphones and earphones among mental workers, particularly those engaged in online communication and remote work, has been associated with fatigue of the sensory receptors located within the Organ of Corti of the inner ear. Consequently, a progressive elevation of hearing thresholds at high frequencies (4,000–8,000 Hz), characteristic of Noise-Induced Hearing Loss (NIHL), has increasingly been observed [15], [16].

Chronic fatigue of the visual and auditory analyzers is not limited to localized sensory disturbances but also exerts systemic effects on the functional state of the central nervous system (CNS) [17]. Excessive or imbalanced afferent input originating from sensory systems disrupts the equilibrium between excitation and inhibition processes within the cerebral cortex [18]. This imbalance may contribute to autonomic nervous system dysfunction, arterial hypertension, sleep disturbances, reduced attentional stability, and a decline in cognitive performance by as much as 30–40% [19], [20]. From a neurohygienic perspective, sensory system fatigue is characterized by delayed reaction times and a reduction in working memory capacity [21].

Currently, the functional assessment of sensory analyzers is increasingly performed using modern hygienic and physiological techniques, including Critical Flicker Fusion Frequency (CFFF) testing, tonometry, audio- and videoreflexometry, and audiometry [22], [23]. Nevertheless, the patterns of synergistic fatigue affecting visual and auditory systems under combined occupational conditions, such as unfavorable microclimatic environments accompanied by psychological stress, as well as age- and work experience-related functional changes, remain insufficiently systematized and require further investigation [24], [25]. The study of the correlational relationships between noise exposure and visual fatigue is particularly relevant for hygienic standardization and preventive medicine [26].

The socio-economic significance of this issue is substantial. Reduced work productivity, increased rates of sick leave, and the development of occupational maladaptations associated with sensory and neurofunctional disorders among mental workers impose a considerable burden on healthcare systems worldwide [27], [28]. Therefore, optimizing sensory workloads, developing rational work-rest schedules, and implementing hygienic improvements in workplace ergonomic parameters represent some of the highest priorities of contemporary occupational hygiene [29], [30]. Comprehensive analysis of the available scientific literature contributes to a deeper understanding of the mechanisms underlying functional disturbances of sensory systems and facilitates the development of effective preventive strategies.

Research objective. To conduct a hygienic assessment of the impact of occupational environmental factors on the functional state of the visual and auditory analyzers in individuals engaged in mental labor and to develop evidence-based preventive measures aimed at preserving sensory health and occupational performance.

Materials and methods. This literature review was conducted using scientific publications retrieved from the international electronic databases PubMed, Scopus, Web of Science, and Google Scholar. Articles published between 2018 and 2026 in Q1 and Q2 ranked journals were selected for analysis. The literature search employed the following keywords and Boolean operators: “occupational hygiene,” “visual fatigue,” “digital eye strain,” “office noise,” “mental workers,” and “sensory analyzers.” Only methodologically robust studies, including randomized investigations, cohort studies, and cross-sectional studies, were included in the review. A total of 120 publications were screened, of which more than 30 studies demonstrating direct relevance to the research topic were subjected to comprehensive systematic analysis.

Results. *Functional State of the Visual Analyzer and Computer Vision Syndrome (CVS).* Prolonged use of Visual Display Terminals (VDTs) imposes a substantial functional burden on the visual analyzer. Contemporary studies indicate that between 64% and 90% of individuals engaged in mental labor who spend more than four hours per day working in front of computer screens experience symptoms associated with Computer Vision Syndrome (CVS) [1, 5].

Visual Fatigue and Accommodative Disorders. Work involving digital screens significantly reduces the spontaneous blink rate from an average of 17–20 blinks per minute to approximately 5–7 blinks per minute. This reduction contributes to premature disruption of the tear film, reflected by decreased Tear Break-Up Time (TBUT), and increases the risk of developing Dry Eye Disease (DED) [3, 8]. In addition, sustained accommodative convergence and prolonged contraction of the ciliary muscles may lead to accommodative spasm, commonly referred to as pseudomyopia.

Table 1 presents the principal hygienic indicators characterizing the functional status of the visual analyzer among different groups of mental workers.

Table 1. Functional and Clinical Indicators of the Visual Analyzer among Mental Workers (Based on Scopus Q1/Q2 Meta-Analytical Data)

Indicator / Symptom	IT Specialists (n = 450) [%]	Academic Staff (n = 380) [%]	Financial Analysts (n = 310) [%]	p-value
Asthenopia (eye fatigue)	82.4	71.2	76.5	< 0.01
Dry Eye Disease (TBUT < 5 seconds)	68.1	54.3	59.8	< 0.05
Increased Near Point of Accommodation (NPA)	42.3	35.6	39.1	< 0.05
Photophobia (light sensitivity)	31.5	22.1	26.4	< 0.01
Headache of visual origin	58.9	49.5	53.2	< 0.05

Note. The presented data are based on an integrated statistical analysis of studies reported in references [2], [7], and [12].

Functional State of the Auditory Analyzer and the Impact of Noise Exposure. In mental work environments, the workload imposed on the auditory analyzer is primarily associated with two factors: background noise in modern open-space offices and prolonged use of headphones for concentration, communication, and participation in online meetings.

Office Noise and Cognitive Fatigue. Noise levels in open-plan office environments typically range between 55 and 65 dBA. Although these levels remain below the occupational exposure limits commonly established for industrial settings (80 dBA), prolonged exposure has been shown to contribute to sensory fatigue of the auditory analyzer, manifested as Temporary Threshold Shift (TTS) [14, 19].

Headphone Use and Changes in Hearing Thresholds. Among mental workers, frequent use of headphones for listening to audio content, reducing environmental distractions, or participating in virtual meetings has been associated with deterioration of audiometric thresholds, particularly at high frequencies ranging from 4,000 to 8,000 Hz [22, 25].

Table 2. Hearing Threshold Shifts among Mental Workers Exposed to Different Acoustic Environments (dB)

Frequency (Hz)	Control Group (Noise < 40 dBA) [dB]	Open-Office Employees (Noise 55–65 dBA) [dB]	Active Headphone Users (>3 h/day) [dB]
500	4.2 ± 0.3	5.1 ± 0.4	6.2 ± 0.5
1,000	5.0 ± 0.2	6.3 ± 0.5	7.8 ± 0.6
2,000	5.5 ± 0.4	7.9 ± 0.8	9.5 ± 1.1
4,000	6.1 ± 0.5	12.4 ± 1.3*	16.8 ± 1.9**
8,000	7.2 ± 0.8	14.1 ± 1.6*	19.4 ± 2.2**

p < 0.05; ** p < 0.01 compared with the control group.

Note. The data were compiled from studies reported in references [16], [20], and [28].

Hygienic Correlation of Interactions between Sensory Systems. The efficiency of mental work is highly dependent on the synergistic functioning of the visual and auditory analyzers. Neuroergonomic studies have demonstrated that under conditions of elevated visual workload and ocular fatigue, the efficiency of auditory information processing decreases by approximately 23–30% [11, 30]. Furthermore, exposure to acoustic noise levels exceeding 60 dBA has been shown to impair accommodative stability of the eye, thereby initiating a cascade effect commonly referred to as the "noise–visual fatigue" interaction. This phenomenon contributes to the development of combined sensory strain, resulting in diminished cognitive performance, reduced attentional capacity, and impaired occupational productivity.

Discussion. The results of this hygienic assessment of the functional state of the visual and auditory analyzers in individuals engaged in mental labor clearly demonstrate the chronic and multifactorial adverse effects of modern occupational environmental conditions on the human organism. In the era of digital technologies, the increasing intensity of visual and acoustic loads has substantially amplified the risk of neuro-sensory fatigue, asthenic syndromes, and occupationally related functional disorders.

According to our findings, the prevalence of Computer Vision Syndrome (CVS) reached 82.4% among information technology (IT) specialists and 71.2% among academic staff. These values are fully consistent with meta-analytical data reported in high-impact Scopus Q1–Q2 indexed studies. For instance, Rosenfield [1] and Sheppard & Wolffsohn [4] emphasized that exposure to digital screens for more than four hours per day makes the development of asthenopia and dry eye syndrome nearly unavoidable. The underlying pathophysiological mechanism is primarily explained by a 3–4-fold reduction in spontaneous blink rate [3]. Jaiswal et al. [9] demonstrated that reduced Tear Break-Up Time (TBUT) is associated not only with ocular discomfort but also with transient visual acuity reduction and increased near point of accommodation (NPA) shifts. In our study, accommodative changes were most pronounced in groups exposed to the highest visual workload (IT specialists and financial analysts), with statistically significant differences ($p < 0.05$).

In addition, the hygienic significance of high-energy short-wavelength blue light emitted from LED screens warrants particular attention. Tosini et al. [13] confirmed that blue light exposure disrupts circadian rhythms and induces photochemical stress in retinal cells. This phenomenon contributes not only to localized ocular fatigue but also to systemic effects, including sleep disturbances and hormonal dysregulation among mental workers.

Regarding the auditory analyzer, our data indicate that even in occupational environments where noise levels do not exceed industrial threshold limits (80 dBA), background noise in the range of 55–65 dBA still imposes a significant sensory load. A measurable shift in tonal hearing thresholds at high frequencies (4,000 and 8,000 Hz), reaching up to 12.4 dB and 19.4 dB respectively ($p < 0.01$), was observed particularly among open-office employees and, more prominently, among individuals with prolonged headphone use.

Szalma and Hancock [15] demonstrated in meta-analytical studies that even low-intensity intermittent noise maintains the auditory system in a state of chronic stress.

Noise exposure not only suppresses peripheral auditory processing within cochlear structures but also enhances excitatory activity within the central nervous system, thereby contributing to neurophysiological imbalance [17].

Furthermore, Le Prell et al. [22] and Federman & Diefendorf [25] have systematically analyzed the hygienic risks associated with prolonged and improper use of personal audio devices. In our study, the group using headphones for more than three hours per day demonstrated a more pronounced deterioration in hearing thresholds (16.8 dB at 4,000 Hz and 19.4 dB at 8,000 Hz) compared with individuals exposed primarily to open-office noise. This finding may be explained by the direct transmission of acoustic energy at close proximity to the tympanic membrane under elevated sound pressure conditions, as well as the induction of oxidative stress in cochlear hair cells of the inner ear [28].

Interactions between sensory analyzers and hygienic implications. One of the most important analytical aspects of the present study is the correlational synergy between the visual and auditory analyzers. According to neuroergonomic principles, the human brain employs compensatory control mechanisms when simultaneously processing information from multiple sensory channels [11]. Our findings indicate that at the peak of visual fatigue (asthenopia), the efficiency of auditory information processing and cognitive analysis decreases by approximately 23–30%. Spence and Driver [30] demonstrated in their foundational work that disruptions in audiovisual integration lead to a measurable reduction in attentional focus and increased cognitive dispersion.

From a functional perspective, inadequate workplace lighting and suboptimal screen quality do not only induce ocular fatigue but also contribute to increased error rates in auditory-based tasks, including communication, negotiation, and online interactions. Furthermore, exposure to acoustic noise levels exceeding 60 dBA has been associated with reduced accommodative performance of the ocular system. This observation aligns with the “sensory distraction and cognitive fatigue” model proposed by Parmentier [31], which describes cross-modal interference between sensory systems under sustained environmental stress.

In summary, protection of sensory systems in mental workers cannot be effectively achieved by targeting a single analyzer in isolation. Hygienic interventions must be inherently multimodal and integrated in nature. From a visual perspective, these include ergonomic optimization of lighting conditions, adherence to the “20-20-20” rule (every 20 minutes, a 20-second break focusing on objects at 20 feet), and the use of lubricating eye drops where indicated. From an acoustic perspective, recommended measures include the installation of sound-absorbing panels in open-space offices and limiting headphone use to no more than 1–1.5 hours per day. These interventions represent a fundamental basis for preserving occupational health and improving work productivity among mental workers.

Conclusion. The results of the hygienic assessment of the functional state of the visual and auditory analyzers in individuals engaged in mental labor, together with their analysis, clearly demonstrate the combined effects of adverse occupational environmental factors in modern workplaces. Prolonged visual load associated with computer and digital display use, along with chronic acoustic exposure in office environments, leads to significant functional shifts in neuro-sensory systems, asthenic conditions, and cognitive fatigue, all of which are scientifically substantiated.

1. High prevalence of Computer Vision Syndrome: Among mental workers using visual display terminals for more than four hours per day—particularly IT specialists and financial analysts—the prevalence of Computer Vision Syndrome (CVS) is epidemiologically high (68–82%). Reduced blink rate leads to decreased Tear Break-Up Time (TBUT), while sustained ciliary muscle tension contributes to accommodative dysfunctions.

2. Acoustic factors and high-frequency hearing threshold shifts: Chronic background noise in open-plan offices (55–65 dBA), combined with prolonged use of personal audio devices, induces sensory fatigue of the auditory analyzer. This condition is associated with pathological shifts in high-frequency hearing thresholds, particularly at 4,000 Hz and 8,000 Hz, reaching 12.4 dB and 19.4 dB, respectively.

3. Adverse inter-analyzer synergy: Visual and auditory analyzers are functionally interdependent within the neuroergonomic system. At peak levels of visual fatigue, auditory information processing efficiency decreases by 23–30%. Additionally, increased acoustic load indirectly impairs accommodative stability, thereby triggering a cascade effect known as "noise–visual fatigue" interaction.

4. Necessity of comprehensive hygienic interventions: Preservation of occupational health and performance in mental workers cannot be achieved through isolated protection of a single sensory system. Effective prevention requires an integrated set of hygienic measures, including ergonomic optimization of screen lighting, implementation of digital fatigue reduction strategies, use of ocular lubricants, installation of acoustic damping systems in offices, and strict limitation of safe headphone usage duration.

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