Assessment of working conditions and informational loads on car drivers

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Abstract. The article provides an overview of risk factors that are caused by the working conditions of car drivers and provides an example of a methodology for assessing visual loads that were measured using a digital video recorder. To assess real visual loads on a car driver, a method for simultaneous recording of information of visual load and heart rate has been developed and tested. The proposed method made it possible to establish a correlation between the dynamics of the flow of visual traffic information and the response of the driver's body in the form of response changes in the pulse. The effectiveness of the method was shown and the correlation of video fragments and pulsograms with R = 0.4 was established. The results of the work are applicable to assess the working conditions of car drivers, when visual stress is a leading factor in working conditions, in order to prevent fatigue and road traffic accidents.

1. Introduction
Drivers' working conditions are a health and safety issue. According to the WHO, approximately 1.25 million people worldwide die each year from road traffic accidents (RTA), and there are 20-50 million cases of non-fatal injuries, their frequency may increase and become the 5th leading cause of death by 2030 [1]. President of the International Automobile Federation, Special Representative of the UN Secretary General for Road Safety Jean Todt noted the high mortality rate in Russia and made recommendations, including legislative ones. According to the traffic police, in 2018 more than 168 thousand accidents occurred on the roads of Russia. They killed more than 18 thousand people, almost 215 thousand were injured. Of these, 2/3 of the dead are pedestrians injured in RTA in the dark.

The labor activity of drivers as a type of operator activity is associated with neuro-emotional and visual stress. Work requires tension of attention, memory, fast sensorimotor coordination, high speed of perception of visual and auditory signals. Physical activity is due to the need to maintain a long-term working position "sitting", which leads to a state of hypokinesia.

A good example is the activities of taxi drivers who work in difficult conditions, deal with problem situations, must comprehend them, identify the problem and find ways to solve it. At the same time, the driver is often limited in time, being late becomes tantamount to an error and can lead to further complication of the problem situation.
In the driver's work the intellectual loads are assessed to the 3rd class of the 2nd degree of harm according to “Guide on Hygienic Assessment of Factors of Working Environment and Work Load. Criteria and Classification of Working Conditions. R 2.2.2006-05”. Approved by the Chief State Sanitary Doctor of the Russian Federation G. G. Onischenko on July 29, 2005.

The ILO has published guidelines for the prevention of stress in bus drivers [2]. The medical and economic consequences of RTA for society were estimated [3]. The occupational hygiene issues of drivers are described in monographs [4, 5]. Among foreign works, we note the work on working conditions, health and the availability of medical services for truckers [6], analysis of diseases of the cardiovascular system and the frequency of heart attacks [7, 8], as well as mental health and sexual dysfunctions of trailer drivers [9, 10].

Recently, researchers from Nofer Institute (Lodz, Poland) investigated the reactions of bus drivers in an emergency on a stand simulator [11] and developed a gaze tracking method to assess the driver's visual strategy [12]. The influence of weather and other conditions on driver fatigue has been studied [13], as well as the issues of medical contraindications to work in the occupation [14]. Eye-tracking is considered a promising method in these studies, but such stands and tools are very expensive and have been built over the years.

A similar development for preventing accidents due to the driver falling asleep was developed at the Institute of Higher Nervous Activity and Neurophysiology of the Russian Academy of Sciences. There is video surveillance of the posts of the Ministry of Internal Affairs, traffic police and security services when working with displays [15]. Recently, the Traffic Regulations were supplemented by clause 26 "Rules for controlling the time of movement of a vehicle and rest" (applies to trucks weighing more than 3.5 tons and buses). Unmanned vehicles are among the priorities of the National Technology Initiative (https://asi.ru/nti/): artificial intelligence (AI) systems are used in solving critical problems, when the incorrect operation of AI systems is associated with a risk to human life and health, etc.

The aim of [16] was to find out how gender (male and female) and gender roles (masculinity and femininity) and their interactions were associated with driving skills and participation in road accidents among young drivers. 217 young drivers (131 males and 86 females) completed a questionnaire that included a short form of Behm's gender roles, an inventory of driver skills, and questions about incident history and background information. The effects of gender and gender roles were tested on baseline variables using Poisson, negative binomial, and hierarchical regression analyses. It was found that gender predicts the number of general, active and passive accidents, as well as perceptual-motor skills. While masculinity scores positively predicted perceptual and motor skills, femininity scores positively predicted safety skills. There is growing evidence that it is more difficult for women to adjust to shift work compared to their male counterparts, and that sleep problems may largely explain this difficulty [17]. The literature indicates that women who work in shifts report poor sleep quality and experience reproductive impairments, an increased risk of breast cancer, and a higher risk of metabolic and cardiovascular disorders.

Sensory loads are caused by the visual analyzer being the main source of information about the environment on the road while driving. The duration of concentrated observation, the density of light and sound signals, the presence of a large number of objects of simultaneous observation determines the work of the driver as the activity of the operator. With the help of the organ of hearing, the driver assesses the serviceability of the vehicle's mechanisms, assesses the traffic situation transmitted by sound signals by other road users. The strength and frequency of the beeps are a warning to other drivers. By ear and visually, the driver perceives the data from the navigation system of the smartphone.

The load on the auditory analyzer takes place in conditions of interference during spoken speech and corresponds to the permissible class 2. The load on the speech apparatus is insignificant - class 1.

There are many publications about human vision. It was found that vision is ideally adapted to the task of extracting conceptual information from visual input with each new fixation of the eye 3-4 times per second, thus the brain processes images in 13 ms [18].
The brain can support two functional streams – visual and auditory – while driving and listening to the radio or using navigation [19]. The known effect of increasing the speed of detection of visual stimuli with the introduction of extraneous sound [20].

Thus, in the literature, among the factors of working conditions and the labor process of drivers, informational visual loads for a complex dynamic road environment are not taken into account, which are largely responsible for driver fatigue and the risk of accidents, especially in the dark. In addition, there are no methods for recording and assessing the flow of information (the so-called bit rate) as an important indicator that determines traffic safety. Also, there is no work on the correlation of the bit rate with the physiological reactions of the driver.

2. Material and methods
A method has been developed for the simultaneous registration of information visual loads and the pulse of a car driver using a digital video recorder (DVR) and a pulse rate monitor. The 720p camera is justified by its prevalence and the pulse was recorded with a monitor at the wrist.

When driving a car driver, a video stream from the road is recorded on a DVR and the pulse is checked as an indicator of the driver's functional state. It is important that the recording on the DVR is time synchronized with the pulse. This video stream was divided into segments of equal length, each of which was mapped to the heart rate at the corresponding time. The segment size was set with a heart rate monitor resolution of 8 s. After measurements, the data were analyzed for a correlation analysis between the intensity of visual information and heart rate and calculated for each situation separately.

The algorithm for measuring visual load included the following stages: a) determination of the observation window (interval heart rate measurement); b) the video signal was subjected to computer processing with division into fragments equal to the width of the observation window, with each window synchronized in time with the measurement of the pulse. Fragments of the footage were evaluated by the volume of disk space: the more information in a fragment, the higher the level of visual load.

The algorithms for assessing the visual and auditory load on the operator are identical. In the first case, the data from the video recorder were analyzed, which is fed to the driver's visual analyzer, and in the second case, the audio data are fed to the auditory analyzer. An experienced professional driver, male, 48 years old, 19 years of experience took part in the research. The duration of the trip was about 5 minutes on a road about 3 km long and included intersections.

3. Results and discussion
420 man-days were analyzed by the method of chronometry of the study of the taxi driver service in Moscow during the first shift. The overall assessment of the density of signals and messages showed that the driver receives an average of 675 light and sound signals per 1 hour of work.

The method of assessing information visual loads on vehicle operators provides an objective assessment of the impact of these loads on the functional state of the driver's body. In addition to the standard situations, the following situations were analyzed: difficult road conditions, traffic at an intersection, traffic on a highway in a city with traffic lights, traffic in a traffic jam and difficult weather conditions: bright sunlight, traffic in fog, at night.

In the course of the study, the dependence of the driver's heart rate on information visual loads was analyzed, which was assessed using DVR data.

In some cases, correlation analysis has shown a high correlation between the video signal and the operator's heart rate, especially in difficult driving conditions. When processing these data, a correlation was revealed that confirms the influence of information visual loads on the functional state of the driver. An example of the resulting graph is shown in Figure 1.
As can be seen from the graph in the figure, changes in the curves of the amount of information and heart rate correlate with almost every fragment, as evidenced by the correlation coefficient $R = 0.4$. The only exceptions are the start and end fragments. This is due to the initial traffic and low still image rate, since video compression algorithms are based on the fact that only keyframes are encoded, and only changing objects are encoded during transitions between them. The more dynamics and the amount of information in the frame, the larger the fragment size.

The remaining discrepancies in the dynamic curves can be explained by equipment imperfections, measurement errors and the fact that the driver may not react to some external driving factors. Note that from the point of view of visual perception, all sequences are statistically significant, since each new fixation of the eye occurs 3-4 times per second [16], so that the duration of each video fragment takes the place of 24-32 fixation of the eye, and this is a statistically large sample.

Despite the limited capabilities of the method, the teeth of the curves of the "information impulse" of the image make it possible to establish the presence of the "dose – effect" relationship. This allows an assessment of the occupational risk of drivers.

4. Conclusions
The proposed method for assessing information visual loads on vehicle operators made it possible to establish a correlation between the dynamics of the flow of visual information and the response of the driver's body, in the form of measured changes in his heart rate.

In the described implementation, the method turned out to be informative. Despite some limitations, the method can be useful for predicting the effectiveness of actions, especially in bad weather and at night, when visual perception of the movement of the environment is especially important. It is possible to automate the method for the implementation of relevant projects, which will make it possible to use this method to assess fatigue with excessive information loads and health risks and thereby reduce the likelihood of accidents.
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