ASSESSING THE INFORMATION FLOWS AND ESTABLISHED THEIR EFFECTS ON THE RESULTS OF DRIVER'S ACTIVITY

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Abstract:

The modern person in an era of information breakthrough faces the problem of choosing and processing information coming to her. Human activities in the systems "driver – vehicle - road - environment" - not an exception. The role and importance of information in all spheres of human activity have increased significantly.

The paper aims to find and assess the patterns of information flow impact on the driver performance in the "driver - vehicle - road - environment" system.

Electroencephalography (EEG) method using the Neurocom hardware and software complex used to determine the change in the electrical activity of the driver's brain during the processing of input information; electrocardiography method using the hardware and software complex «Cardiosens», used to determine the fatigue level of the driver during research; tabular method of double letter cancelation test, involved in determining the time of distraction from the performance of the driver's core activity in laboratory experiments.

Using mathematical modelling methods and methods, mathematical models of EEG and ECG parameters influence on the time of distraction from execution by the driver of the main activity were obtained.

Regression models of the influence of the aggregate of the quantitative characteristics of the intensity of fast (beta-rhythm – β and gamma-rhythm – γ) and slow (delta- rhythm – δ and theta-rhythm –θ) EEG signals are proposed. The regression equations obtained for determining the regularities of the influence of information flow on the results of activity of road users are defined. Set up that the time of the driver's distraction from performing the core activity can reach from 0,94 s. to 4,77 s depending on particular conditions. Information flows arising from the location of noticeable advertising in the driver's field of vision when driving a vehicle, distract his attention from 0,23 s. to 2,81 s.

The practical significance of obtained results is the possibility to use them in coordinating the location of advertising structures and organizing the work of drivers while driving a vehicle.

Key words:
EEG, driver, telephone, billboard, road advertisement, driving behaviour

1. Introduction

The main control element in the traffic system is the driver, which specifically determines the vehicle direction and speed at each moment during driving (Eboli et. al., 2017). All the engineering design of schemes and driving modes are connected in modern conditions with drivers with the help of technical means such as road signs, road markings, traffic lights, scoreboards, sending devices that are means of information. During driving, the main and necessary source of information for the driver is the road environment (road signs, traffic control devices, road users, dashboard in the car). The information load or data stream coming to the driver is constantly increasing due to the rapid growth of information technology. Today, mobile phone, TV, radio equipment, roadside advertising is an integral additional source of information for any driver. Switching attention, even partial, to the source of information can reduce the reliability of the driver, which in turn will increase the likelihood of an accident.

The paper has been a continuation and extended version of conference paper (Dolya, et. al, 2014). On the first stage, the paper analyzes existing research sources on information and their impact on driver activities; analysis of existing studies of the impact of information from 3rd, 4th classes on the characteristics of the driver's activity; special tests for the activity assessment of work activity. According to the theoretical background, the part has been highlighted unsolved issues of information flows and their impact on the driver, set purpose and hypothesis. Next part of paper organized as follow: describing experimental technique to test the hypothesis; making laboratory and field research; analysing obtained data and built regression models dependence curves of the time of abstraction from the performance of the main activity; than conducted field research of information flows on the results of the activities of road users for confirm laboratories hypothesis; on final stage made conclusions. The structural-logical scheme of research was designed to achieve the goal, fig. 1.

Affecting information flows on the driver's performance consisted of two parts: laboratory studies and field studies. Laboratory studies have been made in two stages: first part of the study is to determine the EEG activity in a calm state; the second part determines the EEG activity of the tester during the passage of Double letter cancellation test (DLCT) by Bourdon (Taylor, 1999; Diller et. al., 1974). Obtained time reaction data and ECG curves are comparing with each other. For analyzing time reaction, video recording method had been used. The regression analysis method and the dependence curves of the time of abstraction from the performance of the main activity were calculated taking into account the quantitative characteristics. Field research has made in a real environment for the driver using EEG method and video registration of driver activities.

2. Theoretical background

2.1. Sources of information and their impact on driver activities

Various environmental factors (dazzling light, slippery road, lack of markup, etc.) (Thiffault & Bergeron, 2003), factors in the vehicle and its characteristics (comfort, power, maneuverability, etc.) (Lin, Tang, Zhang & Yu, 2005) and personal human qualities at a specific time: monotonous driving in the transport flow, aggressive riding, temperament, etc. (Eboli, Guido, Mazzulla & Pungillo, 2017) can cause driver's fatigue.

The conditions for obtaining information largely determine the tension of the driver and the correspondence between the information received and the objective reality. In the conditions of continuous increase of the IT component in the life of the society (telephone, roadside advertising, radio, etc.) there is a constant accompaniment of the driver in the vehicle. Today, due to the increase of the IT component in the life of society (telephone, roadside advertising, radio, etc.), the driver is characterized by conditions of perception of information in which, due to lack of time, there are situations when a person becomes unable to achieve the goal or achieving the goal requires additional psycho-physiological and energy costs.

Information coming to the driver when moving, from the point of view of the complexity of tasks, can be divided into four classes (Gavrilov, 1990): 1st class – traffic flow; 2nd class – road route; 3rd class – intersections, adjoining, stops of the city passenger transport, building, road signs; 4th class – elements of the road environment: trees, pillars, road signs, which are on the side and partition strip.
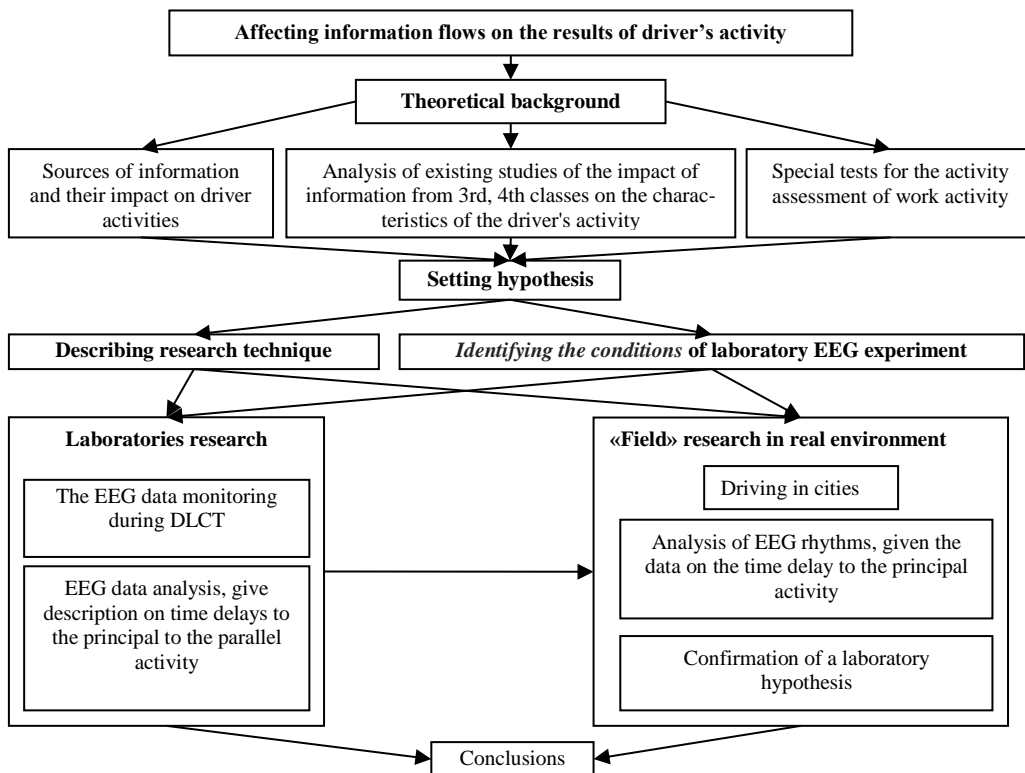
Fig. 1. Stages of the research

3rd and 4th classes of information are the least studied in modern science, because they require special methods of human research (Cai, Lin & Mourant, 2007) and precision equipment for data collection (Gavrilov, Linnik & Banatov, 2002).

Another problem of research is the allocation of the necessary information in the data stream for further analysis (Gavrilov, 1976). The set of such components in one study has not been presented so far.

2.2. Analysis of existing studies of the impact of information from 3rd, 4th classes on the characteristics of the driver's activity

A driver in the Driver-Vehicle-Road-Environment («DVRE») system (Amditis, Pagle, Joshi & Bekiaris, 2010) is a complex probabilistic system, the effect of which can only be predicted with a greater or lesser degree of probability, due to a large number of secondary factors that determine the driver's behavior and the diversity of the psychophysiological state of the driver. Thus, the driver «in the DVRE system» acts as a performing element, seeking to ensure optimal mode of operation of the system in all situations. Perceiving the road situation with the sensory organs (visual analyser), the driver determines the mode of movement of the vehicle. When analysing the suitability of the selected mode of traffic in a traffic environment (Zukowska, 2015), the driver receives additional information about the possibility of safe travel and makes changes to the already established mode of movement.

The technique for determining the width of the carriageway of the road is developed, taking into account the driver's emotional load, which is based on:

- dependencies of the time interval of influence on the driver (his emotional state) of the cars, moving from the left and right sides, from the total number

of cars in the stream (Richter, 1976; Gaca, & Pogodzińska, 2017);

- dependencies of the influence of the road environment (kilometre post or sign, the shield of the signpost, a tree, etc.) on the driver's emotional stress (Piechulla, Mayser, Gehrke & Konig, 2003);

- dependencies of driver's emotional stress evolution on a distance to obstacles on the left and on the right (De Waard, 1996).

The complexity of perceiving the entire amount of information coming to the driver is the lack of time to process it and make the right decision, which increases the likelihood of an accident. In the studies conducted by the ROMIR Monitoring holding, commissioned by the Association of Communication Agencies of Russia and commissioned by the Technical Committee for Standardization № 467 by the Rostekhregulirovaniye (the Federal Agency for Technical Regulation and Metrology) «Outdoor advertising and information signs for public places» there was carried out a study of the effect of external advertising on drivers, and a rating of factors capable of leading to the accident, as well as the rating of the factors creating real emergency situations on the basis of a survey of 1,255 respondents. As a result of the conducted research, in the rating of factors that, in the opinion of the surveyed drivers, theoretically can lead to the emergency situations, dynamic and traditional outdoor advertising share 12th place (7% each). For comparison, 9% of respondents named the behaviour of traffic police officers as an emergency factor, 11% - cars of special services and government with flashing lights, 12% - mobile phones and pedestrians, which are located near the road. The most dangerous, according to respondents, is the specific behaviour of another vehicle (58%), the inadequate behaviour of a pedestrian crossing the roadway (57%) and natural phenomena (42%). However, it should be noted that the data obtained by interview methods express subjective opinions of the respondents. Therefore, they need to be compared with information of a more objective nature, obtained in the course of experimental studies or in combination with other methods.

In their studies Edquist, Horberry, Hosking & Johnston (2011) and Cackowski & Nasar (2003) on the effect of the presence or absence of billboards on the characteristics of driving, full-scale research methods were used. Drivers participating in this experiment did not know the research topic, their car was equipped with front-view cameras, showing the driver's face from two sides, and the car was equipped with other auxiliary technical equipment (speed sensor, lane deviation sensor, GPS navigation). As a result of the research, it was revealed that the presence of billboards does not cause changes in the driving characteristics with respect to the visual behaviour of the drivers, the retention or the speed of the lane.

However, in this work, the psychophysiological state of the driver was not taken into account during the experiment. It should also be borne in mind that the time delay in looking at a particular object is characterized only by the time it takes to receive the information, but does not reflect the time taken to process the information received and to take the appropriate decision as a result of its processing. It is known that there is an optimal amount of incoming information, the processing time of which activates the attention of the driver and corresponds to the safe driving of the car (Prasolenko, Galkin, Burko, 2017). The short-term distraction of attention from the main source of information or short-term overload of information increases the response time to the current situation on the road, which directly leads to an increased risk of accidents.

Based on the presented analysis, scientists have already studied the influence of the following types of information on the characteristics of the driver's activity (Galant & Merkisz, 2017; Urie, Velaga & Maji, 2016): 1. Traffic flow: vehicle speed in the flow; interaction with other vehicles in the stream; traffic intensity; traffic density. 2. Route of the road: visibility distance; Curve radii and profile; areas of roads with a homogeneous road environment; smooth road; lane width; the number of lanes. 3. Road conditions: trees, pillars; traffic signs and road equipment and making. 4. Vehicle: control devices; dimensions; colour and shape vehicle, technical characteristics. 5. Additional sources of information: Billboards, road advertisement; mobile phones; TV devices, radio devices, etc. The last Additional sources of information are less research up today.

2.3. Special tests for the activity assessment of work activity

In psychological practice, the functional states diagnosis is most often carried out on the basis of

assessing the success of a certain type of activity. At the same time, the dynamics of the quantity indicators, the quality and speed of the task, and the underlying changes in the corresponding psychological functions are analysed. The real work activity of a person can serve as an object of analysis. The main indicators of the change in state, in this case, are the shifts in the quantitative and qualitative characteristics of the effectiveness of the work, mainly on their external manifestations (Pauzié, Pachiaudi, 1997). The main psychological means of diagnosis is the use of short tests that characterize the effectiveness of various mental processes when solving the relevant behavioural problems (Dorrian, Lamond, Kozuchowski & Dawson, 2008). In this case, the problem of assessing the functional state appears as a typical psychometric task – to describe and quantify the event under the influence of certain causes (Hockey, 2003).

For diagnostics of states, practically each of the techniques developed in experimental psychology can be used to evaluate the effectiveness of processes of perception, attention, memory, thinking, etc. (Newell & Simon, 1972). These include Bourdon's proof test, the Schulte tables used to characterize attention, the combining Ebbinghaus method (Ebbinghaus, 1983), the paired association method, the Krepelin continuous counting techniques, designed to analyse intellectual processes.

In road research, red-black tables are usually used to study the stability of human attention in various states of the central nervous system (for example, in the process of developing fatigue or recovery), random number tables for studying the performance of visual search (Wilson & Russell, 2003). Proof-reading (deletion of given letters or numbers from a set of randomly arranged signs), which allows estimating the speed of reception and processing of information is also used. The duration of the task performance characterizes the state and performance of mental functions loaded with a kind of operator activity, similar to the test tasks. The case of interest for engineering research is not the duration of the test tasks themselves, but the dynamics of its change under the influence of the investigated factors. The test task speed depends very much on the personal qualities of the testers, and its relative change reduces the individual difference in the assignment and is a reliable characteristic of the influence of the factors studied on the

dynamics of changes in the performance indicators of the testers.

2.4. Hypothesis

The information flows influence on the driver's performance raises the question of the rational amount of information that a driver should receive in the process of moving at a particular moment in time. The amount of information will affect the time to delay the reaction of the driver. Thus, it can be assumed that Additional sources of information do not affect the driver in any way (H1) or this influence is minimal and, in the opposite case (H2), the influence of Additional sources of information has a significant effect and causes the driver to distract from the core process of driving. In laboratorie, we prove the hypothesis about human distraction while making the DLCT. The question is asking simultaneously during the core process. If hypothesis 2 is confirmed, we will conduct an experiment in a road environment for proving it for the driver. The paper aims to find and assess the patterns of information flow impact on the driver in the "driver - vehicle - road - environment" system.

3. Research Results
3.1. Research technique

For the purpose of carrying out scientific research within the paper's framework, a hardware and software complex Neurocom (Universal Psychodiagnostic Complex UPDK-MK) was used to study the electrical activity of the brain and a hardware (Petsyukh, et. al., 2016) and software complex designed to record the electrical activity of the heart – Cardiosens.

The Neurocom has a 19-channel biopotential amplifier with minimum input noise (0.8 μV) and common-mode rejection (> 140 dB), which allows the complex to be used in a typical room. The software of this complex makes it possible to calculate a number of indicators using special mathematical methods (Sergiyivna, Grigorivna, Adamivna, & Sergiyivna, 2012). During the recording of EEG, two main methods are used: bipolar and monopolar. The study used a monopolar record – the activity of one tap at an electrically neutral point (Desimone & Duncan, 1995).

In the Cardiosens system, a digital 3-channel microprocessor-based cardiograph is used as a portable ECG monitor recorder, recording an electronic

signal to a removable SD/MMC flash card (Zhuk et. al,, 2017).

The study is conducted in the laboratory under natural light. During the experiment, the tester occupies a convenient position. With the help of a special helmet, small electrodes are attached to the head of the examinee and are connected by wires to the electroencephalograph (Figure 2).

Before the beginning of the experiment, the tester is informed about the EEG method and its painlessness. A standard EEG scan of the brain is carried out for 20-30 minutes to obtain reliable data, since a special helmet, which exerts minimal pressure on the head of the tester, can cause unpleasant, painful sensations in the course of a prolonged experiment.

For the purity of the experiment and the reduction in the measurement error, in the first stage of the study, the quality of the recording of the electroencephalogram is determined.
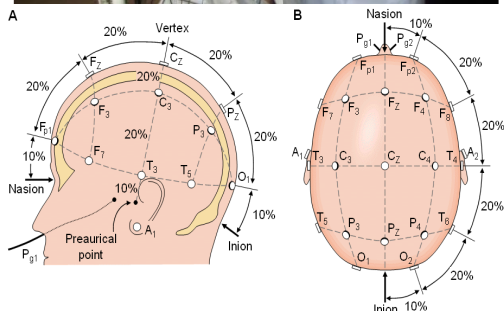

Fig. 2. Attaching of the EEG equipment

During the recording of the EEG, in addition to the electrical activity of the brain, other sources of electromagnetic energy are recorded; they lead to

the appearance of so-called artefacts of the EEG signal components caused by the neural activity of the brain (Uchiyama, et. al., 2003).

Classification of artefacts (Jasper, 1958): muscular artefact; oculographic artefact; cardioartefact; an artefact of pulsation; spiralartefakt; skin-galvanic artefact; gloss kinetic artefact; extraphiophysiological artefact. In the «Neurocom» complex software filters are applied and it is possible to use the ICA-technology for recognition of an artefact and its rejection. All available technologies for combating artefacts do not, however, completely exclude their significance in the recording of EEG (Zhuk, Kovalyshyn & Tcir, 2015).

At the first stage of the study, the conditions for conducting a laboratory experiment using an electroencephalograph will be determined, and it will help to reduce the number of artefacts to a minimum due to consideration of the human factor and environmental factors. In this study, two testers participated to determine the strength of the manifestation of all types of artefacts.

At the second stage of the study, the relationship between the EEG indices and the psychological DLCT was recorded.

The study involved 12 men aged 20-30 years. The EEG of the tester was recorded in a state of calm observation with open eyes. The recording was performed with 19 active electrodes monopolar in the passband of 0-70 Hz with a sampling frequency of 250 Hz. The duration of recording was limited to complaints of the tester in the EEG equipment attachment zone and amounted to 35-45 min. Survey of testers on their painful sensations in the helmet attachment area allows drawing a conclusion that during the investigation of the influence of information flows on the results of the experiment, the standard comfort mode for the duration of the experiment should be considered 20 minutes.

The study consisted of four parts:

1) recording of a background sample of 5 minutes duration in a calm mode with open eyes;

2) recording of a background sample of 5 minutes duration while passing the DLCT;

3) recording a background sample of 5 minutes duration while passing the DLCT in parallel thinking conditions;

4) repeated recording of a background sample of 5 minutes duration while passing the DLCT in parallel thinking conditions.

The obtained EEG pattern is characterized by individual variability both in general form and in individual features (Jeong et. al., 2006; Just, Keller & Cynkar, 2008). At the same time, the individual-specific EEG pattern of a person, having formed up to 15-18 years, persists throughout life; certain changes are possible only in old age. Taking this into account, our experiment includes the first part of a 5-minute study, which measures the «normal» bioelectric activity of each person's brain that participated in this experiment.

The first part of the study is needed not only to determine the EEG activity of the tester in a calm state with the eyes open, but also to identify and correct various obstacles that may cause the appearance of extra-physiological artefacts.

The second part of the experiment is needed not only to determine the EEG activity of the tester during the passage of the DLCT, but also to identify and correct various obstacles that can cause the appearance of oculographic and the muscle activity artefacts.

DLCT should last from 5 to 10 minutes. During all parts of the study, a 5-minute interval was used, which allows obtaining objective test values and three measurements within the same experiment. The number of measurements is important in view of the fact that some of the EEG recordings where artefacts were found were removed from further analysis.

The third and fourth parts of the study have the same technology of the experiment: the tester performs the DLCT, which is for him the main activity and the main source of information retrieval and processing; at the same time, the laboratory assistant distracts the subject, asking questions for an easy mathematical calculation (Table 1), to which the tester must answer correctly, without being distracted from his basic function.

Table 1. An example of the task of obtaining secondary information and its analysis

№	Example	Respondent's answer (+/-)
1	$7 + 10 - 5 = 12$	+
…	$6 + 8 - 5 = 9$	−
23	$15 - 6 + 8 = 17$	+
Σ questions asked		Σ correct answers
23		17

Before the beginning of the second stage of the study, the examinee received a detailed instruction on conducting the DLCT using the procedure. The test form was given to the tester before the start of the second, third and fourth parts of the second stage of the study.

For calculation of quantitative indicators of attention on the DLCT: the amount of information; actual performance; an indicator of the stability of concentration of attention; the accuracy of the task,%; an indicator of the stability of concentration of attention.

By the notion of «rhythm» on the EEG, we mean the kind of electrical activity that corresponds to the state of the brain and is associated with certain cerebral mechanisms. When describing the rhythm, its frequency is noted, peculiar to a certain state and part of the brain; the amplitude and individual characteristic features of its oscillations in time depending on changes in the functional activity of the brain. Each hemisphere of the brain consists of four parts, from which the parameters of all EEG rhythms were obtained for each of the active electrodes: frontal (Fp_1, Fp_2, F_3, F_4, F_7, F_8), parietal (C_3, C_4, P_3, P_4), temporal T_3, T_4, T_5, T_6) and occipital (O_1, O_2). Odd numerical indices correspond to electrodes of the left hemisphere of the brain, and even − to the right hemisphere of the brain. The occipital part of the brain is located above the cerebellum and corresponds to the zone in which associative connections are formed between different parts of the brain that unite the information that comes from them and provide such complex functions as thinking, learning, memory, and speech (Just, Keller & Cynkar, 2008). It should also be noted that the posterior parts of the brain contain zones of visual sensations (Posner & Petersen, 1990), which for the driver are the most important channel for obtaining information. Taking into account all the above, as well as studies of oculographic artefacts, in the analysis of EEG rhythms, we take into account the values obtained from the occipital active electrodes (O_1, O_2).

Analysing the above data, we can conclude that the excess information (additional questions) affects the development of fatigue during the experiment. Indicators of the DLCT are calculated for the entire duration of the experiment (5 minutes) and do not indicate changes in the reception of information at the exact moments of time, therefore the data ob-

tained are not taken into account in further studies. These calculated indicators do not indicate the influence of different amounts of incoming information on the results of the main activity of the tester in real time.

At the third stage of the study, the relationship between the EEG indices and the time delay in processing the information received by the tester during the performance of the main activity was determined, due to a diversion to obtaining information from secondary sources.

Simultaneously with the fulfilment of this task, the tester received information from another source which was not related to the main activity. A secondary source of information in this experiment was the perception by the auditory analyser of questions that were asked. One of the important tasks within the framework of this study is to correctly answer the questions posed when passing the DLCT. In the process of testing, the tester was asked questions, to which he had to answer correctly, without being distracted from his main task – the DLCT. The questions were oral examples of an easy mathematical calculation, consisting of two actions, and were used in the experiment as an additional source of information.

During this experiment, video surveillance of the work of the tester was conducted, with the help of which the time of abstraction from the performance of the main activity was recorded (an example of a video signal is shown in Figure 3).

In order to analyse the EEG data, temporary samples were selected in each probe, corresponding to the time of abstraction from the main activity of the testers. The time of distraction is determined by a video recording of each sample, it is the time when the tester ceased to perform his main function (passing the DLCT), distracted by the questions posed to him.

46 EEG sections of 1-3 s. duration, free from artefacts, were analysed. The analysis involved an active diversion with the most expressive signal. In order to assess the functional state of the cerebral cortex according to EEG data, it is first of all necessary to determine the quantitative characteristics of fast and slow rhythms in a certain period of time. With the help of Neurocom's software, the following quantitative characteristics of EEG rhythms were obtained: average amplitude, dominant frequency, power spectral density of dominant fre-

quency, the power of frequency range, the percentage of total signal power, and the centre of gravity of range.

The fourth stage of the study is the analysis of the EEG indicators taking into account the obtained data on the time of abstraction from the performance of the main activity (during the parallel measurement of the ECG to determine the degree of fatigue of the tester). The course of the experiment is similar to previous studies with the additional use of the hardware and software complex «Cardiosens».

Fig. 3. Example of pointing of the camera during the observation of the work of the tester

All parameters of ECG signal registration, such as the stress index of regulatory systems (stress index) and PARS, reflect and characterize the psychophysiological state of a person with high accuracy. Regardless of the length of the ECG signal recording, the 5-minute recording segments were considered as base samples in the data analysis. The data obtained from the corresponding recording segments in the conducted experiment were to be compared with the background record. Background recording of the ECG signal should be conducted in quiet conditions for at least 5 minutes. The general functional state of the tester is diagnosed based on the PARS values analysis (Grigorova, Davydich, 2015).

One of the most commonly used physiological methods of assessing a person's functional state, except for the ECG, is the EEG. EEG measures the bioelectrical activity of the brain and determines the change in its position over the course of a particular activity. EEG is adequate to the analysis of changes in the functional state of the brain from 0.01 seconds to tens of seconds, which, on its part,

allows to determine the change in human functional state in response to constant changes in the conditions of any type of activity. Application of complex registration of psychophysiological indicators, such as ECG and EEG, makes it possible not only to determine the functional state of the tester but also its changes during the experiment.

Based on the results of the analysis, 56 EEG sections of 1-5 s. duration, free from artefacts, were analysed. The analysis involved an active diversion with the most expressive signal. Using the software of the Neurocom complex, quantitative characteristics of the EEG rhythms were obtained.

3.2. Laboratories research

The tester had to carry out the DLCT, which were his main activity and the main source of information received by the tester through the visual analyser. Simultaneously with the fulfilment of this task, the tester received information not related to the main activity from another source. One of the important tasks within the framework of the research was to correctly answer the questions posed in the form of oral examples for an easy mathematical calculation consisting of two actions, without being distracted from the main task – the DLCT.

During this experiment, video surveillance of the work of the tester was conducted, with the help of which the time of abstraction from the performance of the main activity was recorded.

In order to analyse the EEG data, temporary samples were selected in each sample, corresponding to the time of abstraction from the main activity of the testers. The time of distraction is determined by a video recording of each sample, it is the time when the subject ceased to perform his main function (passing the DLCT), distracted by the questions posed.

The results of the third stage of the study, that is the EEG analysis, were processed using statistical methods with the help of the STATGRAFICS Centurion program. The linear equations (1-4) were obtained by the regression analysis method and the dependence curves (Figures 2-5) of the time of abstraction from the performance of the main activity were calculated taking into account the quantitative characteristics of the intensity of fast (β, γ) and slow (δ, θ) EEG rhythms, reflecting the exciting and inhibitory processes in the cerebral cortex.

Models of changing the time of abstraction (I think that is better to write:" abstraction time changing" but you have to choose this) from the performance of the main activity ("main activity performance" if you want)(τ), taking into account the specific weight of beta-rhythm (β) and gamma-rhythm (γ), characterizing the exciting processes in the cerebral cortex, are as follows:

$$\tau = 5,165 - 0,0796 \cdot \beta; \tag{1}$$

$$\tau = 4,315 - 0,151 \cdot \gamma, \tag{2}$$

where τ – time of distraction from the implementation of the main activity, s; β, γ – specific gravity of beta-rhythm and gamma-rhythm, reflecting the exciting processes in the cerebral cortex.

Dependence of the change in the time of distraction of the tester from the performance of the main activity (τ), taking into account the specific gravity of the beta-rhythm (β) (Figure 4) and gamma-rhythm (γ) (Figure 5), which reflect the exciting processes in the cerebral cortex from full power signal, to which the signals of $\alpha, \beta, \gamma, \delta, \theta$ - rhythms are related, are linear in nature and indicate that as the percentage of signals from these rhythms increases, the time of abstraction from performing the main activity decreases.
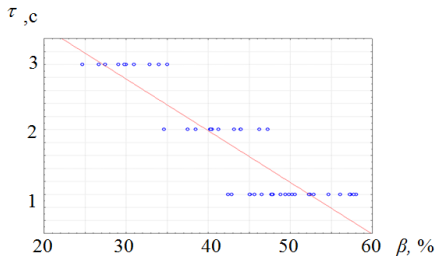
Models of changing the time of abstraction from the performance of the main activity (τ), taking into account the specific gravity of the delta rhythm (δ) and theta rhythm (θ), characterizing the inhibitory processes in the cerebral cortex, are as follows:

$$\tau = -0,629 + 0,126 \cdot \delta; \tag{3}$$

$$\tau = 0,1586 + 0,1929 \cdot \theta, \tag{4}$$

where δ, θ – specific gravity of the Delta-rhythm and theta-rhythm, reflecting the inhibitory processes in the cerebral cortex.

Dependence of the change in the time of distraction of the tester from the performance of the main activity (τ), taking into account the specific gravity of the Delta-rhythm (δ) (Figure 6) and theta-rhythm (θ) (Figure 7), which reflect the inhibitory processes in the cerebral cortex from full power signal, to which the signals of $\alpha, \beta, \gamma, \delta, \theta$ –

rhythms are related, are linear in nature and indicate that as the percentage of signals from these rhythms increases, the time of abstraction from performing the main activity increases.

τ ,c

Fig. 4. Dependence of the change in the time of abstraction from the performance of the main activity (τ) considering the specific gravity of the beta-rhythm
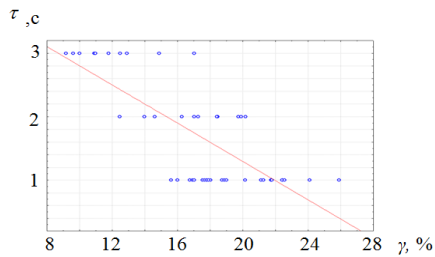
τ ,c

Fig. 5. Dependence of the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the gamma-rhythm

Further, statistical equations and regression methods were used to derive linear equations (5-8) and build the dependences (Figures 6-9) of the time of abstraction from the performance of the main activity, taking into account the quantitative characteristics of the prevalence of excitatory and inhibitory processes in the cerebral cortex: fast ($\beta + \gamma$) and slow ($\delta + \theta$) rhythms of the EEG, as well as the forces of exciting and inhibitory processes in the cerebral cortex: fast ($\beta - \gamma$) and slow ($\delta - \theta$) EEG rhythms.
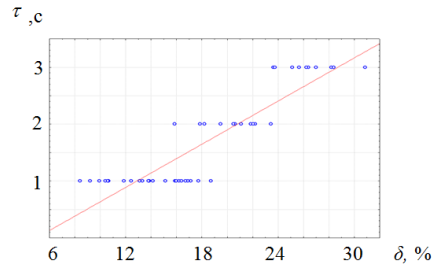
τ ,c

Fig. 6. Dependence of the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the delta rhythm
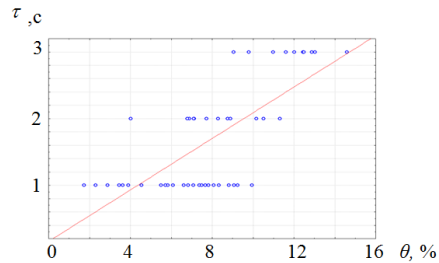
τ ,c

Fig. 7. Dependence of the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the theta rhythm
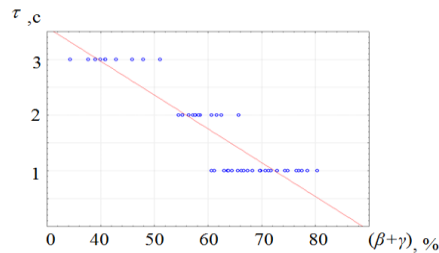
τ ,c

Fig. 8. Dependence of the change in the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the prevalence of the excitatory process in the cerebral cortex
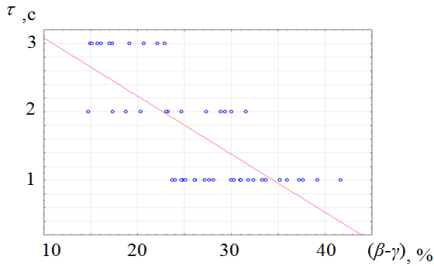
Fig. 9. Dependence of the change in the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the excitatory force in the cerebral cortex

Models of changing the time of abstraction from the performance of the main activity, taking into account the specific gravity of the prevalence and force of the excitatory process in the cerebral cortex, are as follows:

$$\tau = 5,401 - 0,061 \cdot (\beta + \gamma); \qquad (5)$$

$$\tau = 3,925 - 0,085 \cdot (\beta - \gamma), \qquad (6)$$

where $(\beta + \gamma)$, $(\beta - \gamma)$ − specific gravity of the prevalence and force of the excitatory process in the cerebral cortex, respectively.

Models of changing the time of abstraction from the performance of the main activity (τ), taking into account the specific gravity of the prevalence and force of the inhibitory process in the cerebral cortex, are as follows:

$$\tau = -0,572 + 0,086 \cdot (\delta + \theta); \qquad (7)$$

$$\tau = 0,071 + 0,156 \cdot (\delta - \theta), \qquad (8)$$

where $(\delta + \theta)$, $(\delta - \theta)$ – the specific gravity of the prevalence and force of the inhibitory process in the cerebral cortex, respectively.

Dependence of the change in the time of distraction of the tester from the performance of the main activity (τ), taking into account the specific gravity of the prevalence of the excitatory process (Figure 8) and the specific gravity of the excitatory force (Figure 9) in the cerebral cortex, are linear in nature and indicate that as the percentage of signals from these rhythms increases, the time of abstraction from performing the main activity decreases.

Dependence of the change in the time of distraction of the tester from the performance of the main activity (τ), taking into account the specific gravity of the prevalence of the inhibitory process (Figure 10) and the specific gravity of the braking process force (Figure 11) in the cerebral cortex, are linear in nature and indicate that as the percentage of signals from these rhythms increases, the time of abstraction from performing the main activity increases.
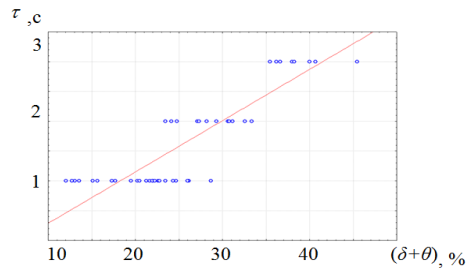

Fig. 10. Dependence of the change in the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the prevalence of the inhibitory process in the cerebral cortex
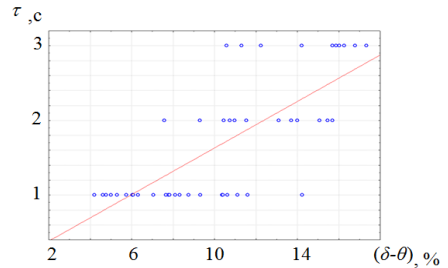

Fig. 11. Dependence of the change in the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the braking process force in the cerebral cortex

The given regression equations have statistical significance, while the value of the linear correlation tends to 1, which for equations (3–4, 7–8) indicates the presence of a direct linear relationship between the variables considered, and for equations (1–2, 5–6, 9–10) of the inverse linear connection. The calculated value of Fisher's criterion for models of changing the time of abstraction from the

performance of the main activity, taking into account the EEG indices (1–10) reflects the informative nature of the model, while the average approximation error is large enough; however, in the framework of the study, the construction of these models is necessary for determining the character of the dependence in constructing a general mathematical model of influence of information flows, which is displayed by EEG indicators, for the time of distraction from the performance of the driver's primary activity.

In order to form a general model of the influence of information flows on the time of the driver's distraction from performing the main activity using the Student's criterion, the most significant ones were found out of all the above factors, which turned out to be quantitative characteristics of the intensity of fast (β, γ) and slow (δ, θ) EEG rhythms.
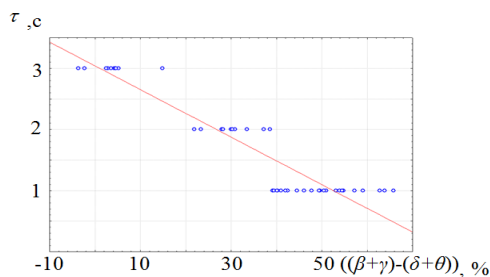

Fig. 12. Dependence of the change in the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the prevalence of excitatory and inhibitory processes in the cerebral cortex

In addition, the dependences of the time of abstraction on the performance of the main activity (τ), taking into account the advantages of the prevalence of the exciting and inhibitory processes (($\beta + \gamma$) – ($\delta + \theta$)) and on the prevalence of the excitatory and inhibitory processes (($\beta - \gamma$) – ($\delta - \theta$)) were analyzed. Using the regression analysis, linear equations (9–10) were obtained and graphs (Figs. 12-13) of these dependencies were built.

Models of changing the time of abstraction from the performance of the main activity (τ), considering the specific gravity of the prevalence and force of the excitatory and inhibitory processes in the cerebral cortex, are as follows:

$$\tau = 3,038 - 0,039 \cdot ((\beta+\gamma) - (\delta+\theta)); \qquad (9)$$
$$\tau = 2,759 - 0,067 \cdot ((\beta-\gamma) - (\delta-\theta)), \qquad (10)$$

where $((\beta+\gamma) - (\delta+\theta))$ – specific gravity of the prevalence of excitatory and inhibitory processes in the cerebral cortex; $((\beta-\gamma) - (\delta-\theta))$ – specific gravity of the strength advantage of excitatory and inhibitory processes in the cerebral cortex.
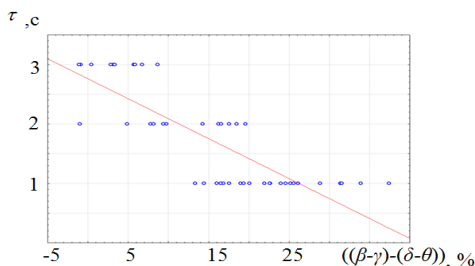

Fig. 13. Dependence of the change in the time of abstraction from the performance of the main activity (τ) taking into account the specific gravity of the prevalence of excitatory and inhibitory processes in the cerebral cortex

Based on the analysis of quantitative characteristics of the intensity of the fast (β, γ) and slow (δ, θ) (Prasolenko, Lobashov, & Galkin, 2015). EEG rhythms constructed a general model of the impact of information flows that appears EEG, at the time of driver's distraction from performing its principal activity is as follows:

$$\Delta\tau_{M1} = 2,733 + 0,0423 \cdot \delta + \\ + 0,0295 \cdot \theta - 0,039 \cdot \beta - 0,018 \cdot \gamma, \qquad (11)$$

$\Delta\tau_{M1}$ – while diverting drivers from performing their primary type of activity reflected EEG.

The results of calculations of the model parameters are given in Table 2, the statistical evaluation of the model − in Table 3. The resulting Fisher criterion (Table 3) shows the influence of informative model of information flows. Multiple correlation coefficients reflect a high degree of closeness of the connection. Assessment of the adequacy of the resulting model (11) was carried out in terms of average error of approximation, the value of which

is equal to 10.86 %, which corresponds with the limits and indicates the adequacy of the model.

In the fourth stage of the research organization of an experiment carried out in the same manner as in the third stage, with the additional use of hardware and software «Cardiosens». At this stage our task was to determine the degree of operator fatigue, there are different methods for determining fatigue (Jeong, et. al., 2006). In our studies, we used the method allows the ECG in real time to determine the degree of fatigue.

Table 2. Statistical evaluation of the general model of the information flows impact on the time of driver distraction from the main activity, considering the performance of EEG

Factors	Percent delta-rate signal from the total power of the signal in the cerebral cortex	Percent theta-rate signal from the total power of the signal in the cerebral cortex	Percent beta-rate signal from the total power of the signal in the cerebral cortex	The percentage of gamma-rate signal from the total power of the signal in the cerebral cortex
Designation, dimension	δ, %	θ, %	β, %	γ, %
Coefficient	0,0423	0,0295	-0,039	-0,018
Standard error	0,329	0,0056	0,009	0,004
Student's t-test: calculated tabular	8,296 1,98	7,613 1,98	3,184 1,98	-9,639 1,98

The mathematical model of the impact of information flows was built based on analysis of the

data obtained during the fourth step, considering the performance of EEG and ECG at the time of the driver's distraction from performing basic activities:

$$\Delta \tau_{M2} = \begin{pmatrix} 5,302 + 0,0899 \cdot \delta \\ +0,052 \cdot \theta \\ -0,0721 \cdot \beta - 0,055 \cdot \gamma \end{pmatrix} \left(\frac{P_r}{P_n}\right) P_r^{\left(1 - \frac{P_r}{P_n}\right)}, \quad (12)$$

$\Delta \tau_{M2}$ – while diverting drivers from their main activity, reflected EEG and ECG; P_r – value of the index activity of regulatory systems in the billing period; P_n – the value of the index activity of the regulatory systems of the background sample.

Table 3. The results of the assessment of the overall impact of the model information flow at the time of driver's distraction from the main activity, considering indicators

Data	Values
Multiple correlation coefficient, %	90,86
The average error of approximation, %	10,86
Fisher's exact test: settlement tabular	241,04 2,46

The results of calculations of the model parameters are given in Table 4. Average value of the approximation error for the model (12) is 9.32 %, which corresponds to the limits and indicates the adequacy of the model. Compared with the model (11), the value of the average error of approximation which is 10.86 %, we see that by incorporating ECG in the model (12), managed to get a more accurate model of the impact of information flows at the time of driver distraction from performing its core activities.

Table 4. Statistical evaluation of the general model of the impact of information flows at the time of driver's distraction from the main activity, considering the performance of EEG and ECG

Data	Values				
Designation, dimension	$\left(\frac{P_r}{P_n}\right) P_r^{\left(1-\frac{P_r}{P_n}\right)}$	$\delta \cdot \left(\frac{P_r}{P_n}\right) P_r^{\left(1-\frac{P_r}{P_n}\right)}$	$\theta \cdot \left(\frac{P_r}{P_n}\right) P_r^{\left(1-\frac{P_r}{P_n}\right)}$	$\beta \cdot \left(\frac{P_r}{P_n}\right) P_r^{\left(1-\frac{P_r}{P_n}\right)}$	$\gamma \cdot \left(\frac{P_r}{P_n}\right) P_r^{\left(1-\frac{P_r}{P_n}\right)}$
Coefficient	5,302	0,0899	0,052	-0,0721	-0,055
Standard error	0,714	0,011	0,018	0,008	0,009
Student's t-test: calculated tabular	7,42167 1,98	8,34781 1,98	2,8517 1,98	-8,6942 1,98	-6,4535 1,98

The results of the assessment of the overall impact of the model information flow at the time of driver distraction from the main activity, considering the performance of EEG and ECG showed next indicators: the Multiple correlation coefficient – 99,11 %; The average error of approximation – 9,32%; Fisher's exact test: settlement – 913,1; tabular– 2,46. Based on the data shown in Table 4, it's calculated Fisher criterion more table index.

3.3 Field research of the impact of information flows on the results of the activities of road users

The study involved 10 drivers aged from 24 to 45 years with a driving experience of 6 to 12 years, with different types of temperament and different sex. For the analysis, data from 45 studies were obtained, at 10 sites with a total collection time of 15 hours. A total of 90 video records were analysed and 121 cases of revealing the influence of additional sources on the driver were detected, fig. 14.

The first stage is the determination of the possibility of carrying out electrophysiological studies of the EEG and ECG in full-scale conditions. Two cars with different gearboxes (mechanical and automatic one) were chosen. The purpose of this stage of the study is to identify all possible obstacles in the equipment (artefacts) when recording EEG and ECG signals. The route of movement of the ring road of the city of Kharkov was chosen.

Under laboratory conditions, the electrodes of the Cardiosens Holter were fixed on the tester, the electrodes of the electroencephalograph Neurocom were attached to a car that was parked in the authorized location at the beginning of the section of the chosen route.

The influence of the information received from the telephone conversation and from the road advertising noticeable for the driver as additional sources of driver distraction from road conditions, which for the latter is a source of mandatory information, is determined to take into account the model obtained (12). Using the model of the influence of information flows at the time of distraction of drivers from the performance of their main activity (12), the dependences shown in Fig. 15 were built.

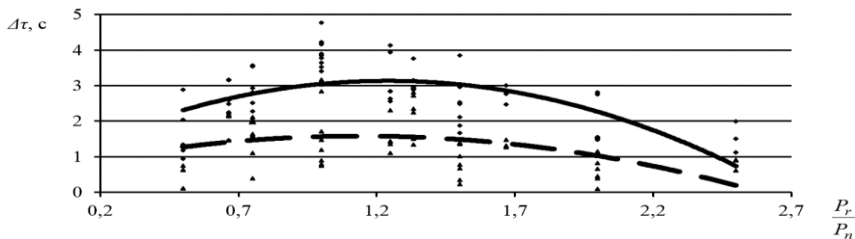Fig. 14. View of the experiment while driving

Fig. 15. Dependences of the time change of the driver's distraction from the performance of the main activity, taking into account his functional state when receiving information obtained from a telephone conversation and roadside advertising:

▬ ▬ ─telephone conversation influence; ▬ ▬ – non-road advertising influence.

The obtained dependences (Fig. 15) indicate that after the beginning of the main activity of the driver and increase of fatigue, the time of abstraction to additional sources of information decreases.

This is due to the fact that the driver is focused on processing basic information from the road and the environment. As can be seen from Fig. 15 additional information obtained from a telephone conversation during the driver's primary activity distracts him twice as much as the information that the driver receives from the revision of roadside advertising.

4. Conclusions

The analysis of scientific approaches and methods for determining the regularities of the information flows influence on the results of activity of road users allows us to conclude that the driver's EEG should be used as an indicator of the intensity of attention when driving in various road and transport situations; though using only EEG method does not provide sufficient information about the mental tension of the driver. It is established that the greatest effect can be achieved in the case of complex fixation of all psycho-physiological indicators. In addition, the EEG allows more accurate assessment of the impact of road conditions on the reliability of the driver for a certain period.

The study of the literature sources allowed the following methods to be reasonably involved: the EEG method using the Neurocom hardware and software complex used to determine the change in the electrical activity of the driver's brain during the processing of input information; ECG method using the hardware and software complex «Cardiosens», used to determine the fatigue level of the driver during research; tabular method DLCT, involved in determining the time of distraction from the performance of the driver's main activity.

The regression equations obtained for determining the regularities of the influence of information flow on the results of activity of road users are linear in nature, and the calculated Fisher's criterion is larger than the tabulated value for each of the models, which indicates their satisfactory informativeness.

The technology of studying the influence of information flows on the results of the operator's activity in the system «man – tool of labour – object of work – working environment» with the filtration of a significant number of artefacts in laboratory and field studies involving the EEG with the help of the Neurocom complex has made it possible to identify the dependencies.

The suggested mathematical model of the influence of the set of quantitative characteristics of the intensity of fast (β, γ) and slow (δ, θ) EEG rhythms for the time of abstraction from the main activity of the operator indicates that it can be used both for theoretical and practical purposes, the indicators of this model have the following meaning: Fisher's calculated criterion – 241,04; Fisher's table criterion – 2,46; coefficient of multiple correlations – 90,86%; the average error of approximation is 10,86%.

The proposed mathematical model of the influence of the aggregate of the quantitative characteristics of the intensity of fast (β, γ) and slow (δ, θ) EEG rhythms, taking into account not only the EEG indices, but also the ECG, and the time of distraction from the primary activity of the driver, indicates that, in contradistinction to the above, it is more acceptable for use in theoretical research and practical purposes, as its indicators have the following values: calculated Fisher's criterion is 913,1; Fisher's table criterion is 2,46; coefficient of multiple correlations – 99,11%; the average error of approximation is 9,32%.

Information flows from the driver's conversation on the phone with the BLUETOOTH HANDS-FREE system while driving the vehicle to distract him from performing the main activity to a large extent. So, the time of the driver's distraction from performing the main activity can reach from 0,94 s. to 4,77 s.

Information flows arising from the location of noticeable advertising in the driver's field of vision when driving a vehicle, distract him from performing the main activity and are important. So, the time of the driver's distraction from performing the main activity can reach from 0,23 s. to 2,81 s.

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