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Обзорная статья

ПСИХОФИЗИОЛОГИЯ НЕВНИМАТЕЛЬНОСТИ И УТОМЛЯЕМОСТИ У ВОДИТЕЛЕЙ АВТОТРАНСПОРТНЫХ СРЕДСТВ, ОТВЛЕКАЮЩИХСЯ НА ЭЛЕКТРОННЫЕ УСТРОЙСТВА

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Резюме. *Цель исследования* – изучение психофизиологических особенностей и возможностей профилактики невнимательности и утомляемости у водителей автотранспортных средств, отвлекающихся на электронные устройства.
Материалы и методы исследования. Выполнен анализ 45 публикаций на русском и английском языках, найденных с помощью баз Cyberleninka, PubMed, Elibrary, ScienceDirect.
Результаты исследования и их анализ. Отвлечение внимания на электронные устройства у водителей автотранспортных средств приводит к их еще большему утомлению как следствию попыток сочетать вождение с несвязанными с ним действиями. Отвлечение на мобильный телефон может спровоцировать все формы потери внимания – слуховую, зрительную, биомеханическую, познавательную. Сделан вывод, что в настоящее время недостаточно распространены алгоритмы анализа усталости/отвлечения внимания у водителей автотранспортных средств.

Ключевые слова: *водители автотранспортных средств, дорожно-транспортные происшествия, мобильные телефоны, навигационные системы, невнимательность, отвлечение внимания, психофизиологические особенности, смартфон, утомляемость, электронные устройства*

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Review article

PSYCHOPHYSIOLOGY OF INATTENTION AND FATIGUE IN CAR DRIVERS DISTRACTED FOR ELECTRONIC DEVICES

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Summary. *Investigation purposes* – a researching of psychophysiological features and an opportunity of inattention and fatigue prevention in car drivers distracted for electronic devices.
Materials and methods of the investigation. An analysis of 45 publications in Russian and English found using Cyberleninka, PubMed, Elibrary, ScienceDirect data bases was conducted.
Investigation results and their analysis A distraction of car drivers for electronic devices make them instant fatigued because of attempts of combining of driving and with unrelated to it actions. A distraction for mobile phone can stimuli all forms of attention looses – auditory, visual, biomechanical, cognitive. A conclusion was made that nowadays algorithms for attention tiredness / distraction analysis in car drivers are not distributed enough.

Key words: *attention distraction, car drivers, electronic devices, fatigue, inattention, mobile phones, navigation systems, psychophysiological features, smartphone, traffic accidents*

Conflict of interest. The authors declare no conflict of interest

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Efficiency of driving depends on the psychophysiological features of the driver, experiencing significant loads on the central nervous (CNS) and analytical systems [1, 2]. It has been established that impaired driver attention while driving increases the risk of road traffic accidents (RTAs) by 5 times [3-5]. In the total number of all and major accidents, the share of accidents caused by driver fatigue is 10-20 and 40% respectively [5, 6].

The aim of the study is to review scientific publications devoted to the study of psychophysiological features and possibilities of prevention of inattention and fatigue in motor vehicle drivers who are distracted by electronic devices.

Materials and methods of research.

The search and analysis of 45 scientific publications on the problem was performed in the databases Cyberleninka, PubMed, Elibrary, ScienceDirect. Preliminary search in Yandex and Google revealed the following most relevant keywords in Russian and English: driver distraction/attentiveness/ inattentiveness; psychology of driver fatigue/ inattentiveness; reasons of driver inattentiveness/attentiveness; physiological signs of driver inattentiveness/attentiveness; devices/methods of driver distraction/attention to electronic devices — navigation system, cell phone, smartphone, panel, display, video-recording device

Results of the study and their analysis. Deviations from the normal psychological state of drivers of motor vehicles increase the risk of accidents and complicate the processes of perception/processing of information. In the Russian Federation there is no physiological testing of drivers, including the study of such psychophysiological characteristics as discipline, emotional stability, self-control [7, 8]. It should also be noted that extraversion/neuroticism directly affects the tendency to distraction while driving, and such factors as monotonous environment, long travel time, passive actions, dark time of day, lack of sleep, emotional state, medication use, lead to impaired attention/fatigue in drivers [3, 5, 9]. The field of vision of the driver depends on the speed of the car: at 0 km/h — ~120°; at 20-80 km/h — 80-30°; at 100 and 160 km/h — 22° and 5° respectively. As a result, visibility deteriorates, and the sound of the engine acts on attention concentration as a kind of "lullaby" [10].

Objects and forms of distraction in drivers

The forms of distracted attention of drivers have been identified: 1st — visual form — interference/limitation of visual field, withdrawal/shifting of eyes from the road; 2nd — auditory — distracting sounds; 3rd — biomechanical/physical — distraction with hands off; 4th — cognitive or cognitive form — reduction of reaction time due to distraction/processing of information [11-13]. Cell phone distraction provokes all forms of attention loss [11, 13]. Other distracting objects include: screens of devices in the field of view — DVR, audio-visual, infotainment, and navigation (NS) systems; visual/hand-held interference; elements of the passenger compartment; and searching for objects outside the field of view [11-15]. Distraction to electronic devices — more often in younger drivers — affects aberrant speed violations, and gaze distraction is associated with increased crash risk — especially in older drivers [16, 17].

The likelihood of distracted driving increased with the use of wireless devices — navigation and non-driving devices, particularly text messaging devices (Figure) — [18-20]. Interaction with in-car devices not related to driving tasks (radio; screen gadgets; HVAC — heating/air conditioning system) takes 0.83% of the time of the trip and occurs 4.6 times more often than "benchmark" driving [21]. Assessment of cognitive/visual attention in drivers aged 21-36 and 55-75 showed that the latter had a lower task rate and a higher rate of interaction with electronic devices (adjusting radio/voice commands, searching through the NS) [22]. The rates of workload during driving increase when using cell phones and navigation systems, as well as in urban and nighttime conditions compared to those in rural areas and in the daytime [12, 13, 23].

When using a NS with a small display, the level of cognitive/visual distraction is higher [12, 24]. Comfortable — on the upper side of the dashboard — position of a portable NS with a small viewing angle and a large display format leads to reduction of the driver's gaze time and increase of its (gaze) frequency [24]. For long/unique routes, using the NS takes 5% of the trip time: 40% for the first 10% of the time and 35% for slow driving (up to 10 km/h). When driving fast, the probability of distraction to the NS is the same [25]. In general, there is now a diverse range of devices that contribute to driver distraction, leading to impairment of all forms of attention, increasing workload indicators and, consequently, reducing the timing of driver fatigue.

Driver distractions on the cell phone/smartphone

Multitasking negatively affects driving performance and is more common in young drivers when they use a cell phone [26, 27]. Using near-infrared spectroscopy, high bilateral prefrontal and parietal cortical cortex activity was found to correlate with smartphone distraction levels in drivers behind the wheel, indicating changes in overall driving performance [19]. The development of smartphone features, including navigation functions and cab apps, has led to dependence on device options in the absence of effective regulation of "browsing" behavior [28]. A survey of students in Italy found that women were more likely to perceive risk in multitasking/mobile phone use while driving than men, aiming for sensation seeking, perceptions of self-efficacy in a multitasking environment [26].

Ways to detect distraction and fatigue in drivers

The following typical movements for distraction/fatigue are identified: dorsal flexion (distraction), its combination with rapid head elevation and dorsal hyperextension — fatigue/sleepiness. Other signs of distraction: head rotation/shaking and "anterior body" - -head/body forward movement [17]. Increased RR-interval in electrocardiogram

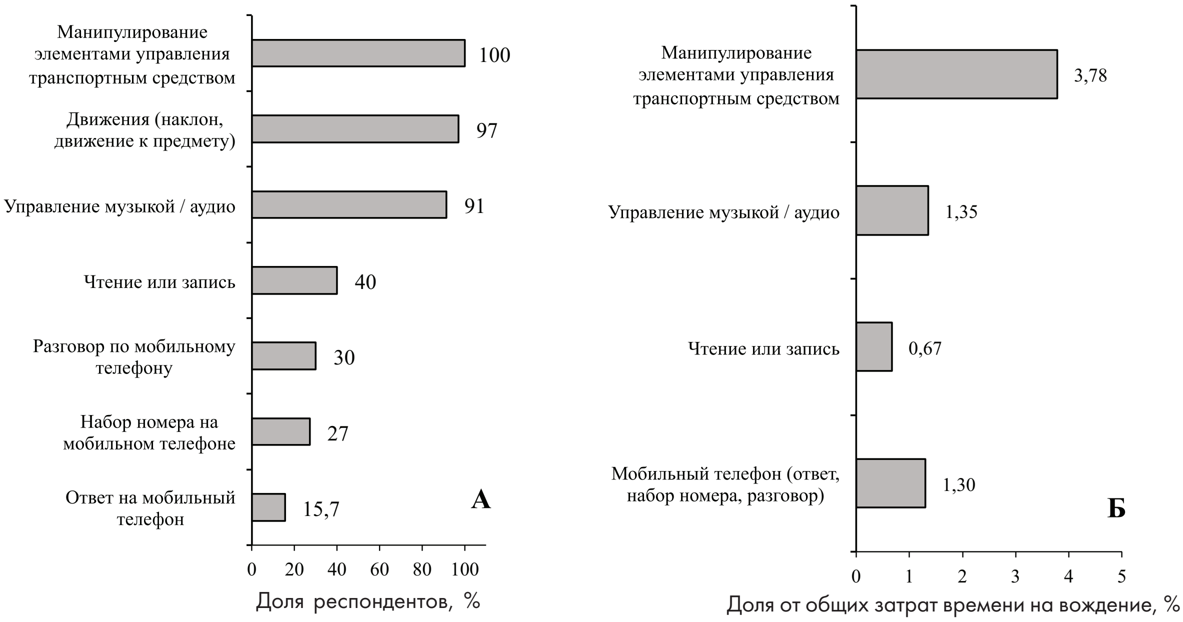

Рисунок. Доля водителей (А) и временны́х затрат (Б) при отвлечении внимания по различным причинам, по данным [19]
Figure. The share of drivers (A) and time spent (B) with distraction for various reasons. It is compiled according to [19]

(ECG) recording is observed when using a cell phone — the signal changes due to contraction of skeletal muscles of the hands and appearance of artifacts allowing to classify body gestures [29]. Breath/pulse rate monitoring, as well as action monitoring via pulse radar, showed the possibility of non-invasive monitoring of driver fatigue, his visual, manual and cognitive distraction to the phone [30].

Thus, differences in distraction patterns depending on the age/sex of drivers have been identified, but not enough research has been done to find clear patterns. Distraction/fatigue occurs as a result of drivers being in multitasking mode. Electrocardiography as a research method is interesting in examining the physiological aspects of distraction, but its application is difficult due to the need to attach electrodes to the human body.

Driver fatigue and its prevention

Distraction events are more likely to occur than fatigue, the risk of which increases with increasing travel time/number of stops with a greater tendency to drowsiness in the elderly [31]. The influence of automation, a monotonous driving environment, leads to the appearance of a passive state of fatigue already after 15-35 min of driving and, compared to the use of manual control, to increased time of looking at the speed display and slower reaction to the event [32, 33]. When stimulating a tired driver, habituation (to repetitive stimuli) must be considered. Exposure to short-wave (blue) light at night, decreased ambient temperature, odor (peppermint essential oil) and vibration stimulation reduce the severity of driver fatigue, but the effect of the last three options lasts only 5-10 min [34].

Successes in preventing distraction in drivers

The use of a Google Glass™ clear head-mounted display just above the right eye to receive messages has been found to increase the responsiveness of experimental participants more than viewing a smartphone, but there is a potential for increased distraction [35]. The use of Android Auto and CarPlay apps has proved difficult due to complex interfaces that require a lot of visual and mental attention from the driver [36]. In some cell phones the driving mode is represented by the "eye-tracker" system, which notifies the driver about the distraction of his attention and the transition of the phone to a simple limited mode of operation [23]. Placing the entertainment console on the passenger side allows you to delegate some functions to him [13]. Analysis of the possibility of using the windshield display showed that respondents prefer the display windows in the dark mode with a high opacity of the background at high brightness conditions and automatic change in the dark to a greater transparency [37]. Of the presented methods of distraction prevention, the most effective is the "eye-tracker" system, but it is not widespread, and the other systems need refinement/modification of functions.

Systems for driver distraction/fatigue assessment

A self-learning ADAS system with tactile/auditory sensors and camera is based on facial expression recognition, effective in non-invasive driver condition monitoring and establishing a correlation between inattentive facial expression and an accident [38, 39]. Fatigue/distraction analysis is available using two algorithms: KNN, which monitors fatigue symptoms by eye/mouth aspect ratio with alarm generation; CNN, which perceives driver actions with situation prediction [40]. By applying frequency-modulated continuous wave radar (FMCW) systems with spectrogram, its trajectory and range/time estimation, data on recognition of typical forms of inattentive driver behavior with an average recognition accuracy of about 95% have been obtained [41]. A driver fatigue detection system has been developed consisting of a control unit, an electronic engine control system and two video cameras, with the function of signaling, stopping the car and triggering an alarm [42].

There are examples of successful application of algorithms of the eye tracking analysis, detection of yawning/head position, heart rate variability: Attention Assist (Mercedes-Benz) detects driving style/steering wheel movement during fatigue/inattention; Front Assis (Volkswagen) — steering wheel rotation/pedal use; Driver Alert Control (Volvo) — reads the ratio of road markings and steering wheel turns; Emergency Assist (Volkswagen) — reacts to dangerous shortening of distance to another vehicle [2]. Numerous data from the electroencephalograph attached to the forehead on the ratio of rhythmic energy and frontal asymmetry coefficient can be useful in the fatigue/distraction detection device [43]. A correlation of brain α-wave with salivary cortisol concentrations has also been found, which may be useful for monitoring fatigue in the driver [44]. Using a dedicated ER system for smartphones, it has been found that each type of inattentive driving (pushing the body forward, turning back, eating/drinking) has unique patterns on the Doppler audio signal profiles [45]. Since distraction/driver fatigue detection systems are not widespread enough, it is necessary to solve the problem of their availability to drivers and the formation of safe driving behavior in the latter.

Conclusion

Thus, psychophysiological features and patterns in drivers during distraction and fatigue while driving have been identified. It has been established that dangerous driving behavior can be identified through the analysis of electroencephalography and electrocardiography. However, according to the authors, who have performed an analysis of scientific publications, the most effective and comfortable are "smart" systems with a camera that record the facial expression and body position of the driver while driving and are capable of self-learning through the accumulation of patterns of behavior of the person behind the wheel of the car.

There is a need for further research for:

- Application of these systems to form an accessible and consumer-attractive device aimed at preventing accidents;
- Stimulation of the driver when he/she is fatigued, and the introduction into his/her consciousness of the need to concentrate while behind the wheel in order to form the correct use/non-use of screen devices while driving.

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