Defining Duration of Driver Reaction Time Components Using the NeuroCom Complex

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Abstract. The research defines components of driver reaction time under different conditions. The duration of a latent period and time of respective response to a stimulus are determined. It is traced how driver reaction time depends on the complexity of the situation the driver was exposed to. With the help of the NeuroCom complex, computer program and processing of video recordings, the main components of driver reaction time were defined to be information in-flow to the cerebral cortex, detection and recognition of a stimulus, making a right decision and respective reaction. The obtained results can be used for determining dynamic gauge and braking distance of a vehicle, which, in its turn, influences the road safety.

Key words: driver reaction time, latent period, functional state.

INTRODUCTION

The reliability of drivers to a large extent depends upon the speed and accuracy of their respective responses to stimuli (jamming on the brakes, wheel turning, gear shifting, etc.), particularly under the conditions of fast motion [1 – 3]. The probability of a right decision under such conditions depends on the influence of the functional state (FS) of a driver on objective quantitative indicators which characterize the process of perception of the road conditions. Driver reaction time is one of such indicators [4]. In most cases, braking distance of a vehicle as a result of an emergency brake application depends on the driver reaction time. Therefore, study of this psychomotor response and possibilities to reduce it taking into account driver's FS is of a great importance for road safety improvement [5].

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The reaction time of a driver is an important indicator of his/her professional activity. The studies [6-7] have established that processing of the information by a driver is not a passive reflection of statistical signal characteristic but an active search for problem solving, particularly in the field setting.

Standards of driver reaction time vary between different countries. In European countries, driver reaction time equals 0.75 s when calculations are related to the traffic in cities or towns, and 2.5 s when they are carried out in the countryside [8]. In Ukraine, excellent drivers apply emergency braking with the reaction time of 1.16 s [9]. The reaction time also depends on the intensity of driver's attention, i.e. on the degree of attention strain for perception of complex and simple road situations. Under the conditions of city traffic, when attention intensity is quite high, the driver reaction time is significantly lower. Czech and Slovak researchers believe that, when the application of brakes is prepared to, the driver reaction time is 0.6-0.7 s, and when attention of a driver is distracted, the reaction time increases to 1.1-1.7 s [10-12].

Reactions can be simple or complex. A simple reaction means the ability to respond quickly and unambiguously to a signal which is known in advance. The time of a latent period of a simple motor response to a signal is 0.2 s [13]. A complex reaction is connected with the choice of a needed action from a range of possible ones. It requires much more time. It is believed that the average time of a complex reaction of a driver is 0.8-1.0 s. This time can vary from 0.4 to 1.5 s [5].

OBJECTIVES

Driver reaction time is a manifestation of a complex mental process. Understanding, prognostication and managing this reaction is possible only when psychophysiological mechanisms of the integral perceptual experience are revealed. When driver's response to stimuli is studied without taking into account his/her FS, it is impossible to explain such factors as varied time of response to the same signal, change of a reaction with time or lower values of the reaction time when a driver is considerably tired as compared to the periods of his/her optimal productivity [6].

However, know only driver reaction time is not sufficient. The important role is attributed to the time of making an adequate decision (the latent period), which largely depends on a driver's FS. Therefore, psychophysiological characteristics of a driver have to be taken into account in the research. This will enable defining the duration of components of driver reaction time. For this purpose, it was decided to use the NeuroCom complex [14], which on the basis of electroencephalogram (EEG) records allows describing excitatory and inhibitory processes in the cerebral cortex if a person is exposed to different kinds of stimuli.

THE MAIN RESULTS OF THE RESEARCH

The profession of driver is always connected with dangerous situations when the time of sensorimotor reaction plays an essential role. A driver does not only have to perceive great amount of information but also analyze it quickly and, consequently, make right decisions and perform a respective action [15].

Methodologically, there are two difficulties in studying driver reaction time [16]:

- determining the moment of zero time reference, that is the moment of signal occurrence,
- evaluating the degree of signal unexpectedness for a driver.

Most often the reaction time is understood as the period of time which includes stimulus detection, its recognition, making the decision and taking a respective action [17].

According to modern ideas concerning the mechanism of perception of surrounding signals by a driver, the process of formation of the reaction time generally can be illustrated with a block diagram (Fig. 2). The time span between the moment of signal occurrence and the start of a respective action is the reaction time of a driver.

Experimental research was conducted both in the field and in the laboratory settings. To study the process of information in-flow to a driver in details, the NeuroCom complex has been used. One stage of the experimental part is shown in Fig. 1.

On the basis of electroencephalogram (EEG) records, the complex gives a possibility to characterize excitatory and inhibitory processes in the cerebral cortex when exposed to different kinds of stimuli, define the duration of information in-flow to the cerebral cortex, the time of detection and recognition of a stimulus, and the time needed to make a right decision (fig. 3).

Besides, EEG records enable defining the FS of a driver when the experiment is carried out. The main characteristics of this record are frequency and average amplitude of α, β, θ, δ and γ rhythms [14]:

- alpha rhythm is registered when the driver has closed eyes, relaxed musscles, and is in the quiescent state. This rhythm is blocked with photic stimulation, increased attention and mental workload,
- the amplitude of beta rhythm grows with attention increase, mental strain or emotional arousal,
- gamma rhythm increases with making decisions which require the maximum of concentrated attention,
- low-amplitude (20-30 μV) oscillations of delta rhythm can be registered in the quiescent state during certain forms of stress and prolonged mental work,
- theta rhythm is most expressed during light sleep, hypnoidal state.

Values of frequency and amplitude of EEG rhythms, obtained through the use of the NeuroCom complex, for each type of the experiment are presented in Table 1.

Fig. 1. Registration of EEG recordings while conducting the research

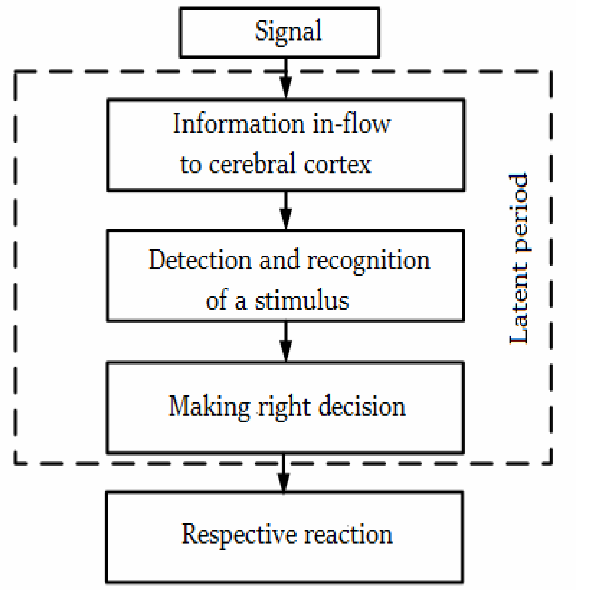

Fig. 2. Block diagram of the formation of driver reaction time

When the tests are underwent in simple and difficult situations, the indicators of α, β, θ, δ and γ rhythms of EEG (see Table 1) increase by 15-20 % on average in comparison to the results of the background test (in the quiescent state).

Comparing the information load in a simple and difficult situation, the indicators of beta, gamma and delta rhythms increase (mental workload, concentration of attention, prolonged mental work), and indicators of alpha and theta rhythms fall down (quiescent state) as the task becomes more complicated.

In order to define the time of driver's simple and complex reaction in the laboratory setting, the previously developed computer program consisting of two tests is used along with the NeuroCom complex. The first test of this program was created on the basis of dangerous situations which occur with drivers behind the wheel. The main goal is to recognize a dangerous situation in a picture which appears among other ones, and respond to it.

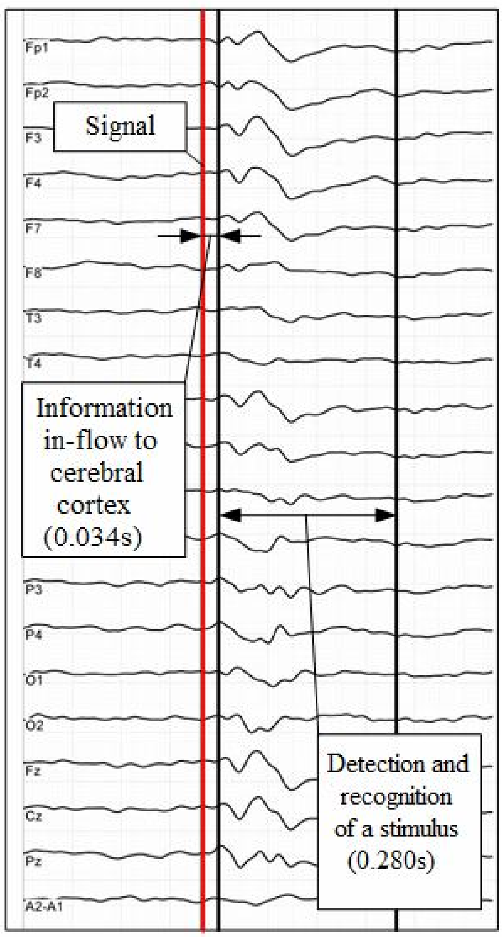

Fig. 3. The fragment of EEG records in the process of defining the duration of driver reaction time components

The second test requires responding with a respective reaction to each signal which is fed onto the screen [16].

Figure 4 depicts the cumulative curve of interval allocation of the latent period (the NeuroCom complex) and driver reaction time (the computer program) in the laboratory setting.

Table 1. Values of frequency and amplitude of EEG rhythms

Type of the experiment	EEG rhythm	alpha	beta	gamma	delta	theta
Background test	Frequency, Hz	9.28	13.67	40.34	0.73	7.81
	Amplitude, μV	23.15	10.58	3.32	15.96	8.42
Completion of the test in simple situations	Frequency, Hz	10.33	18.10	41.22	2.18	7.26
	Amplitude, μV	9.31	11.13	6.92	17.21	8.07
Completion of the test in difficult situations	Frequency, Hz	10.45	19.16	40.62	2.27	6.89
	Amplitude, μV	7.25	12.49	8.05	16.88	6.87

Duration of a latent period in the laboratory setting varies from 0.13 s to 0.79 s when the values of reaction time are between 0.54 s and 1.92 s (see Fig. 4). A fraction of a latent period in the total driver reaction time falls between 26 and 37%. This means that as the situation gets more complicated, the time for detecting, recognizing and making a right decision by a driver increases.

Considering the total reaction time without taking into account difficulty of decision making, the latent period constitutes 30% (0.576 s) on average. Therefore, in some complicated situations the time for making an adequate decision is longer than the reaction time in simple situations.

As a rule, in order to define driver reaction time in situ, the most common methods such as using radio communication, video camera, and taking measurements with the help of an assistant are used [17 – 18]. When the components of the reaction time of a driver behind the wheel were defined, all positive aspects of these methods were taken into account [19, 20].

No special training areas to conduct the research were arranged. All works were carried out on auto-roads. With a car on the move, constant video surveillance of the traffic situation was performed. Drivers were sent different kinds of signals which had to be responded to with a respective reaction. Doing this, the drivers had to adhere to a specified motion mode [4].

This method allows measuring the time of a simple braking reaction (when the traffic light is red) and of a complex situation (when each signal has to be responded to with a respective reaction). Moreover, the complex reaction was connected with memorizing a sequence of signals occurrence (fig. 4).

Statistical distribution of the driver reaction time during real driving is shown in Figure 5.

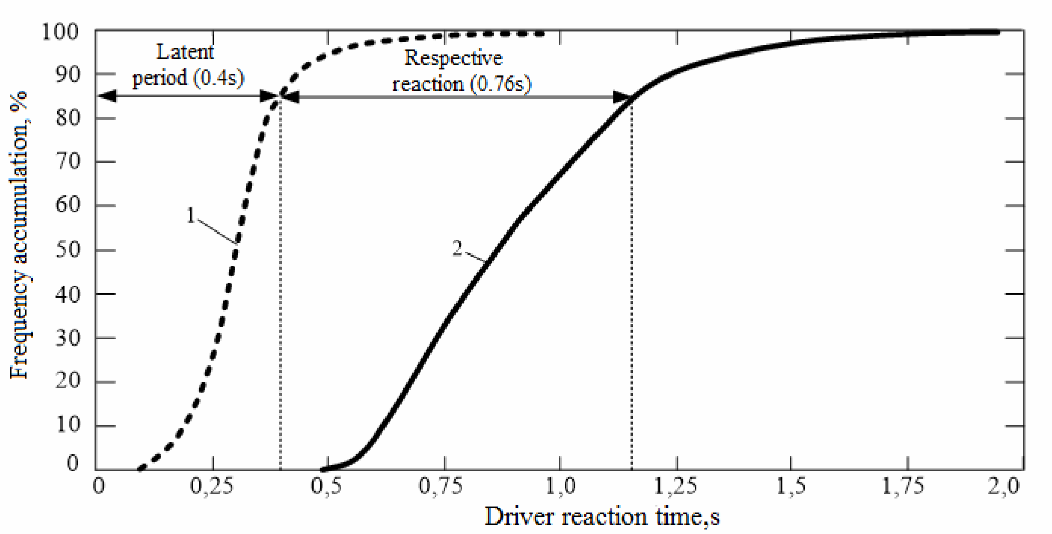

Fig. 4. Cumulative curve of interval allocation of the latent period (curve 1) and driver reaction time (curve 2) in laboratory setting

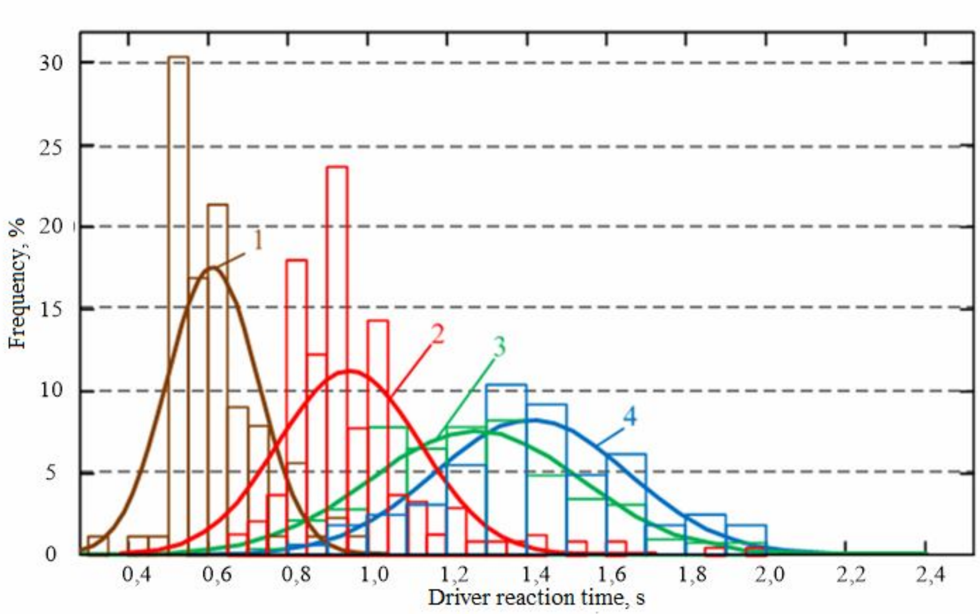

Fig. 5. Histograms of the interval distribution of driver reaction time in simple and difficult situations: 1 – a simple reaction; 2 – a complex reaction during braking; 3 – a complex reaction during wheel turning; 4 – a complex reaction to a recurring signal

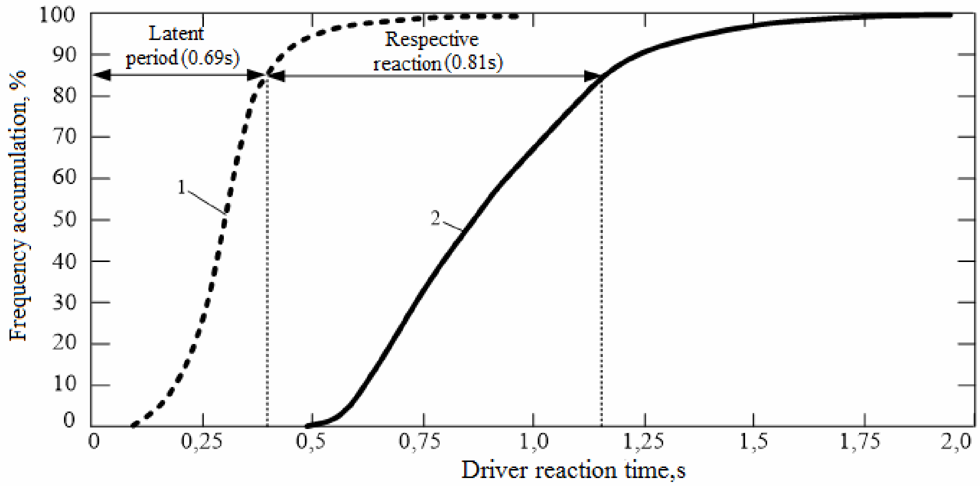

Fig. 6. Cumulative curve of interval allocation of the latent period (curve 1) and driver reaction time (curve 2) in field setting

Table 2. Driver reaction time in various situations

Situation Complexity	Setting	Duration of reaction time components, s				Total reaction time
		Latent period			Respective reaction	
		Information in-flow to cerebral cortex	Detecting and recognizing a stimulus	Making a right decision		
Simple	Laboratory	0.034	0.109	0.127	0.503	0.773
	Field		0.151	0.295	0.710	1.190
Difficult	Laboratory		0.290	0.465	1.131	1.920
	Field		0.312	0.724	1.360	2.430

The time of a simple reaction to brake application is the lowest, and the time of a complex reaction increases as it complicates and, on average, is twice as long as the time of a simple reaction (see Fig. 5).

Plotting the interval distribution of the latent period duration and driver reaction time in the field setting (Fig. 6 revealed that the minimum reaction time of a driver is 0.4 s, and the maximum one is 2.430 s.

In its turn, the time of a latent period in situ varies from 0.25 to 1.07 s. On average, the fraction of a latent period is 45% from the total driver reaction time.

The table below summarizes the duration of components of driver reaction time (Table 2) combining the findings obtained under different conditions using the NeuroCom complex and a number of other means.

According to the research of the reaction time components, the time of information in-flow to the cerebral cortex in different situations is 0.034 s on average. To detect and recognize a stimulus takes on average 0.216 s (15%) of the total driver reaction time, to make a right decision 0.403 s (27%), and to respond respectively 0.926 s (58%). The time of a latent period constitutes on average 41% of driver reaction time (see Table 2).

CONCLUSIONS

The research has allowed assessing variation of driver reaction time depending on the complexity of decision making in the laboratory and field settings. With the help of the NeuroCom complex, computer program and processing of video recordings, the main components of driver reaction time were defined to be information in-flow to the cerebral cortex, detection and recognition of a stimulus, making a right decision and respective reaction. The obtained results can be used for determining dynamic gauge and braking distance of a vehicle, which, in its turn, influences the road safety.

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