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THE TEST METHODS AND THE REACTION TIME OF DRIVERS

METODY BADAŃ A CZAS REAKCJI KIEROWCÓW*

The paper presents issues related to determination of the driver's reaction time. A brief review of methods for determining the reaction time of drivers has been conducted. The results of own researches on the reaction time of drivers in pre-accident situations have been presented. The scenario of an accident situation according to which they were conducted has been presented. The presentation includes results of measurements of the reaction time set in the three test environments: on a test track, in a driving simulator and on the psychological aptitude test stand. A comparison of the obtained reaction time values has been conducted and the correlation between them has been determined.

***Keywords:** drivers' tests, the reaction time of drivers, test methods.*

W artykule przedstawiono zagadnienia związane z wyznaczaniem czasu reakcji kierowcy. Przeprowadzono krótki przegląd metod wyznaczania czasu reakcji kierowców. Zaprezentowano wyniki własnych badań dotyczących czasu reakcji kierowców w sytuacjach przedwypadkowych. Omówiono scenariusz sytuacji wypadkowej, według którego zostały one przeprowadzone. Przedstawiono wyniki pomiarów czasu reakcji wyznaczone w trzech środowiskach badawczych: na torze badawczym, w symulatorze jazdy samochodem oraz na stanowisku do badań psychotechnicznych. Dokonano porównania otrzymanych wartości czasu reakcji i wyznaczono korelacje pomiędzy nimi.

***Słowa kluczowe**: badania kierowców, czas reakcji kierowców, metody badań.*

1. Introduction

Motor vehicle accidents are inherent in traffic and are usually the result of many different reasons that occur in an emergency situation (including human error).

In different countries the risk to participate in road accidents is different, and differences between countries are quite significant. Therefore, periodic analysis of accidents are made for both quantitative and qualitative assessment of their causes [11, 14]. But in order to determine how a particular driver's performance could affect the course of a road accident, it is very often necessary reconstruct an accident in detail. For such reconstruction usually carried out using specialized computer programmes, it is necessary to use multiple parameters characterizing both a vehicle, a driver behaviour and environmental conditions. While the vehicle parameters and environmental conditions are relatively easy to determine, however in case of a driver it is generally difficult to estimate the rules. The action of the driver is dependent on many factors: fatigue, stress, experience in driving a motor vehicle, etc. One of the parameters characterizing driver's behaviour that is necessary for reconstruction is the reaction time. It is worth mentioning that the driver's reaction time is one of the basic parameters which have a very strong influence on the final outcome in the analysis of the course of the accident, and their recommended values are given in the manuals and training materials for court experts.

Depending on the value of a driver reaction time an expert takes for analysis of the accident may depend on the extent of any fault of a driver.

Most of literature report values of reaction time obtained in the tests on the so-called reaction on a simple stimulus (single beep or light) - in which a driver during the study is to react on one of the control elements of a car (brake pedal, handbrake lever, steering wheel). Examples of such studies are very well known and widely used until recently with the results of M. Burckhardt, and H. Burg [1]. In these studies, which were made on the actual way involved two cars driving behind each other. A test driver of a second car was to react to brake lights that light up of the car in front. A total of 41 persons have been examined in this way during these studies. During 1 hour (time for the test of 1 participant) was recorded about 100 reaction time values, which means that subsequent reactions of the driver followed on average every 40 seconds. Reaction time values determined by this method have been adopted by resolution of the symposium of the German forensic experts (20 Deutsche Verkehrsgerichtstag in Goslar, 1982 [4]) and have been widely used in Germany in the 80's and 90's. According to this recommendation, but also because of much more careful, than in other cases, a statistical processing of results carried out, they were widely regarded as one of the most correct and reliable. This is confirmed by the fact of their citation in the major publications of books on the dynamics of braking [2] or the reconstruction of road accidents [26].

A similar method of measurement Nishida [18] used in his study. The literature is full of other descriptions of test methods of drivers' reaction time to a single stimulus, such as the special ring tone [25], or a single light pulse of a stimulator, stuck on the windscreen [5, 15].

In real road situations (except driving in a column), the driver reacts to complex stimuli and the behaviour of the driver trying to avoid an accident involves both braking and (or) turning a steering wheel.

In the literature 10 - 15 years ago it is difficult to find data on the reaction time in which both the stimulus and the driver's reactions are complex. In many studies of reactions to complex

(*) Tekst artykułu w polskiej wersji językowej dostępny w elektronicznym wydaniu kwartalnika na stronie ***www.ein.org.pl*** stimuli carried out frequently simulated situations were highly simplified. For example, in papers [5, 16], tests of reactions to stimuli were the tests using the lights stuck on the windscreen of the car before the driver. The driver had to react both to a colour and light system, which have a manoeuvre assigned to them – for example weak or strong braking, turn left or turn right, etc.

In recent years, studies on the roads or tracks increasingly rely on the implementation of certain selected, recognized as representative, contract accident scenarios. Examples are the tests described in paper [17], in which on a track was simulated a perpendicular car intrusion to the crossroads. The authors of this work carried out a similar scenario in the tests described in [10, 22, 23]. Another example might be testing the driver's reaction to a small children's bike [15] pushed out (from behind a parked car in the right lane).

In studies aimed at introducing an assistant system, in the recent period, it became popular to use air-filled dummies made of a thick foil in the shape and dimensions of the vehicle [9, 20, 21] to support different research scenarios such as „sudden braking" 'sudden bypassing", etc.

In summary, it can be concluded that the number of this type of research available in the literature is small and covers only some specific cases. In addition to the lack of data for certain situations, other important drawbacks of the data obtained in this way are:

- their obsolete for the present population of drivers (grown-up and adjusted to the environment with a large variety of complex technical equipment);
- lack of data on high-risk groups, particularly young drivers aged 18 to 25 years (in this group, road accidents in the European Union countries, including Poland, are the main causes of death);
- their origin countries (e.g. Germany or the USA) with significantly differing levels of development of the motorization and the conditions under which it operates (the density and organization of traffic, condition of roads and markings, the share of motorways in the overall road network, the method of driver training, etc.).

In view of the above conclusions, the authors focused on one indicator of driver's performance, which is the reaction time and have decided to carry out research designed to extend knowledge in this field. They were to help find answers to questions about the possible correlation between drivers' reaction time obtained with different testing methods.

2. Test methods of drivers' reaction time

Despite years of research, yet has not been developed a method that most professionals in the field of accident reconstruction would be considered by far the best one for determining the reaction time of drivers. Generally, you can specify the following ways to implement this type of research:

1. Tests on psychological aptitude test stands for drivers (or similar).
2. Experiments on roads or testing tracks.
3. Research in driving simulators.
4. Study (observation types) in the actual road conditions.

The authors of this publication, in a study of driver behaviour in pre-accident situations determined drivers' reaction times in the first three research environments for the same group of 30 drivers.

2.1. Studies on simple testing stands

The study aimed to determine the reaction time of drivers conducted on simple stands historically have been used first. Currently, such tests can be encountered only occasionally but they are generally regarded as a complementary test. These studies, however, have been applied commonly by psychologists to evaluate its suitability for the profession of the driver, and many publications appear the values obtained in this way the reaction time.

In the studies that use this method by the authors the times of simple and complex reactions have been determined [10]. Determination of a simple reaction time was based on the driver's reaction to a single simple stimulus - light or sound. Driver's reaction was to press a key at the time of the appearance of a stimulus. The research of a complex reaction consisted in a specific type of stimulus - the light colour or sound, has been assigned with a specific manipulator on which the driver should press with a hand or foot

2.2. Experiments on roads or test tracks

Studies on roads or test tracks are recognized by majority of professionals as the best way to simulate traffic situations [16], to perform various vehicle dynamics studies [19], as well as determining the reaction time. Opportunity to reflect actual conditions of vehicle motion, the parameters of the road, as well as the ability to measure the reaction time in a real car are undeniable advantages of such studies. However, the value of results obtained in this way and their usefulness for the analysis of certain types of accidents, strongly depends on way the experiment is conducted. In recent years, the tests of the behaviour of drivers tests based on certain scenarios of accidents are performed on test tracks. These include generally a very specific road situation, and therefore the value of reaction time obtained in this way are also limited in their scope of use.

The study conducted by the authors, widely described in [10, 12, 22, 23] include a scenario in which on the track was simulated a perpendicular intrusion of car at the crossroads. Schematic test scenario is given in figure 1.

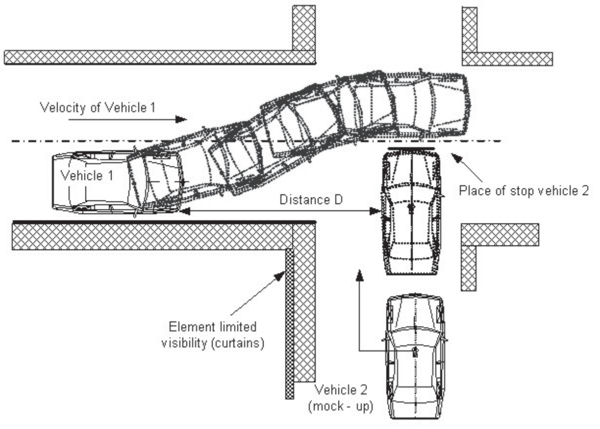

Fig. 1. Schematic scenario of an accident situation

The driver of the "Vehicle 1" moving at a speed V1 is forced to react to avoid collision with vehicle 2 which enters the crossroads without giving it priority – fig. 1. This scenario was based on observation of the actual situation at the crossroads located in Kielce (fig. 2).

Fig. 2. Real crossroads

Picture of the implementation of research conducted by the authors shown in fig. 3.

A detailed description of the tests carried out on the track is given in [12].

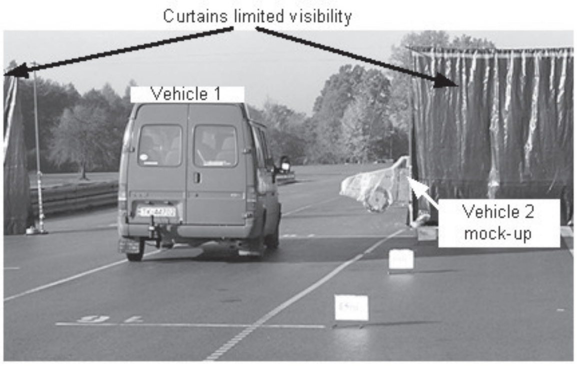

Fig. 3. Realisation of a scenario during research on a track

2.3. Research in driving simulators

The development of computer technology influenced significantly propagate research in simulators. Driving simulators are devices in which the driver directs the car using the same control elements, like in a real car (the accelerator pedal, brake, steering wheel), but the car traffic is implemented in a virtual environment [3]. Simulators can be divided into: dynamic simulators, which in addition to mapping the traffic situation on the big screen, inertial forces acting on the driver are mapped, for example during braking or in a curvilinear motion and static simulators in which these forces are not mapped.

One of the indisputable advantages of simulators is the possibility of an exact match to the environment and to perform such scenarios which implementation of the road conditions would be impossible or would involve danger. During the research carried out by the authors in the simulator [13] a selected, the same to tests on the track scenario has been realised (fig. 4).

Fig. 4. View of imitation the crossroads in the simulator

3. The analysis of the obtained values of reaction time

In this analysis, the influence of research methods on the reaction time values obtained are presented on the basis of authors' own research. The advantage of such a comparison is that during research an identical accident situation has been carried out (fig. 1). In order to obtain a high degree of surprise of drivers, the studies strongly reduced the visibility of the driver by installing curtains on the track, for example, in the simulator by mapping a high hedge and used so-called "empty runs" in which the obstacle does not appear. The same group of drivers was tested in various research environments. Were also consistent for the whole research of results' analysis.. A detailed description of these studies can be found in the works: [7, 8, 12].

Basic studies were carried out on Kielce Track and in the AutoPW driving simulator [10] at Warsaw University of Technology. The task of the drivers was aiming to avoid a collision with an obstacle, the driver himself decided whether only to brake or carry out only avoidance manoeuvre or perform both of these manoeuvres simultaneously. This feature, according to the authors, makes conditions similar to the real situation, in which the driver is not imposed on his behaviour. The results obtained have been confronted with the results of tests on a test psychological aptitude stand of drivers.

The analysis of research results used the concept of risk time. **Risk time** is defined as the time period allowed to the driver after noticing the obstacle to a possible collision with it. It is used by the driver for actions to avoid any accident or its consequences. Risk time used by the driver to perform defensive actions was calculated as the ratio of the car distance from the obstacle at the time of accident risk appearance (fig. 5) to its speed. This parameter, as shown by the analysis carried out in the work of authors [9, 24], is a very important parameter characterizing a pre-accident situation and driver behaviour. Tests were conducted for 15 different time values of risk time for three speeds 40, 50 and 60 km/h and five distances from an obstacle 10, 20, 30, 40, 50m.

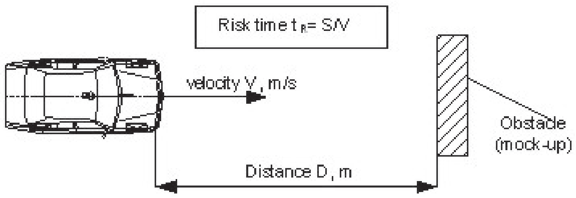

Fig. 5. Determination of risk time

Detailed results of the analysis of drivers' reaction time in the event of accident risk based on research carried out on Tor Kielce have been presented in the article [9].

In the present study the reaction times are as follows:

- mental reaction time, understood as the time since the appearance of an obstacle to the start of leg from the accelerator, hereinafter referred to briefly: "the accelerator pedal" reaction time;
- psycho-motor reaction time when braking, determined as the time from emergence of an obstacle to the onset of the brake pedal force, hereinafter referred to briefly: "brake" reaction time;
- psycho-motor reaction time during a turn, determined as the time from emergence of an obstacle to the onset reaction to the steering wheel, hereinafter referred to as: "turn" reaction time.

Dependence of reaction time for particular emergency braking manoeuvres, i.e., braking with a foot brake, engine braking and steering have been shown in fig. 6. For all the manoeuvres of the dependence of the risk time function is linear. The average reaction time value and standard deviation (value in parentheses) for selected values of risk time has been presented in table 1.

Similarly, the values of the reaction time of drivers during testing in the simulator have been determined. Graphical comparison of results has been shown in fig. 7. In the case of reaction time results obtained in the simulator, presented dependent on risk time, we can say that they also have a linear character. Examples of reaction time values obtained in the simulator are shown in table 2.

Psycho-technical research has been conducted on the same group of drivers. Each of the drivers was examined twice. Obtained results are presented in fig. 8. The average values of simple reaction time have been compared with the reaction time obtained during the experimental tests, both on the track and in the simulator.

Determination has been made of the R correlation coefficient of simple reaction time compared to the reaction time set for the turning manoeuvre and braking with a foot brake for all

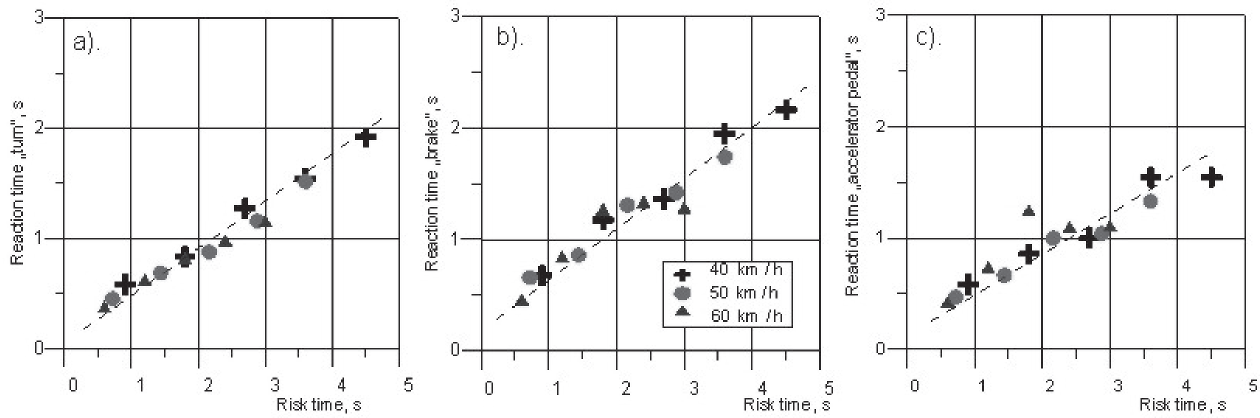

Fig. 6. The reaction time of drivers in the risk time function obtained during testing on the track; a) "turn" reaction time , b) "brake" reaction time , c) "accelerator pedal" reaction time

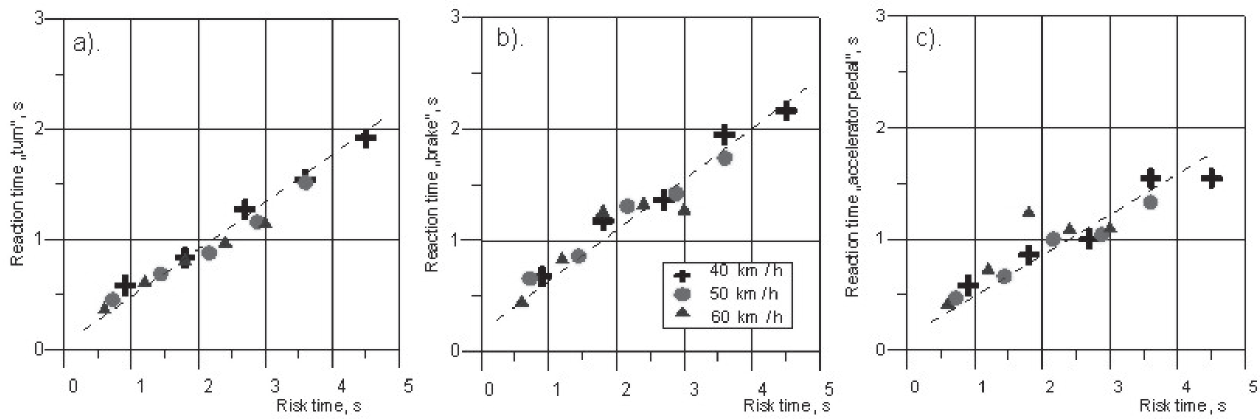

Fig. 7. The reaction time of drivers in risk time function obtained in a simulator a) „turn" reaction time, b) „brake" reaction time , c) „accelerator pedal" reaction time

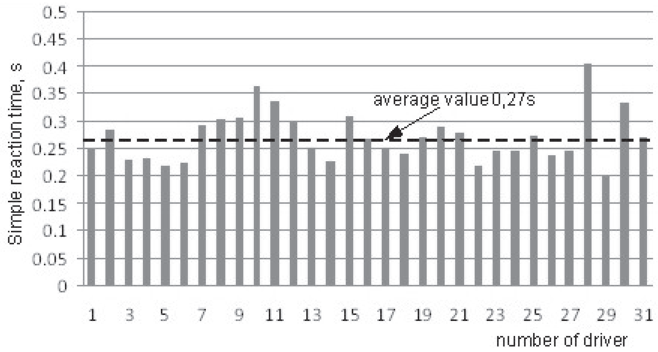

Fig. 8. Simple reaction time

Tab. 1. Summary of sample values of reaction time obtained on the track

Reaction time	Risk time, s				
	0,72	1,44	2,16	2,88	3,6
Mental "Accelerator pedal"	0,47 (0,10)	0,66 (0,16)	0,99 (0,15)	1,04 (0,37)	1,5 (0,56)
Psycho - motor performance during braking „Brake"	0,65 (0,08)	0,85 (0,15)	1,31 (0,20)	1,42 (0,31)	1,85 (0,48)
Psycho - motor during a turn „Turn"	0,45 (0,09)	0,68 (0,16)	0,87 (0,29)	1,15 (0,21)	1,54 (0,56)

Tab. 2. Summary of sample values of reaction time obtained in the simulator

Reaction time	Risk time, s				
	0,72	1,44	2,16	2,88	3,6
Mental "Accelerator pedal"	0,35 (0,19)	0,45 (0,11)	0,51 (0,17)	0,66 (0,19)	0,81 (0,36)
Psycho-motor performance during braking „Brake"	Brak reakcji	0,64 (0,15)	0,73 (0,18)	0,92 (0,33)	0,96 (0,22)
Psycho-motor during a turn „Turn"	0,43 (0,06)	0,49 (0,13)	0,62 (0,21)	0,81 (0,39)	1,23 (0,58)

the samples (with different values of initial risk time). Correlation coefficients values for simple reaction time and reaction time - „brake" is shown in table 3 and for the simple reaction time and reaction time - „turn" (table 4). These correlations were determined for the results obtained on the track and in the simulator.

Obtained low and even negative correlation coefficient values indicate that there is no correlation between simple reaction time determined at the stand and the time determined in the research on track and in the simulator, both the turning reaction and braking.

The second study was to examine complex reaction time values. The results obtained are presented in fig. 9.

According to the authors there was a trial to determine the inter-relationship between the values of reaction time. Correlation coefficients were determined for the complex reaction time, and brake reaction time (table 5) and turning of wheels (table 6) obtained in studies on the track and in the simulator. In this case, also low or even negative correlation coefficient values have been obtained.

Tab. 3. The correlation coefficients between simple reaction time and the values of "brake" reaction time (time for different values of risk time)

Risk time, s		0,6	0,72	0,9	1,2	1,44	1,8	1,8	2,16	2,4	2,7	2,88	3,0	3,6	3,6	4,5
Truck	R	-0.124	-0.037	-0.348	-0.470	-0.141	0.446	-0.184	-0.034	-0.468	-0.620	-0.487	-0.395	-0.193	-0.461	-0.106
simulator		-	-	-	-0.104	-0.004	-0.085	-0.129	0.236	0.133	0.213	0.155	0.199	0.126	0.222	0.145

Tab. 4. The correlation coefficients between simple reaction time and values „turn" reaction time (for different values of risk time)

Risk time, s		0,6	0,72	0,9	1,2	1,44	1,8	1,8	2,16	2,4	2,7	2,88	3,0	3,6	3,6	4,5
Truck	R	0.277	-0.354	-0.017	-0.318	-0.307	-0.319	-0.092	-0.188	0.068	0.008	-0.014	0.120	-0.154	0.141	-0.200
simulator		-0.466	-0.771	-0.219	0.209	0.054	0.364	0.446	0.576	0.094	0.395	0.520	0.203	0.220	0.461	0.117

Tab. 5. The correlation coefficients between complex reaction time and the values "brake" reaction time (time for different values of risk time)

Risk time, s		0,6	0,72	0,9	1,2	1,44	1,8	1,8	2,16	2,4	2,7	2,88	3,0	3,6	3,6	4,5
Truck	R	0.324	-0.289	-0.163	-0.023	-0.074	0.192	-0.093	-0.050	0.007	-0.083	-0.180	-0.095	0.055	0.031	0.134
Simulator		-	-	-	0.062	0.145	-0.213	-0.204	-0.020	-0.034	-0.371	-0.148	0.066	0.075	-0.276	-0.118

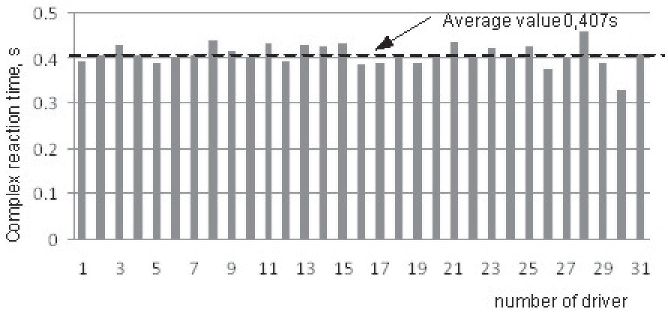

Fig. 9. Comparison of the complex reaction time

Tab. 6. The correlation coefficients between complex reaction time and values of „turn" reaction time (for different values of the time risk)

Risk time, s		0,6	0,72	0,9	1,2	1,44	1,8	1,8	2,16	2,4	2,7	2,88	3,0	3,6	3,6	4,5
Truck	**R**	0.128	0.030	0.001	-0.207	-0.311	-0.177	-0.027	-0.092	0.162	-0.085	-0.120	-0.220	-0.064	-0.049	-0.191
simulator		-0.304	-0.971	-0.144	0.133	0.211	0.302	0.077	0.158	-0.071	0.473	0.159	0.016	0.194	-0.176	-0.075

4. Conclusions

The values of the reaction time of drivers assigned to each set of manoeuvres on the track and in the simulator is characterized by a linear dependence of risk time. Both of these values are closely correlated. Through the results can be seen, however, that the reaction time of drivers obtained in the simulator for all tested manoeuvres achieves smaller values in relation to the measured values on the track.

The reason is that drivers are aware that they driver a car in a virtual environment, so even very violent manoeuvres are safe. You can "with impunity", without any consequences to perform rapid turns, leave off a road, drive through fences, gates, etc. During the test on the track the drivers act in a way not to lead to a dangerous situation of rapid overloading the car, the roll-over, etc.

The resulting accuracy has been also indicated in the literature [6]. The difference between the published opinions and the results in the present study lies in the fact that in the cited works a fixed value time difference obtained on the track and in the simulator has been given. According to [6] reaction times on the track are longer by 0.3 s for the brake and did not differ for the reaction with a turning. According to Mc Gehee and others [17] the reaction times on the track are longer by 0.1 seconds for the braking and 0.03 s with a turning. The research presented in this paper shows that this difference is not constant, but varies depending on the risk time characterizing of a given trial (see figure 10).

The obtained values of the measured reaction time as a psychological aptitude test stand have been compared with those obtained on the track and in the simulator (fig. 11). The figure contains lines corresponding to the simple and complex reaction times, even though it is a constant, not depending on risk time.

While analogizing graphs of fig. 10, we can say that simple and complex reaction time is significantly shorter than obtained for the same drivers during testing on the track or in the simulator. Only in the case of a determined reaction time for trials with very small values of risk time (0.5-1.0 s), they are similar. It is worth noting that only for "turn" reaction time, the difference in values between the track and simulator weakly depends on risk time, so it is close to a constant value. When we analyse "brake" and "accelerator pedal" reaction time, it then was can notice, that them the greater the risk time value, the greater the difference between the results obtained on the track and in the simulator.

When you present the obtained results of reaction time for each maneuver in a single graph (fig. 11), one can say that in the case of testing on the track, the reaction time for "accelerator" is less since the "turn" one. The highest values of reaction time have been obtained for "brake".

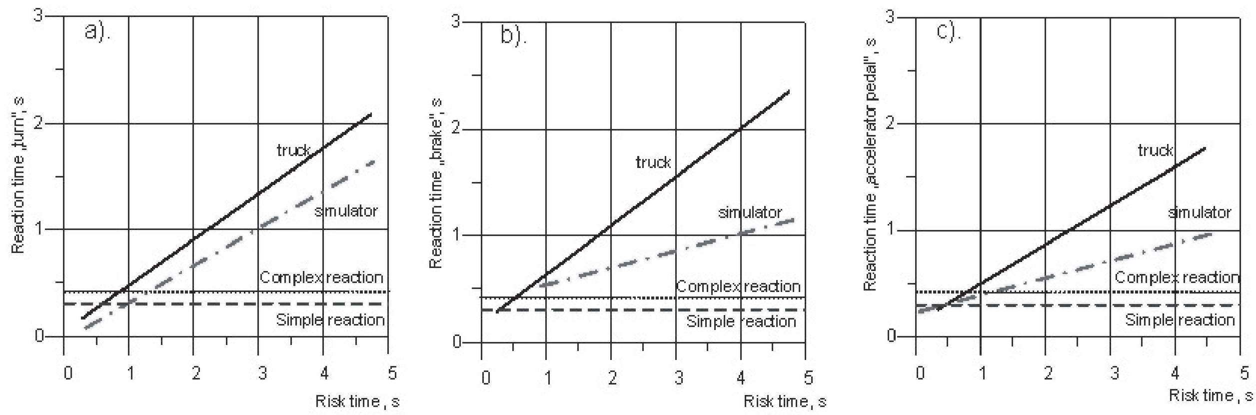

Fig. 10. Comparison of the time for considered manoeuvres: a) "turn" reaction time, b) "brake" reaction time , c) "accelerator pedal" reaction time

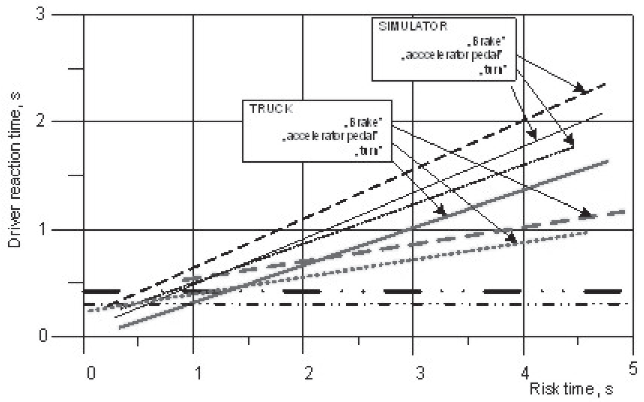

Fig. 11. Comparison of the reaction time

If the average reaction time of drivers in the simulator generated the lowest values have been determined for the “accelerator” reaction time and the highest for the “turn”.

You need to be aware, however, that the above-mentioned behaviour of drivers, each sequence of manoeuvre has been determined for a particular scenario of a pre-accident situation. For other scenarios, the situation of the driver’s mode of action may vary. Therefore, the authors in their attempt for further work is to determine the impact of different scenarios on obtained reaction time of drivers.

Determined correlation coefficients between “brake” and “turn” reaction time in relation to the simple and complex reaction time are very small, and in many cases even negative. In total, 120 studies conducted correlation only in 4 cases the absolute value of the correlation coefficient was greater than 0.5.

No correlation has been found with the results of the experiment on the track and the simulator shows that the reaction time obtained in studies on simple psychological stand can not be treated as the actual reaction time of drivers in traffic situations and can not be used in the reconstruction of road accidents.

This conclusion is very important because in some publications the reaction time determined in similar stands is taken as the actual reaction time of drivers in the analysis of the accident.

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