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Assessment of Driver's Reaction Times in Diverisified Research Environments

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Abstract

Reaction time is one of the basic parameters that characterize the driver and very important in the analysis of accident situations in road traffic. This paper describes research studies on the reaction time evaluation as conducted in three environments: on a typical device used in the transport psychology labs (the so-called reflexometer), in the driving simulator (autoPW) and on the driving test track (the Kielce Test Track). In all environments, the tests were performed for the same group of drivers. The article presents the characteristics of research in each environment as well as shows and compares exemplary results.

1. Introduction

One of the basic methods used by experts during the reconstruction of road traffic accidents are various types of mathematical models of the man-vehicle-environment system. The correctness of expertise performed, in addition to a purely

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human dimension associated with the ruling of guilt and punishment, is also of great economic importance related to the compensations paid by insurance companies.

Among the many factors, affecting the accuracy and reliability of accidents analyses that are conducted using such methods, the most important are: the complexity of models – the car motion model, the human activity model, the collision model, and so on, here also referred to as "validation" of models, up-to-datedness and accuracy of input data estimates, skills and know-how of an expert.

Among other input data, one of the key ones used in the computations that are carried out in the accident reconstruction process is the "reaction time", i.e. the time that elapses since the moment a danger occurred until the moment at which the driver began to affect one of the vehicle control mechanisms. Research studies aiming to develop and update a database containing reaction times of road vehicle drivers are the subject of this paper. The studies were carried out under the research project N509 016 31/1251. They were conducted by three teams: from Kielce University of Technology (the leader), Warsaw University of Technology, and Cracow University of Technology.

2. Reaction Times Determination Issues

Drivers' reaction times data is one of the essential components in the training materials and manuals for court expert witnesses as well as automobile engineering and road traffic appraisers. Many publications present data values that differ from each other, often very significantly. Whereas to a large extent, the final decision on whether a driver is guilty or not may depend on what values shall be used for the analysis performed by the court expert witnesses.

These differences often result from different research methodologies (tool – research environment, testing methodology, multiplicity and "composition" of the group of the respondents, the way of presenting the results). Looking from the accident reconstruction suitability standpoint of view, one should note that no method has been developed so far that could be clearly regarded as the best one. Generally, there are four methods (research environments) that used for this type of studies:

- tests at stations for conducting psychological studies of drivers (or similar),
- experiments on the roads or test-tracks,
- tests in driving simulators,
- testing (of observational type) in actual traffic conditions.

Evaluation of reaction time in psychological studies is one of the testing sets performed in psychological laboratories to assess a general ability of the person tested to drive mechanical vehicles. These studies are characterized by years of methodological practice and the way of assessing their results, e.g. [12]. In the case of reaction time, the so-called reflexometers are used. The reaction time is assessed as a period from the appearance of the pre-set light or sound stimulus until the subsequent behavioral response, i.e. when the corresponding button on the desktop is pressed.

In case of data originating from experiments on the road or the test track, the most common are the testing results of reaction on the so-called simple stimulus (single sound or light signal), however, the way of driver's response is also simplified – it has to affect one of the vehicle control components (working brake pedal, handbrake lever, steering wheel), [1, 2, 9, 17]. Results of this type of research studies are often published as a recommendation to experts, e.g. [1, 19].

In actual road traffic situations (except for driving e.g. in a column on the highway where we react to the "stop" light of the car driving ahead of us), the driver reacts to complex stimuli. However, in reference sources 10-15 years ago, it is difficult to find data on reaction times in which complex are both the stimulus and the driver's reaction (like in real life accident situations). Being aware of this, the research studies were carried out to check reactions for complex stimuli, but were often in highly simplified situations. For example, in papers [2, 9], the lights of pulse generators stuck on the windscreen of the car were used in the studies to test reactions for the complex stimulus.

In recent years, research studies on roads or testing tracks increasingly involve implementation of certain selected, recognized as representative, and agreed accident scenarios. In their earlier works [3, 6, 13, 14], authors of this paper presented those types of tests.

The development of simulation techniques, growth in computers efficiency and image-generating systems has allowed to build virtual environment for drivers testing – the driving simulators. They are increasingly being used in drivers testing. Their use increases the independence from weather conditions and promotes higher reproducibility of results [3, 8, 10].

Other type of studies, as the "observation" in real traffic conditions, should also be mentioned. Those studies often rely on analysis of records from video cameras (e.g. monitoring) placed along the roads [11]. The assessment result (reaction time), however, strongly depends here on arbitrary assumptions of an observer as to the initial moment of the emergency situation (and thus also the stimulus).

To summarize this brief review of the reference sources, one may conclude that such studies are essential where the response times are determined not towards the stimulus or the simple stimuli system, but towards a certain simulated accident risk situation. The number of results, available in the reference sources, for this type of testing is rather small and includes only the selected special cases.

3. Performed Research Characteristics

3.1. General description of research studies

The research studies were conducted in the years 2008-2010 on a group of 104 drivers. They were men aged 19-64, but the dominant group (75%) was young drivers at 19-25 years of age. Such structure was not accidental. The statistical data indicates that such drivers pose the greatest danger on the road (see e.g. [18]).

Measurements were carried out in three testing environments:

- at the station for psycho-technical testing (MCR gauge),
- in the driving simulator autoPW,
- at the testing track (The Kielce Track).

The same persons were tested in each environment.

A methodology, proposed by the psychological laboratories was used in measurements taken at the station for psycho-technical testing. Its closer description is provided in item 3.2.

In studies performed in the simulator and on the testing track, the basic assumption of the studies was that reaction times will be determined for a complex situation, not a simple stimulus. A realistic accident risk situation was simulated involving sudden appearance of a roadblock. A general diagram of this situation is illustrated in Fig. 1.

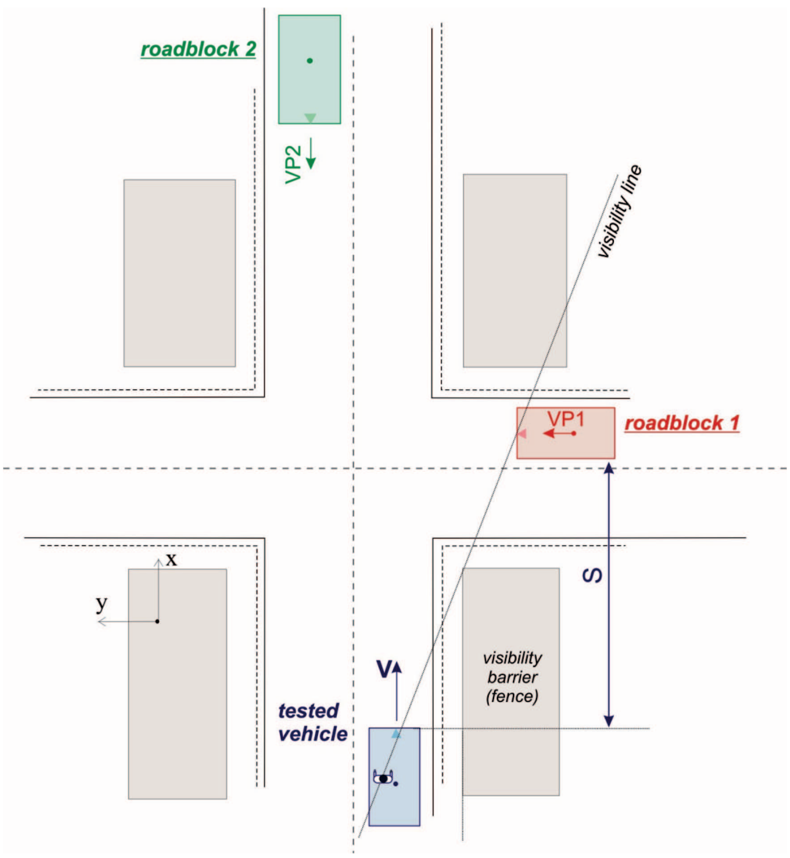

Fig. 1. Diagram of the analyzed risk situation

A road intersection with a limited visibility (urban area) is considered here. The tested driver drives a vehicle at a velocity V. At a certain distance S, the roadblock 1 ”invading” the intersection began to be visible, thus forcing the driver's action to avoid collision. Drivers were not imposed the way of behavior. Depending on their own assessment of the situation, they decided about how to take a defensive maneuver (braking only, solely by-passing the roadblock, or both operations simultaneously) and with what ”intensity”. Three representative risk situations were selected for the implementation of collision: with a passenger car, with a pedestrian, and with a truck. In the passenger car scenario, there was an additional roadblock in the form of a vehicle approaching from the opposite direction (roadblock 2 in Fig. 1).

A notion of risk time was used when formulating the research studies concept. It has been defined in previous papers produced by the authors [3, 6, 7], as the time which a driver has since the moment the roadblock was noticed until a possible collision with it and that time can be used by the driver to perform defensive actions. It may be formulated by a simple relationship between the velocity of the vehicle tested and the distance from the roadblock at the initial moment:

$$t_r = \frac{S}{V} \tag{1}$$

Based on previous experiences [3, 13, 14], the risk time was assumed in the hereto presented research studies to range from 0.3 s to 3.6 s. The assumed risk time value was being obtained by mutual combination of velocity at which the tested vehicle was moving (ranging from 36 to 65km/h) and a distance from the roadblock at the time when it was noticed (in the range of 5 to 50m). For safety reasons, no tests were carried out with risk time lower than 0.5 s in the studies that were performed on the testing track. The parameters of individual trials are illustrated in Table 1.

Table 1

Trials parameters implemented in tests in simulator and on the testing track

Trial No. (s – trials in simulator only):	**1s**	**2s**	**3s**	**4s**	5	**6s**	7	8	9	10	11
Risk time [s]	**0.3**	**0.35**	**0.4**	**0.45**	0.5	**0.554**	0.6	0.72	0.8	0.9	1.0
Tested vehicle velocity V [km/h]	60	51.4	45	40	36	65	60	50	45	40	36
Distance from the roadblock at the time of its occurrence S [m]	5	5	5	5	5	10	10	10	10	10	10
Trial No.:	12	13	13	15	16	17	18	19	20	21	22
Risk time [s]	1.2	1.44	1.8	1.8	2.0	2.16	2.4	2.7	2.88	3.0	3.6
Tested vehicle velocity V [km/h]	60	50	40	60	36	50	60	40	50	60	50
Distance from the roadblock at the time of its occurrence S [m]	20	20	20	30	20	30	40	30	40	50	50

Other specific information about individual tests and sample results shall be presented in paragraphs 3.3 and 3.4.

3.2. Tests using MCR device

Fig. 2 presents the device that was used for testing. This system consists of a control panel with four contact buttons (3 and 4), signaling semaphore (2) and microchip meter (1) and the so-called connection system (5).

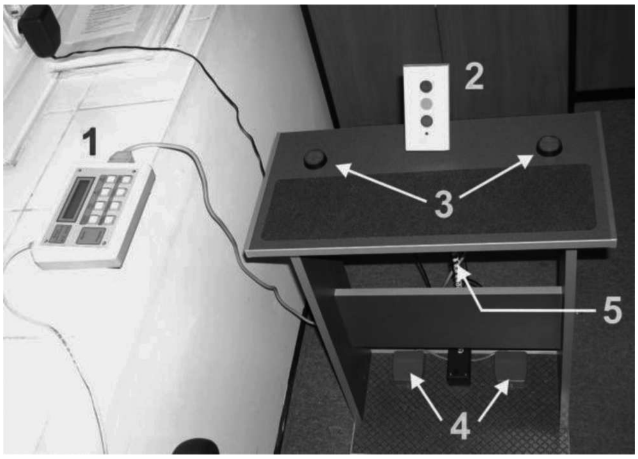

Fig. 2. Device for Measuring Reaction Time MCR - 2001E:
1 – central unit MCR – 2001 E – microchip meter of reaction time; 2 – semaphore (signaling device – the light and sound stimuli trigger); 3 – „manual" manipulators (right and left buttons); 4 – „foot" manipulators (right and left pedals); 5 – connection system

The task of the measurement system is to measure human reaction time to stimuli in the form of sound and light signals. The microchip time meter via the connection system forces generation of an appropriate stimulus in the semaphore: either one of the three light-emitting diodes (LED) turns on or a beep is heard. The semaphore consists of three LEDs in red, green, and yellow colors and a horn. Exposure time of each stimulus is 0.5 s.

The task of the person tested is to press the corresponding keypad (turning on the appropriate switch) on the control panel. The microchip system measures the time from the triggering of the stimulus until the switch makes the connection. The device can operate in measuring mode of the so-called simple reaction and complex reaction. In simple reaction mode, the time is measured from the occurrence of any stimulus until any reaction of the person examined: pressing one of two manual switches or one of the two foot switches. The further presented results refer to a simple reaction in the manual mode. In the complex reaction mode, each stimulus is assigned to an appropriate switch (e.g. red light – left hand switch, yellow light – right hand switch, green light – right foot switch, a beep – left foot switch; assignment of the stimuli and switches is programmable, and a standard scheme was provided that had been used in studies). In this mode, if the tested person uses a different switch than that assigned to the stimulus then it is treated as so-called "wrong response." The number of stimuli, which each of the drivers has undergone, is 50 both when simple and complex reaction times are measured. The measurement results are illustrated in Fig. 3.

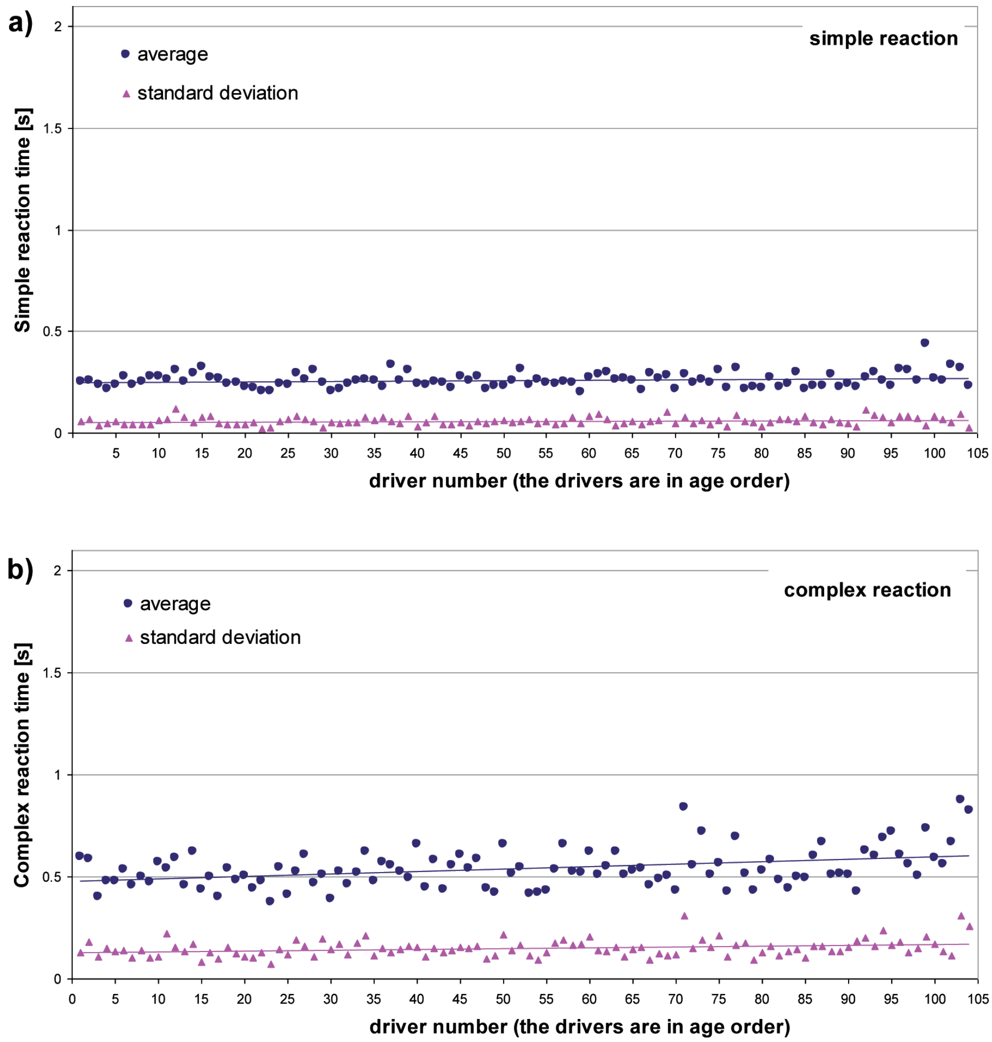

Fig. 3. Times of the simple reaction (a) and of the complex reaction (b) for 104 drivers, obtained in tests using the gauge MCR – 2001E (the drivers are in age order)

Average time of the simple reaction ranged between ca. 0.20 and up to 0.33 seconds (with one exception which stated the result of about 0.44 s). The standard deviation was at about 0.05-0.06 s (the lowest value of 0.02s, the largest one 0.12s). In the case of complex reaction, the average times were significantly longer (more than twice): from about 0.40 to about 0.73 s (in isolated cases, more than 0.8 s); higher was also the scatter of results – the standard deviation is generally within the range of 0.10-0.20 s (the extreme values are: 0.07 s and 0.31 s). For older drivers, the values recorded and provided were generally higher. They partly reflected by the plotted trend lines. However, full assessment and conclusions for the presented results (in terms of age) will be the subject of a separate study.

3.3. Testing in driving simulator autoPW

The driving simulator autoPW is located in the Vehicle Motion Simulation Research Laboratory at the Faculty of Transport of the Warsaw University of Technology [8]. It is the laboratory station that allows for testing a driver in the staged vehicle traffic conditions, including pre-accidental situations in traffic. The basic components of the simulator are: natural cab originating from a middle-class passenger car with a complete set of interior equipment (Fig. 4), the main screen and the side one (which, using the projectors, display image seen through car windows), the system of measuring position sensors of the vehicle controls (pedals of accelerator, brake, clutch, gear lever, dashboard switches), a computer system of the simulator, and data acquisition system.

Fig. 4. The interior of the car cab in the driving simulator

Graphics capabilities of the driving simulator autoPW allow for visual mapping of the actual road intersection. The intersection of streets Kosiarzy and Piechoty Łanowej, located in Warsaw was selected for holding the tests. The picture of that intersection and the way of its mapping in the simulator is illustrated in Fig. 5. Images of detached houses in the simulator were made based on actual natural pictures. The geometrical and spatial parameters (mutual distances, width of roadway, sidewalk, etc.) and colors were also reproduced in detail.

Fig. 5. Intersection of streets Kosiarzy and Piechoty Łanowej in Warsaw (the actual image and its mapping in the simulator)

As mentioned in section 3, three different scenarios were used for the course of the accident situation: a collision with a passenger car, with a pedestrian, and with a truck (known respectively as: scenario I, II and III). Fig. 6 presents examples illustrating their implementation. In each scenario, every driver was performing 22 tests that differed in risk time (see section 3 and Table 1). In total about 7 000 measurement tests were carried out (not counting the so-called "empty" trips) in which all the data were recorded on the driver's actions performed on the vehicle controls components (the steering wheel, pedals) as well as vehicle traffic and roadblock (or roadblocks). Fig. 7 presents a sample output resulting from the recorded data analysis. This is a summary of average reaction times and their standard deviations on the brake pedal, received in the scenario I (Fig. 6) as a function of risk time. Each "point" on the diagram means the average score for the 104 drivers for a given risk time. There is a strongly visible dependence of the reaction time on the risk time. The average reaction time starts from about 0.5 seconds for the lowest ones up to ca. 0.9 s for the highest risk times being considered. The smallest scattering of the results was reported for the risk time range from about 1.0 to 1.5s, which is evident in the marked area between quantiles of 0.1 and 0.9 (the smallest "width" of the area).

For comparison purposes, Fig. 8 contains analogical results for reaction time on the steering wheel. Here is even stronger dependence of the reaction time on the risk time. The average reaction time increases from about 0.3 s for the lowest risk times up to about 1.2 s for the highest ones. In this case, the lowest scattering of results was reported for the risk time range from about 0.3 up to 1.0 s, which is evident in the marked area between quantiles of 0.1 and 0.9.

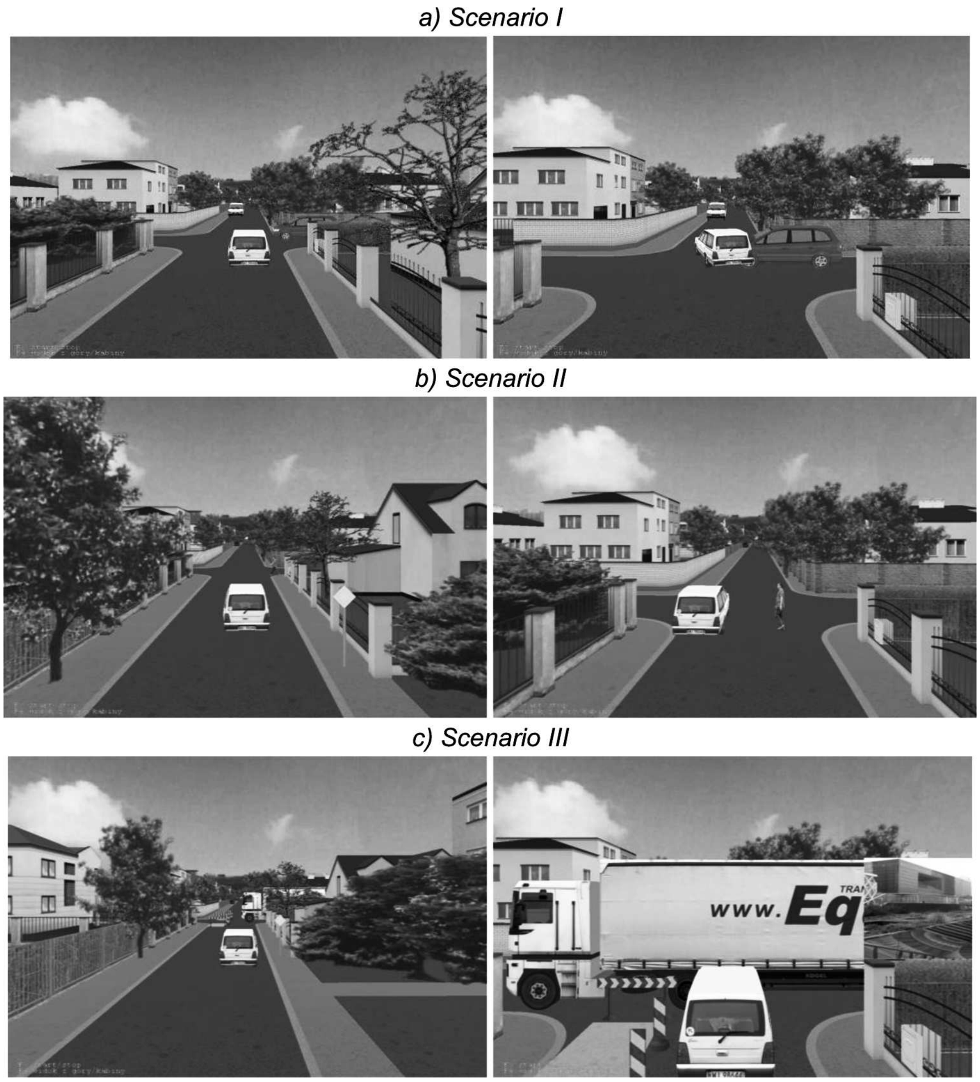

Fig. 6. The sample implementation of tests in the driving simulator autoPW (selected images from one of the trials) for three scenarios (a) scenario I, (b) scenario II, and (c) scenario III

3.4. Testing on the Kielce Track

Similarly as in the case of tests performed in the driving simulator, the basic assumption of the road tests implementation was to reflect a realistic accident situation and assess time of the complex reaction. For this purpose, the system of mock-ups was built on Kielce Testing Track to imitate a reduced visibility of roadblocks. Also, a special system for their guidance and driving was designed to allow testing in the assumed and secure manner. The test car was equipped in with proper measuring equipment that enables recording of the car motion parameters as well as driver's

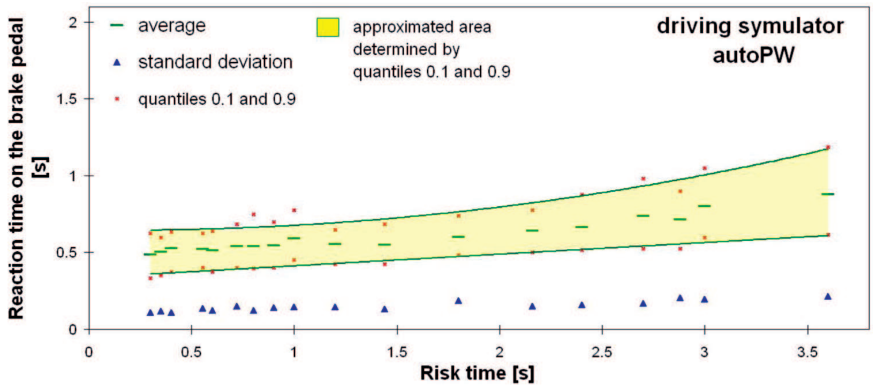

Fig. 7. Reaction time on the brake pedal for scenario I in the driving simulator

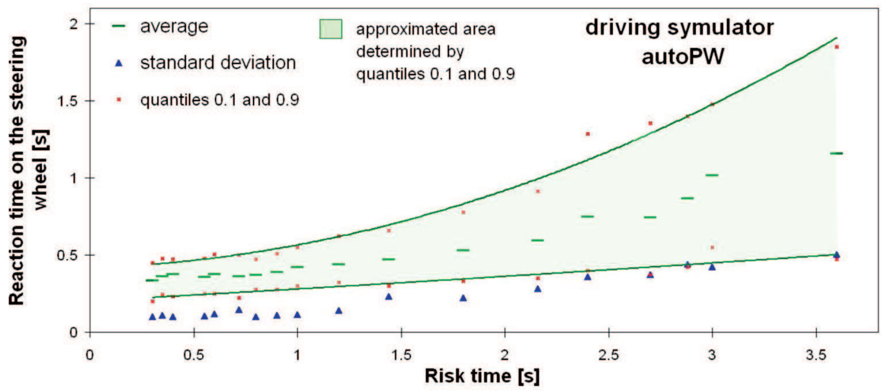

Fig. 8. Reaction time on the steering wheel for scenario I in the driving simulator

impact on the control mechanisms. As is the case of tests performed in the simulator, three hazard scenarios were carried out: collision with the passenger car (Scenario I), collision with a pedestrian (Scenario II), and collision with a truck (scenario III). In the case of scenario I, there was additionally a vehicle coming from the opposite direction – the so-called roadblock 2 (see Fig. 1). Fig. 9 shows examples of the research tests implementation.

Each of the tested drivers performed 17 attempts that differed in risk time (see section 3 and Table 1). In total about 6 500 measurement tests were carried out (not counting the so-called "empty" trips). Fig. 10 presents a sample output resulting from the recorded data analysis. This is an example that corresponds to the results obtained from the simulator and presented in Fig. 7 – the average reaction time and the standard deviation on the brake pedal in risk time function, obtained in the scenario I. Each "point" on the diagram means the average score for all the drivers for the given risk time. There is a strongly visible dependence of the reaction time on the risk time. The average reaction time starts from about 0.9 s for the lowest risk

Fig. 9. Exemplary implementations of track tests (selected images from the of the trials) for three scenarios (a) scenario I, (b) scenario II, and (c) scenario III

times up to ca. 1.5 s for the highest ones being considered. The smallest scattering of the results was reported for the risk time range from about 1.2 up to 2.2 s. In the marked area between quantiles of 0.1 and 0.9, the range of risk times is more evident than in the case of tests in the driving simulator where the reaction time distribution is more focused.

A comparison of quantiles 0.1 (the bottom line) and 0.9 (the upper line) shows another interesting pattern. Making some simplification here, one can assume that the quantile 0.1 illustrates the ”best” drivers, while the quantile 0.9 – ”the weakest ones”. In the case of the first ones, the situation was more dangerous (and the lower risk time) the reaction time was shorter. However, in the case of the ”weakest” drivers the reaction time increased in situations of the greatest risk (at the lowest risk times).

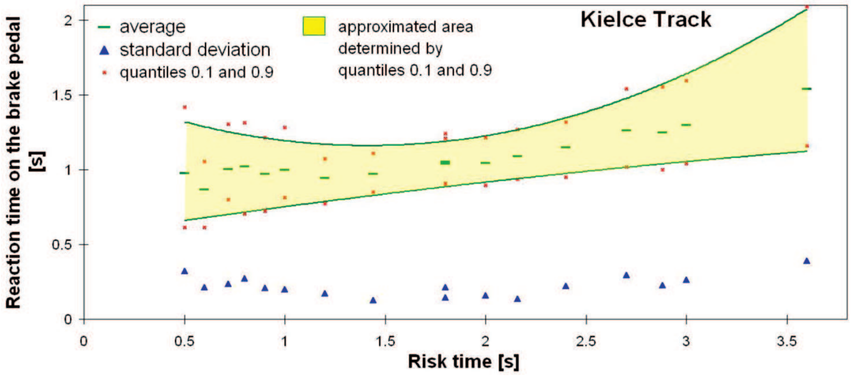

Fig. 10. Reaction time on the brake pedal for scenario I on the testing track

As in the case of tests performed in the simulator, for comparison, Fig. 11 contains analogical results for the reaction time on the steering wheel. Here also is visible even a stronger dependence of the reaction time on the time of risk. The average reaction time increases from about 0.6 seconds for the lowest risk times up to about 1.5 s for the highest ones. The smallest scattering of results occurs for a similar risk time range – from around 1.2 up to 2.2 s.

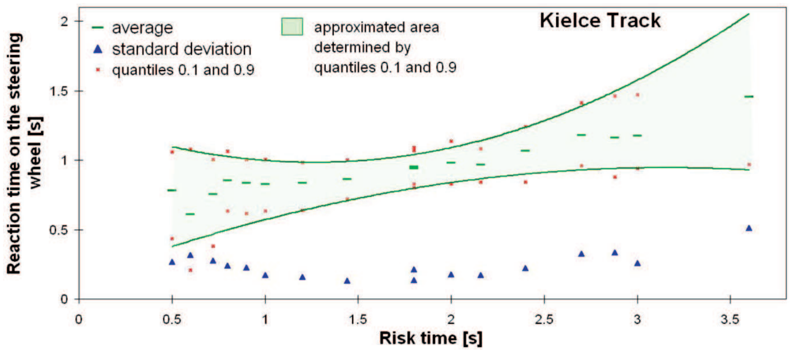

Fig. 11. Reaction time on the steering wheel for scenario I on the testing track

4. Conclusion

The third section presents three different methods to assess the car driver's reaction time. Exemplary results obtained through their use were illustrated. Testing the same research group while (wherever it was possible) maintaining the full compliance of testing conditions (the same test scenarios in the simulator and on the testing track), allow for making reliable comparisons. A comprehensive analysis of all results continues to be carried out. Based on the hereto presented results, the most general observations are as follows:

– the reaction times are the smallest at the psycho-technical test MCR station. In particular, this refers to the so-called simple reaction;
– in the case of the complex reaction tested on the MCR station, the values of average times are close to values obtained in the simulator for the lowest risk times;
– test conditions at the MCR station differ significantly from conditions similar to driving a real car;
– in case of research studies in the simulator and on the testing track, a strong correlation was found between the reaction time and the parameter characterizing the ”scale” of accident risk – the risk time: the longer risk time – the longer reaction time;
– for low times of risk, the reaction time on the brake pedal is clearly longer than the reaction time on the steering wheel; for the higher times – the differences are becoming increasingly smaller; This effect is visible both in the case of testing on the track and in the simulator;
– due to testing conditions, test results on the track can be considered as the most realistic;
– the reaction time values in the simulator are lower than those obtained in similar measurement conditions on the testing track. A strong correlation was found between the results for these two environments as indicated in the previous studies [3, 6].

As already mentioned herein, the analyses of the results obtained continue to be carried out. They refer not only to the reaction time on the brake pedal (as in the illustrated examples), but also to the diversity of the time in different vehicle control components (pedals of accelerator, clutch, and also the steering wheel). Analyzed are also the type of reaction, its ”intensity” and the efficiency for given parameters characterizing an event (scenario, risk time, velocity, a distance from the roadblock, etc.). Also personal and individual characteristics of the tested persons, such as: – age, professional qualifications at hand, vehicle driving experience, etc. are taken into consideration. Partial results of those studies can be found in [4, 5, 15, 16].

By comparing general methods, the following can be stated. The use of MCR type of gauges is convenient because of the costs of research, the possibility of testing on large statistical samples, and the repeatability of results. However, an attempt to treat the results as representative for the analysis of accident situations raises serious doubts. The results obtained in a real car on testing track and for a realistic driving situation should be considered as the most realistic results. However, one must remember about the high costs of such research studies (measuring equipment, access to the testing track, the research logistics, time consumption), difficulties in maintaining the comparability of the conditions (weather conditions), and safety issues are also significant. From the point of view of e.g. the need to carry out tests for a single person (e.g. for the expertise of accident), this examination seems to be practically unfeasible. A good solution here may be the driving simulator. One should be aware of the drawbacks of such devices (simplifications, animated images), and also not inconsiderable costs of their use in drivers testing. However, the independence of the research studies from weather conditions and a relatively short duration of tests performed in the simulator is very tempting. The use of the simulator will be however possible upon checking whether there is a correlation between the results obtained on this device and the tests performed on the testing track. Its existence was demonstrated for the average reaction times [3, 6]. Further analyses should be conducted to verify whether there is also a correlation for many tests, carried out for a single driver in both research environments.

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