DETERMINING OF DRIVER REACTION TIME ON THE "autoPW-T" TEST MACHINE

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Summary

Results of author's research work on the determining of driver reaction time, carried out on a prototype test machine "autoPW T", have been presented. The machine was built at the Faculty of Transport of the Warsaw University of Technology and it can be used for performing tests known from typical laboratory "psycho-technical examinations" (reaction time measurements on "reflex testers") on the one hand and, on the other hand, for evaluating driver's reactions at the operation of real vehicle controls (steering wheel as well as brake, accelerator, and clutch pedals) during a simulated drive with a prescribed speed. Apart from a brief description of the test machine and its capabilities, results of the examination of about 100 drivers have been presented, which included a comparison of the reaction times measured for the steering wheel and brake pedal being operated. The measurement results quoted were obtained from four different tests, i.e. the testing of simple reaction on the steering wheel, simple reaction on the brake pedal, complex reaction, and reaction at emergency braking. They have been shown in the form of histograms of the average values and standard deviations of the reaction times and other statistical parameters of the distributions obtained for the whole population of the drivers examined. Differences in the reaction time values depending on specific test types, with reference to the central measure of the distribution (average value) and the measure of dispersion of the distribution (standard deviation value), have been pointed out.

Keywords: driver examinations, driver reaction time, psycho-physical driver characteristics

1. Introduction

The reaction time (or the time of psycho-physical reaction) of a driver is defined as the time that elapses from the instant when a potential collision situation in the road traffic occurs or is noticed by the driver to the instant when the driver takes a specific collision-avoidance action (i.e. begins to act on a specific vehicle control element) [1, 2, 7, 8, 9]. It is a parameter of great importance in deliberations on road safety (concerning the issue of avoiding an accident or collision in a hazardous situation having emerged) and when the road accident reconstruction issues are concerned [7]. Professional drivers are periodically subjected to "psycho-technical examinations" at transport psychology laboratories [2, 10]. One of the elements of such examinations is the measurement of the

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reaction time and the result of such a measurement is one of the criteria of assessment of the vehicle driving capability of the person involved [2, 10]. However, measurements of this type are carried out in laboratory conditions, according to very simplified procedures, which considerably differ from real conditions (cf. e.g. [6]).

The "autoPW T" machine having been built at the Warsaw University of Technology makes it possible to carry out tests similar to those performed at transport psychology laboratories, but in more natural driver work conditions, with making use of natural vehicle control elements. The machine enables determining the driver reaction time at the operation of the steering wheel as well as brake, accelerator, and clutch pedals and measuring other quantities that characterize the way how the driver operates a specific element (e.g. brake pedal force, brake pedal force rise time, time of moving the foot from the accelerator pedal onto the brake pedal, etc.). The construction and operation of the "autoPW T" machine and examples of its driver examination applications have been presented in subsequent parts of this paper.

2. The "autoPW T" driver examination machine

The "autoPW T" machine resembles the driver work place in a passenger car, with its ergonomic characteristics having been maintained (see Figs. 1 and 2). It was built with partial financing from the EU resources (within cooperation with the VISEB Group on the APROSYS project of the 6th EU Framework Programme) and, in another part, from the funds contributed by the Faculty of Transport of the Warsaw University of Technology.

Fig. 1. General view of the "autoPW T" test machine during a driver examination

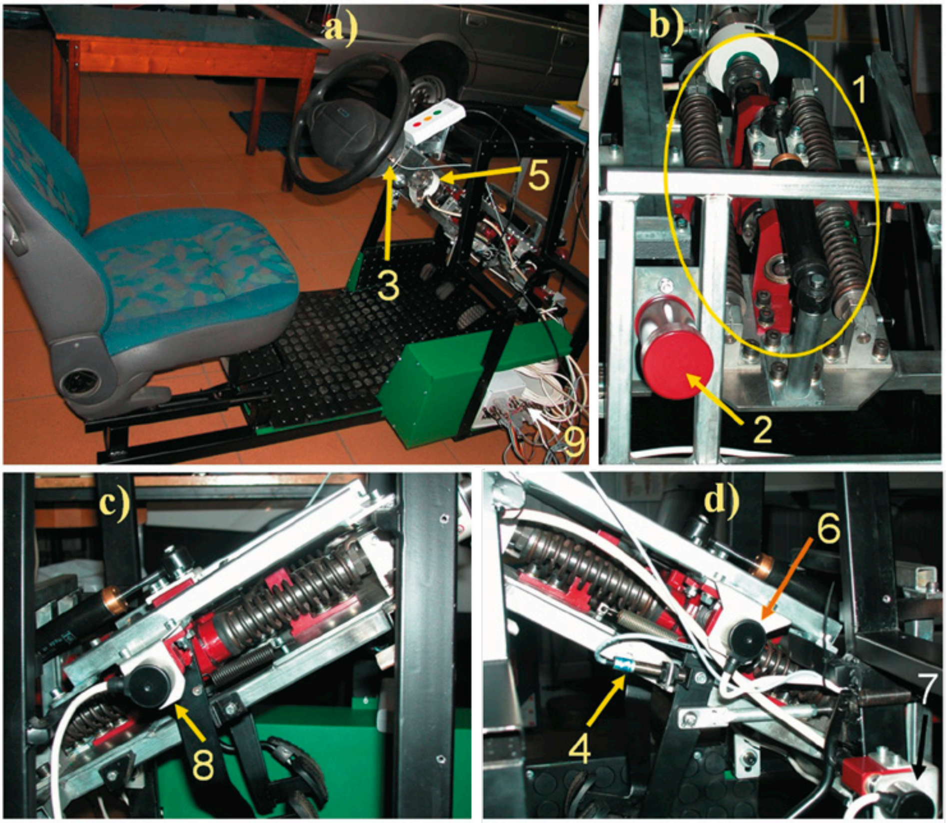

Fig. 2. Views of the "autoPW T" test machine with its covering panels having been removed; a) – general view; b) – front view; c) – left-side view; d) – right-side view: 1 – steering wheel resistance mechanism; 2 – brake pedal resistance mechanism; 3, 4 – steering wheel and brake pedal proximity sensors; 5, 6, 7, 8 – rotational-impulse sensors (encoders) of steering wheel, brake pedal, accelerator pedal, and clutch pedal positions; 9 – box with a matching and adjustment system

The test machine consists of the following major components (see Fig. 2):

- machine base with a driver seat (including a seat fastening system with a seat position adjustment system);
- steering column (with adjustable angular position);
- mechanism to simulate the steering system resistance to steering wheel operation;
- brake pedal mechanism;
- mechanism to simulate the brake system resistance to brake pedal operation;
- accelerator pedal and clutch pedal mechanisms;
- measuring and recording system with a computer and software;
- panels covering the chamber where the above mechanisms and systems are accommodated.

The vehicle control mechanisms and elements (pedals and steering wheel with its column) as well as the driver seat, together with their spatial arrangement, have been adapted from a small passenger car. An important feature of the test machine is the representation of the real resistance put up by the vehicle control mechanisms.

A schematic diagram of the measuring system has been presented in Fig. 3. This system comprises four optoelectronic incremental angular position sensors (incremental encoders, used to determine the positions of the steering wheel and three pedals) and two inductive proximity sensors. Thanks to the encoder signals, such parameters can be evaluated as driver reaction time at the operation of individual vehicle controls (steering wheel as well as brake, accelerator, and clutch pedals), rising rate of the signals representing the operation of individual vehicle controls (e.g. brake pedal force rise time or time of increase in the steering wheel turning angle), and signal "intensity" (e.g. the maximum value of the force applied to the brake pedal or the amplitude of the steering wheel turning angle). The proximity sensors were applied so that information about the bare reaction time could be quickly obtained, without analysing the signal that represents the operation of a specific control element (for this quantity to be determined from the encoder signals, the signal curves recorded must be separately analysed, see also Section 3 of this article). The reaction time is thus determined with an accuracy of ±1 ms.

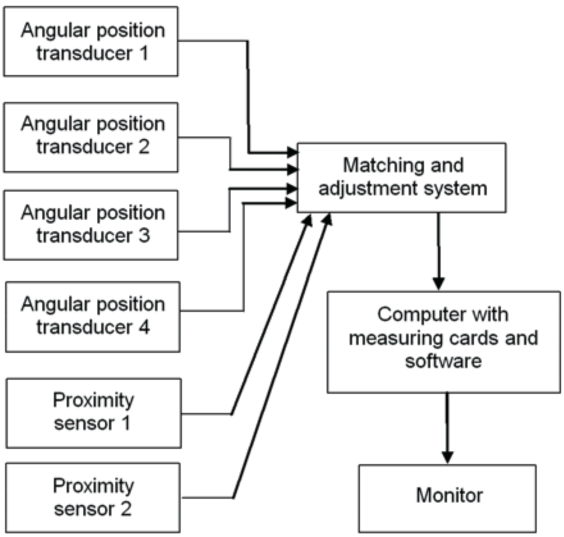

Fig. 3. Schematic diagram of the measuring system of the "autoPW T" test machine

A detailed description of the construction of major components and systems of the test machine under consideration has been given in publications [3, 4].

One of the ideas to be implemented in the test machine was a possibility of using test methods similar to those employed at typical tests carried out at transport psychology laboratories to measure the driver reaction time (see e.g. [6, 10]. This was one of the reasons for using a set of stimuli that would be identical to the one to which the person examined is normally expected to react, i.e. three light signals displayed on the monitor screen (see Fig. 1) and one acoustic signal. Apart from this, the simulation of a drive has been made possible by coupling the accelerator pedal position with a speedometer image displayed on the monitor. This is an important feature of the test machine because thanks to that, the driver can be examined in a situation when his/her attention is focused on performing a specific function, i.e. maintaining a specific drive speed in this case. The sequence of the stimuli being produced and their number can be programmed. In addition to this, the examination of both the "simple reaction" and the "complex reaction" is possible.

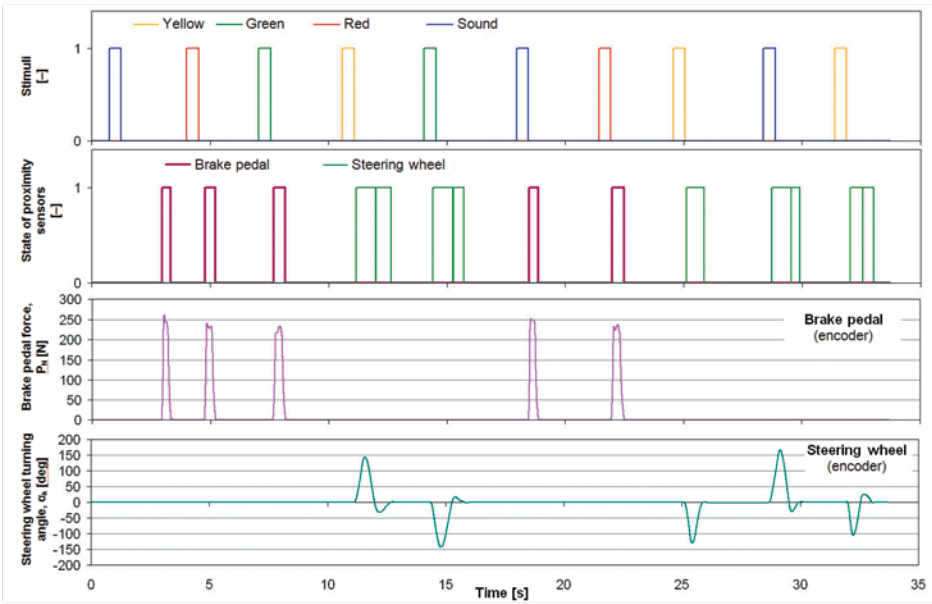

Fig. 4. Example record of the signals obtained from a single test (described in the text)

3. Example of a single test

This Section is to demonstrate the measuring capabilities of the "autoPW T" test machine. Fig. 4 shows an example record of the signals obtained from a test. The graphs represent the time histories of the following signals, proceeding from top to bottom: the state of individual stimuli (0 – "off"; 1 – "on"); signals received from the proximity sensors (0 – "off", i.e. inactive position; 1 – "on", i.e. driver's reaction on a specific control is detected); brake pedal force; and steering wheel turning angle (the values of the brake pedal force and steering wheel turning angle have been determined from the encoder signals). The curves indicate 10 driver's "reactions" (5 reactions on the steering wheel and 5 reactions on the brake pedal).

Figs. 5 and 6 present some selected driver's actions on the brake pedal and steering wheel, with showing which parameters can be evaluated and how this may be done. The following parameters are meant here: time (t_r) of a reaction being applied to a specific control element, reaction rise time (t_n), maximum value (max) of the reaction and, in the case of the brake pedal, average value (sr) of the brake force (read during the period when the force is "stabilized"). The selected curves represent the "second" reaction pulse in Fig. 4 (the instant of about 5 s) for the brake pedal and the "fourth" reaction pulse (the instant of about 11 s) for the steering wheel.

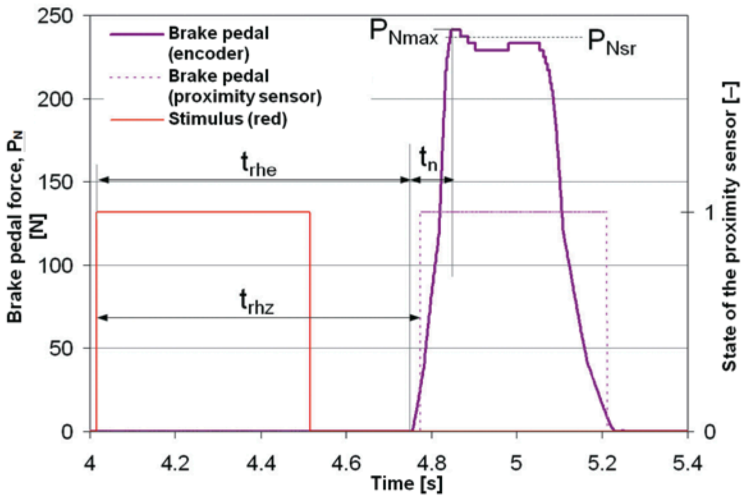

Fig. 5. Parameters of a driver's action on the brake pedal

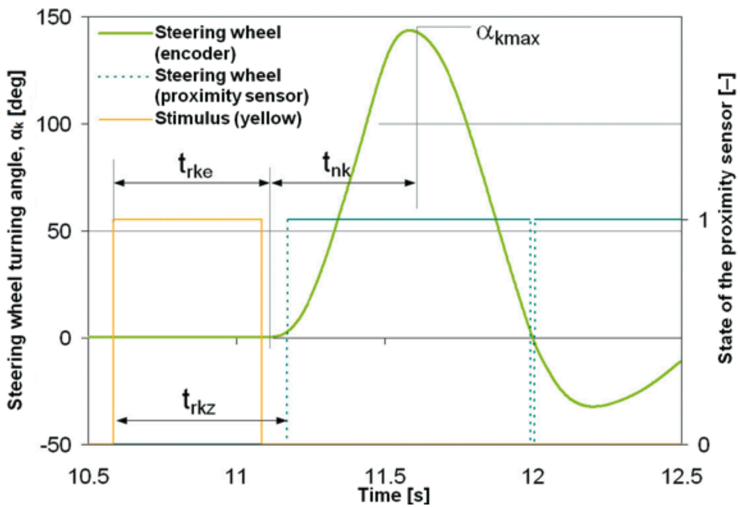

Fig. 6. Parameters of a driver's action on the steering wheel

The reaction time is determined in two ways. At the first method, this time (t_{rz}) is measured with the use of the proximity sensors, from the beginning of the period of a stimulus being produced (i.e. from the rising edge of the stimulus signal) to the actuation of the proximity sensor of the specific control element (i.e. to the rising edge of the reaction signal). This measuring method is convenient when the reaction time is to be quickly determined. The other method consists in determining the reaction time (t_{re}) from the time history of the values of the parameter under consideration, i.e. from the encoder signals. In this case, too, the reaction time tre is measured from the instant when the stimulus begins to be produced to the instant when a driver's reaction is detected to appear on the specific control element (i.e. when a qualitative change in the value of the quantity measured is detected). At this method, however, the signal value vs. time curves must be subjected to a separate thorough analysis after the test completion.

The characteristic parameter values for the curves shown in Figs. 5 and 6 have been given in Table 1. The reaction time values determined with the use of the proximity sensors exceed those determined from the encoder signals. This may be explained by the threshold values at which the proximity sensors are actuated.

Table 1. Driver reaction parameters for the curves shown in Figs. 5 and 6

Parameter	Brake pedal	Steering wheel
Reaction time, based on proximity sensor signals	t_{rhz} = 0.759 s	t_{rkz} = 0.587 s
Reaction time, based on encoder signals	t_{rhe} = 0.740 s	t_{rke} = 0.559 s
Signal rise time	t_{nh} = 0.107 s	t_{nk} = 0.442 s
Maximum signal value	P_{Nmax} = 241 N	α_{kmax} = 143.6°
Average signal value	P_{Nsr} = 233 N	–
Difference $t_{rhz} - t_{rhe}$	Δt_{rh} = 0.019 s	Δt_{rk} = 0.028 s

4. Evaluation of driver reaction time at the operation of the steering wheel and brake pedal

The results of measurements of both the quantities under consideration, obtained for a population of n_k = 101 drivers (males aged from 20 to 25 years, with diversified experience in vehicle driving), were compared with each other. Each of the persons examined were subjected to tests similar to that described in the preceding Section and underwent four tests in the conditions as specified below:

A. Test of a simple reaction on the steering wheel, at a simulated drive with a prescribed speed, with reacting to every stimulus by turning the steering wheel.

B. Test of a simple reaction on the brake pedal, at a simulated drive with a prescribed speed, with reacting to every stimulus by applying brakes, i.e. by pressing firmly the brake pedal. During the test, the driver had to move his foot from the acceleration pedal onto the brake pedal.

C. Complex reaction test, corresponding to the determining of complex reaction time on "reflex testers" at transport psychology laboratories (see e.g. [5, 6, 10]). During such a test, every stimulus should trigger a predefined driver's reaction. A procedure typical for such a test was adopted, i.e. a "red" signal should cause a reaction of the left hand (in this case, the steering wheel was to be turned to the left); a "yellow" signal should cause a reaction of the right hand (in this case, the steering wheel was to be turned to the right); a "green" signal should cause a reaction of the left leg (in this case, the clutch pedal should be pressed); an acoustic signal should cause a reaction the right leg (in this case, the brake pedal should be pressed). This test was carried out without simulating a drive.

D. "Emergency braking" test, similar to test B, but in this case, the person examined was to press the brake pedal simultaneously with the clutch pedal.

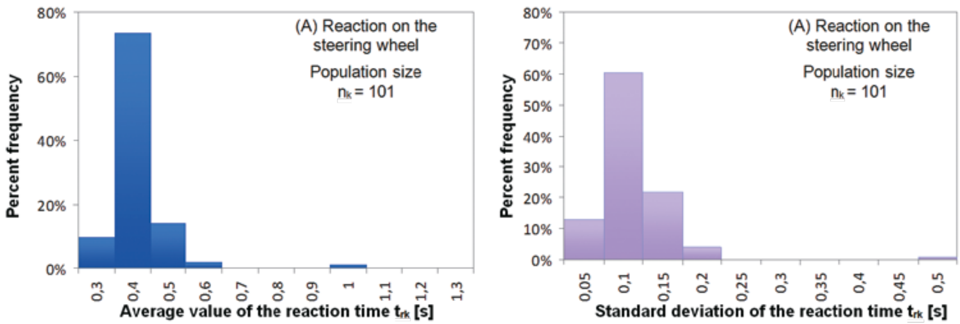

Fig. 7. Test A. Time of driver reaction on the steering wheel: histograms of the average value (left) and standard deviation (right)

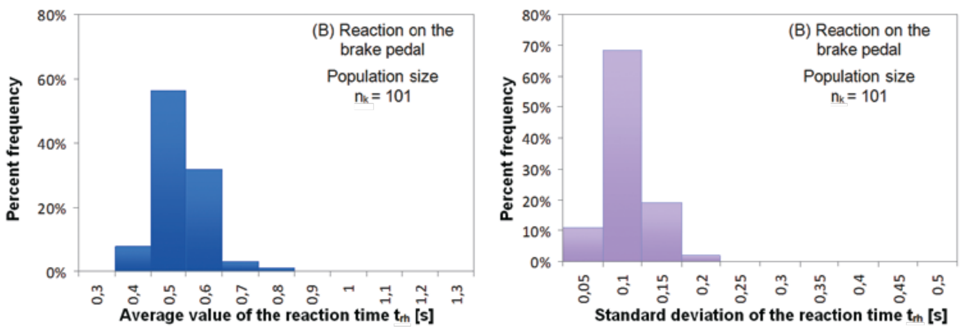

Fig. 8. Test B. Time of driver reaction on the brake pedal: histograms of the average value (left) and standard deviation (right)

During each individual test, the driver examined was subjected to 20 stimulating signals. The article presents results of the evaluation of the following parameters: time of the reaction on the steering wheel (test A), time of the reaction on the brake pedal (tests B and D), and time of the complex reaction, in the form as adopted at the "psycho-technical" examination, without specifying the control element on which the reaction was monitored (test C). Statistical maps were defined for the time of reaction on the two vehicle control elements, i.e. on the steering wheel and the brake pedal. Histograms of the average driver reaction times and the standard deviation of this quantity, obtained at the tests of each type, have been presented in Figs. 7–10.

Moreover, the values of statistical parameters of the reaction time distributions obtained at tests A, B, C, and D for the whole population of the measurement results (at each test, 101 drivers examined × 20 measurements = 2 020 samples) have been given in Table 2.

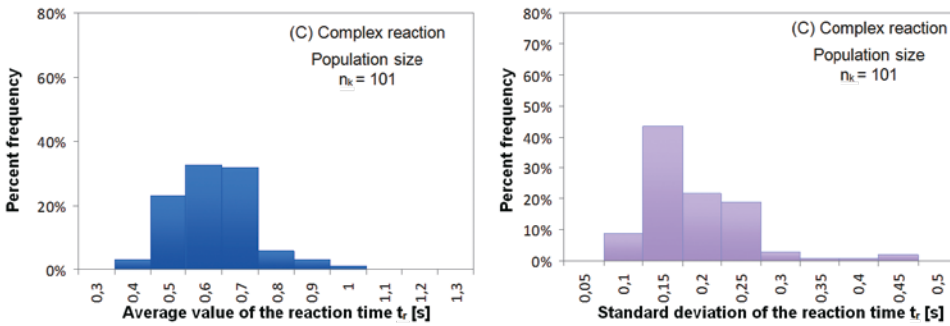

Fig. 9. Test C. Time of complex driver reaction: histograms of the average value (left) and standard deviation (right)

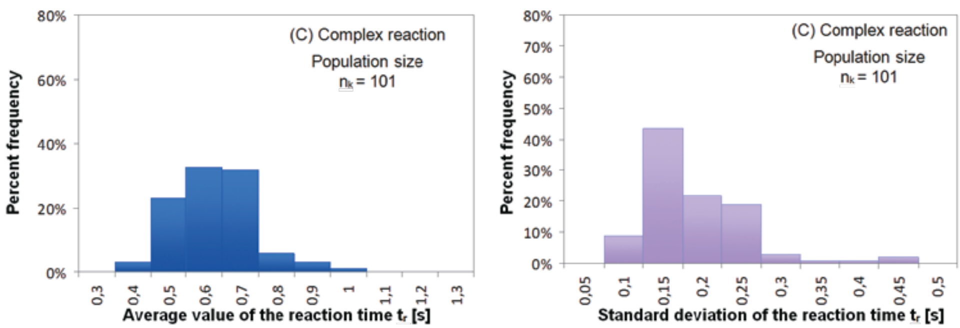

Fig. 10. Test D. Time of driver reaction on the brake pedal (at "emergency braking") : histograms of the average value (left) and standard deviation (right)

Table 2. Selected descriptive statistics of the driver reaction time at tests A, B, C, and D

Test type	A	B	C	D
Reaction type	Simple	Simple	Complex	Simple
Element on which the reaction time was measured	Steering wheel	Brake pedal	Steering wheel, brake pedal	Brake pedal
Average value [s]	0.362	0.487	0.576	0.522
Median [s]	0.348	0.486	0.575	0.519
Standard deviation [s]	0.079	0.065	0.101	0.071
Range [s]	0.695	0.381	0.527	0.331
Minimum value [s]	0.262	0.32	0.374	0.391
Maximum value [s]	0.957	0.701	0.901	0.722
Coefficient of variation [–]	0.219	0.134	0.175	0.137
Kurtosis/skewness	31/4.5	0.9/0.5	0.5/0.6	–0.4/0.4
Sample size [–]	101×20	101×20	101×20	101×20
0.1-quantile [s]	0.306	0.409	0.462	0.435
0.9-quantile [s]	0.429	0.569	0.698	0.620

The predominating interval, which included the average time of reaction "on the steering wheel" (at test A) was the one from 0.3 s to 0.4 s (the results falling within this interval were achieved by more than 70 % of the drivers examined). For the brake pedal (test B), the average driver reaction time was somewhat more dispersed and shifted towards the higher values. The intervals 0.4–0.5 s and 0.5–0.6 s predominated (about 56 % and about 31%, respectively).

When comparing the values of the time of reaction "on the steering wheel" and "on the brake pedal", one can notice that the average values differed by about 0.125 s from each other (i.e. the reaction time measured on the brake pedal exceeded that on the steering wheel by about 35 %. Approximately, this difference may be assumed to represent the average time of moving the foot from the accelerator pedal onto the brake pedal. The recorded value of this difference (0.125 s) corresponds to the data given e.g. in [7].

A measure of the repeatability of the reaction time may be its standard deviation. It can be noticed that the distributions of the standard deviation of the time of reaction on the steering wheel (test A) and on the brake pedal (test B) are close to each other in both qualitative and quantitative terms. In both cases, the interval from 0.05 s to 0.10 s predominated, as it covered 60–70% of the cases. For the standard deviations of the reaction times measured on both the steering wheel and the brake pedal, the next intervals on the ranking list were those from 0.10 s to 0.15 s and below 0.05 s (about 20% and about 10% of the cases, respectively).

Interest may be aroused by a comparison between the results obtained on the "autoPW T" test machine at tests B and D. In both cases, the reaction time was measured on the brake pedal, but at test D, the driver examined was to press "at the same time" the clutch pedal. This additional task was visibly reflected in the results achieved. The average reaction time grew from 0.487 s to 0.522 s (i.e. by about 7%). The dispersion of the measurement results increased as well: the range between the 0.1 quantile and the 0.9 quantile grew from 0.160 s to 0.185 s (by 16%). This tells of a significant impact of this effect.

The highest values of both the positional measures and the dispersion parameters could be seen at test C, dedicated to complex reaction. The average value of the reaction time at this test (0.576 s) was markedly higher than it was at the other tests, although the question whether the reaction time was measured on the steering wheel or the brake pedal was not taken into account. Similarly, the standard deviation (0.101 s) and range (0.527 s) were definitely higher in this case. In qualitative terms, this is consistent with the published results of "psychological" tests carried out at transport psychology laboratories with the use of equipment classified under the category of "reflex testers"; see e.g. [5]. This effect illustrates the time needed for a decision to be made by the driver. In conclusion, the nature of the distributions presented (Figs. 7–10, Table 2) should be highlighted. All of them are similar, in qualitative terms, to the normal distribution, but they are more or less asymmetric, i.e. right-skewed (with positive values of the skewness coefficient). This is consistent with the remarks presented in [11] regarding the nature of the distribution of driver reaction time values. At that work, where tests were carried out with the use of a different method and on a different group of people, the distribution of driver reaction time values was also found to show positive skewness.

5. Recapitulation

In this article, a prototype test machine built for determining the driver reaction time during the operation of real motor vehicle controls has been presented. The possibility of evaluating this parameter of driver's work and of indicating important differences between the persons examined has been shown. Results of the tests carried out have confirmed diversification of the reaction time depending on the type of a vehicle control element and on the complexity of the situation encountered (simple or complex reaction). The average time of a simple reaction to operate the brake pedal (about 0.487 s) is longer by more than 30% in comparison with that measured at the operation of the steering wheel (about 0.362 s, on average). This difference (of about 0.125 s, on average) may be considered as approximately illustrating the time of moving the foot from the accelerator pedal onto the brake pedal. An additional task given to the driver examined, in this case the requirement of pressing the clutch pedal when the reaction time was measured on the brake pedal, resulted in a somewhat longer (by about 7%) average reaction time. In all the three cases of testing the simple reaction, the dispersion measures were on a similar level (with being slightly higher at the performing of an additional task). At the complex reaction, both the average reaction time and the dispersion of distribution of the measurement results were markedly higher.

The presented features of the test machine and the results of the driver examinations carried out with the use of this machine have shown usability of the machine as an alternative in relation to the simple "reflex testers" used at transport psychology laboratories. However, the examination conditions still differ from the conditions of driver's work in natural road traffic. As an important direction of further work, it may be suggested to compare the measurement results obtained on the "autoPW T" test machine with the reaction time values determined with the use of other methods and to investigate the impact of individual features of the drivers examined (e.g. age or experience) on the measurement results.

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