Driving Simulator as a Tool for Reaction Time Measurement

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Abstract. The reaction times of a driver were measured in a driving simulator environment in this article. Young drivers under the age of 26 were the focus of the study. They cause many accidents. Each participating driver provided basic information later used for mathematical-statistical analysis. The main advantage of driving simulators is limitless usage. It is possible to simulate situations that would be unacceptable in real road traffic. Therefore, this study could focus also on drivers influenced by alcohol. The main goal of the article is to evaluate the reaction times. Then it was possible to evaluate if gender, practice, and alcohol, statistically significantly affect the reaction time. We also focused on drinking before driving for a smaller number of drivers. For these mathematical-statistical purposes, we used a one-sample t-test, paired-samples t-test, and independent-sample t-test.

Key words: simulator, driver behavior, automotive safety

1. Introduction

In general, human error is a source of more than 90% of road accidents [1; 2; 3]. It is possible for a pedestrian, cyclist, or another road user to make a mistake. The driver is the one who causes the most accidents [4]. Road accidents are also caused by fatigue and stress [5]. Many researchers have focused on professional drivers’ accidents [6; 7]. Road accidents caused by alcohol are also dangerous [8; 9]. They frequently include a young driver who is inattentive and prone to drink-driving. Scientific research has diverse interpretations of the term ‘young drivers.’ Most of these drivers are between the ages of 18 and 26. However, in some research, the highest age limit may be different. For example, in [10], the authors concentrated on a group of 18 to 20-year-olds, in [11], the Romanian study focused on 18 to 24-year-old drivers, and in [12], the Belgian study focused on 17 to 24-year-old drivers. On the other hand, [13] concentrates on 16 to 24-year-old drivers, among other things. The mix of young drivers and alcohol has been the subject of several investigations. For example, in Greece, the legal age for driving while intoxicated is 18. A study of 241 young Greek drivers (aged 18-24) indicated that young drivers who often consumed alcohol in their life were more likely involved in an accident [14]. In addition to alcohol, poor driving experience also contributes to higher accident rates for young drivers [15]. Men are more prone than women to drink alcohol, according to another study [16]. Other researchers [17; 18; 19] claim that after drinking, people are more likely to engage in dangerous behaviour and aggressiveness. Other research, such as [20], has found that men and women have different
characteristics. Male risk perception is lower, implying that they drive more carelessly [21; 22]. The effects of alcohol on drivers were investigated in a study [23]. The main goal of this study was to investigate the impact of alcohol consumption on drivers' behaviour at STOP signs and at traffic light intersections. It was a lab experiment that included the driving simulator. The results revealed a considerable difference between sober and drunk drivers. A driving simulator will be used also this study. A driving simulator is a device that models the operation of a road vehicle in a virtual environment that is as realistic as possible [24; 25; 26].

The driving simulator is a complicated device that consists of many parts. Its software is a vital component. It influences the simulation's quality and the simulator's ability to be used for research [27]. The University Science Park at University of Žilina has a training driving simulator available for research purposes. The essential difference between the research driving simulator and the training driving simulator is in the purpose of use:

a) **Training driving simulators** are used to train new drivers and are commonly found in driving schools. In Methodical Instruction number. 22/2005 on technical requirements for training driving simulators [28] dated September 26, 2005, the name 'training driving simulator' appears. The basic requirements for teaching driving simulators are outlined in this guideline. For example, there is a requirement for a projection area of at least 180 x 130 mm, as well as various sound, vehicle dynamics, and virtual environment requirements. Researchers use training driving simulators very rarely, such as in the study [29], or to assess the efficiency of training at driving schools [30].

b) **Research driving simulators** are used in research institutes, universities, and the automotive industry. Their key advantage is their ability to adjust to the experiment's present requirements. It means they need an open system in which the virtual environment, vehicle, and its features may all be changed. They were used in studies on fatigue research [31; 32], crossing intersections [33], lane change behaviour [34; 35; 36], driver error rate [37], driver glare [38] or human - vehicle interaction research in general [39]. Simulators also have great potential in autonomous vehicle research [40; 41; 42].

2. Used equipment and methodology of the research

The goal of the study was to measure and evaluate young drivers' reaction times. We aimed to find if there were differences in reaction times between men and women. The difference in reaction time before and after drinking alcohol was also measured. The experimental driving simulation was ensured by the SNA - 211 REN training driving simulator [43; 44]. The people who took part in this study had never used a driving simulator before. As a result, they had to be retrained before their timed ride. The drivers got around ten minutes to become used to the setting and simulator controls. Each driver was allowed to practice starting, braking, turning, and shifting gears. Other used equipment is shown in the Figure 1.

![Figure 1](image1.png)

**Figure 1.** Used equipment: (a) Training driving simulator in SNA – 211 REN; (b) External video camera for recording; (c) AlcoCheck X400L. Source: Processed by authors.
During the individual measurements, three people were in the laboratory: the driving simulator supervisor, the recording person, and the tested driver. During the measurements, the other participants in the research task were in another room. Before their ride, it was vital to ensure that they had not seen the obstacles or virtual environment.

The drivers' reactions lasted from the moment they were confronted with an unexpected situation until they pressed the brake pedal. The scenery and braking were recorded using the computer program Corel VideoStudio. It was installed on the PC that was used for the driving simulator. An external camera was also used to record the footage. The AlcoCheck X400L was also used to test the drivers' breath for alcohol. The results obtained were not used in the statistical analysis.

The measurement process was divided into three sections described in the following lines:

1. Unexpected obstacle
   During the first measurement, the drivers were focused but did not expect an obstacle. The obstacle in the virtual environment was the running animal from behind the tree across the road. The reaction time of the driver was recorded as the time interval between the obstacle animation trigger and the moment of activating the brake. We did not evaluate the success of the obstacle stop in this article.

2. Expected obstacle
   The second measurement continued after the first. The scene for evaluating reaction times went on, but the drivers were already known what the purpose of their driving is. As a result, the reaction time should be even shorter than it was for the first unexpected obstacle. The drivers were more cautious during this test. They took a quick glance at the edge of the road.

3. Drunk-driving
   Not all drivers completed additional tests due to technological issues. As a result, only ten drivers were picked for the last portion of the test. In the fourth and fifth parts of the research, all the drivers agreed to drink alcohol. Regardless of weight or other circumstances, each driver drank 200 ml of 35 percent alcohol. Each driver was given ten minutes to complete this task. His journey started in a simulated environment after a 10-minute break.

3. Evaluation of measured data

During two reaction time measurements, we were able to measure the reaction times of 30 drivers in total. In the following paragraph, all data collected throughout these experiments will be presented in the separate tests. In this article, we will use the t-test to test the hypotheses described in the following lines. First, we verify that the mean value of the reaction times in the first measurement is equal to 0.8 seconds, which is the middle of the table value for the concentrated driver who does not expect the obstacle. We assume that the mean value will be shorter than the table data, but we will verify this hypothesis at the significance level $\alpha = 5\%$.

3.1. One-Sample t-Test

We will divide the individual tests into points of the procedure so that, in addition to the results themselves, we will also point out the procedure of statistical testing. We performed the One-Sample t-Test from the data in Table 1.

| Driver | Reaction time | Driver | Reaction time |
|--------|--------------|--------|--------------|
| 1      | 0.60         | 2      | 0.73         |
| 3      | 0.95         | 4      | 0.72         |
| …      | …            | 27     | 0.67         |
| 28     | 0.68         | 29     | 0.65         |
| 30     | 0.46         |
One-Sample t-Test has the following procedure:
First, it is necessary to determine the hypotheses: H₀: The mean value of the reaction times of the concentrated drivers is 0.80 seconds: \( \mu = 0.80 \) s. H₁: The mean value of the reaction times of the concentrated drivers is less than 0.80 seconds: \( \mu < 0.80 \) s.
Calculation of test criterion (1), where \( x \) is the arithmetic mean of all measured reaction times (0.7317) and \( \mu_0 \) is the mean value – we have chosen 0.80 s. The parameter is \( n \) - the number of all measurements (30), and \( S \) is standard deviation, which in this case is (0.1661).

\[
t = \frac{x - \mu_0}{S} \cdot \sqrt{n} \tag{1}
\]

We computed that the test criterion has a value of -2.2522 using the formula. In this example, the critical field is provided by relation (2), where 0.05 is the level of significance. As a result, we check for the value \( t_{0.05}(29) \), which is 1.699, in the quantile tables of the Student's distribution.

\[
W_a = \{ t \leq -t_{1-a}(n - 1) \} \tag{2}
\]

Subsequently, we can add to the formula itself as follows (3):

\[
W_a = \{ -2.2522 \leq -1.699 \} \tag{3}
\]

As a result, the critical field is met. Therefore, we reject the original hypothesis H₀ in favour of the alternative hypothesis H₁. The answer in this example is: At a significance level of 5%, the mean value of the reaction times of the concentrated drivers is less than 0.80 seconds.

3.2. Independent-Sample t-Test

We used the also the Independent-Sample t-Test. This test for independent selections is a widely used approach for determining the difference between the two groups' averages. In Table 2, there is a dataset used for this type of test.

| Gender/driver | 1  | 2  | 3  | 4  | ... | 12 | 13 | 14 | 15 |
|---------------|----|----|----|----|-----|----|----|----|----|
| Male          | 0.48 | 0.63 | 0.82 | 0.48 | ... | 0.75 | 0.71 | 0.59 | 0.43 |
| Female        | 0.88 | 0.64 | 0.94 | 0.88 | ... | 0.89 | 0.75 | 0.64 | 0.62 |

Independent-Sample t-Test has a similar calculation process as One-Sample t-Test:

We determinate two hypotheses: H₀: the mean reaction time of men and women is the same: \( \mu_M = \mu_W \). H₁: the mean value of the reaction time of men and women is not the same (it is different): \( \mu_M \neq \mu_W \).

In the test criterion (4) \( \bar{x}_1 \) is the arithmetic mean calculated from all measured reaction times of men and \( \bar{x}_2 \) of women. The number of measurements is \( n_1 \) (men) and \( n_2 \) (women). In the case of this test, the measurements may be different, as they are not paired. \( S_1 \) and \( S_2 \) are standard deviations, which in this case are at the level \( S_1 = 0.1472 \) and \( S_2 = 0.1356 \). After substituting, we find that the test criterion has a value +1.910. After substituting, we find that the test criterion has a value +1.910.
The critical field in this case is given by (5), \( \alpha \) is the level of significance, in our case 0.05. It follows from the quantile tables of the normal distribution \( N(0,1) \) we look for the value \( u_{0.975} \), which is 1.960.

\[
W_u = \left\{ |u| \geq u_{1-\frac{\alpha}{2}} \right\}
\]

(5)

Subsequently, we can add to the formula itself as follows (6):

\[
W_u = \{1.910 \geq 1.960\}
\]

(6)

From this, we can conclude that the critical field is not met and therefore we accept the original hypothesis \( H_0 \). The answer in this case is: The mean reaction time of men and women is the same at a significance level of 5%. However, as can be seen, the test criterion is very close to the critical range.

3.3. Paired-Sample t-Test

The Paired-Sample t-Test was the third one we used. This test compares the values of a variable for the same respondent in two different experimental conditions. In our case, we will use this test to compare the reaction time before and after drinking alcohol. The structure of the input data is in the following table (Table 3).

| Driver | 1   | 2   | 3   | …  | 8   | 9   | 10  |
|--------|-----|-----|-----|----|-----|-----|-----|
| 3rd attempt (alc.) | 0.75 | 0.91 | 1.13 | … | 0.69 | 0.83 | 0.77 |
| 4th attempt (alc.)  | 0.85 | 1.28 | 0.95 | … | 0.56 | 1.19 | 0.75 |

The process of testing with the Paired-Sample t-test is as follows:

We determined two hypotheses: \( H_0 \): The mean value of the reaction times of the drivers in the sober state and under the influence of alcohol is the same; \( \mu_S = \mu_D \). \( H_1 \): The mean value of the reaction times of drivers in a sober state and under the influence of alcohol is not the same (it is different); \( \mu_S \neq \mu_D \).

Calculation of test criterion (7), in which \( \bar{D} \) is the arithmetic mean of all mutual deviations (differences) between two experiments. The number of measurements is denoted as \( n \). It is also necessary to calculate the standard deviation \( S_D \) from all values of the mentioned differences for the calculation of the test criterion.

\[
T = \frac{\sqrt{n} \cdot \bar{D}}{S_D}
\]

(7)

After substituting, we find that the test criterion has a value -2.6181. In this case, the critical field is given by (8), \( \alpha \) is the level of significance, in our case 0.05. It follows from the above that in the tables in the quantile tables of the Student's distribution we look for the value \( t_{0.975} \) (9), which is 2.2620.

\[
W_u = \left\{|t| \geq t_{1-\frac{\alpha}{2}}(n-1)\right\}
\]

(8)

Subsequently, we can check (9) the fulfilment or non-fulfilment of the critical field:
\[ W_a = \{2.6181 > 2.2620\} \]  

From (9) we can conclude that the critical field is fulfilled and thus we reject the original hypothesis \( H_0 \) and accept the alternative hypothesis \( H_1 \). The answer in this case is: At a significance level of 5%, it was shown that \( H_1: \) The mean value of the reaction times of drivers in the sober state and under the influence of alcohol is not the same (it is different).

4. Conclusion
From the point of view of the experiment itself, in this study, we were able to evaluate the reaction times of 30 drivers, which is not a sufficiently representative sample. In Slovakia, there are 244,663 registered drivers in the 17-24 age group. According to Sample Size Calculator, with a population of 244,663, Confidence Level 95%, Confidence Interval 5, we would need a sample size of 384 people. However, this was not possible in our case. For this reason, we verified the statistical significance by testing hypotheses.

Another goal of the paper is educational purpose. This article shows how it is possible statistically evaluate data. Therefore, students at the university can use described methods for their thesis. For this reason, all four tests are performed not by software (through the so-called p-values), but by traditional calculation.

This research brought several results. In the first test, the tabular value of the reaction time of the concentrated driver, which does not expect a stimulus, was not completely confirmed. Reaction times were shorter, probably due to the lack of distractors during the ride.

Statistical testing also confirmed that the reaction time of men and women is approximately the same. However, in this case, it is possible that similar reaction times occurred due to similar people in the selected sample. All the young drivers were students or graduates of a technical university. It means that this could have an impact on the results.

With the Paired-Samples t-Test, we tested the hypothesis of prolonging the reaction times of drivers under the influence of alcohol. The reaction times were indeed even shorter during some attempts. However, in general, at a significance level of 0.05, it can be stated that the times are different and, of course, shorter in the sober state.

From this article, the danger of drunk driving is evident. However, it is also clear from many other studies [45; 46; 47]. In terms of statistics, we have pointed out that the basic characteristics (median, mode, arithmetic mean, or standard deviation) are insufficient in similar research. It is necessary to assess statistical significance.

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