Objective methods of assessment of influence of alcohol on driving safety – study performed driving simulators

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Abstract: - The paper is focused on an introduction of a set of experiments focused on objective methods used for detection of driving impairment caused by influence of different level of alcohol in blood. It introduces the initial experiments which were performed on our driving simulators; it describes proposed methodology of measurements and data analysis. It covers also the issues of testing track creation and measurement procedure protocol. Finally the results of data analysis and proposals for further utilization of these tools and methods are presented.

Key-Words: - Driver's impairment, Alcohol, Driving simulation

1 Introduction

Alcohol behind the steering wheel is still a very serious problem. Car accidents indisputably caused by the influence of alcohol make at least within Czech Republic 5% from all the accidents [1]. This is what police statistics say. Unfortunately the true is much more serious. The official police statistics have in the evidence of serious accidents but on the other hand there exists a great number of lighter incidents which are not registered in police records.

Although in many countries over the world drinking before driving totally prohibited, there are still many countries in which certain level of alcohol in blood is allowed. This level differs from country to country and it's based more on the local customs than on objective reasons. The problem of decision which we amount is acceptable and safe for driving is still open. Our task is to develop a battery of tests which could be reliably used for the experiments dealing with impaired driving under the influence of alcohol (and farther other drugs).

Such experiments are very dangerous and in normal conditions are at the edge (or behind) of the law. Such experiments are almost unfeasible to be done in normal traffic. If they are performed on the special closed road (proving grounds, testing polygons), a common traffic should be excluded. This condition limits the range of possible tests. Use of driving simulators gives us several advantages. Besides its safeness it brings wide range of possibilities of simulation of different situation. Moreover all the probands can pass the experiment under same condition.

2 Experiment

2.1 Testing procedure

Alcohol as a matter influencing the human neural system, aimed to change the human mood and behavior, can negatively influence skills in prediction, thinking mechanisms, reception and workout of information and also muscle coordination. The main negative impact on the driver is an overall slump of CNS and a center of movement coordination. Respecting this knowledge we build up the experiment so that it is possible to detect objectively those factors which are directly caused by the influence of alcohol. Main task for us was to prove correlation between the alcohol blood level and drivers errors. Our focus was on the investigation driving under the influence of the levels in between 0 – 2 ‰ [3].

The experiment was composed of the driving on the simulators (under influence of alcohol), tests focused on driver's attention and coordination of movements and filling out of anamnesis questionnaires. The drivers had to pass training rounds so that they would be skilled enough during the experiment itself and the results are free from influence of a learning. All of them had eaten before entering the experiment. All the experiments were done under medical supervision.

2.2 Cohort

Because of the fact that the aim of this investigation was to develop a methodology, there was only a representative ample of probands. We preferred those drivers who had been already familiar with simulator driving and for that reason their behavior is not influenced by the simulator itself.

The testing cohort was composed of five active non-professional drivers (Table 1).

Table 1: This table describe years, weight, height, blood alcohol level [$^{0}/_{00}$] and amount alcohol [g]:

Proband	Years	Weight	Height	MAX alcohol	Amount
1	24	87	185	0,9	80 g
2	25	92	193	0,9	96 g
3	26	75	177	1,3	80 g
4	24	87	185	1,4	96 g
5	27	73	180	2,1	112 g

2.3 Testing tracks

Experiments focused on alcohol influence present very specific tasks. For that reason it was necessary to create specifically designed testing circuits on which our probands were driving [4].

I. Testing polygon

The experiment was performed on the polygon modeled in virtual reality. The track is composed of several parts. The first part presents slalom with cones distanced 30m from each other. The length is 300m. The second slalom is of the same type but inter distance between cones (Fig.2) is lowered down to 25m, than there is narrow corridor and part where the driver should follow the line with the car left wheels (Fig.1). Last driver's task was precise stop on transverse line.

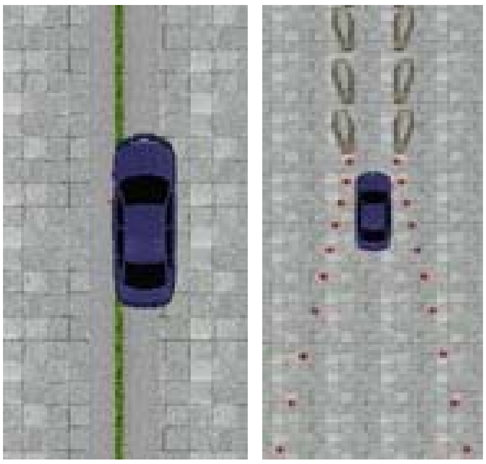

Fig.1: Bird's view on the testing track; segments with particular tests

Fig.2: Screenshot from the testing polygon

The probands were instructed to pass the testing circuit as fast and as correct as possible.

II. Testing polygon – secondary task

The test was done on the same circuit as the previous one. The difference was that the driver had to fulfill also a secondary task besides driving itself. The secondary task was a simple computation (addition of two-digit number).

III. Testing polygon 3 – two lane road (Fig.3)

The circuit its approximately 12 km long. It is compost of two parts; the first is presented by the straight road of 3km length, the second part is slightly curvy (with curves of radii 2 to 6 km). On the road there are equidistantly placed semaphores (with green and red lights only) where the driver is expected to stop on the red signal. The drivers were instructed to keep speed of 80km/h all the time unless the red signal appeared. The semaphores are placed in such an arrangement that the driver has at least two or three of them in his field of view.

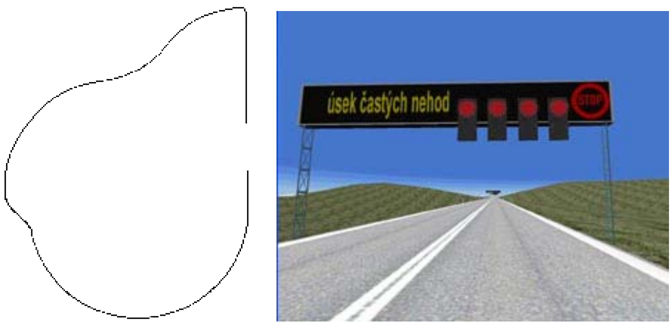

Fig.3: Left – top view on the testing circuit, Right – screenshot from the scenery with traffic lights

The driver now had to fulfill following three primary tasks:

- Keep the predefined speed
- Keep his lane
- Stop immediately on the red signal

2.4 Testing Protocol

The protocol of measurements is as follows:

- Filling in the entry questionnaire
- Filling in the anamnesis questionnaire
- Psychometric tests (horizontal and vertical nystagmus, walking and turning, Romberg's test, one leg stay, finger-nose test)
- Measurements of alcohol blood level
- Driving on the simulator

All the probands had to pass all the tests once without any influence of alcohol. During the testing drives all the probands drove on 3 types of testing circuits.

After completing first round of tests (questionnaires, driving…) the drivers took their first dose of alcohol. During 2 hours of experiment the drivers took 6 doses of 16g of alcohol each. The intervals in between two successive doses were increased during experiment.

2.5 Measured data

From the point of view of objectivity it is possible to subdivide measurement in to two parts objective measurement and subjective measurement. The situation is illustrated on a following picture (Fig. 4). Outputs from the simulator are included in set of objective measurement. It is possible to record mainly the speed of the car (simulator), the trajectory, deviation from proper lane (to border or to contra-flow-line) [2]. These three outputs combined with reaction time are basic outputs for analysis of the effect different physical or mental strains during the process of driving the car simulator). On the simulator it is possible to measure also movements of pedals (throttle, brake) and movements of steering wheel. In addition to these simulator outputs it is possible to place additional devices in the simulator or on experimental driver (proband). Outputs from these devices are also included in set of objective measurement. For example measurement of reaction time to different stimuli, movement of head of the experimental driver or camera record. The outputs, which appear very important, are measurements of EEG signal or ECG signal.

Subjective measurements represent for example the analysis of subjective questionnaires, where the experimental driver describes own state before measurement, after measurement or during the process of driving the car / simulator.

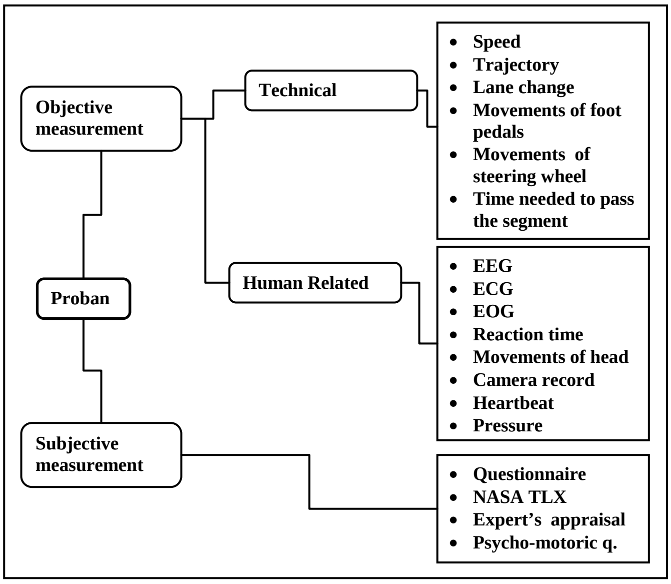

Fig. 4 Hierarchical structure of measured data

Since the main task for the methodology is to discover the objective manifestations of driver's impairment of correct driving, we investigated mainly in objective measures. We focused mostly on those outputs which are directly coupled with process of driver's regulation (continuous correction actions). Reactions on the throttle, break pedal and steering wheel seem to be most relevant. Beside these, also the analysis of the trajectory should give the evidence of driver's impairment.

3 Data Analysis

Following paragraphs should sketch possible methods of analysis of above described measured data and consequent methodology of classification of driver's performance. We treated the outputs form the two different testing circuits separately.

3.1 Two lane road circuit

Probands drove on a closed circuit equipped with traffic lights. Drivers were instructed to react as fast as possible on the red signal. After switching to green they had to speed up to 80km/h and keep this speed.

3.1.1 Reaction Time

The response time to the stimuli (reaction time) is one of the basic measures which testifies about driver's vigilance. It seems to be pretty reliable and most objective from all those which we can use for correlation with other measures [6] (Fig.5).

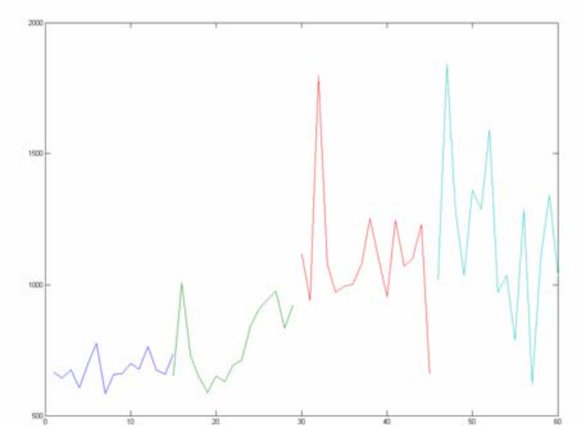

Fig.5: Example of driver's RT related to the actual alcohol blood level. Particular levels are the same as in the following picture (RT-brake pedal dependence).

The driver was instructed to stop as soon as he/she recognized the red signal on the semaphore. The semaphores are placed more or less equidistantly in straight segments and before curves. The red signal on the track is randomly generated when the car approaches the semaphore.

3.1.2 Speed press of break pedal

All the tested drivers exhibit relation between the response on the brake pedal and the speed of the pedal depression. With increase of the response time a speed and consequently force of the pedal depression also increased. The longer the response lasted the more effort to compensate it with higher force. In those cases, when there was no significant prolongation of response time with higher blood alcohol level, almost no pedal depression speedup was noticed [7] (Fig.6).

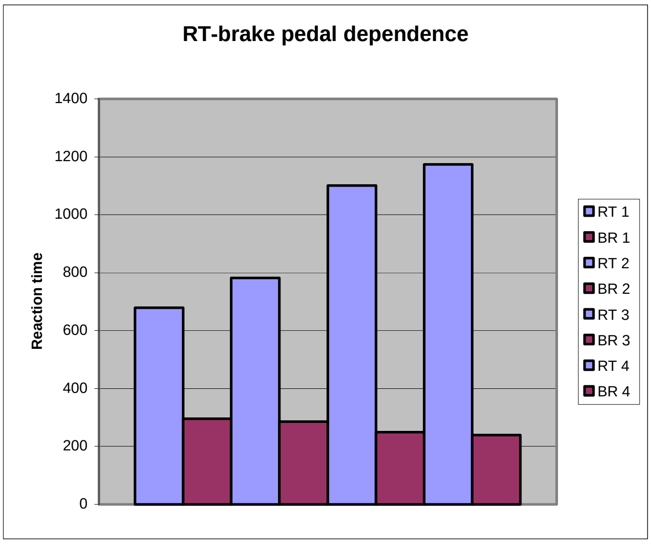

Fig.6: Dependence reaction times and reaction on brake pedal.

An example of reaction times (RT) and times needed to depress maximally the brake pedal is shown in the graph Fig.6. RT presents an average time between the red signal and start of braking maneuver. Time needed to depress the brake pedal is measured as a first contact to maximal depression.

Each average covers approximately 16 values.
RT1 and BR1 with 0 alcohol level
RT2 and BR2 – 0,4 per mille
RT3 and BR3 – 1,7 per mille
RT4 and BR4 – 2,1 per mille

3.1.3 Deviation from an Ideal Path

In the studies of driver vigilance and level of the actual attention, there are frequently analyzed the trajectory keeping and weaving. Lane departure is very useful when finding serious driver's state but not suitable for statistical analysis which is the topic of this paper. We looked mainly for overall variance. From the contemporary research it is also possible to say that the movement of car within the lane borders (originated in steering wheel movements) could be promising marker of driver's impairment of safe driving.

3.2 Proving ground (testing polygon) circuit

Drivers drove on the testing polygon. They were instructed to drive as fast and as good as possible.

3.2.1 Steering wheel movement velocity and its variance

The driver is permanently in contact with the steering wheel as it is only one control tool on which he/she keeps his/her hands in standard situation. Therefore the record of the driver is controlling movements of the steering wheel could serve as a basis of very good information of his/her driving abilities.

3.2.2 Changeability of car speed

Some of the probands exhibit higher variation of speeds with higher level of alcohol in their blood. To prove this theory much more experiments have to be performed.

3.2.3 Time needed to drive correctly through a segment

Beside other measures, an overall time needed to pass the circuit (i.e. successfully fulfill the task) was investigated. The passes where a driver's error occurred were excluded form this analysis.

Table 2: This table describe time needed to pass the tracks vs. blood alcohol level.

		Test 1	Test 2	Test 3	Test 4	Test 5
Proband 1	Time	3:15	3:22	3:36	3:30	3:25
	Cones (hit)	0	0	0	2	4
	Level of alcohol	0	0	0,1	0,5	0,9
Proband 2	Time	3:20	3:36	3:55	3:26	3:41
	Cones (hit)	0	0	0	0	0
	Level of alcohol	0	0	0,1	0,5	0,9
Proband 3	Time	3:37	3:41	3:29	3:53	3:39
	Cones (hit)	0	1	0	2	1
	Level of alcohol	0	0	0,1	1,2	1,3
Proband 4	Time	3:01	3:08	3:18	3:02	3:07
	Cones (hit)	0	0	0	0	1
	Level of alcohol	0	0	0,1	1	1,2
Proband 5	Time	2:55	3:01	3:00	3:15	3:32
	Cones (hit)	0	0	0	1	4
	Level of alcohol	0	0	0,2	1	2,1

Test1 – The last test round before the measurement started – the proband have no idea that he/she is recorded
Test2 – Reference round – no alcohol
Test3 – Driving the simulator 15 the first dose
Test4 – Driving the simulator 60 minutes after. The drivers started to do more errors - hitting or missing of cones
Test5 –Probands exhibit more aggressive behavior, they tried to go as fast as possible but without respecting the prescribed rules and tasks (speed and lane keeping) and they did serious errors (hitting or missing of cones).

The next table shows times of particular rounds, number of hit cones and corresponding alcohol blood level.
The tests 1-5 correspond to the tests describer upper as "polygon I" and 6-9 as "polygon II" (i.e. with secondary task). Loaded with the secondary task the drivers drove slower and they did less errors.

Table 3: This table describes time needed to pass the tracks vs. blood alcohol level during counting.

		Test 6	Test 7	Test 8	Test 9
Proband 1	Time	x	x	x	x
	Cones (hit)	x	x	x	x
	Level of alcohol	x	x	x	x
Proband 2	Time	4:09	4:11	4:10	3:53
	Cones (hit)	0	0	0	0
	Level of alcohol	0	0,3	0,6	0,9
Proband 3	Time	4:22	4:15	4:58	5:28
	Cones (hit)	0	0	0	0
	Level of alcohol	0	0,1	0	1,3
Proband 4	Time	3:15	3:22	3:26	3:30
	Cones (hit)	0	0	0	0
	Level of alcohol	0	0,5	1,1	1,2
Proband 5	Time	3:22	3:30	3:35	3:58
	Cones (hit)	1	0	1	0
	Level of alcohol	0	0,4	1,7	2,1

4 Conclusion

From the experiments performed up to now and the analysis which we made upon the measured data, it is possible to derive very promising results. Use of driving simulators in this area of research is indisputable although one can feel that they cannot fully replace tests done in a real traffic. On the other hand real traffic experiments are very dangerous and expensive and cannot give us possibility of repeatable conditions and driving situation like the driving simulators do.

From the results of analysis it is possible to derive that drivers under influence of alcohol are less concentrated and their driving performance is lower. This is apparent even from very low alcohol blood levels. They drove more aggressively and did more errors (starting with 1 per mille, number of their cone hits increased significantly, starting with 0.5 per mille, prolongation of reaction time appeared). On the other hand, if they were loaded with secondary tasks they drove much more safely but the time of driving was incomparable longer. It was proven that the response time increased with alcohol blood level but the intensity of braking (and applied force on the brake pedal increased) was higher.

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