ORIGINAL ARTICLE

Occurrence of critical driver's behavior as a result of alcohol intoxication

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Abstract

OBJECTIVE: Operator's movements are one of the areas where variability is undesirable. Vehicle driving is probably the most frequent operator movement in society where errors can result in serious social, medical and economic consequences. In this article we focused on the influence of moderate alcohol intoxication (less then 1.0 g/kg) on right hand movement variability during manual gear selection and on driving ability.
METHODS: The test took place in a laboratory setup in a passenger vehicle simulator. Simulated traffic lights were used to stop the car and hand movement was measured by kinematical analysis with the use of a motion capture system.
RESULTS: Large variability in blood alcohol concentrations were observed as well as large intra-individual hand movement variability and reaction time to visual stimulus.
DISCUSSION: The findings are somewhat ambiguous. Research outcomes did not confirm the hypothesis about the impact of moderate alcohol intoxication on movement variability. On the other hand, in some cases the observed data indicate critical behavior regarding safe driving and response to particular traffic situations.

INTRODUCTION

The importance of research on a driver's operator movements is underlined by the fact that in 2005 in the European Union (EU) 46 676 persons died as a result of traffic accidents (Belanger 2008). Moreover, traffic accidents cause high fiscal damage (close to 2% of gross national product), and they have a negative effect on social area. Therefore in 2000 the EU announced an ambitious plan of halving the number of people killed on European roads from 50 000 to 25 000 by 2010. In order to reach this goal the number of traffic casualties would have to drop by 37% (7.4% annually). However, in reality the number of deaths declined only by 20% (4% annually) between 2001 and 2007 (Anderson 2008).

Alcohol impaired driving is a quite frequent negative social phenomenon with a deteriorating effect on a driver's abilities. Although the number of alcohol-related traffic accidents have been decreasing throughout the EU, alcohol continues to be an important cause of road traffic crashes, contributing annually to at least 17 000 deaths on EU roads (Anderson 2008). According to the European Transport Safety Council, car-crash fatalities, caused by alcohol consumption, dropped by 12 percent a year in the Czech Republic, by 10 percent a year in Germany, by 2 percent a year in Hungary, and by 1 percent a year in the U.K. between 1997 and 2005. According to the study Spain, Finland and Lithuania registered annual increases of 1 percent or 2 percent. Driver's minimal alcohol allowance and its effect on driving performance is continually discussed. Research considers influence of alcohol on driving abilities from many aspects. Nevertheless, besides some information on time analysis of foot-pedal handling (Cantin *et al.* 2004; Zhang *et al.* 2007), the impact of alcohol on fine coordination of relatively simple and highly automated hand movements has not been properly studied so far. Publications dealing with hand movement variability are scarce.

METHODS

The influence of alcohol intoxication on right hand movement during gear changing and car operating was investigated. An optical motion capture system was used to register hand movement and a car simulator was used to obtain car operation data.

Six male subjects participated in the experiment. The work was approved by a medical ethics committee and the subjects gave their informed consent to participate. The study was conducted during one week. Each participant was measured twice on two consecutive days. Each day the subject drove on the simulator for two hours without any break; the first day in a sober state, the second day under the influence of a controlled dose of alcohol (40% liquor). Blood alcohol concentration (BAC) was targeted to 1 g of absolute ethanol per 1 kg of blood [g/kg]; the amount of consumed alcohol was derived from the Widmark formula (Widmark 1981). BAC was measured 30 min, 45 min, 60 min, 120 min a 180 min after consumption.

The adaptive car simulator used in this experiment was based on the Skoda Superb and installed in the Laboratory of System Reliability at the Faculty of Transport Science at the Czech Technical University in Prague. The simulator consists of a driver cockpit and two overhead projectors displaying virtual scenarios. The simulator was equipped with a semi-automatic six-speed TipTronic gearbox where the gear is changed by pushing the gear shifter forward (higher gear) or backward (lower gear) and shifter returns automatically to the starting position.

The simulated driving took place on a circular course approximately 7.5 km long. A simple circle with minimal curves and without traffic was selected. The simulated road and surrounding countryside resembled a single-lane connecting road, but not a highway. Traffic lights were simulated every 300 m (see Figure 1A) and a red light was randomly switched on (at intervals of 60 to 150 seconds) and thus the driver had to stop. At the subsequent green lights, the driver had to use the gear shifter and accelerate the car to the recommended travel speed of 90 km/h.

During the gear changing procedure the right hand movement was registered by means of the optoelectronic motion capture system Qualisys (five Oqus-300 cameras). Eight passive reflective markers (size 12 mm) were placed on the steering wheel, gear shifter and right arm as follows (see Figure 1B): middle of the wheel, highest point on the wheel (wheel centered), gear stick1, gear stick2, first metacarpus, fifth metacarpus, procesus styloideus ulnae, procesus styloideus radii. The hand movement from wheel to gear stick and back was registered.

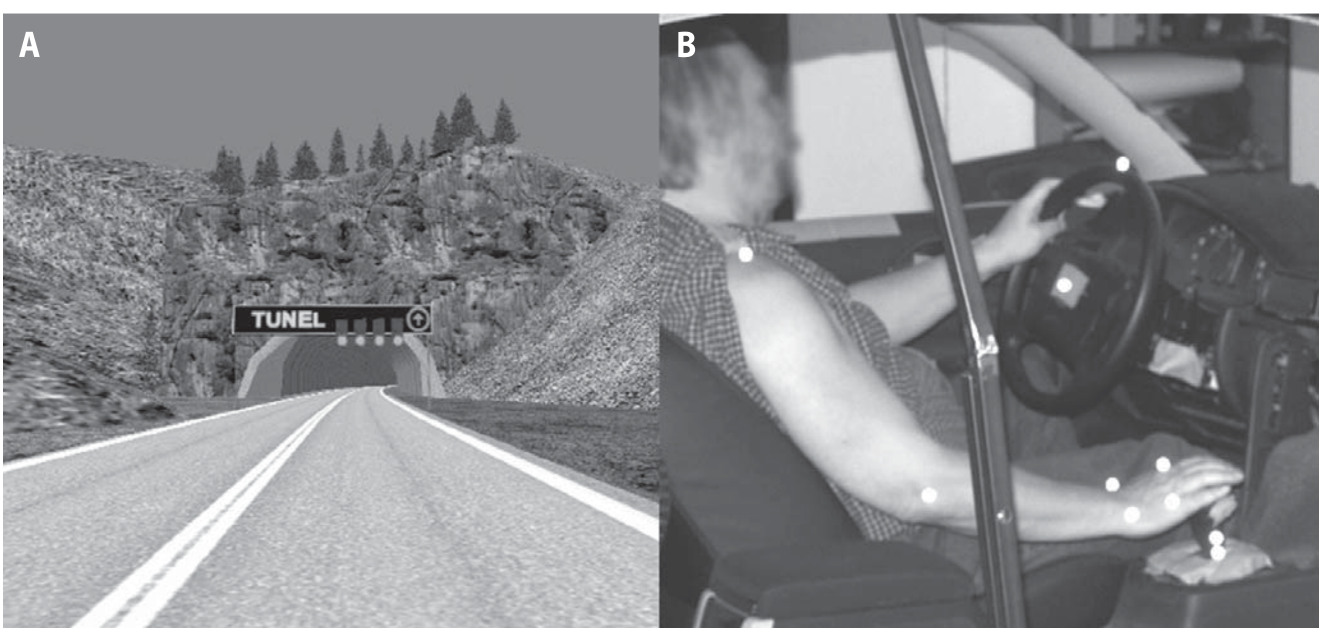

Fig. 1. A) Simulated environment with traffic lights; B) Marker placement

RESULTS

Alcohol

Surprisingly, large differences between the expected and measured BAC were found (see Figure 2). The initial level of BAC was in accord with expectations; the maximum BAC was reached 30 to 60 minutes after consumption, and was significantly lower (0.58 g/kg) than the theoretical (1.0 g/kg). The relationship between the measured BAC, time of the day, and stomach content was proven.

Hand movement

It was assumed that alcohol intoxication would lead to an increase in hand movement speed. Therefore the time needed to move the hand from the steering wheel to the gear stick was measured. The results reveal that movement time is not less then 0.417 sec, but it can be longer than 1.5 sec (see Table 1). Significant changes in hand velocity were found. Nevertheless, the direction of the changes remains unclear (see Figure 3).

The driving task did not require maximum hand speed; in other words, the driver was relatively free to decide how fast the hand should move to successfully accomplish the task. We can assume that the more time restrictions are applied to task accomplishment, the more pronounced alcohol influence will be.

If alcohol intoxication caused increased variability and reduced the accuracy of hand position at the moment of stick touch, the alcohol impaired driver would miss the head of the shifter more often, and thus would face dangerous traffic situations more often. If this were true, alcohol would lead to an increase in the variability of hand position on the gear stick. This assumption was not confirmed. See Figure 4 showing differences in the standard deviations of hand position against the gear stick, both right–left and forward–backward direction.

The position of the middle of palm was between 0.007 and 0.043 m sideways, and 0.018 and 0.070 m in forward–backward direction (see Table 2). It is interesting that lateral variability was approximately half of forward–backward direction variability. It might be explained, by the shape of the hand and gear stick head. Whereas in the forward–backward direction the gear can be changed with the tips of fingers, the same as the proximal end of the palm (range of motion is cca 15 cm); the lateral width of the hand is cca 8 cm, and therefore accuracy in lateral direction must be much higher and more precisely controlled.

The hand position where the stick is touched showed large variability (up to 7 cm), but from the point of view of successful accomplishment of a motion task (gear change), these differences can be considered acceptable and it seems that they do not negatively influence neither ability to reliably change gears nor traffic safety.

Tab. 1. Movement time (from steering wheel to gear stick).

Subject	Mean [s]	St.dev. [s]	Median [s]	Minimum [s]	Maximum [s]
MK	0.685	0.152	0.675	0.417	1.292
TM	0.681	0.126	0.650	0.433	1.117
MP	0.740	0.143	0.733	0.442	1.375
PS	0.769	0.226	0.700	0.425	1.567
MT	0.643	0.117	0.633	0.425	1.050
AT	0.969	0.221	0.942	0.550	1.742

Tab. 2. Range of hand position at contact with the gear stick.

Subject	MK	TM	MP	PS	MT	AT
Frontal plane [m]	0.018	0.024	0.009	0.028	0.043	0.007
Sagittal plane [m]	0.034	0.033	0.032	0.018	0.050	0.070

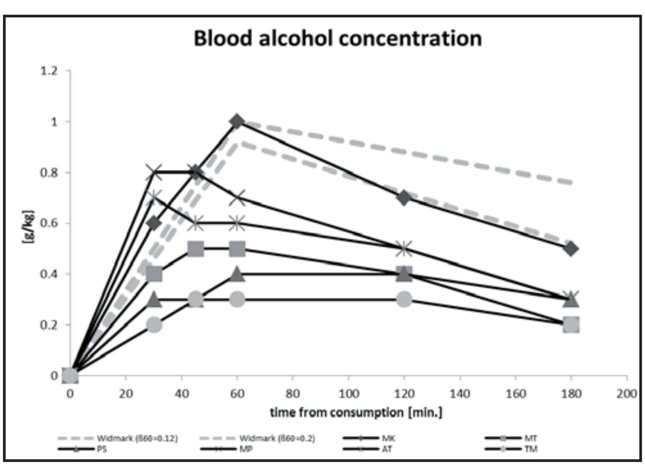

Fig. 2. Measured BAC (solid lines) compared to expected BAC (dash lines). ß60 represents alcohol breakdown rate [g/h].

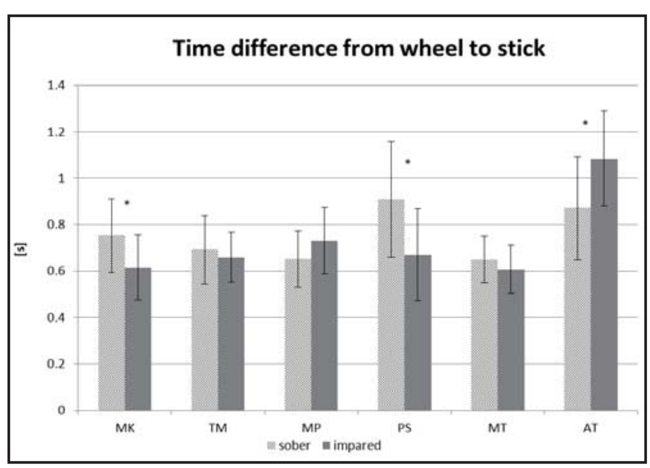

Fig. 3. Time difference of hand movement (* - statistically significant, p=0.01)

Driving simulator

The influence of alcohol on reaction time (RT) at red traffic lights and average car speed (measured as time per one round) was examined. We assumed that alcohol would negatively affect RT. RT was measured as the time from switching the red traffic light on, to the moment of full release of the accelerator pedal. The situation of apparently delayed RT was found in every subject. Rarely did subjects stop the car behind the traffic light (in intersection). In one case the driver even missed the red light and did not stop at all.

The shortest RT was 0.375 sec and the longest 2.391 sec, representing at the speed of 90 km/h a representative distance of almost 60 m before the car starts to slow down. That means that the car would travel more than 100 m until coming to a full stop.

Table 3 presents the number of reaction times longer then 1.5 sec and its percentage occurrence on both days. 1.5 sec corresponds approximately to a threefold standard deviation and represents a significantly delayed response to visual stimulus. According to our measurement, this situation happens in 1% of all cases!

Figure 5 presents the comparison of RT in the sober state and under alcohol influence. Five subjects showed a slowdown in reaction time after alcohol consumption. Two subjects showed statistically significant changes in RT, but one of them had a quicker RT and the other one slower RT. We assumed that the influence of alcohol could manifest itself more distinctively at the beginning of a ride, but this hypothesis was confirmed only in one subject (see Table 4).

Additionally, the average car speed for each round was measured. The results show that under the influence of alcohol every subject drove faster; four subject's speed increase was statistically significant (see Figure 6).

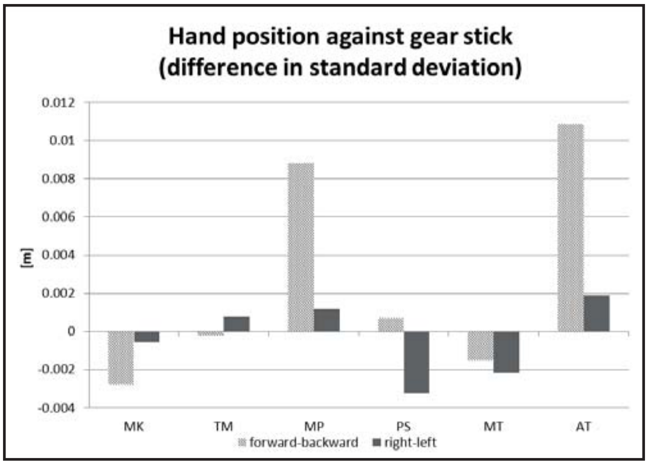

Fig. 4. Standard deviation differences of hand position at contact with the gear stick in the right-left direction and forward–backward direction.

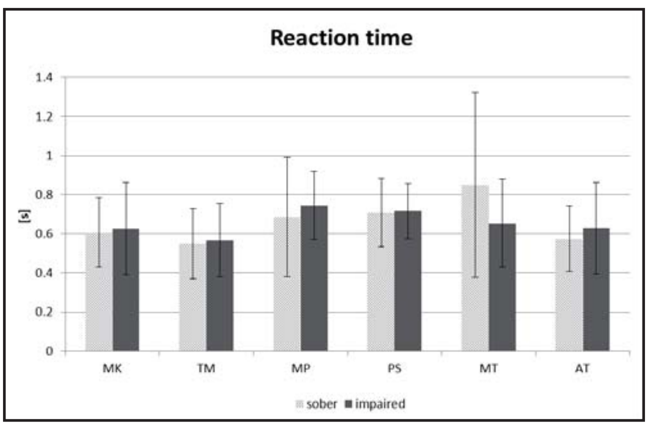

Fig. 5. Reaction time in respect to alcohol influence (entire ride average).

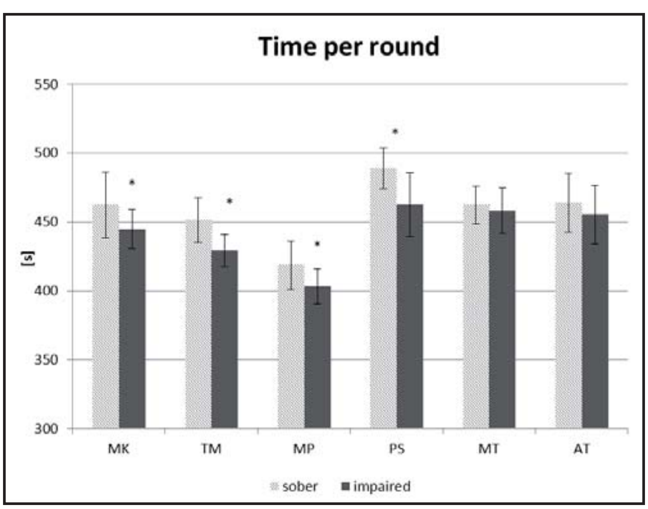

Fig. 6. Time difference per one round in the sober and alcohol intoxicated state stick (* - statistically significant, *p*=0.01)

DISCUSSION

There is a plethoric body of literature dealing with the effect of small doses of alcohol on motor functions, but the results are inconclusive because small doses of alcohol have both stimulative and inhibitory effect. This problem is addressed for example by Rohrbaugh *et al.* (1988) or Grant *et al.* (2000) who recommend intravenous administration of alcohol.

Tab. 3. Occurrence of RT >1.5 sec.

Subject	MK	TM	MP	PS	MT	AT
n (time>1.5 s)	1	0	1	1	7	2
% of cases	2.94	0.00	0.94	0.95	7.00	1.86

Tab. 4. Statistical significance of difference in RT at the sober state compared to the alcohol intoxicated state.

Subject	MK	TM	MP	PS	MT	AT
Whole ride	0.802	0.608	0.021	0.350	0.012	0.235
First 10 stops	0.384	0.044	0.748	0.153	0.147	0.087

Research is very often aimed at studying the effect of various factors on driving. Already relatively small doses of alcohol (less then 1 g/kg) has a negative effect on driving ability and can lead to less accurate lane keeping (Vakulin *et al.* 2007; Harrison & Fillmore 2005; Arnedt *et al.* 2001, Verster *et al.* 2009), slower reaction time (Allen *et al.* 2009, Howard *et al.* 2007, Zhang *et al.* 2007), negligent driving, speeding and omitting traffic regulations (Vakulin *et al.* 2007). These findings correspond with our results.

We found very few publications regarding the variability of movement in motor vehicle driving and the influence of other factors on hand movement variability. There are some publications on pedals handling (Cantin *et al.* 2004; Zhang *et al.* 2007), but kinematical analysis of hand movement in the car cockpit was not done. Therefore, we cannot compare our findings with other researchers. The total number of hand movements of all subjects on both days was more then 1 500. We did not record a single case of missing the gear stick, but the TipTronic gearbox simplifies the movement task and we can estimate a higher occurrence of misplacing the hand with manual gearboxes. We conclude that the measured range of hand position was lower than critical. We assume that the movement variability would increase if the driver was forced to accomplish the task in a limited time (as fast as possible), especially in combination with other factors (e.g. alcohol intoxication). In this case the occurrence of errors (missing the gear stick) would increase. We did not record any such case during this experiment.

The increase in average car speed under alcohol influence is well documented in the literature (Harrison & Fillmore 2005, Lenné *et al.* 2010).

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