EFFECTS OF SMALL DOSES OF ALCOHOL ON DRIVER PERFORMANCE IN EMERGENCY TRAFFIC SITUATIONS

by

Hans Laurell

REPORT No 68 A

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FOREWORD

The reported study was sponsored by The National Swedish Road Safety Office.

The experiments were carried out in Dec., 1974 and Jan., 1975 in Denmark with the kind aid from Danish authorities and from representatives of the Danish Council of Traffic Safety Research.

The blood samples taken to establish the blood alcohol concentrations of the participating drivers were analyzed at the Department of Alcohol Research, Karolinska Institutet, Stockholm, under the auspices of Prof. L. Goldberg, to whom we are also greatly indebted for his good advice.
SUMMARY

The effects on driver performance of blood alcohol concentrations below 50 mg% were studied in two contexts: 1. in a critical car driving situation involving emergency braking and evasive maneuvers and 2. in a "surprise" situation that followed the first one and featured the sudden appearance of a man-shaped obstacle blocking the road-way. The results indicate the detrimental effects of alcohol at a total BAC-average of 42 mg%; in the braking and maneuvering task, drivers under the influence of alcohol hit significantly more pylons and took significantly longer distances to stop. There was also a strong tendency for alcohol to impair performance in the surprise situation. Under the influence of alcohol five drivers out of ten collided with the obstacle; this was the case for only one driver out of ten in the control (non-alcohol) condition.
INTRODUCTION

As far back as in the beginning of this century, alcohol was recognized as a hazard in connection with traffic. In 1914 a report was published pertaining to the determination of blood alcohol levels of car drivers (Widmark 1914). Since that time many scientific studies have been carried out to investigate the impairing effects of alcohol on driver performance. Research has evolved along four major lines:

1. the comparison of accident rates for drivers having driven while intoxicated with those free from alcohol,
2. the indirect method of studying performance on laboratory tasks that have an assumed relation to traffic safety,
3. studies of the effects of alcohol on tasks which resemble driving - particularly the operation of driving simulators,
4. experiments relating alcohol consumption to performance in driving real cars on closed courses.

The level of blood alcohol concentration (BAC) where the impairing effects become distinguishable has been studied within all four investigative lines. All the research points to the same general conclusion, namely that alcohol does impair driving performance. In the case of some studies, especially those done with low levels of BAC, the justifiability of this conclusion is questionable, due to loose ties between the tests used and real world traffic situations.

With regard to accident statistics, it is usually concluded that from a 80 mg% and up there is a steep increase of risk although some studies find a threshold increase of risk in the interval between 10-16 mg% (Fox 1967, Holcomb 1938, Smith and Popham 1951).

Results from laboratory tasks indicate that perceptual functions as well as coordination and reaction times are affected at low doses of alcohol (Goldberg 1970, Kelly et al, 1970).
Concerning simulator studies Drew et al (1959) have shown negative correlations between BAC and simulator performance. Significant impairment of performance was also noted by Loomis and West (1958) and Stening and Dureman (1975), using doses of alcohol producing BAC's below 50 mg%.

The impairing effects of alcohol have also been detected in real car driving on closed courses at BAC's well above 80 mg%. Bjerver and Goldberg however, in a now classical study (1950) where they compared the performance of a control group with that of a group of drivers who had consumed beer or distilled spirits, found a 27.9% impairment at 48 mg% for the alcohol as compared to the control group. The driving task involved a series of backing, parking and starting manoeuvres requiring very accurate positional control of the vehicle. The authors concluded that "the threshold of impairment of driving ability in expert drivers......is an alcohol concentration of....35 mg% to 40 mg% in the blood". Also, Huntley and Perrine (1971) in a closed course, gymkhana study found: that 44% more poles and pylons were upset in the alcohol than in the no-alcohol condition. The difference however was not significant at a mean BAC of 43 mg%. Another often cited study was carried out by Lovibond and Bird (1970) who showed non-competition drivers to be markedly impaired at a BAC of 50 mg%. However, they fail to provide any statistical analysis to prove any significant difference from a control group. Many other studies on closed course driving have also established significant degradation of performance due to alcohol consumption. These results, however, have been obtained at higher BAC's, e.g. Coldwell et al (1958), Longhetti and Barnett (1965), Kielholz (1969).

Although considerable energy seems to have been spent on finding measures that might detect the effects of alcohol, many studies bear little resemblance to real world traffic situations in which alcohol associated accidents occur - other than the fact that a real car is used. Parking, precision maneuvering and low speed have been predominant characteristics of these studies. A technique attempting to remedy this deficiency was employed by Huntley, Perrine and Kirk (1973). The driving task included an emergency stopping situation and an evasive
maneuver and was shown to be sensitive to the effects of alcohol. However, the BAC of their subjects was 90 mg%. According to Goldberg (1970), in emergency situations the critical BAC is estimated to be 20 - 40 mg% whereas in a task requiring less complicated performance the critical level is estimated to be 40 - 50 mg%. BAC's around 50 mg% are of special interest because some countries already have adopted laws that incriminate driving with higher alcohol concentration and others are considering laws to that effect.

The present study centered on subjects with BAC's below 50 mg% in a demanding emergency type task - a task that any driver could have to face any day. The driving task was also designed to rule out possible efforts of momentary compensation for the impairing effects of alcohol. Such efforts can often be suspected in experiments where the subjects know the precise point or instance of measurement. This bias could be avoided by employing a technique which leaves uncertain where and when the stimuli will appear. By adding to this a situation which is a total surprise in a relaxed phase of the experiment, chances would be that motivational and related experimental bias effects could be reduced.
METHODS

Procedure

The driving task consisted of a situation where the roadway is suddenly blocked; this required emergency braking and an evasive maneuver. In order to be able to perform correctly the driver had to: 1. brake hard; 2. release the brake pressure in order to be able to... 3. swerve; 4. realign the car; and 5. brake hard to a full stop. All subjects practiced the driving task for a total of two hours. Correct behavior and the consequences of incorrect behavior were demonstrated by the experimenter, who also gave the subjects feedback as to their performance and instructions for improvement.

All training was carried out in daylight. During the training sessions emphasis was also placed upon the subjects' learning to maintain the prescribed 50 km/h.

The experimental sessions started as soon as it was completely dark. Four drivers were tested each night. All four subjects were, for practical reasons, taken together to a caravan, at the test track and were given instructions neither to try to watch nor to discuss each other's performance before, during, or after the experiment. The subjects were told that the number of experimental trials "could" vary depending on the number of no-signal trials. Each subject however had to go through a total of 18 experimental trials (i.e. 8 emergency actions and 1 no-signal trial with or without alcohol in the first session and the same number in the opposite condition in the second session). In addition there was one "warm-up" trial preceding the test each night. After having made all test trials on the second night and upon returning to the starting point for an assumed tenth trial the drivers - without any pre-notion - suddenly, in the light from the dipped head lights, saw an obstacle blocking the path. Either of swerving or braking actions released a camera shutter to take a picture of the obstacle at the moment or reaction. In order to test the possibility of momentary compensation for the impairing effects of alcohol in a forward situation the "surprise" was repeated with the instruction to the drivers to brake as soon as they
could see the man-shaped obstacle. Instructions were also given not to reveal the surprise to the other subjects. Blood and breath sampling then completed the subjects' participation and they were taken to a railway station for the journey home.

Course

A 500 m closed section of a four-lane motorway was used as the site. On this closed course two separate settings of rubber pylons were set out. The smaller setting was used only for pretraining of the emergency braking and evasive maneuver. The longer one was used for training as well as testing and consisted of eight emergency openings as seen in figure 1. Each subject used all 8 evasive openings in random order each night.
Figure 1. Specifications of pylon setting.
All specifications as presented in the figure were adapted to the vehicle and to the road surface conditions so as to make the task difficult enough to provide a fine-graded measure of performance (i.e. no driver should be able to negotiate the course without hitting pylons and getting some stopping distance). The obstacle for the surprise situation was matte darkgrey, 1 m high and 40 cm wide.

Subjects

The subjects were twenty-six men, their ages ranging from 19 to 31 with a mean age of 24.5 (st.dev. = 3.3, median = 23.5); the majority were university students. Six subjects took part in the pilot study and ten in each of the two parts of the main study. Their mean distance driven during the last twelve months was approximately 12 000 km with a range from 2 000 to 20 000 km. Seven of the subjects did not own a car. The drinking habits were quite similar for all subjects - consumption of alcohol a couple of times per month and at each occasion an amount equivalent to approximately 8 cc. of ethanol 100%. Their payment was made dependent upon performance in the two experimental sessions in a manner described under "measurement of dependent variables".

Vehicle

The experimental vehicle was a 1966 Volvo Station Wagon. For the presentation of the stopping signal to the driver two red brake-lights were placed on the fenders. The car was also equipped with a 35 mm camera inside the windshield and an electronic flash unit attached to the front bumper. This equipment was triggered by the subjects either braking or turning the wheel 60°. In order to make it easier for the driver to maintain the required speed, the accelerator pedal was equipped with an extra spring making it hard to press the pedal beyond a point corresponding to 50 km/h in third gear.
Emergency action stimulus

The two red brake lights were triggered at a distance of 7 m from the emergency opening. The trigging action was performed by a photocell and a lamp throwing light at a reflector placed, invisibly to the driver, among the pylons. The reflector was placed in randomized order in premarked positions at any of the eight emergency openings. The subjects were told to use the very first available opening as soon as the lights come on.

Alcohol - administration and measurement

The subjects had a light meal 4 – 5 hours before the experimental sessions. Alcohol was served in the form of scotch whiskey without ice or water. A dose of 1.5 ml of whiskey per kg of body-weight was used in the pilot study and experiment A, whereas in experiment B a dose of 1.3 ml/kg was ingested. The time allowed for consumption of the alcohol was 15 min. Immediately prior to driving three capillary samples were taken from the fingers.

This procedure was repeated as soon as a subject had completed his driving task. Breath samples were also taken with an Alcolmeter in both instances. Driving them commenced 60 min after the start of drinking and lasted for approximately 25 minutes. The capillary samples were then refrigerated and taken to the Department of Alcohol Research at Karolinska Institutet, Stockholm, where they were analyzed with an automated enzymatic ADH-method (Goldberg & Rydberg, 1965).

Measurement of dependent variables

1. Emergency situation:
   Angle of car: both bumpers had been marked into quarters. Each quarter, protruding into the adjoining lane from the correct position after the car had come to a full stop rendered a 2 sw.cr (40 c USA) reduction of payment from the initial value of 22 sw.cr ($ 4.40 USA) per trial.
Stopping distance was measured from the first pylon in the emergency opening to the front of the car - minus 7 m.

Payment was reduced by 1 sw.cr (20 c USA) per meter. Precision down to 25 cm.

Pylons hit or moved: a simple summation of pylons, knocked down or moved. Each pylon rendered a reduction of 1 sw.cr (20 c USA).

Faulty decision: no evasive manoeuvre, turning in the wrong direction or at the wrong place all resulted in a reduction of 15 sw.cr ($ 3.00 USA).

2. Surprise situation:
Distance of reaction: photographic registration of the obstacle at the moment of reaction and measurement of obstacle size on the negative under a microscope.
RESULTS

The means per trial and ranges of payment reduction on three measures in the three different parts of the study are presented below. In addition the figures present the BAC-means of three blood samples taken immediately prior to driving and the means of three samples taken directly after the driving. They also show the total mean, taken to be the estimation of BAC during the actual driving.

BAC before driving 50 mg%, range 43—55 mg%
BAC while driving 47 mg%, range 42—50 mg%
BAC after driving 43 mg%, range 39—47 mg%

Pilot study:
In the pilot study, performance, as far as pylons and stopping distance are concerned, deteriorated for all subjects between control and alcohol conditions. Tests of significance of the difference between conditions, made with the Sign test (Siegel 1956) give p = 0.015 for both measures. The same method applied on angle of car, where three subjects showed deteriorated
performance and three subjects improved performance, yielded no significant difference. Figure 2 also shows BAC during actual driving to have been fairly close to the intended 50 mg%, and indicates decreasing BAC from before- to after-measurement. This was the case for all six subjects.

**Figure 2.** BAC before driving 46 mg%, range 30—64 mg%, BAC while driving 42 mg%, range 24—61 mg%, BAC after driving 37 mg%, range 18—57 mg%.

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**Experiment A:**

In experiment A eight subjects were affected in a negative way by alcohol in measures: pylons and stopping distance. This shows a significant difference (p = 0.055) whereas "angle of car" again did not reveal any significant differences between conditions. Five subjects improved their performance and five had their performance impaired. As for BAC the same tendency as was shown in the pilot study is again evident. All ten sub-
Subjects had lower BAC's after driving - a mean reduction of 9 mg% in 25 min.

Experiment B:
In experiment B the number of pylons that were hit increased in eight cases, decreased in one case and remained the same in one as calculated from control to alcohol conditions. The difference between conditions is significant (p = 0.02). This is also true of stopping distance (p = 0.055), where two subjects improved their performance and eight took longer stopping distances. As for "angle of car" nine subjects showe impaired performance and one improved his performance with alcohol - a significant difference (p = 0.011). In this part of the study two subjects were shown not to have reached the elimination phase of the blood alcohol curve. The other eight subjects had lower BAC's after driving than before.
Figure 5. Absolute numbers of false actions in alcohol and control conditions. Sums over all three parts of the experiment. These actions were carried out by four subjects in the control and five subjects in the alcohol condition.

False actions:
The small absolute number of false actions carried out during the experimental sessions did not provide a basis for statistical testing. However, the number of false actions carried out in the control condition — all three parts taken together was 4 as compared to 10 in the alcohol condition.
Illustrated in figure 6 is the performance on three measures of the ten subjects that reached the lowest BAC's. Eight subjects hit more pylons in the alcohol condition whereas two subjects obtained lower scores. The difference between conditions is significant (p = 0.055). Exactly the same relation also holds true for "stopping distance". The measure "angle of car" however does not reveal any significant differences between conditions. Performance deteriorated for six subjects and improved for four from control to alcohol conditions.

A comparison has also been made of possible differences related to the order of presentation of the two conditions. Thus, if the results from the 13 subjects driving with alcohol in their
first session and no alcohol in the second are grouped together and compared with the ones of the reverse order, we find no significant differences.

The overall mean of rank order correlations between performance in control and alcohol conditions was 0.69, as calculated via Fisher's Z.

As for the surprise situation, a series of circumstances reduced (strong wind gusts, blowing the obstacle away) the number of tests successfully carried out. These circumstances (repeated camera failure) also made the use of the photographic distance measuring method impossible. Thus only collisions or safe stops could be registered. A total of ten subjects were tested while under the influence of alcohol and another ten subjects in the control condition. The results are presented in figure 7. Since repeated measurements could not be made, the results of the two groups of subjects in the emergency situation were tested for possible differences. However, no significant differences between the two groups were found.

![Figure 7](image)

When the procedure was repeated to test for a "pull-onself-together-effect" all subjects made safe stops.
DISCUSSION

The results give clear evidence of the degrading effects of alcohol upon driving performance in emergency situations. Detrimental effects are found to exist at blood alcohol concentrations below 50 mg% - the overall mean of BAC's being 42 mg%. The ten subjects who happened to reach BAC's in the range between 24 and 40 mg% show the same impairment of performance. The differences between conditions are significant for the two measures: "pylons" and "stopping distance". The variations in sensitivity of the third measure - "angle" - both between subjects and between parts of the study, probably could be attributed to variations in importance assigned to this variable by the subjects. Admittedly it could be considered somewhat artificial and was originally only used in order to standardize the driving behavior of the subjects.

As can be seen in the figures, there were tendencies for ranges to be wider, the maximum values to be higher and also the minimum values to be higher in the alcohol condition than in the control condition. As far as the "pylons" measure is concerned, these tendencies constitute significant differences between the two conditions. The difference in blood alcohol concentrations between parts A and B of the study were too small to justify separate conclusions. No significant difference was found between BAC's as tested with the Mann-Whitney U-test. As for the surprise situation, the loss of data and the crude observational method, stating only collision or no-collision, give little justification for safe conclusions in a statistical sense. However, a tendency for impairment of performance can be observed, much the same as in the rest of the study. The results are in good accordance with Bjerver and Goldberg's (1950) results in that effects of alcohol were demonstrated below 50 mg%, although the driving tasks were different. Taylor and Stevens (1966) came to much the same results at a mean BAC of 66 mg% in a study which also included a surprise situation. Good accordance also exists between these results and the results from several simulator studies, indicating impairing effects of alcohol below 50 mg%.
The same goes for estimations of thresholds of influence and increased accident risks being in the BAC-interval 20-40 mg% in traffic situations (SOU 1953:20).

There are reasons to believe that the results underestimate rather than overestimate the true differences between driver performance in emergency situations under the influence of alcohol and performance under sober conditions.

Thus the drivers were subjected to stress by taking part in an experiment, by being observed and by knowing that on each experimental trial an emergency situation would occur. This, according to Wilkinson and Colquhoun (1963), could reduce the effects of alcohol. This interpretation is also in accordance with the Hawthorne effect which indicates that an individual who knows that he is observed in an experiment may try extra hard and thus, in this case, try to compensate for the impairing effects of alcohol. The compensation would be especially likely at lower BAC’s (Perrine 1973). In traffic situations it is thus possible that differences between sober performance and performance under the influence of alcohol would be even greater. The fact that the subjects had practiced the driving task very thoroughly also indicates a possible underestimation of true differences. There are indications that well-learned skills are less vulnerable to the effects of alcohol than unfamiliar ones (Lovibond and Bird 1970). Critical and emergency situations occur with low frequency in everyday traffic, thus providing very few chances to practice and get used to the handling of such situations. Milner (1972) expressed it this way: "it is likely that if a drug is shown to affect driving skills in an experimental situation, its effects are probably even more pronounced in general driving behavior". Another reason to believe that the observed effects of alcohol by no means constitute a potential maximum is the fact that they were observed in the elimination phase of the BAC-curve in all cases but two, as indicated by the before- and after driving means of BAC. According to Kielholz, Richter and Hobi (1975) and many others, the impairing effects of alcohol are most pronounced in the absorbing phase of the intoxication.
The reliability of the results is emphasized by the fact that the results are virtually the same in all three parts of the investigation, making them replications of one another as far as procedures and results are concerned.

As for the validity - the investigation suffers from the usual setbacks inherent in all situations that are not real traffic but semi-laboratory. The test situation was developed from typical situations that are employed in most driver improvement courses where emergency maneuvering is in the syllabus. The relevance of this evasive manoeuvre is illustrated by figures presented in the Swedish Experimental Safety Vehicle Programme (Samuelsson et al 1973, see also Favero 1975). In a statistical skid accident study they found 10.5% to be locked wheel accidents. Out of these, 19% were running into another vehicle from behind. Almost all of these could have been avoided by evasive manoeuvres. 93.8% stayed in the same lane when they were about to run into the car in front of them. Comments from the subjects also indicate that they considered the task relevant to safe driving and its artificiality was not felt.

Unfortunately it was not within the scope or resources of this study to demonstrate what aspect of the driving task was most affected by alcohol intoxication. Rather the purpose has been to study the effects of alcohol in a generalizable situation containing most of the ingredients that could enter a traffic situation that puts heavy demands on the driver. Thus, if one is willing to accept the semi-laboratory driving performance as representative of full-scale driving performance, then this study has shown the detrimental effects of very low BAC's in situations demanding fast reactions, attention, rapid decision-making and precise and accurate action of the driver.

It should be pointed out that the absolute figures per se are of minor importance since they are to such great extent dependent upon such factors as the vehicle, the lay-out of the pylon setting, the friction between tyres and road-surface and so on. What is more important is the impairment as such.
REFERENCES


INSTRUCTION

Your task will now be to drive the car through the middle lane at 50 km/h. You should drive as well as possible, i.e., you must try not to hit any pylons. In order not to hit pylons it is recommended that you keep your gaze directed far ahead of the car all the way while passing through the pylon setting. This makes it simpler to maintain a straight line.

When the signal— the red braking lights in front of you— comes on, you must swerve into the first emergency opening ahead of the car. You must not wait for an opening further away— one that you easily and safely could drive into, but must make use of the very first one.

You must also see to it that you get the car fully into the adjoining lane, so that no part of the car is left protruding out into the "blocked" middle lane, which might cause it to be run into from behind.

You should use the driving technique that you just practiced, i.e., short and firm braking, release the brake pressure, swerve realign the car and finally brake hard to a full stop after having realigned the car. Your first consideration should be to use the right opening. You must not hit any pylons while driving through the middle lane, of course.

Your next consideration should be to hit as few pylons as possible during the evasive manoeuvre. Then you should try to take as short a stopping distance as possible.

Your performance will affect the size of your reward. Thus, starting will 22 Sw.cr. per trial, this amount will be reduced by:

- 15 Sw.cr for a faulty decision, i.e., the use of a wrong opening or no maneuver at all
- 1 Sw.cr. per 1/8 of the car's bumpers protruding out of the lane
- 1 Sw.cr. per pylon hit or moved out of position
- 1 Sw.cr. per meter of stopping distance, as measured from a certain pylon in each opening to the front bumper of the car
Emergency action stimulus

Evasive maneuver