NHMRC ROAD ACCIDENT RESEARCH UNIT
THE UNIVERSITY OF ADELAIDE

THE EFFECT OF BLOOD ALCOHOL CONCENTRATION ON LIGHT AND HEAVY DRINKERS IN A REALISTIC NIGHT DRIVING SITUATION

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Research Report 1/90

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9441

INFORMATION RETRIEVAL

LAURELL H, McLEAN AJ, KLOEDEN CN (1990) : THE EFFECT OF BLOOD ALCOHOL CONCENTRATION ON LIGHT AND HEAVY DRINKERS IN A REALISTIC NIGHT DRIVING SITUATION. Adelaide: NHMRC Road Accident Research Unit, The University of Adelaide.

KEYWORDS : alcohol/ driving (veh)/ drunkenness/ blood-alcohol content/ night/ impairment/ skill (road user)/ tolerance*/ South Australia*

ABSTRACT : An experiment was conducted to test the effect of alcohol on actual driving behaviour. An instrumented vehicle was used to record driver performance on 8 laps of a 6 km course at night. Target detection, lane tracking, curve taking and speed regulation were used as measures of performance. Each of the 24 male subjects were tested at BACs of zero, .05g/100mL and .10g/100mL. To examine the possible effects of habituation to alcohol, 12 of the subjects were light drinkers and 12 were heavy drinkers. For 6 of the 7 measures, alcohol was found to be detrimental to driving performance although the effect at .05 was much smaller than that at .10 and failed to reach statistical significance. There was no evidence of any difference between the light and heavy drinkers.

* Non IRRD Keywords

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ISBN 0 908204 15 9
March 1990

INTRODUCTION

That alcohol has an adverse effect on driving performance and road safety is now beyond question. There is less agreement on what level of blood alcohol concentration (BAC) should be selected as the legal limit for drivers.

Data from road accidents and from roadside surveys in the United States and Australia (Borkenstein et al. 1964; McLean et al. 1980) indicate that the risk of involvement in an accident increases at driver BACs above .05g/100mL, with the rate of increase being much greater above .08g/mL. This is consistent with the fact that 91 per cent of drinking drivers who died in crashes in South Australia were above .05 and 85 per cent were above .08g/mL (Holubowycz and McLean 1988). However, in other parts of the world much higher risks have been associated with lower BACs. Glad (1987) claimed that the risk of being killed in a road accident in Norway increased 13 times for drivers with BACs between .05 and .10 compared with zero BAC.

Further information on risk can be gained experimentally. Studies of various factors, for example glare recovery, tracking performance, coordination, etc., have shown that performance is affected adversely at BACs as low as .01-.03 (Moskowitz and Robinson 1987). Driving simulator studies by Drew et al. (1958) showed reduced driving proficiency at BACs of .02-.03. In actual car driving tasks, adverse effects on driving performance have been shown at BACs of .03-.04 (Bjerver and Goldberg 1950; Laurell 1979; Johnston 1983).

Various measures of driving performance have been used in experimental studies. Laurell (1979), in night-time tests, and Bjerver and Goldberg (1950), in a study of driving performance in a gymkhana, used target detection and tracking precision. The measurement of target detection distance has been shown to provide a sensitive indication of impairment in monotonous driving situations (Laurell and Lisper 1978). Tracking performance has been used by Johnston (1983) and Louwerens et al. (1987) among others and has been shown to be a very sensitive measure of the effects of alcohol.

Habituation to alcohol has been shown to be associated with reduced impairment. Goldberg (1943) demonstrated this using sensory-motor tests. Moskowitz et al. (1979), who measured hand steadiness and body sway at various BAC levels, found that although both moderate and heavy drinkers began to show impairment at a similar level of BAC, the rate of increase in impairment was less among the heavy drinkers. Consequently, it might be expected that, at a particular BAC, drivers who are regular heavy drinkers would exhibit less impairment than those who drink alcohol infrequently.

The experiments reported in this paper were designed to test the effect of alcohol on the night-time driving performance of light and heavy drinkers. Night driving was chosen because that is when drivers' BAC levels are highest (eg: McLean et al. 1980). It was also hoped that the collaborative nature of the study, bringing together Swedish and Australian researchers, might yield greater insight into the weak association between previous experimental studies and much of the epidemiological data on alcohol and crashes.

METHOD

Twenty-four subjects (12 light drinkers and 12 heavy drinkers) drove around a 6 km course on three night-time occasions after drinking a placebo or an amount of alcohol designed to result in a BAC level of .05 or .10 during the test. An experimenter accompanied the subject driver, periodic BAC readings were taken and measurements were made of driver performance in terms of target detection distance, capacity to maintain a given speed, tracking ability on straight and curved sections and the frequency of errors.

Subjects

Subjects were recruited by advertising for volunteers for a driving experiment. Respondents were told that the experiment would involve drinking alcohol and driving with BAC levels of up to .10 and that the average remuneration would be about $A250. Seventy-eight volunteers were willing to participate; they were screened for drinking habits by the Computer Lifestyle Assessment questionnaire (Bungey et al. 1989) and 12 'light' drinkers and 12 'heavy' drinkers were selected. 'Light' drinkers were those who indicated that they drank alcohol no more than once or twice a month and had less than three drinks per occasion; 'heavy' drinkers were those who reported drinking five or more times a week, had at least 28 standard drinks per week, and had five or more drinks per occasion at least five times per month.

All 24 subjects were males aged between 19 and 55 years; the median ages were 27.0 and 27.5 years for the light and heavy drinkers respectively. Most of the subjects were Royal Australian Air Force (RAAF) personnel; the others were members of a sporting car club.

Subjects were given full information about the experiment, including the fact that they could cease to participate at any time, and were asked to sign a consent form stating that they were not on any medication. They were asked not to drink alcohol on the day of each test and to have only a light meal (the same on all three occasions) and no coffee in the four hours before each test. Details of actual food intake and any major deviations from normal work and rest patterns in the appropriate periods were recorded prior to each test. The subjects also had to arrange to be driven home after each test was over. Subject convenience determined the interval between tests; this ranged from 1 to 14 days.

Vehicle

The vehicle was an a 1981 Holden VC Commodore L station wagon fitted with automatic transmission, a second brake pedal for the experimenter and a micro-processor-based data logging system described in detail below.

Course

The main runway and the sealed taxiways of an air base provided a six kilometre track which consisted of four straight sections joined by one left hand and three right hand curved sections. Drivers were told to keep just to the left of a yellow centre line on the taxi ways and a white edge line on the main runway. Each test comprised eight laps of the track.

Targets

The targets were 45cm x 45cm pieces of plywood with firm supports and ballast weights to prevent displacement by wind. They were covered with dark grey fabric and were fitted with reflectors which were positioned so that light emitted from a side-mounted light source on the instrumented vehicle was reflected back to a photo-diode also mounted on the vehicle. This system was used in recording target detection distances.

Targets were placed at various positions along the straight sections of the track. On the left side there were 15 designated points, each with a close-in position (four metres left of the track 'centre' line) and a far-out position (seven metres left of the track 'centre' line); on the right side, targets were placed two metres to the right of the track 'centre' line, but at any position along the straight sections of the track.

The targets were positioned according to a scheme involving three different lay-outs which were systematically rotated over the three tests for each subject. In any one test there were four left-side targets for detection in each of six laps of the course and three targets in each of two laps. In addition, one right-side target appeared in each lap at a random position along one of the straight sections. Therefore, each test session required the detection of 30 left-side targets and eight right-side targets; these were arranged so that only one target could be seen at any one time.

On each lap, the targets were repositioned by an experimenter following the instrumented vehicle in a second vehicle. In order to minimize disturbance, the second vehicle maintained a minimum distance of approximately 500 metres from the test vehicle and the rear view mirrors of the instrumented vehicle were adjusted to prevent the driver seeing the lights of the second vehicle.

Test Conditions

All tests were conducted at night. There were very few lights visible beyond the boundaries of the base; however, moon phases and other activities at the air base caused some unavoidable variation in ambient light.

In order to minimize variability in the contrast conditions throughout the experiment, driving took place only when the road surface was dry. The headlights and windscreen of the instrumented vehicle were cleaned prior to each session.

Test Drinks

The test drink, consumed through a straw from a capped cup, was a mixture of 95% ethanol in water and cordial. The three test drinks, each given on a different night in a sequence which varied between subjects, were:

i) placebo - 1mL ethanol in 550mL water + cordial

ii) .05 condition - 0.5g ethanol/kg body weight in 550mL water + cordial

iii) .10 condition - 1g ethanol/kg body weight in 550mL water + cordial.

Subjects were not told which drink they received on a particular night. To diminish the possibility of detecting the absence of ethanol by taste, the 1ml of ethanol in the placebo condition was added via the straw shortly before administration.

Practice Session

Prior to the three test nights, a practice session was held during which the subject was given full instructions and a practice drive, including target detection, around three laps of the track.

Driving Instructions

Before each test, the subjects were told to: drive at 60 ± 2 km/h on straight sections and at a comfortable speed on curves; keep the car just to the left of the centre line; apply the brake momentarily on detecting a close-in target on the left; press the horn momentarily on detecting a far-out target on the left; report verbally any targets on the right; and stop at the end of every second lap for a BAC reading.

Financial Incentives

Before each test, the subjects were told that the payment would be $40 a night. However, $1 would be deducted for each target that was either missed or incorrectly signalled, and for each deviation of more than 2 km/h from 60 km/h on straight sections, and $2 would be deducted for signalling a nonexistent target. For every instance of correctly identifying a target at a distance of more than 65 metres, $1 would be added.

Test Protocol

Experimental sessions were of approximately two hours duration and incorporated the recording of recent history of food intake, work conditions and sleep pattern; an initial breath test to confirm a zero BAC; the consumption of the test drink over a period of 20 minutes; a 20 minute rest period during which a breath test was performed at 10 and 15 minutes; driving instructions and, finally, the test drive of eight laps of the track. Further breath tests were conducted in the car just before starting and after every second lap.

Measurement of Blood Alcohol Level

A Lion Laboratory Alcolmeter S-D2 was used to obtain BACs from breath samples to the nearest .005 g/mL.

Measurement of Dependent Variables

The on-board computer of the test vehicle was described in detail by Dods (1982) and Fraser (1982). It recorded time and distance travelled, the vehicle's lateral displacement from the centre line of the track, lateral acceleration, brake pedal and horn activation, and the passing of targets on the left using the system described earlier.

Because of limitations in the computer's storage capacity, data was only recorded during the 100 metres leading up to each target and during the negotiation of one of the curves. The driver was unaware of the activation of the computer.

Dependent Variables

The following dependent variables were calculated from the recorded data:

detection distance for close-in targets - distance between the car and the target at the moment that the brake pedal was depressed (measured 15 times / subject / night);

detection distance for far-out targets - distance between the car and the target at the moment that the horn was operated (measured 15 times / subject / night);

lateral position range - range of the distance of the car from the 'centre' line over the 100 metres leading up to a target (measured 30 times / subject / night);

curve taking instability - area enclosed by the curve of the roadway and the path taken by the car (measured 8 times / subject / night);

velocity in straight sections - instantaneous velocity of the car 100 metres before each target (measured 30 times / subject / night);

velocity deviation - difference between the velocity of the car and 60 km/h, 100 metres before each target (measured 30 times / subject / night);

number of mistakes per night - total number of times that an target was missed or incorrectly identified (out of 30 targets / subject / night).

The seven performance scores for each subject on each night comprised six average scores derived from each of the first six variables, as well as the total number of mistakes.

The right-side targets were employed to prevent the drivers from concentrating only on the left side of the course; neither the detection distance nor the number of mistakes was measured.

RESULTS

BAC Levels

The alcohol dose administered to each subject was based on body weight. However, other factors influence the blood alcohol concentration which results from the ingestion of a given amount of alcohol. Therefore, the actual BACs of the subjects often differed from the target BAC, substantially so in some cases.

In the .05 BAC tests the average BAC reading for all subjects was .043 (range .020-.068) and the average peak BAC reading was .049 (range .020-.075). In the .10 BAC tests the average BAC reading for all subjects was .109 (range .076-.157) and the average peak BAC reading was .123 (range .085-.180).

Tables 1-4 show the actual BAC readings taken during the course of the experiment for light and heavy drinkers in the .05 tests and light and heavy drinkers in the .10 tests respectively. The light drinkers reached a higher mean BAC level in the .05 tests (.045 vs .041) and a lower mean BAC level in the .10 condition (.104 vs .113).

The peak BAC level for the subjects occurred about half way through the experiment.

Table 1: Blood alcohol concentration readings for the light drinkers in the 0.05 g/mL condition

Subject	BAC1	BAC2	BAC3	BAC4	BAC5	Mean	Max.
1	.035	.035	.040	.040	.035	.037	.040
2	.045	.040	.050	.045	.040	.044	.050
3	.045	.045	.050	.045	.035	.044	.050
4	.035	.035	.045	.040	.035	.038	.045
5	.045	.045	.050	.045	.040	.045	.050
6	.065	.065	.060	.055	.055	.060	.065
7	.030	.030	.030	.025	.020	.027	.030
8	.035	.035	.035	.035	.035	.035	.035
9	.040	.040	.055	.045	.040	.044	.055
10	.045	.050	.050	.045	.030	.044	.050
11	.065	.075	.075	.070	.055	.068	.075
12	.050	.050	.050	.055	.045	.050	.055
Mean	.045	.045	.049	.045	.039	.045	.050

Table 2: Blood alcohol concentration readings for the heavy drinkers in the 0.05 g/mL condition

Subject	BAC1	BAC2	BAC3	BAC4	BAC5	Mean	Max.
13	.045	.045	.040	.035	.035	.040	.045
14	.060	.060	.050	.050	.050	.054	.060
15	.020	.020	.020	.020	.020	.020	.020
16	.035	.035	.030	.025	.015	.028	.035
17	.065	.065	.065	.055	.050	.060	.065
18	.055	.060	.050	.045	.040	.050	.060
19	.070	.065	.060	.055	.050	.060	.070
20	.045	.050	.060	.050	.045	.050	.060
21	.030	.025	.035	.020	.020	.026	.035
22	.030	.040	.035	.035	.040	.036	.040
23	.035	.045	.050	.045	.050	.045	.050
24	.025	.035	.030	.025	.020	.027	.035
Mean	.043	.045	.044	.038	.036	.041	.048

Table 3: Blood alcohol concentration readings for the light drinkers in the 0.10 g/mL condition

Subject	BAC1	BAC2	BAC3	BAC4	BAC5	Mean	Max.
1	.070	.080	.080	.090	.085	.081	.090
2	.080	.075	.105	.115	.080	.091	.115
3	.075	.075	.085	.085	.080	.080	.085
4	.070	.070	.075	.075	.090	.076	.090
5	.155	.165	.180	.155	.130	.157	.180
6	.095	.095	.090	.080	.080	.088	.095
7	.095	.090	.115	.100	.090	.098	.115
8	.095	.110	.125	.150	.120	.120	.150
9	.105	.105	.110	.105	.095	.104	.110
10	.060	.075	.135	.110	.115	.099	.135
11	.145	.135	.135	.150	.140	.141	.150
12	.105	.105	.130	.105	.095	.108	.130
Mean	.096	.098	.114	.110	.100	.104	.120

Table 4: Blood alcohol concentration readings for the heavy drinkers in the 0.10 g/mL condition

Subject	BAC1	BAC2	BAC3	BAC4	BAC5	Mean	Max.
13	.150	.150	.140	.130	.120	.138	.150
14	.100	.110	.120	.130	.130	.118	.130
15	.110	.130	.130	.140	.120	.126	.140
16	.085	.105	.105	.115	.095	.101	.115
17	.105	.120	.130	.135	.130	.124	.135
18	.100	.110	.105	.090	.080	.097	.110
19	.085	.095	.095	.090	.085	.090	.095
20	.110	.120	.125	.120	.110	.117	.125
21	.110	.135	.120	.140	.125	.126	.140
22	.095	.110	.115	.125	.105	.110	.125
23	.105	.120	.115	.125	.110	.115	.125
24	.105	.095	.115	.095	.085	.099	.115
Mean	.105	.117	.118	.120	.108	.113	.125

Driver Performance Results

The mean values of the seven performance variables are presented in Tables 5-11 for light drinkers, heavy drinkers and all drinkers combined at each of the three BAC levels (zero, .05, .10). There was no consistent difference between the performance of the light drinkers and the heavy drinkers at the three BAC levels over the seven variables.

Table 5: Detection distance for close-in targets (metres)

Target BAC	Light Drinkers	Heavy Drinkers	All Drinkers
0.00	60.8	59.2	60.0
0.05	59.7	58.8	59.3
0.10	56.8	54.9	55.9

Table 6: Detection distance for far-out targets (metres)

Target BAC	Light Drinkers	Heavy Drinkers	All Drinkers
0.00	73.6	67.7	70.7
0.05	71.7	66.0	68.9
0.10	64.7	59.2	62.0

Table 7: Lateral position range (centimetres)

Target BAC	Light Drinkers	Heavy Drinkers	All Drinkers
0.00	18.9	18.3	18.6
0.05	19.4	19.6	19.5
0.10	21.5	22.4	22.0

Table 8: Curve taking instability (metres^2)

Target BAC	Light Drinkers	Heavy Drinkers	All Drinkers
0.00	3.8	4.9	4.4
0.05	4.6	5.1	4.8
0.10	5.2	6.0	5.6

Table 9: Velocity in straight sections (km/h)

Target BAC	Light Drinkers	Heavy Drinkers	All Drinkers
0.00	60.9	60.8	60.8
0.05	60.5	60.8	60.6
0.10	60.0	60.3	60.2

Table 10: Velocity deviation (km/h)

Target BAC	Light Drinkers	Heavy Drinkers	All Drinkers
0.00	1.56	1.50	1.53
0.05	1.47	1.75	1.61
0.10	1.67	1.95	1.81

Table 11: Number of mistakes per night

Target BAC	Light Drinkers	Heavy Drinkers	All Drinkers
0.00	2.3	1.8	2.0
0.05	2.2	2.7	2.4
0.10	3.0	3.3	3.1

Analyses of variance were carried out for each of the seven performance variables to test the effects of the three independent variables: blood alcohol concentration (zero, .05, .10); sequence of tests (1, 2, 3) - an indication of learning effect; and drinking status (light, heavy). None of the interactions between these three independent variables was statistically significant. The results of these analyses are presented in Table 12.

Table 12: Statistical significance of the variation in the 7 dependent variables due to blood alcohol concentration (BAC) the learning effect and drinking status (light vs heavy drinkers)

Variable	BAC	Learning	Drinking
Detection distance for close-in targets	p < .01	p < .01	NS
Detection distance for far-out targets	p < .001	p < .001	NS
Lateral position range	p < .05	NS	NS
Curve taking instability	p < .05	NS	NS
Velocity in straight sections	p < .05	p < .1	NS
Velocity deviation	p < .1	p < .05	NS
Number of mistakes per night	p < .1	p < .001	NS

The mean values for each of the seven variables, at each BAC level, were then compared. The statistical significance of the observed differences was assessed using a least significant difference estimate at the 5% level. The results are presented in Figures 1-7. All of the seven variables except the one relating to "velocity in straight sections" showed the same trend: the mean level of performance at the .10 level was statistically significantly worse than at the zero level; at .05 the mean values were not statistically significantly different from those at the zero level but all six indicated a small deficit in performance.

The "velocity in straight sections" variable (Figure 5) showed a decrease in the average velocity with an increase in BAC, although only the difference between the zero BAC level and the .10 level was statistically significant. The difference was very small (less than 1 km/h) and was well within the target speed of 60 ± 2 km/h.

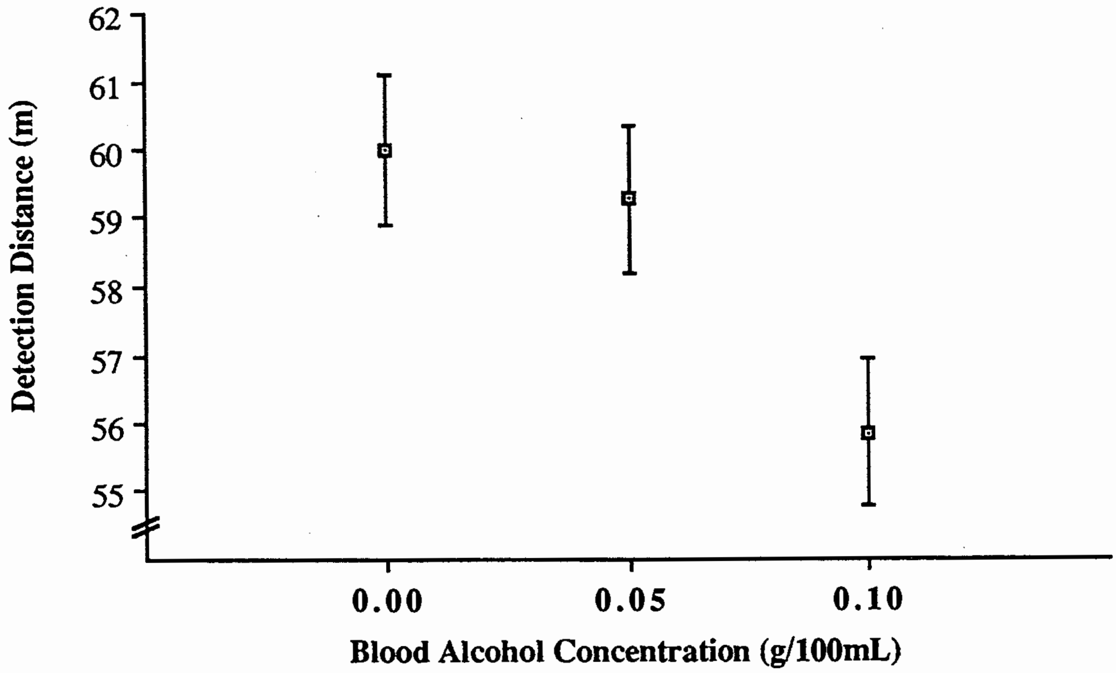

Figure 1: Detection distance for close-in targets

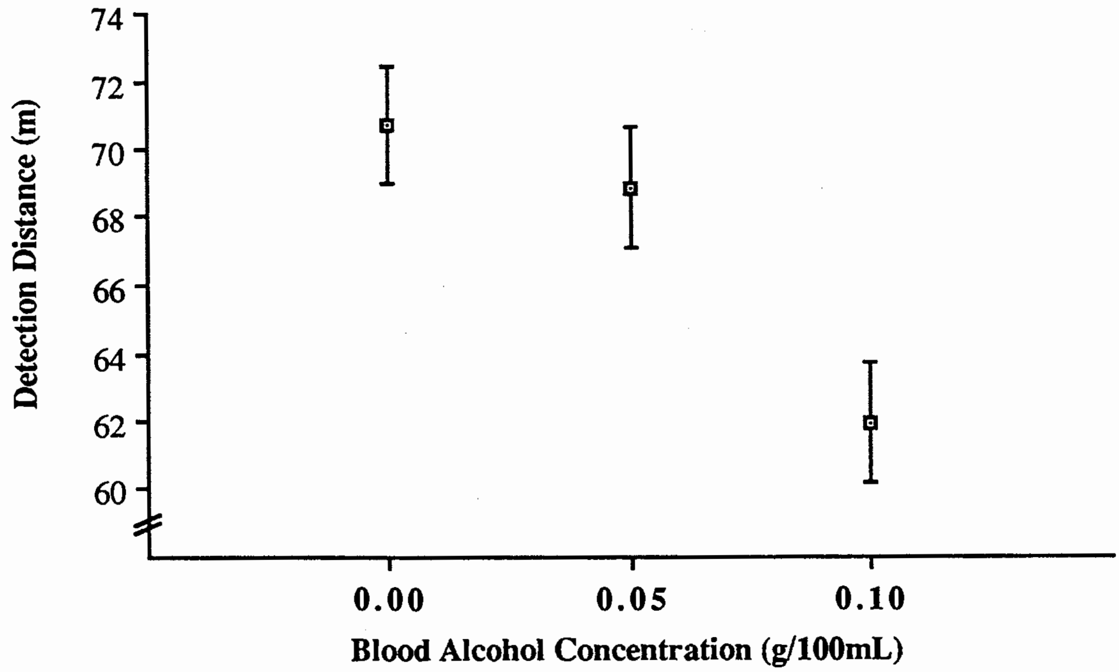

Figure 2: Detection distance for far-out targets

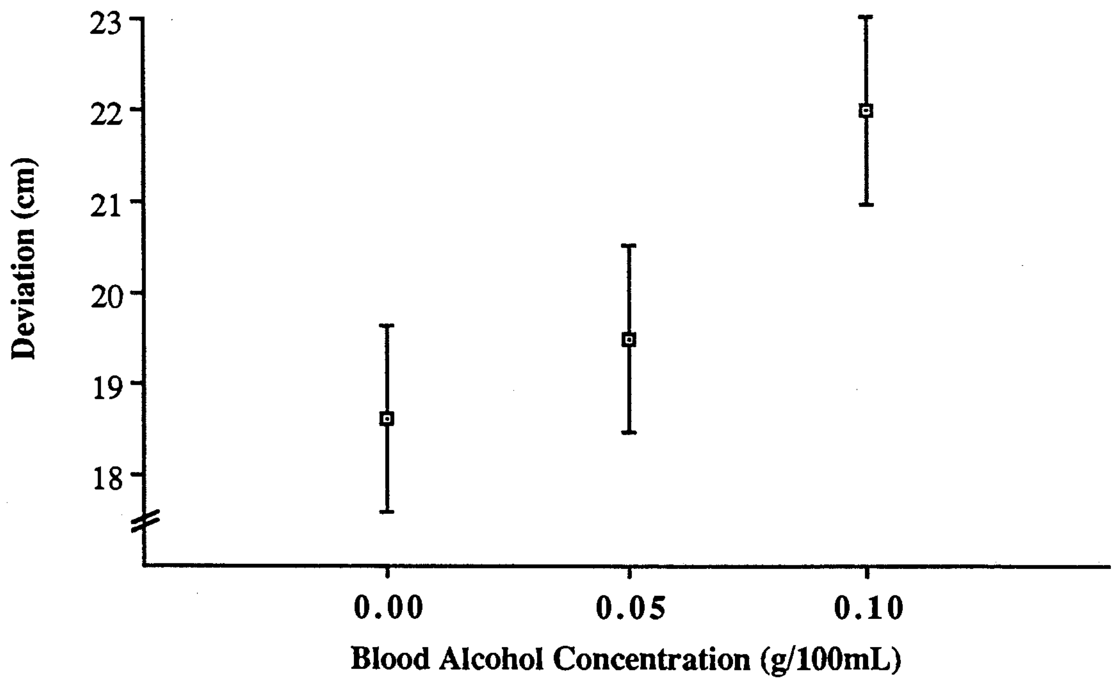

Figure 3: Lateral position range

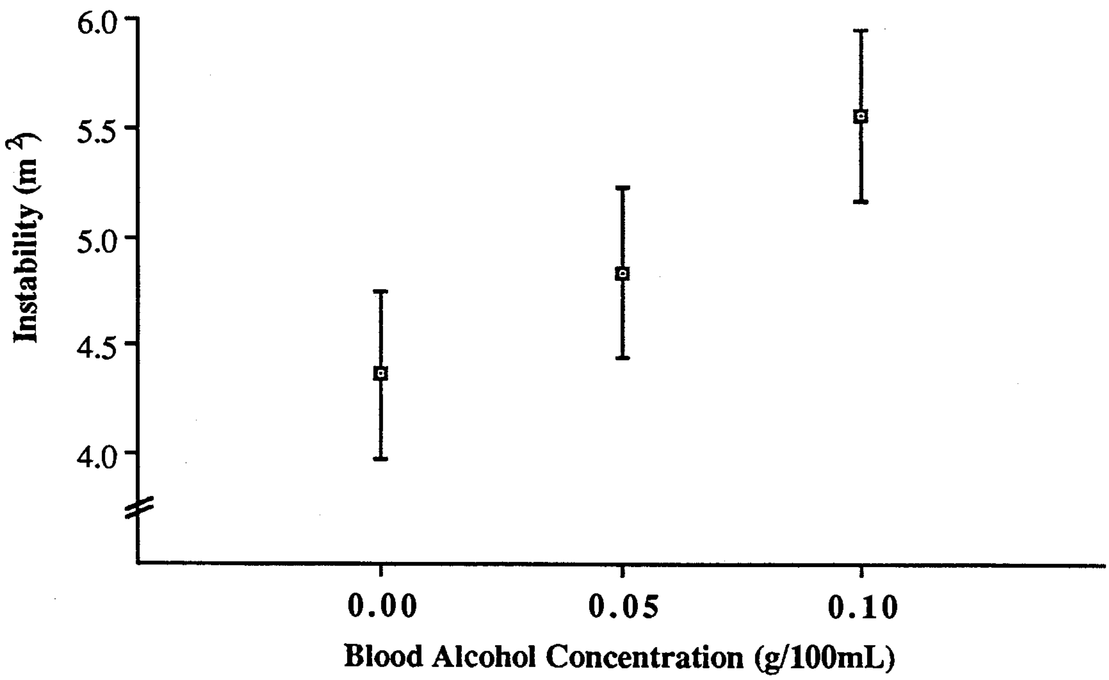

Figure 4: Curve taking instability

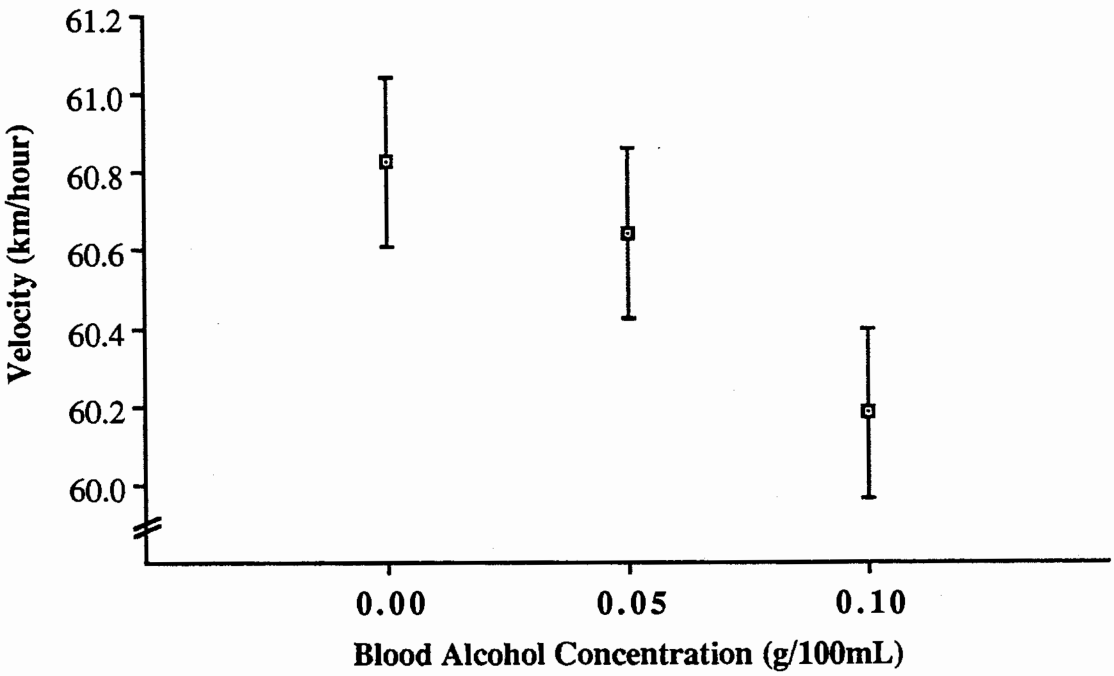

Figure 5: Velocity in straight sections

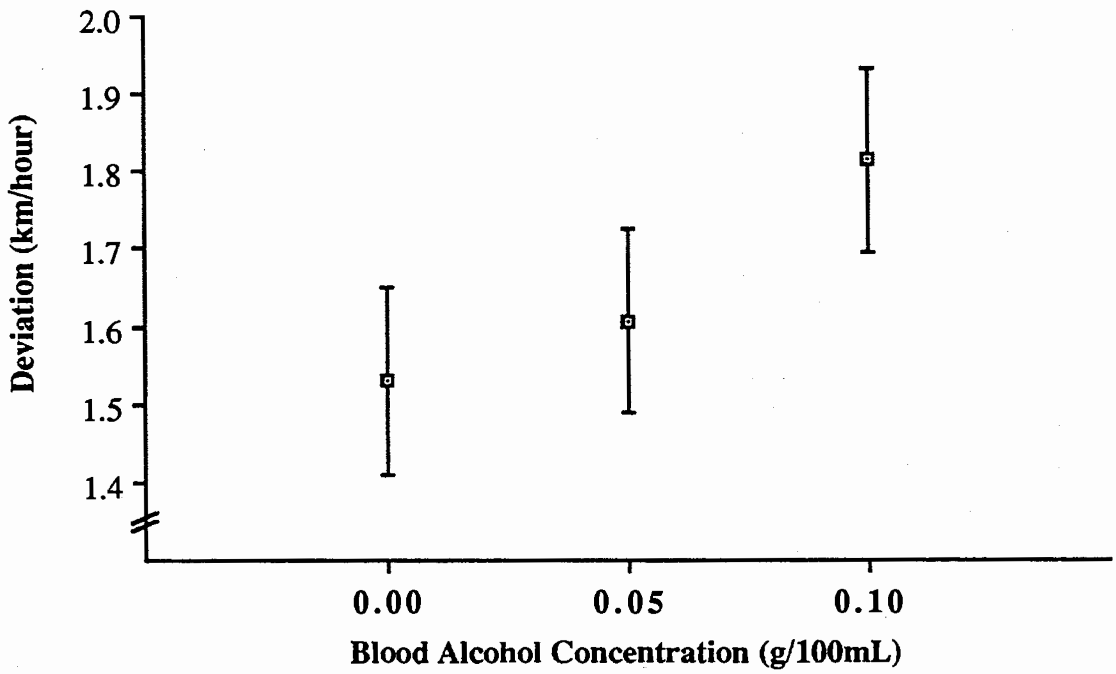

Figure 6: Velocity deviation in straight sections

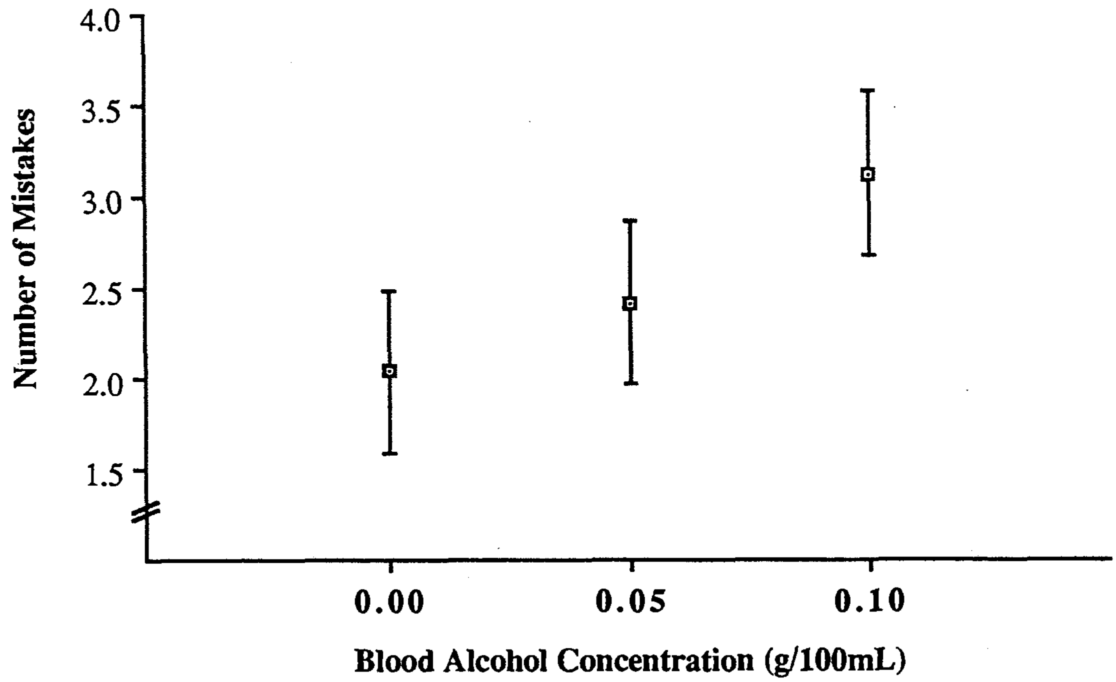

Figure 7: Number of mistakes made per night

DISCUSSION

The results of these experiments show clearly that BAC levels of .10 or more seriously impair night-time driving performance. Such an effect was expected on the basis of previous studies (eg: Laurell and Lisper 1978; Johnston 1983). At BAC levels of approximately .05 a similar, albeit not statistically significant, effect was apparent; six of the seven measures showed a tendency towards poorer performance in the .05 level compared with the placebo condition.

It is possible that a strong motivation factor influenced the results and it is reasonable to believe that such a factor would have a more pronounced effect at lower than at higher BACs. However, further experimentation is needed to test this possibility. It should be noted that a similar degree of motivation is not present under normal driving conditions, especially late at night when driving is likely to be a monotonous task. Furthermore, there is some evidence that the introduction of a secondary task to the experiment may have resulted in greater impairment at both target levels of BAC (Brewer and Sandow 1980).

A strong learning effect was evident for most of the variables: a statistically significant effect was found for detection of both close-in and far-out targets, velocity in straight sections, velocity deviation and number of mistakes made. The experimental design took this possibility into account and the rotation order of test conditions should have prevented this factor from influencing between-group comparisons in any systematic way. Factors such as the very occasional appearance of air base fire trucks on the track and the turning on or off of nearby base lights may also have introduced some additional random variation into the results.

These experiments did not support the hypothesis that the results for light drinkers would differ from those for heavy drinkers at the BAC levels used in this experiment. What differences existed in actual, as opposed to target, BACs were negligible between these two groups at .05 and very slightly (less than .01 g/100mL) favoured the light drinkers at the .10 target level.

Any real effect of habituation to alcohol, if it exists, may require larger sample sizes for detection in view of the factors discussed above affecting variation between individual results. It is also possible that although an habituation effect is distinguishable for relatively simple tasks, it is diminished with more complex tasks such as those required of drivers in this study.

In conclusion, this study has shown that alcohol does have a detrimental effect on driving ability with performance deteriorating rapidly with increasing BAC level. There was no evidence of habituation to alcohol in the experimental tasks and BAC levels used in this experiment.

ACKNOWLEDGEMENTS

We gratefully acknowledge the financial support provided for this project by the South Australian State Government Insurance Commission (SGIC), the National Health and Medical Research Council and the Swedish Government Road and Traffic Research Institute. We are also indebted to the Australian Road Research Board (ARRB) for permission to hire its instrumented vehicle; to Dr. Ian Johnston for his valuable input into the design of the investigation; to the electronics workshop of the Medical School at The University of Adelaide for help with the extra instrumentation of the vehicle; to the Royal Australian Air Force (RAAF) for allowing access to facilities at RAAF Base Edinburgh and to the air traffic controllers who facilitated our work; to the Drug and Alcohol Services Council (DASC) in Adelaide for permission to use the Lifestyle Assessment Program developed by Skinner; to other staff of the NHMRC Road Accident Research Unit for their support and valuable input and especially to Myrene Kilminster for her endurance and patience whilst driving the "chase vehicle". Finally, the willing cooperation of the subject drivers made this study possible.

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