TRANSPORT RESEARCH LABORATORY

TRL REPORT 226

VALIDATION TRIAL FOR TESTING IMPAIRMENT OF DRIVING DUE TO ALCOHOL

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EXECUTIVE SUMMARY

The new TRL driving simulator is based on a medium sized car which is surrounded by screens on which are projected computer generated images. The images are produced by Silicon Graphics computers which use Multigen databases of the road system being modelled. The driving simulator can be used for the testing of impaired driving in complete safety. TRL has also developed a number of other tests requiring varying degrees of cognitive ability and control. A study was carried out by Irving and Jones (1992) using these tests as well as an earlier moving belt driving simulator. The Irving & Jones study showed that the different tests were able to detect impairment and that driving simulators were a valuable tool for testing impaired drivers in a controlled and safe environment.

The main objective of this study was to validate the use of the simulator to model events which could distinguish between measures of driving performance for subjects who were impaired through different dose levels of alcohol. A secondary objective was to investigate the relationship between 'real' road driving tasks and similar simulated tasks.

A trial was conducted with a placebo dose and a low and high dose of alcohol using a cross-over design where subjects were their own controls. This means that subjects were given both alcohol dose levels and the placebo during different visits to the test facility, they could thus be compared with themselves thereby eliminating the between subject variability. Baseline measures were made on some of the tasks, and were analysed as appropriate.

Eighteen female subjects aged between 30 and 50 years of age were required to perform both simulator based and non-simulator based tasks. The subjects took these tasks on three separate occasions receiving each time a different treatment (placebo, low alcohol or high alcohol).

The non-simulator tasks produced measures of:

- adaptive tracking speed - a measure of how well subjects could complete a simple computer based tracking task
- reaction time to hazards shown on a video
- lateral deviation while driving - a measure of their 'wobblyness' when driving on the TRL test track small loop

The simulator based tasks produced measure of:

- following distances at different speeds - measures of the distance from a vehicle being followed and how this distance varied
- average reaction times - a reaction time measure to vehicles braking and lane changing suddenly
- lateral deviation while driving on a non-circular loop - a measure of 'wobblyness' similar to the non-simulator based measure

The results from comparing these measures under the influence of different levels of alcohol showed that impairment can be detected. The adaptive tracking task, being a single minded task, was the most sensitive, whereas the average distances when following another vehicle on a simulated motorway did not distinguish between levels of impairment at all. It is probably fair to comment that tasks that require concentration or a fairly quick reaction were those where impairment was detectable. The tests used and their results will act as the benchmark for the performance of the new simulator.

The conclusion from this study is that TRL have a range of tests which can be used to distinguish different impairment levels. The graphics based driving simulator can be used to simulate different driving tasks in complete safety which can distinguish between high levels of alcohol impairment, and the results from the simulation curve following task are positively correlated with the 'real road' equivalent task.

VALIDATION TRIAL FOR TESTING IMPAIRMENT OF DRIVING DUE TO ALCOHOL

ABSTRACT

The new TRL driving simulator is based on a medium sized car which is surrounded by screens on which are projected computer generated images. The images are produced by Silicon Graphics computers which use Multigen databases of the road system being modelled.

The main objective of this study was to validate the use of the simulator to model events which could distinguish between measures of driving performance for subjects who were impaired through different dose levels of alcohol. A secondary objective was to investigate the relationship between 'real' road driving tasks and similar simulated tasks.

A trial was conducted with a placebo dose and a low and high dose of alcohol using a cross-over design where subjects were their own controls. Baseline measures were taken on some of the tasks. Subjects were required to take simulator and non-simulator tasks which included a real driving task on the TRL small loop. The results indicate that different levels of alcohol can be detected on both simulator tasks and non-simulator tasks, the high alcohol dose of 80 mg/litre resulted in the greater deterioration of driving performance.

The relationship between the 'real' driving task on the TRL test track correlates positively with the results from the similar simulated task thus demonstrating that the simulator is indicative of what happens in 'real' driving.

1. INTRODUCTION

The Transport Research Laboratory has a fixed based driving simulator which could be used for the testing of impaired driving in complete safety. It has also developed a number of other tests requiring varying degrees of cognitive ability and control. A study was carried out by Irving and Jones (1992) using these tests as well as an earlier moving belt driving simulator. This study showed that the different tests were able to detect impairment and that driving simulators were a valuable tool for testing impaired drivers in complete safety.

The new TRL driving simulator had not been used for any impairment studies other than for small projects conducted for the media. These studies and the analysis of the results that lead to the questioning of what tests should be done using the simulator, what data should be extracted, how is that data analysed and what validity does the data have.

The main purpose of this project is to conduct a study using the new simulator and the newly developed tests and compare the results to the same tests used on the old simulator. The old simulator had been used to run two impairment studies; one published report which showed the sensitivity of the tests, and the second for Synthélabo Recherche. The tests used and their results will therefore act as the benchmark for the performance of the new simulator.

2. BACKGROUND

The current TRL simulator uses computer generated images and whereas the moving belt simulator could only show a three lane motorway, the current simulator can model any road system. This study replicates much of the earlier work by Irving & Jones but also includes more complex driving tasks such as interacting with other vehicles and driving round curves.

One advantage of being able to model complex driving simulation routes is that 'real' roads can be simulated and the performance of driver behaviour on 'real' road can be compared to that on 'simulated' roads. This study tested drivers on the TRL test track small loop and also on a simulated small loop.

The purpose of this study was to demonstrate that the new TRL computer graphics simulator is able to detect impairment of drivers on driving tasks of different complexity. Further that the results obtained are consistent with the driving performance on real and simulated roads.

In this context, alcohol was administered at two different levels plus a placebo dose to volunteer subjects who took a series of different tests. This study has replicated the earlier work of Irving and Jones, and has demonstrated that the computer generated graphics simulator is more efficient than the moving belt simulator in being able to detect impairment.

3. EXPERIMENTAL DESIGN AND ANALYSIS

The experimental design was a three treatment cross-over with subjects being tested in three periods. A Williams design (1949) was used which ensured a complete balance, and efficient estimation of effects. Baseline measures were also taken for some of the tests.

The analysis used the SAS-GLM package for the analysis of variance, (ANOVA). The sums of squares was partitioned sequentially, with subject being the first factor, followed by period, treatment and carry-over. The effect due to differences between subjects was thus removed prior to testing for period, treatment and carry-over effects. (The effect of a treatment which persists after the end of the treatment period is referred to as a carry-over effect). If the carry-over effect is not significant then a cross-over analysis is appropriate and the analysis can continue and will excluded any carry-over factor. (In practice no carry-over effects were found for any of the analyses and so this is not reported in the text). If there was a significant treatment effect then contrasts were used to compare placebo v low alcohol, placebo v high alcohol and low alcohol v high alcohol. Mean treatment values were also compared using the Student-Newman-Keuls (SNK), multiple range test. This is one approach for controlling the overall probability levels when comparing several mean values, if this is not done then spurious statistically significant results may be reported.

4. TREATMENTS AND PROTOCOL

Three treatments were administered with each subject being given a different treatment on each of their three visits. The allocation of subject to treatment was random and the experimental design was fully balanced. The treatments were either a placebo or a low (40 mg/l) or high (80 mg/l) dose of alcohol.

Subjects were checked on arrival and at regular intervals during testing. Subjects were checked on an acceptance day to establish how much alcohol was required to produce the desired alcohol dose level, and during the trial they were given appropriate doses to give the level of alcohol as required. They were 'topped-up' as necessary to achieve or maintain the required level. Diagram 1 shows the average alcohol levels during the study. A more complete description of the dosing, the criteria for inclusion and the protocol is given in annex A.

5. NON-SIMULATOR TASKS

5.1 ADAPTIVE TRACKING TASK

This is a laboratory based test, not directly associated with driving. It is a joystick-controlled two dimensional pursuit tracking task, displayed on a large CRT, the degree of difficulty of which is continuously modified by performance feedback. It was first described by Borland and Nicholson (1974) and has been extensively used in studies of drugs and alcohol.

The measurement variable is the mean tracking speed in metres/sec. It is the mean of the tracking speed sampled every 100ms over a 5 minute period. The higher the average speed the greater the success in tracking.

A baseline measure was obtained from subjects shortly after they arrived and before they were given any of the treatments. After dosing with alcohol or placebo as defined in the study plan, the trial measure of their adaptive tracking was obtained. A summary of adaptive tracking results for the baseline and treatment are given in table 1, the grouping reflects the results from the Student-Newman-Keuls analysis.

The statistical analysis followed the procedures outlined above. A summary of the results from the analysis of variance (without carry-over), for the adaptive tracking under treatment, and the difference from the baseline are shown in diagram 2 and given in the following tables 2 & 3 (there were no significant differences between baseline results):

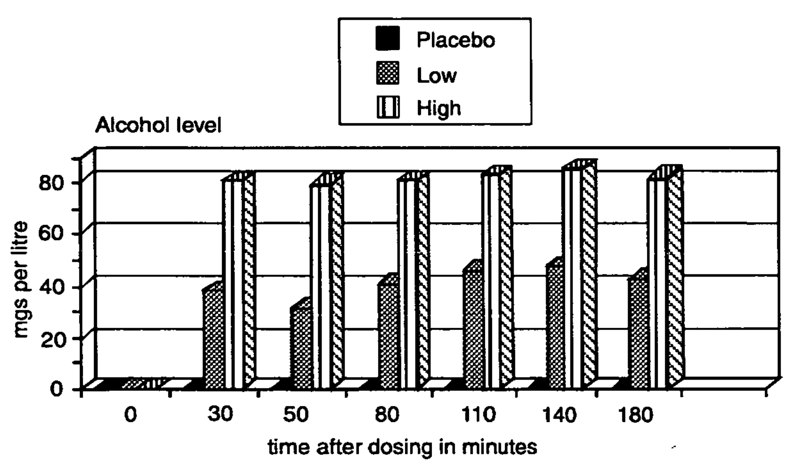

Fig. 1 Alcohol level by time after dosing

TABLE 1

Summary of adaptive tracking results

Measure m/sec	Treatment group	sample size	mean	SNK group†	standard deviation
baseline, no actual treatment given	placebo	18	15.16	A	2.63
	low alcohol	18	14.85	A	2.40
	high alcohol	18	15.19	A	2.78
results when *treatments* were actually given	placebo	18	14.99	A	2.42
	low alcohol	18	13.77	B	1.97
	high alcohol	18	12.62	C	1.40
baseline-treatment (difference between results where treatment were and were not given)	placebo	18	-0.17	A	0.70
	low alcohol	18	-1.08	A	1.35
	high alcohol	18	-2.57	B	2.48

† If the group letter is the same, as in the 'baseline measure', it shows that there are no differences between the mean values, but with different letters as in the 'treatment measure' then there are 3 groups which are statistically significantly different from each other.

The analysis indicates very clearly that the adaptive tracking task can distinguish between groups of subjects who have alcohol levels of 80mg/l from those having no alcohol or 40mg/l. It does not distinguish between subjects who have either had no alcohol or who have 40mg/l. There is some indication that when the difference between the baseline and treatment measure is analysed, i.e. controlling for subject within period, then level of impairment is related to the level of alcohol. There is a monatomic decrease in adaptive tracking performance as alcohol level increases.

5.2 HAZARD PERCEPTION

This test, developed at TRL, uses video-filmed driving sequences shown on a large screen monitor. It requires drivers to make continuous judgements of the level of hazard present, and to react accordingly when a hazardous scenario is presented. The time taken to react to a hazard has been shown to be successful in detecting drivers who had extensive records of previous accidents, (Quimby et al 1986), in distinguishing between novice and expert drivers, (McKenna and Crick1993).

Ten video-filmed driving sequences were shown to the subject on each visit. The balance of scenes was roughly equivalent on each visit albeit that different videos were shown. The average risk and reaction time was measured. Half of the scenes contained driving sequences where a reaction was necessary, the mean reaction time has been used in the analysis. Table 4 summarises the reaction time data, and the analysis of variance is given in table 5.

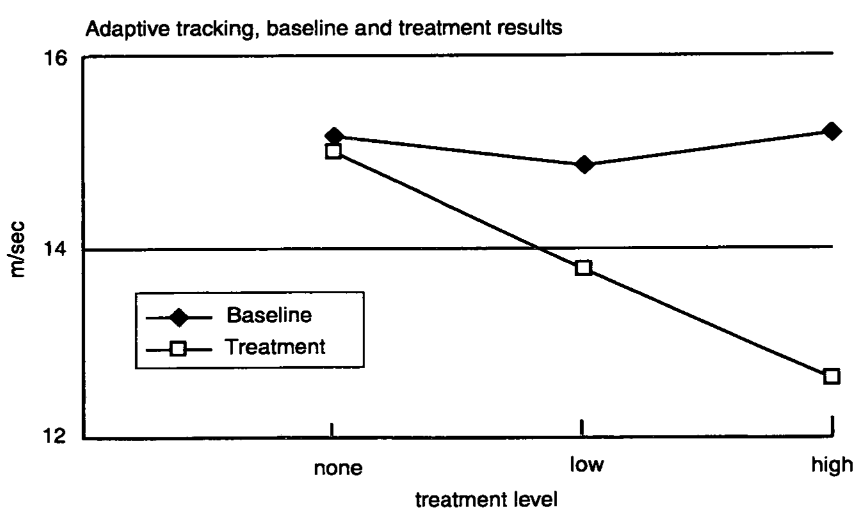

Fig 2 Adaptive tracking by treatment level

TABLE 2

Analysis of variance - Adaptive tracking - results under treatment

Source	df	F ratio	probability†
Subject	17,32	5.96	<0.001
Period	2,32	0.32	NS
Treatment	2, 32	16.00	<0.001
placebo v low alcohol	1,32	8.53	0.006
placebo v high alcohol	1,32	31.98	<0.001
low alcohol v high alcohol	1,32	7.48	0.010

† This is the probability that there is no difference due to the factor being tested, i.e. there is a 0.006 probability that the placebo and low alcohol have the same effect.

TABLE 3

Analysis of variance - Adaptive tracking - (treatment - baseline)

Source	df	F ratio	probability
Subject	17,32	1.50	NS
Period	2,32	0.80	NS
Treatment	2, 32	10.18	<0.001
placebo v low alcohol	1,32	2.89	0.099
placebo v high alcohol	1,32	19.98	<0.001
low alcohol v high alcohol	1,32	7.67	0.009

TABLE 4

Summary of hazard perception results

Measure m/sec	Treatment group	sample size	mean	SNK group	standard deviation
baseline, no actual treatment given	placebo	18	1.29	A	0.35
	low alcohol	18	1.31	A	0.35
	high alcohol	17	1.48	A	0.37
results when *treatments* were actually given	placebo	18	1.23	A	0.31
	low alcohol	18	1.25	A	0.28
	high alcohol	18	1.45	B	0.35

TABLE 5

Analysis of variance - Hazard perception - results under treatment

Source	df	F ratio	probability
Subject	17,32	1.42	NS
Period	2,32	7.41	0.002
Treatment	2, 32	3.30	0.049
placebo v low alcohol	1,32	0.06	NS
placebo v high alcohol	1,32	5.46	0.026
low alcohol v high alcohol	1,32	4.38	0.044

5.3 ROAD LATERAL DEVIATION

This task involves driving a car which is instrumented to measure lateral movement accurately over long curves on a closed test-track. The test is similar in principal to tests used elsewhere in drug/alcohol investigations, see O'Hanlon et al 1982. The metric used was the sum of Fourier components of the difference between the ideal and actual paths round a non-circular 1000m curve, between wavelengths of 20m and 200m.

Subjects drove round the non-circular curve sited on the TRL test track. They drove three times in a clockwise direction and three times in an anti-clockwise direction and the average values for their runs have been analysed. The mean values for the different treatments and directions driven are given in table 6.

The mean value increases with dose of alcohol which suggests that it impairs the subjects' ability to follow a 'perfect' route round the non-circular loop. This is particularly noticeable when driving anti-clockwise on the left-handed route. However, the noise in the data is such that only on the left handed curve were there statistically significant differences. This is seen in the analysis of variance table 7.

6. SIMULATOR MEASURES

6.1 THE DRIVING SIMULATOR

The driving simulator is based on a medium sized saloon car. The car is surrounded by three 3 metre x 4 metre screens to the front providing 210° horizontal x 40° vertical field of view and one similar sized screen to the rear providing a 70° horizontal x 40° vertical field of view, enabling use of all three of the vehicles mirrors.

Images are projected onto the screens by four projectors. The images which are displayed on the screens are generated by Silicon Graphics Reality Engines, using Multigen produced databases of the road system being modelled.

TABLE 6

Lateral Deviation - Sum of Fourier Components

Measure m/sec	Treatment group	sample size	mean	SNK group	standard deviation
right handed curve	placebo	18	117.0	A	22.89
	low alcohol	17	121.7	A	28.34
	high alcohol	16	126.6	A	27.81
left handed curve	placebo	18	106.1	A	23.05
	low alcohol	17	112.6	A B	28.09
	high alcohol	16	121.3	B	34.72

TABLE 7

Analysis of variance - Lateral deviation results

Source	df	F ratio	probability
Subject RIGHT CURVE	17,29	4.52	<0.001
Period	2,29	10.22	<0.001
Treatment	2, 29	0.89	NS†
placebo v low alcohol	1,29	1.00	NS
placebo v high alcohol	1,29	1.54	NS
low alcohol v high alcohol	1,29	0.07	NS
Subject LEFT CURVE	17,29	8.84	<0.001
Period	2,29	2.36	NS
Treatment	2, 29	3.72	0.036
placebo v low alcohol	1,29	1.47	NS
placebo v high alcohol	1,29	7.44	0.011
low alcohol v high alcohol	1,29	2.27	NS

† Not statistically significant at the 0.10 level or better

The system projects the road scene and either autonomous vehicles for use in simple scenarios, where little interaction with the simulator vehicle is required, or intelligent vehicles that relate their behaviour to that of the simulator vehicle.

The car bodyshell is mounted on hydraulic rams which supply motion sufficient to simulate the tilt and roll experienced in normal braking, acceleration and cornering. For the purposes of this trial the car was driven with a manual gear box. A more complete description is given in annex B.

6.2 THE SIMULATED DRIVING TASKS

There were several distinct but linked simulated scenarios which each subject had to drive. Each scenario was designed to provide different measures of subject performance. The scenarios and performance measures are summarised in table 8.

Some of the sections were driven by subjects prior to treatment, this gave some baseline measures and also ensured that they were re-familiarised with the driving simulator.

6.3 SUMMARY RESULTS FOR REACTION TIME EVENTS

This task consisted of driving on a straight section of motorway road. At intervals which would have appeared random to the driver, certain events were generated which involved other vehicles. Either vehicles would pull-in in front of the driven vehicle or would pull-out in front, either type of event required the driver to react by braking. There were four pulling-out events and two pulling-in events and the metric analysed is the average of these.

Diagram 3 of the results is shown below together with a summary table 9 of the results.

There was no significant impairment effect found for pulling-in events (based on just two events), but there was a significant effect when impaired by high levels of alcohol for those pulling-out events with about a 30% increase in average reaction time. The pulling-out events have a much lower average reaction time than the pulling-in events, this suggests that the pulling-out task was more demanding in order to avoid a collision situation. In this more demanding situation then the impairment effect of alcohol was significant.

6.4 SUMMARY RESULTS FOR VEHICLE FOLLOWING TASK

The vehicle following task consisted of following a vehicle on a straight motorway type road. The vehicle in front started at a close but safe distance ahead and the driver had to follow for at a pre-requested speed. Three different sections were used with the speed starting at 40mph then at 50mph and finally at 60mph. The metric analysed was the mean and standard deviation of following distance in metres.

There were no significant differences between the mean values on any of the metrics at any of the speeds. The summary data is presented in the following table 11.

TABLE 8

Simulated tasks and associated measures

Scenario	Performance Measure
Reaction time events Straight motorway section, with braking events when pulling out or pulling in	i) reaction times to pulling-in events ii) reaction times to pulling-out events
Vehicle following events Straight motorway following a vehicle travelling at either 60mph, 50mph or 40 mph and driving close but safe	at each speed: i) mean following distance, (metres) ii) SD of following distance, (m)
Curve following tasks Following left hand non-circular curve of about 1Km radius	i) mean lateral deviation ii) SD of lateral deviation iii) sum of Fourier components similar to the track version
Following right hand non-circular curve of about 1Km radius	i) mean lateral deviation ii) SD of lateral deviation iii) sum of Fourier components similar to the track version

TABLE 9

Simulator measures and results - reaction time events

Measure m/sec	Treatment group	sample size	mean	SNK group	standard deviation
Average reaction time to pulling-in events, (based on 2 events)	placebo	17	2.25	A	0.75
	low alcohol	17	2.35	A	0.79
	high alcohol	17	2.34	A	0.60
Average reaction time to pulling-out events, (based on 4 events)	placebo	17	0.67	A	0.10
	low alcohol	18	0.69	A	0.09
	high alcohol	18	0.85	B	0.31

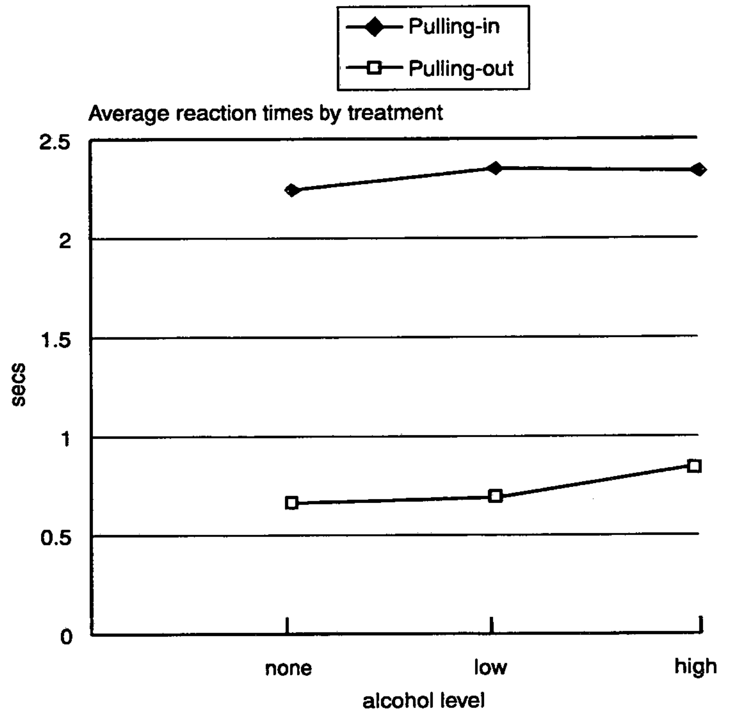

Fig. 3 Average reaction times by treatment

6.5 SUMMARY RESULTS FOR CURVE FOLLOWING TASK

The curve following task required the driver to follow a 1 Km non-circular curve at approximately 30mph. They thus had to make constant adjustments of the steering wheel in order to maintain a smooth path. The task is thus very similar to that described in section 5.3 above. There was a right-handed and a left-handed curve and three metrics were derived for each curve. These are the mean lateral deviation of the vehicle from the edge of the road, the standard deviation of this deviation and the sum of the fast Fourier transform components of the path deviation, (the latter is a measure which has also been used when driving round the TRL small loop).

The summary results are shown in the following tables, and the results from the standard deviation of the lateral deviation are also shown graphically. The only metric which was not statistically sensitive to alcohol impairment was the mean lateral deviation on the right-handed curve.

The analyses of the standard deviation and summed Fourier values are shown in the following tables. They indicate very clearly that these measures are sensitive to impairment effects. The standard deviation increases with increased alcohol levels and thus impairment level, thus showing that drivers are wobbling more from the road edge. Similarly the sum of Fourier values measure also increases with impairment thus providing further evidence of the deviation from the road edge.

TABLE 10

Analysis of variance - Reaction time events

Source	df	F ratio	probability
Subject Pulling-in	17,29	2.52	NS
Period	2,29	2.39	NS
Treatment	2, 29	0.38	NS
placebo v low alcohol	1,29	0.55	NS
placebo v high alcohol	1,29	0.57	NS
low alcohol v high alcohol	1,29	0.00	NS
Subject Pulling-out	17,31	1.38	NS
Period	2,31	3.69	0.04
Treatment	2, 31	5.58	<0.01
placebo v low alcohol	1,31	0.23	NS
placebo v high alcohol	1,31	9.42	<0.01
low alcohol v high alcohol	1,31	7.02	<0.02

TABLE 11

Simulator measures and results - vehicle following task

Measure m/sec	Treatment group	sample size	mean	SNK group	standard deviation
Mean following distance at 40mph in metres	placebo	18	43.17	A	21.48
	low alcohol	18	49.13	A	23.85
	high alcohol	18	50.17	A	20.12
SD following distance at 40mph	placebo	18	4.07	A	2.91
	low alcohol	18	6.37	A	7.42
	high alcohol	18	6.25	A	3.52
Mean following distance at 50mph in metres	placebo	18	51.13	A	28.60
	low alcohol	18	52.98	A	21.35
	high alcohol	18	60.92	A	33.09
SD following distance at 50mph	placebo	18	4.91	A	4.07
	low alcohol	18	5.32	A	3.19
	high alcohol	18	7.70	A	5.88
Mean following distance at 60mph in metres	placebo	18	62.81	A	36.41
	low alcohol	18	59.40	A	36.96
	high alcohol	18	75.17	A	55.50
SD following distance at 60mph	placebo	18	8.63	A	7.02
	low alcohol	18	6.79	A	5.60
	high alcohol	18	6.52	A	3.92

TABLE 12

Simulator measures and results - curve following

Performance Measure	Treatment group	sample size	mean	SNK group	standard deviation
Mean lateral deviation on left-handed curve	placebo	18	2.73	A	0.40
	low alcohol	18	2.75	A	0.31
	high alcohol	18	2.77	A	0.26
SD lateral deviation on left-handed curve	placebo	18	0.37	A	0.10
	low alcohol	18	0.41	A	0.15
	high alcohol	18	0.46	B	0.16
Sum of Fourier values on left-handed curve	placebo	18	1.20	A	0.29
	low alcohol	18	1.27	A	0.39
	high alcohol	18	1.45	B	0.42
Mean lateral deviation on right-handed curve	placebo	18	2.93	A	0.31
	low alcohol	18	2.82	A B	0.23
	high alcohol	18	2.68	B	0.43
SD lateral deviation on right-handed curve	placebo	18	0.34	A	0.14
	low alcohol	18	0.35	A	0.11
	high alcohol	18	0.46	B	0.19
Sum of Fourier values on right-handed curve	placebo	18	1.04	A	0.39
	low alcohol	18	1.08	A	0.35
	high alcohol	18	1.39	B	0.52

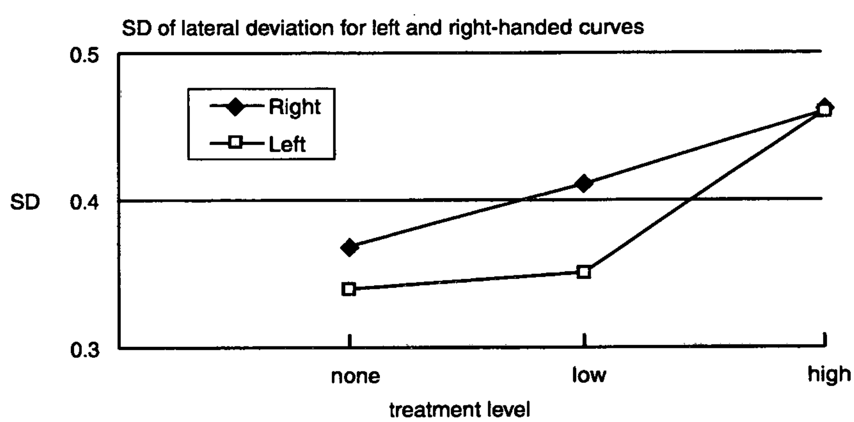

Fig. 4 Standard deviation of lateral deviation

7. ROAD TASK V SIMULATOR TASK

Simulated driving tasks have the advantage of being able to replicate each event and in complete safety. One specific advantage of the new TRL graphic image based driving simulator as compared to the earlier generation moving-belt simulator, (as used in the Irving & Jones study), is that curves can be modelled. It was thus possible in this new study to give drivers a task on the 'real' road and a very similar task on the simulator. Results from these two tasks of curve following as described in 5.3 and 6.4 thus can be compared.

The summed Fourier value metric was derived for both of these tasks, albeit in slightly different ways. There are statistically significant positive correlations between the road and simulator measures (at the 95% level or better), as shown in table 15.

TABLE 13

Analysis of variance - standard deviation of lateral deviation, curve following events

Source	df	F ratio	probability
Subject RIGHT CURVE	17,32	5.99	<0.01
Period	2,32	0.07	NS
Treatment	2, 32	9.38	<0.01
placebo v low alcohol	1,32	0.07	NS
placebo v high alcohol	1,32	15.05	<0.01
low alcohol v high alcohol	1,32	13.03	<0.01
Subject LEFT CURVE	17,32	9.89	<0.01
Period	2,32	4.63	0.017
Treatment	2, 32	7.66	<0.01
placebo v low alcohol	1,32	2.79	NS
placebo v high alcohol	1,32	15.21	<0.01
low alcohol v high alcohol	1,32	4.98	<0.01

TABLE 14

Analysis of variance - Sum of Fourier components, curve following events

Source	df	F ratio	probability
Subject RIGHT CURVE	17,32	7.22	<0.01
Period	2,32	0.58	NS
Treatment	2, 32	10.36	<0.01
placebo v low alcohol	1,32	0.28	NS
placebo v high alcohol	1,32	17.48	<0.01
low alcohol v high alcohol	1,32	13.32	<0.01
Subject LEFT CURVE	17,32	10.79	<0.01
Period	2,32	4.80	0.015
Treatment	2, 32	9.08	<0.01
placebo v low alcohol	1,32	1.22	NS
placebo v high alcohol	1,32	16.96	<0.01
low alcohol v high alcohol	1,32	9.07	<0.01

TABLE 15

Correlations between summed Fourier values

Correlation between		Road based task		Simulator based task	
		left curve	right curve	left curve	right curve
Road	left	-	0.81	0.38	0.29
	right	0.81	-	0.29	0.15
Simulator	left	0.38	0.29	-	0.84
	right	0.29	0.15	0.84	-

The left curve following task is more highly correlated between the road and simulator based tasks. The correlations between the right and left following measures within either the road or simulation based tasks are highly correlated.

8. CONCLUSIONS

There were two main objectives within this study. Firstly and most importantly, to determine if different levels of alcohol impairment could be detected using the new TRL graphics based driving simulator, and secondly to investigate the relationship between 'real' road driving tasks and similar simulated tasks.

i) **Detection of impairment due to alcohol**

- Alcohol impairment has been demonstrated by the adaptive tracking task which distinguished between the different dose levels. The higher the alcohol impairment level the slower the tracking speed.
- The hazard perception task indicated a slower reaction time for the high alcohol level, however this result was confounded by a higher (though not statistically significant) baseline reaction time for the high alcohol level.
- The real driving task round the TRL 1 Km 'small loop' found significant differences in the results when driving in a left-handed direction but not when driving in a right-handed direction. These results are comparable to those as reported in Irving and Jones (1992).
- Alcohol impairment has also been demonstrated by simulator tasks. The average reaction time to a vehicle 'pulling out' was significantly greater for those subjects with high alcohol levels. The difference was about 1/5 of a second, which corresponds to 4 metres when travelling at 20 metres per second, (45 mph).
- The curve following task was also sensitive to high levels of alcohol for both right-hand and left-hand curve following, the standard deviation and the sum of the Fourier transform values were all significantly higher for the high alcohol dose. Again, these results are broadly comparable to those as reported by Irving and Jones (1992).

ii) **Relationship between 'real' road tasks and similar simulated tasks.**

- The relationship between the 'real' driving task on the TRL test track correlates positively with the results from the similar simulated task thus demonstrating that the simulator is indicative of what happens in 'real' driving.

The overall conclusion from this study is that TRL have a range of tests which can be used to distinguish different impairment levels. The graphics based driving simulator can be used to simulate different driving tasks in complete safety which can distinguish between high levels of alcohol impairment. The simulator curve following driving task is positively correlated with a 'real road' curve following task.

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ANNEX A

CRITERIA FOR INCLUSION, DETAILS OF ALCOHOL DOSING AND THE PROTOCOL

CRITERIA FOR TRIAL PARTICIPANTS

- Female
- 30-50 years old
- Average height and weight
- No medical problems
- Taking no prescribed drugs
- No adverse drug reactions
- Smoke less than 10 cigarettes per day
- No excess caffeine intake (less than 6 cups of coffee, tea, coke etc. per day)
- Used to alcohol but a moderate user (between 5 and 15 units per week)
- Driving for 5+ years, No serious accidents in the last 2 years

Familiarisation on use of test equipment

21 subjects who met the required criteria were given a 1 hour familiarisation session on the Driving Simulator, Adaptive Tracking and Hazard Perception laboratory tests.

Study of alcohol absorption and elimination rates

The following three days the individual alcohol absorption and elimination rates were studied. They were also given practice sessions on these days, so that they would be fully conversant with all the test equipment by the time they took part in the trial.

They had been instructed to have a light breakfast of cereal with semi-skimmed milk, toast with low fat spread and decaffeinated tea or coffee. They were transported between home, the laboratory and back by taxi. Arriving at 08:30hrs and returning at 13:30hrs.

The amount of alcohol required to bring them to 80mg / 1000ml blood alcohol was calculated using the Widmark factor c=a/p * r

c = theoretical peak blood alcohol level

a = Total amount of alcohol consumed

p = Weight of the drinker

r = Widmark factor (Ratio of water content of the entire body to that of the circulating blood)

note: This is dependant on age, sex, fatty tissue and physiological factors

mean values of r found by Widmark 0.68 for men and 0.55 for women

Therefore, to obtain a blood alcohol reading of 80mg/ 1000ml for a 9 stone (57Kg) woman Dose = 0.8 * 57 * 0.55

= 25.08gms of alcohol

= 62.70ml of 40% Vodka

The subjects were each given a mouthwash which affected their taste buds. They were then given their recalculated doses. This was 40% Vodka disguised by an equal proportion of American Cream Soda. American Cream Soda was chosen in preference to orange juice, orange cordial, peppermint cordial and various others as it had a strong, sweet taste which disguised the proportion of vodka being administered. The fizziness in the cream soda added to the speed in which the alcohol reached the blood stream.

50 minutes after their pre-calculated dose they were each breathalyser and given a top up dose to maintain the level counteracting the elimination expected. The top up doses were each mixed with an equal quantity of cream soda and in the event of no alcohol top up being required a quantity of cream soda was given with vodka smeared around the rim of the glass so that it smelled and tasted of alcohol.

The regular 30 minute breathalysing and topping up procedure continued for 4 hrs 30 minutes on three consecutive days so that each subjects individual pattern could be ascertained.

THE TRIAL

18 women were chosen to continue with the trial. These were the ones who were found to be most consistent for alcohol absorption and elimination and who could handle the test equipment well.

3 Subjects attended per morning Tuesday to Thursday inclusive, for three consecutive weeks followed by a second group following the same course.

On each visit they were given one of three treatments: placebo, low and high doses of alcohol, (to bring them to nil, 40mg/l, 80mg/l Blood alcohol readings respectively).

A William's design was used for the dose randomisation. Subjects were allocated at random to a subject group, (3 subjects per group), and they then had the treatment as specified for each period. See table below:

Subject group	Period 1	Period 2	Period 3
A	Placebo	Low dose	High dose
B	Placebo	High dose	Low dose
C	Low dose	High dose	Placebo
D	Low dose	Placebo	High dose
E	High dose	Placebo	Low dose
F	High dose	Low dose	Placebo

THE TRIAL SESSIONS

Each subject was collected by taxi from home and returned there at the end of each trial session irrespective of the alcohol dose given.

On arrival at the Laboratory the subjects strictly followed the following schedule.

TIME	ACTIVITY
0:00 -0:10	Breathalyser
0:10 - 0:30	Driving Simulator Baseline - Close following with variable speeds - Lateral deviation; straight followed by curve.
0:30 - 0:45	Hazard Perception - Baseline
0:45 - 0:50	Adaptive Tracking Test - Baseline
0:50 - 1:00	Pre-calculated alcohol dose (half total initial dose)
1:00 - 1:10	Pre-calculated alcohol dose (half total initial dose)
1:10 - 1:20	Absorption of alcohol into the blood system
1:20 - 1:30	Breathalyser to check progress
1:40 - 1:50	Breathalyser and top up alcohol dose 1
1:50 - 2:10	Driving Simulator 1 - Overtaking no opposing traffic. - Overtaking with opposing traffic.
2:10 - 2:20	Breathalyser and top up alcohol dose 2
2:20 - 2:35	Hazard Perception Test
2:35 - 2:40	Adaptive Tracking Test
2:40 - 2:50	Breathalyser and top up alcohol dose 3
2:50 - 3:10	Test Track - Lateral deviation
3:10 - 3:20	Breathalyser and top up alcohol dose 4
3:20 - 3:50	Driving Simulator 2 - Close following with variable speeds, followed by reaction to vehicles intervening. - Lateral deviation; straight line followed by curve.
3:50 - 4:00	Final breathalysation.
4:00 - 4:20	Coffee and Biscuits and Taxi home.

ANNEX B

The driving simulator

The driving simulator is based on a medium sized saloon car, a Rover 414 Sli. The car is surrounded by three 3 metre x 4 metre screens to the front providing 210° horizontal x 40° vertical field of view and one similar sized screen to the rear providing a 70° horizontal x 40° vertical field of view, enabling use of all three of the vehicles mirrors.

Images are projected onto the screens by four front projecting BARCO 800 CRT projectors at resolutions of 1280 x 1024 pixels for the front channel, 960 x 680 pixels for the two side and rear channels and are updated at rates between 20 and 30Hz. The images which are displayed on the screens are generated by Silicon Graphics Reality Engines Onyx, Power and Crimson running Irix, Performer and Multigen. The simulator operator station uses an Indigo2 to provide an interface to the experiment both for development and run time. The station provides the operator with a birds eye view of the road layout and the positions of all vehicles in the driving scenario. This same display provides a continuous representation of the use of the vehicle controls. Other traffic in the driving scenario are also managed by this work station where they can be generated from one of two systems.

The first system provides autonomous vehicles for use in simple scenarios where little interaction with the simulator vehicle is required. They follow 'behaviour descriptions' which determine their actions at speed, distance and time control points. The second system provides intelligent vehicles that relate their behaviour to that of the simulator vehicle (within the confines of a described behaviour), pattern or behave as autonomous intelligent vehicles operating collision detection and avoidance with driving styles ranging from passive through ' normal' to aggressive.

The car bodyshell is mounted on hydraulic rams which supply motion sufficient to simulate the tilt and roll experienced in normal braking, acceleration and cornering. The rams provide; Roll, Pitch and Heave with displacements of ±7°, ±4° and 200mm respectively. The rams are located in the position of the normal car shock absorbers. A further ram provides steering force feedback. For the purposes of this trial the car was driven with an manual gear box.

MORE INFORMATION

The Transport Research Laboratory has published the following other reports on this area of research:

CR 313 Hazard perception in drivers: a methodology for testing and training. F P McKenna and J L Crick. Price code H.

TRL 232 Drinking and driving in Great Britain: a review. G Maycock. £25.

TRL 219 The accident liability of car drivers: the reliability of self-report data. G Maycock, J Lester and C R Lockwood. Price code H.

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