TRANSPORT and ROAD
RESEARCH LABORATORY

Department of the Environment
Department of Transport

TRRL LABORATORY REPORT 907

# DESIGN AND VALIDATION OF A DRIVING SIMULATOR FOR USE IN PERCEPTUAL STUDIES

by

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Crowthorne, Berkshire
1979
ISSN 0305–1293

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Ownership of the Transport Research Laboratory was transferred from the Department of Transport to a subsidiary of the Transport Research Foundation on 1st April 1996.

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ABSTRACT

A simulator is described that can be used to investigate a variety of perceptual factors concerned with driving. It employs a back projection system for presenting a driver's eye view film, in colour, to subjects sitting in a modified car body. The impression of being in a real moving car is increased by providing suitable auditory and vibratory inputs.

Studies designed to validate the use of the simulator as an acceptable research tool are described. It was demonstrated that similar results were obtained in an experiment requiring assessments of risk, irrespective of whether subjects made their ratings while driving around a test route in their own cars or while viewing a film of the route while in the simulator. It was also shown that emotional responses to traffic events in the simulator, obtained by measuring skin conductance changes, were typical of those found in the road situation. The results of a questionnaire completed by the drivers revealed that the simulator provides an acceptably realistic simulation of the driver's perceptual environment.

Possible improvements are discussed and finally a variety of potential uses of the simulator, as a research tool, are given.


## 1. INTRODUCTION

Traffic accidents are often the result of perceptual errors made by drivers[1]. If such accidents are to be prevented it is necessary to obtain a greater understanding of the perceptual tasks involved in driving.

Unfortunately, there are often problems involved in undertaking relevant research on the public roads. For example, traffic and environmental factors are largely uncontrollable and the risks of injury and damage inhibit the scope of any experiments that might increase such risks. The use of simulation techniques overcomes these problems and enables research to be carried out in a controlled and physically risk-free environment. However, there are problems involved in using simulators, for example, they cannot faithfully reproduce all aspects of the driver's task and therefore it is necessary to validate the results of simulator trials before inferences can be made about the real world situation.

This report describes a driving simulator that has been developed at TRRL which is suitable for studying perceptual and cognitive skills and abilities that are relevant to driving. In order to validate the simulation achieved three separate techniques were employed. These were:—

1. Comparing the risk assessments made by subjects driving around a short experimental route, with those obtained from subjects evaluating a film of the same route in the simulator.

2. Measuring the subject's physiological responses to hazards in the simulator.

3. Using a questionnaire to indicate how realistic subjects found the simulation.

The report concludes by describing some of the potential uses of the simulator as a research tool.

## 2. DESCRIPTION OF THE SIMULATOR

The simulator is non-interactive so that the subject's view of the road and the behaviour of his and other vehicles cannot be influenced by, for example, pressing the brake pedal or turning the steering wheel.

It is, therefore, more suited for investigating the perceptual and cognitive aspects of driving rather than any motor skill component, such as steering, braking or gear changing.

The simulator provides subjects with a driver's eye view of the road environment together with the associated noise and vibration. The road and engine noise was recorded while filming and this is used to provide realistic levels of noise and vibration – although using the present equipment it was not possible to provide the low frequency vibration sometimes experienced on the road. Subjects sit in the driver's seat of a shortened car body and view a back projection screen on which is shown a 16 mm colour film of the road environment that was taken using a left-hand drive car with a camera mounted at the driver's normal eye position. Additional realism is provided by giving subjects rear view vision by including views of the interior and right-hand wing mirror (see Plate 1). Also traffic indicator lights within the vehicle function automatically before turns and lane changes.

The projection system employed uses a 9 mm lens, giving the $60^{\circ}$ field of view seen in Plate 1. It was found that a shorter focal length lens produced unacceptable distortion and a longer focal lens produced a too restricted field of view. Although the horizontal field of view of the driver is normally much greater than this, eye movement research[2] suggests that this would be sufficient for a wide range of driving conditions. The vertical field of view provided is similar to that experienced while driving. The subject's eye position is always adjusted such that the angular sizes of objects viewed on the screen correspond to that in the real world.

The view through the side windows and a small portion of his view on the left-hand side of the windscreen are masked off so that laboratory fixtures cannot be seen.

To increase the projection path and remove lateral inversion of the image seen by the subject, a mirror is used (see Figure 1 and Plate 2).

While the appropriate sound and car body vibrations are provided it was not possible to simulate the forces experienced by drivers during cornering and changes of speed. This would have involved tilting the simulator in various axes at appropriate points in the film and it was considered that the additional expense would have been too great for the extra realism that would have been achieved.

Further details concerning the simulator and associated equipment are given in Appendix 1.

# 3. VALIDATION STUDIES

## 3.1 Introduction

Three validation studies were conducted to demonstrate that results obtained in the simulator could be extrapolated to the real driving situation. These involved: (1) comparing risk ratings made in the simulator and on the road, (2) comparing the risk assessment and physiological responses in the simulator to specific traffic hazards and (3) obtaining the subjects' evaluations of the realism of the simulator by use of a questionnaire.

## 3.2 Comparison of risk ratings

In recent years the driver's skill at detecting and recognising potentially dangerous situations while driving, often called 'reading the road', has been shown to be an important factor associated with driving performance[3,4]. It was decided to determine if the simulator was a satisfactory research tool for investigating the driver's ability to assess and appreciate the inherent risks involved in driving. A rating scale procedure, similar to one adopted by Ganton and Wilde[5], was used.

To determine if the risk ratings of subjects in the simulator were equivalent to those obtained while driving on the road, a 16 mile route that included a wide variety of road conditions was selected. A film of this route was made for use in the simulator which lasted approximately 30 minutes. At 45 preselected locations on this route subjects were required to make an assessment of the amount of danger they perceived using an 11 point scale (0–10). A rating of '0' corresponded to 'no chance' of a near miss or accident situation occurring while a rating of '10' meant that there was 'a good chance' of such incidents. The actual instructions given to subjects are given in Appendix 2.

Two groups of subjects were used. One group of 60 subjects made their assessments of danger while driving around the route in their own cars. These subjects were recruited from the general motoring public. Sampling was carried out so that the age profile and proportion of female drivers corresponded with national exposure data. A second group of 10 subjects made their assessments while viewing a film of the route in the simulator. These subjects were laboratory employees but were all non-research staff who had no previous knowledge of the experiment. This was considered to be a sufficiently large group for the simulator trials because all these subjects viewed identical road and traffic conditions unlike the subjects who underwent the road trials.

In order to minimise any effects due to traffic variability all subjects who drove around the route did so at approximately the same time of day (mid-morning) and the film was taken under similar conditions.

Both groups of subjects were cued to give ratings by sounding a brief tone that was demonstrated before the experiment began.

For each subject the 45 locations were ranked in order of perceived risk. For each of the two groups of subjects these rankings were summed for all locations and an overall ranking for each location was calculated. The association between the two sets of ranking was then determined by calculating the Spearman rank correlation coefficient ($r_s$). This was found to be 0.78 which is significant at the 0.1 per cent level.

Table 1 shows the rankings obtained and it can be seen that the largest difference occurred at location 43, a pedestrian crossing. It is likely that this discrepancy occurred because during filming a pedestrian was about to cross, which led to relatively high ratings of risk being obtained in the simulator. However, the crossing was seldom used during the road trials which led to generally lower ratings. In fact, the level of agreement between the two sets of assessments was agreeably high when it is considered that the film may have shown several such atypical conditions.

The agreement found between the results obtained on the road and in the simulator demonstrate the realism of the simulation and show its potential as a tool for looking at certain perceptual aspects of the driver's task.

### 3.3 Physiological responses

A different film, containing a number of serious traffic incidents, some specially staged during filming, was used for this part of the validation. It has been shown that short-term increases in skin conductance occur in actual driving conflict situations[6] and it was expected that such responses would occur in the simulator if the levels of realism achieved were high. To determine if such responses occurred during incidents judged to be serious, a response lever was provided for subjects so that a continuous assessment of perceived risk could be recorded as they watched the film.

The instructions given to the subjects are given in Appendix 3. The response lever provided is shown in Plate 2. Details of how subjects' ratings of risk and skin conductance measurements were recorded are given in Appendix 1.

It was expected that if the simulation was sufficiently realistic, the percentage change in skin conductance would reflect the size of the perceived risk since such changes have in the past been used to indicate increases in emotional tension or subjective risk[7]. The responses to 14 incidents, considered to be relatively hazardous, were examined for the 60 subjects who took part in the road tests of the first validation experiment. Average percentage changes in skin conductance and increases in risk ratings (on a 0–10 scale, where '0' represents no chance of a near miss and '10' represents a good chance of a near miss or accident) are listed in Table 2. For each subject the sizes of these responses were used to rank the driving incidents. For a particular incident the sum of these ranks was obtained and these totals used to produce the final ranking of incidents. In this way two sets of rankings were obtained; one for skin conductance change and the other for the increase in perceived risk. The association between these rankings was tested by computing a Spearman rank correlation coefficient ($r_s$). This was found to be 0.78 which is significant at the 1 per cent level.

It was concluded that because of the level of realism achieved in the simulation, the drivers became sufficiently 'involved' while watching the film to show measurable emotional responses during the hazardous incidents. This result also supports the use of conscious judgement techniques in measuring a driver's perceptual abilities.

### 3.4 Questionnaire study

The 60 subjects who took part in the validation experiment reported above were also required to fill out a short questionnaire designed to assess the perceived degree of realism achieved in the simulation.

## TABLE 1

Comparison of simulator and road risk ratings

| Road location | Rank of rating obtained | | Differences in ranks | |
|---|---|---|---|---|
| | In simulator | On the road | Sign | Size |
| 1 | 25 | 23 | – | 2 |
| 2 | 7 | 1 | – | 6 |
| 3 | 23.5 | 24 | + | 0.5 |
| 4 | 18 | 13.5 | – | 4.5 |
| 5 | 43 | 38 | – | 5 |
| 6 | 39 | 35 | – | 4 |
| 7 | 20 | 17 | – | 3 |
| 8 | 28 | 40 | + | 12 |
| 9 | 35.5 | 41 | + | 5.5 |
| 10 | 35.5 | 45 | + | 9.5 |
| 11 | 3 | 19 | + | 18 |
| 12 | 21 | 25 | + | 4 |
| 13 | 6 | 15 | + | 9 |
| 14 | 38 | 28 | – | 10 |
| 15 | 2 | 10 | + | 8 |
| 16 | 8 | 11 | + | 3 |
| 17 | 19 | 16 | – | 3 |
| 18 | 34 | 20 | – | 14 |
| 19 | 32 | 42 | + | 10 |
| 20 | 1 | 4.5 | + | 3.5 |
| 21 | 45 | 43 | – | 2 |
| 22 | 12 | 7 | – | 5 |
| 23 | 30 | 34 | + | 4 |
| 24 | 4 | 8 | + | 4 |
| 25 | 23.5 | 18 | – | 5.5 |
| 26 | 9 | 12 | + | 3 |
| 27 | 15 | 37 | + | 23 |
| 28 | 29 | 32.5 | + | 3.3 |
| 29 | 14 | 4.5 | – | 9.5 |
| 30 | 11 | 3 | – | 8 |
| 31 | 13 | 9 | – | 4 |
| 32 | 16 | 32.5 | + | 16.5 |
| 33 | 33 | 36 | + | 3 |
| 34 | 37 | 44 | + | 7 |
| 35 | 31 | 22 | – | 9 |
| 36 | 26 | 31 | + | 5 |
| 37 | 22 | 29 | + | 7 |
| 38 | 42 | 39 | – | 3 |
| 39 | 40 | 26 | – | 14 |
| 40 | 17 | 13.5 | – | 3.5 |
| 41 | 10 | 6 | – | 4 |
| 42 | 5 | 2 | – | 3 |
| 43 | 44 | 21 | – | 23 |
| 44 | 41 | 30 | – | 11 |
| 45 | 27 | 27 | – | 0 |

## TABLE 2

Comparison of changes in skin conductance and risk rating in the simulator

| Incident description | Conscious risk assessment | | Skin conductance response | | Difference in rankings |
|---|---|---|---|---|---|
| | Average increase in rating | Overall rank of change in rating | Average % increase in skin conductance | Overall rank of % increase in skin conductance | |
| 1. Parked car in road on rounding right bend | 6.28 | 11 | 3.87 | 11 | 0 |
| 2. Pedestrians in road on reaching brow crest | 5.60 | 9 | 2.08 | 4 | – 5 |
| 3. Another car close follows then overtakes and cuts in dangerously | 6.52 | 12 | 3.51 | 12.5 | + 0.5 |
| 4. Approaching unusual roundabout with right of way on entry, car from right appearing not to give way | 3.34 | 2 | 0.89 | 1 | – 1 |
| 5. Approaching cars over centre line as they pass parked lorries | 4.09 | 3 | 1.15 | 2.5 | – 0.5 |
| 6. Car from left side of road moves quickly to give way line and stops just in time | 5.58 | 10 | 2.92 | 10 | 0 |
| 7. Turning left at a blind corner car is met approaching over centre line | 3.85 | 4 | 1.20 | 2.5 | – 1.5 |
| 8. Overhauling cyclist who without warning suddenly turns right across path | 7.56 | 13 | 4.02 | 12.5 | – 0.5 |
| 9. Approaching a controlled crossing when lights change to amber | 5.16 | 7 | 2.16 | 5 | – 2 |
| 10. Following a car which without warning brakes and turns left | 5.54 | 8 | 2.42 | 6.5 | – 1.5 |
| 11. Rounding a left bend when car pulls out of a side turning into path | 8.42 | 14 | 7.27 | 14 | 0 |
| 12. Overhauling a car on M-way which without warning pulls out to overtake lorry | 4.41 | 5 | 2.99 | 9 | + 4 |
| 13. Passing through light controlled junction when man appears and darts across road | 4.63 | 1 | 2.56 | 8 | + 7 |
| 14. Cyclist pulls out to pass a parked lorry into path of car | 4.60 | 6 | 2.40 | 6.5 | – 0.5 |

It was found that 11 of the subjects thought the degree of realism achieved was 'very high', 26 thought it was 'high' and 21 considered it 'fair'. Subjects remarked on the realism of the visual display although, as expected, the major criticism was lack of visual definition and the restricted field of view.

Because the simulator did not produce inertial forces there was a degree of mismatch between visual and vestibular inputs. This resulted in a few subjects reporting they experienced mild degrees of sickness or nausea while in the simulator. One of the subjects felt sufficiently sick that she required a break, after which she went on to complete the test. It is therefore recommended that for future studies simulator tests should not include manoeuvres suggesting high levels of acceleration, braking or cornering. It was also felt that the 30 minute film was too long and shorter films would be preferable in future research.

## 4. POSSIBLE IMPROVEMENTS

From the results of the questionnaire the chief criticisms of the simulator were that the visual definition was poor and the field of view was limited. Trial tests with 35 mm film have shown that this increases visual definition substantially thus improving the realism of the simulation. Also anamorphic lens systems together with a curved screen could be used to increase the field of view.

## 5. RESEARCH APPLICATIONS OF SIMULATOR

Although the simulator was originally designed as a research tool to study hazard perception skills and abilities in drivers, it is suitable for undertaking research into a variety of the basic perceptual and cognitive abilities that are important in driving.

The continuous assessment of risk while watching a film containing hazardous incidents employed in the second validation allows the moment at which the hazards are first perceived to be established. In this way the time delay between the appearance of a hazard and its recognition may be calculated. In fact Pelz[3] has shown, using groups of undergraduate males, that the time taken to perceive hazardous incidents is related to accident and conviction histories. It is possible that a higher order vision test based on such measures would be more effective in testing drivers for accident liability than, for example, conventional vision tests[8,9].

Research involving an excessive element of danger if it were to be performed on the road, could also be carried out in the simulator. For example, driver behaviour when faced with an emergency situation and the effects of various drugs on certain perceptual aspects of driving could be examined without exposing people to actual danger.

The use of the simulator as a training aid could also be considered. It may be possible to teach perceptual skills to inexperienced drivers and so reduce their high accident risk. Pelz[3] has, in fact, used film of the driver's view of the road in the classroom situation and has reported favourably of its effectiveness.

## 6. CONCLUSIONS

1. There was significant agreement between drivers' risk ratings irrespective of whether these were made while driving their own cars around an experimental route, or while watching a film of the route while in the simulator.

2. Subjects exhibited changes in skin conductance while viewing filmed sequences of potentially dangerous incidents in the simulator. These physiological measures of arousal or stress correlated significantly with conscious judgements of risk made at the same time.

3. Questionnaire results showed that subjects found the simulator provided a realistic 'driving' environment.

4. The simulator provides an adequately realistic environment for the study and training of drivers' perceptual skills. Worthwhile improvements could be made by increasing visual definition and the field of view.

## 7. ACKNOWLEDGEMENTS

The work described in this report was carried out in the Road User Characteristics Division (Division Head: Mr K Russam) of the Safety Department of TRRL. The authors wish to thank members of the Photographic Section at the Laboratory for advice regarding the projection system and for invaluable help in making the films used in the simulator. Thanks are also due to Mrs M Pattinson who obtained the experimental subjects.

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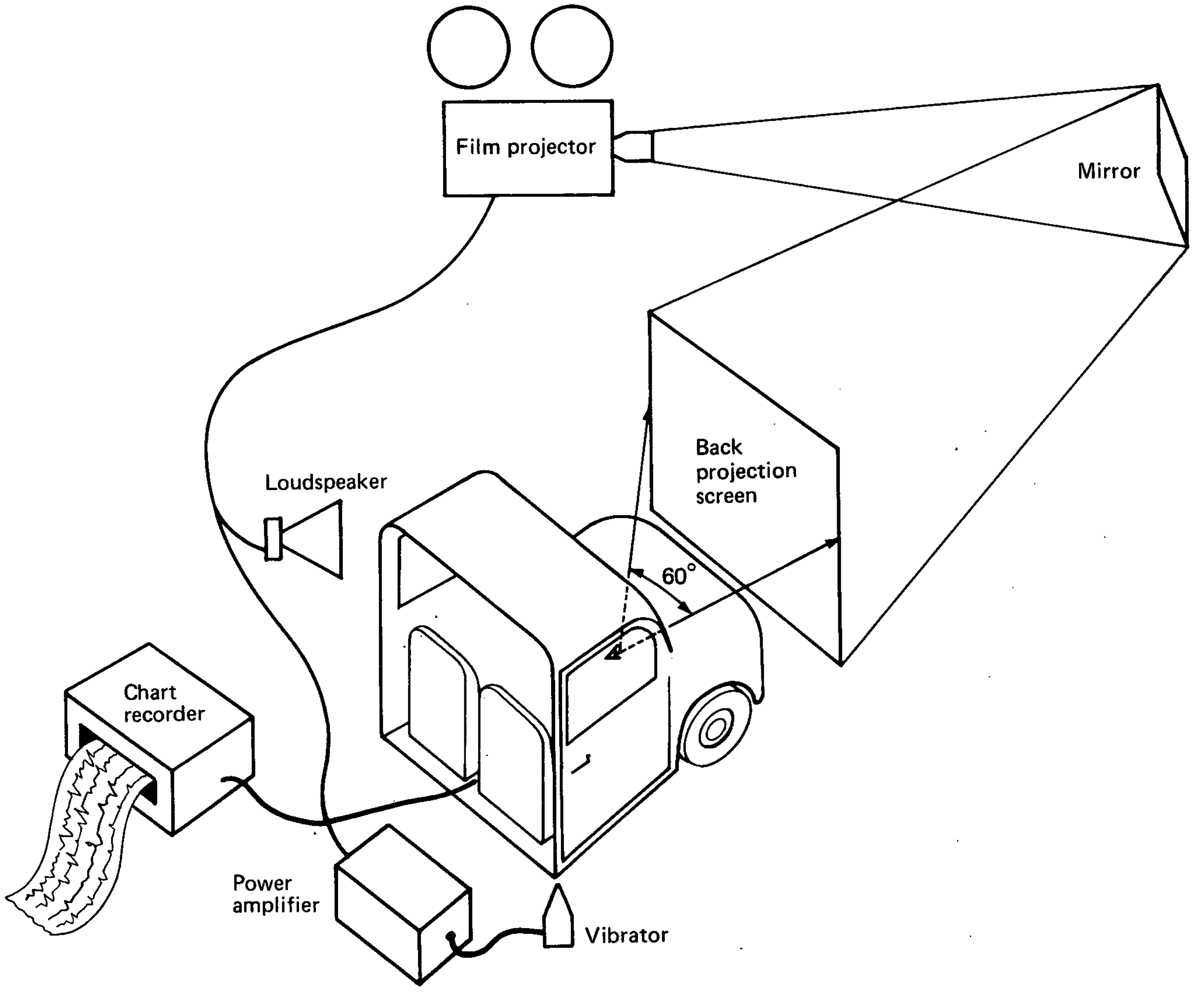


**Fig. 1 DIAGRAMMATIC REPRESENTATION OF SIMULATOR**

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Plate 1 THE SUBJECT'S 'DRIVER'S EYE VIEW' WHEN SEATED IN SIMULATOR

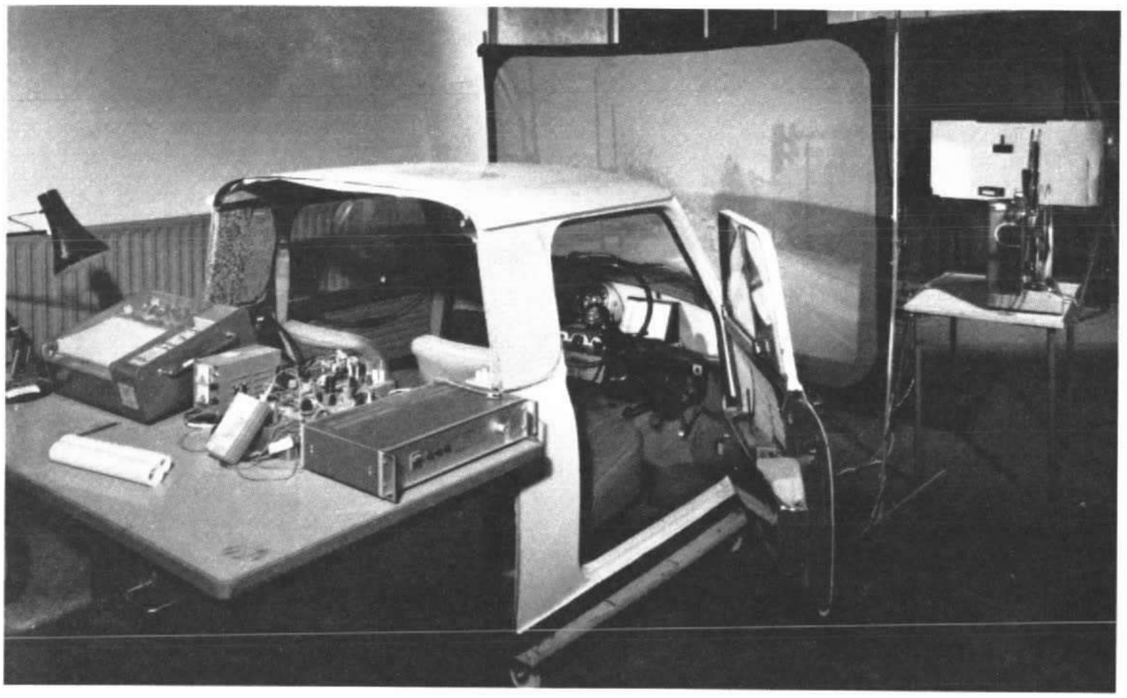

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Plate 2 SIMULATOR AND ASSOCIATED EQUIPMENT SHOWING RISK RATING RESPONSE LEVER IN DOOR POCKET

# 9. APPENDIX 1

ADDITIONAL DETAILS OF SIMULATOR AND ASSOCIATED EQUIPMENT

## 9.1 Car body

A British Leyland Mini with the engine and rear passenger sections removed (for reasons of space) was mounted on a wooden platform at the normal height from the floor – to make entry and exit easier. The doors, side windows, front seats, windscreen, dashboard and car controls were retained intact. The back of the car was sealed with a perspex screen behind which the experimenter and recording equipment were positioned. Ventilation was provided by a fan directing air between the front seats from the rear.

## 9.2 Projection system

A modified Bell and Howell Filmosound 644 projector was used projecting, via a mirror, onto a 1.8 x 1.3 m rear projection screen (Fastfold, made by Commercial Picture Equipment Inc.).

## 9.3 Rear vision

The rear view normally seen in the interior mirror and right-hand wing mirror was provided. Because of space constraints in the camera car the interior mirror appeared at the bottom left-hand corner of the film frame and was hidden by the car body's dashboard in normal viewing. To overcome this the image on the rear view mirror was deflected upwards to its customary interior mirror position by use of a small subsidiary mirror positioned on the larger mirror. To prevent a double image at this point an appropriately sized and positioned non-reflecting mask was also attached to the larger mirror (see Plate 2).

## 9.4 Road and engine noise

During filming the noise generated inside the vehicle was recorded. This was added to the film's optical soundtrack and played back, using the projector's amplifier, through two loudspeakers. It was discovered that the optimum position of the loudspeakers was to have one just in front of the bulkhead (in the position normally occupied by the engine) and one just behind the two front seats. The sound level was adjusted to simulate that experienced in a similar car while being driven.

## 9.5 Vibration

Vibration of the car's body was achieved by amplifying the audio signal from the optical soundtrack using a 50 watt amplifier and using this signal to drive a vibrator (Ling Dynamic Model 409) with a core loading of 2 kg. The vibration thus produced increased with the 'speed' of the car and diminished as the car came to a halt.

## 9.6 Turn indicators

Left and right turn indicators, two flashing lights fitted high on the dashboard to the left and right of the steering wheel plus an auditory 'clicking' noise, were triggered at the appropriate times by means of 300 and 3,500 Hz tones recorded on an additional magnetic soundtrack deposited next to the optical track during processing. These tones activated frequency sensitive switches tuned to these frequencies.

To obtain the audio signal from the magnetic track the film projector was modified. The signal after the pre-amplifier stage was obtained at the volume control potentiometer, the control being set at zero so that the tones would not be superimposed on the road noise. The signal developed across the potentiometer was fed to the buffer amplifier shown in Figure 2 and to three frequency sensitive switches* in parallel (see Figure 3).

The circuits were tuned by the values of resistors and capacitors to respond to frequencies of 300, 1000 and 3500 Hz. The 1000 Hz tone was used to mark events on the chart record (see below).

### 9.7 Response lever

For the recording of the risk rating a lightly sprung control lever directly coupled to a potentiometer was used to generate the signals. The control box was conveniently located in the door pocket near the subject's right hand. Visual feedback of the risk rating was produced by a large meter (1mA DC ammeter) placed just below the windscreen (see Plate 2). To ensure that the chart recorder pen responded quickly to sudden movements of the lever it was necessary to use the amplifier shown in Figure 4.

### 9.8 Skin resistance measurement

Beckman electrodes were attached to the first two fingers of the left hand. Electrode jelly prepared according to instructions given by Venables and Christie[10] was used to ensure good contact but minimal interference with the skin conductance level.

A constant current technique was used and the developed voltage across the electrodes was amplified and used to drive one channel of a chart recorder. A typical response to a dangerous incident is shown in Figure 4.

### 9.9 Chart recorder and measurement of records

A chart recorder (Model H320–3)** was used for recording purposes and a chart speed of 5 mm/s was used.

To allow identification of responses to specific hazards an automatically triggered event marker was used. 1000 Hz coded tones were recorded on the magnetic sound track of the film at points on the film where hazardous incidents occurred. Using a frequency sensitive switch described in Section 9.6, the event marker was energized. The pulses for incidents 46 and 47 are shown in Figure 5 at the top of the chart record.

The increase in risk rating during hazardous incidents was the difference between the maximum level and that before the hazard became visible. Similarly the decrease in skin resistance was calculated and converted to the percentage increase in conductance.

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* Obtainable from Consumer Microcircuits Ltd.

** From Z & I Aero Services Ltd., London.

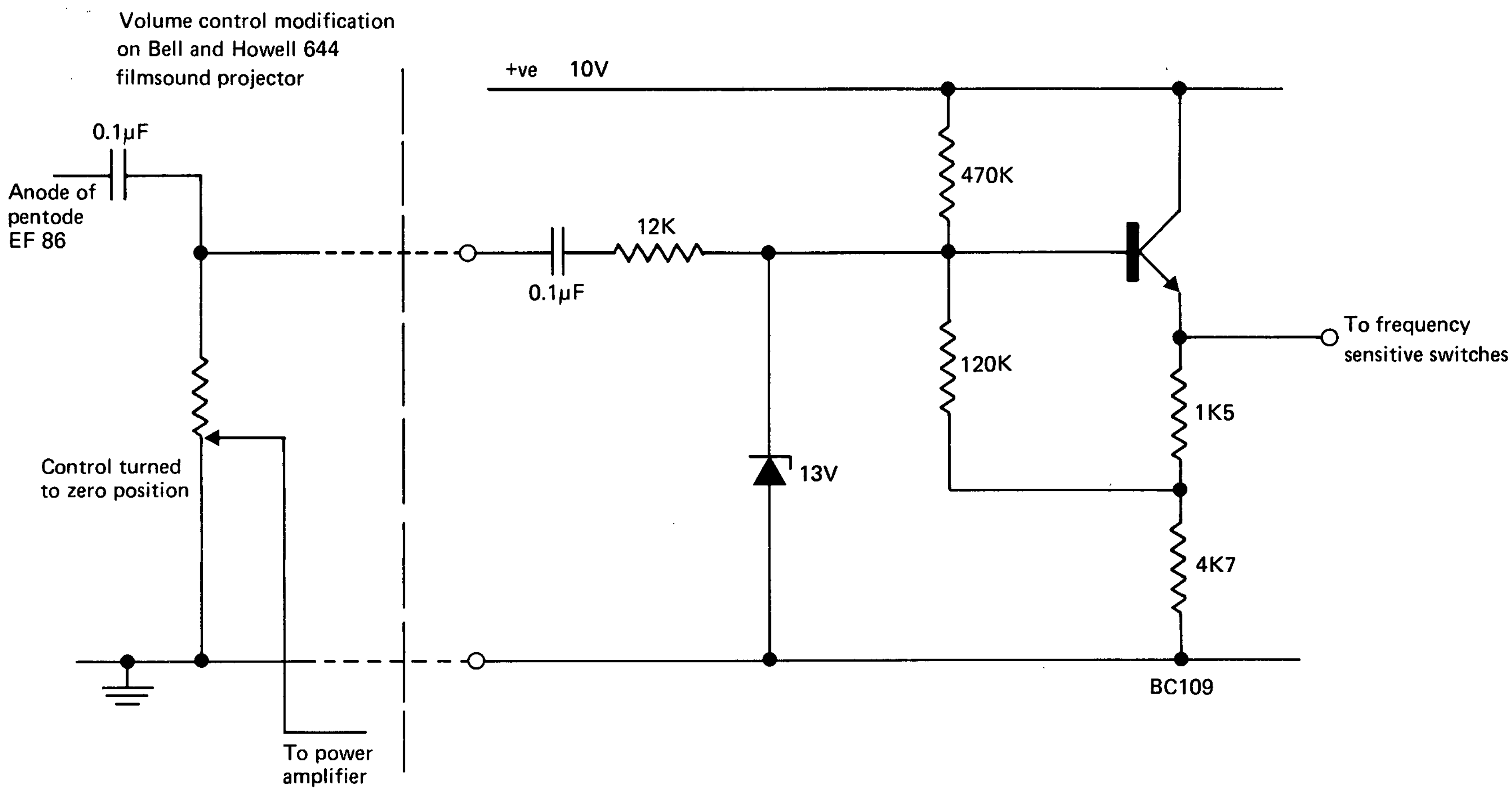
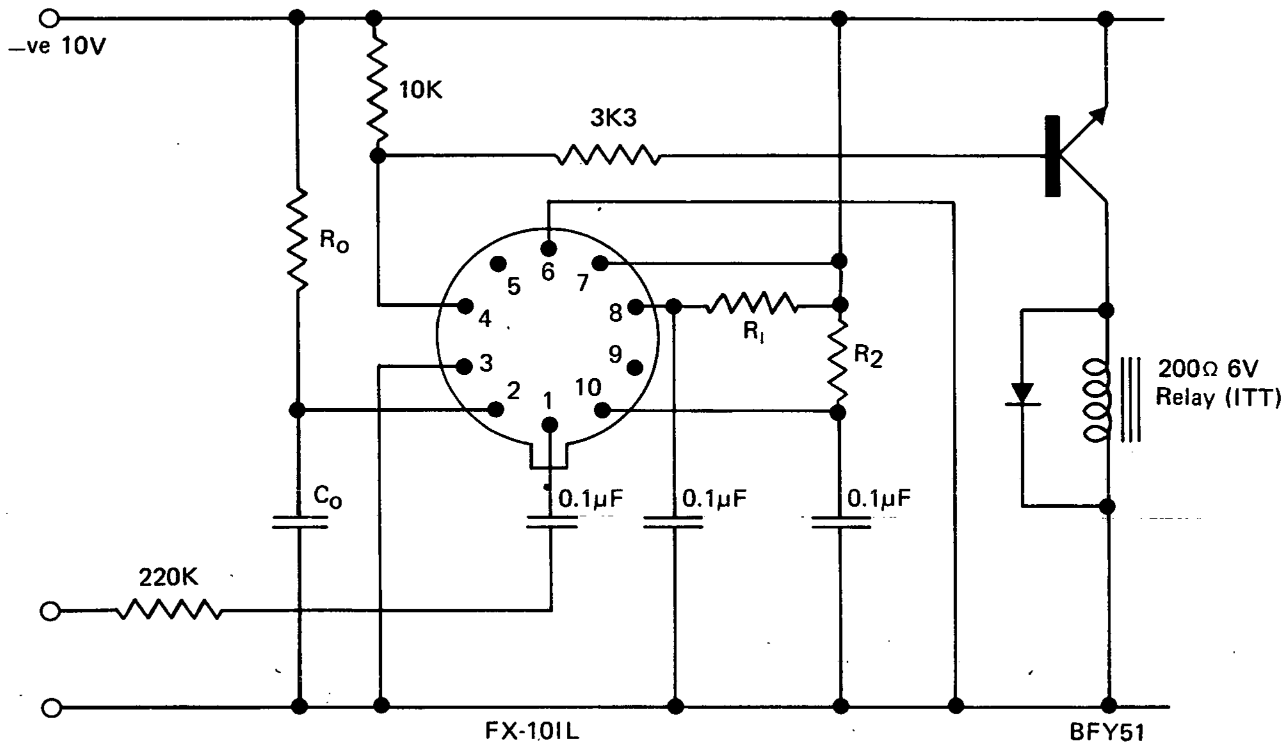
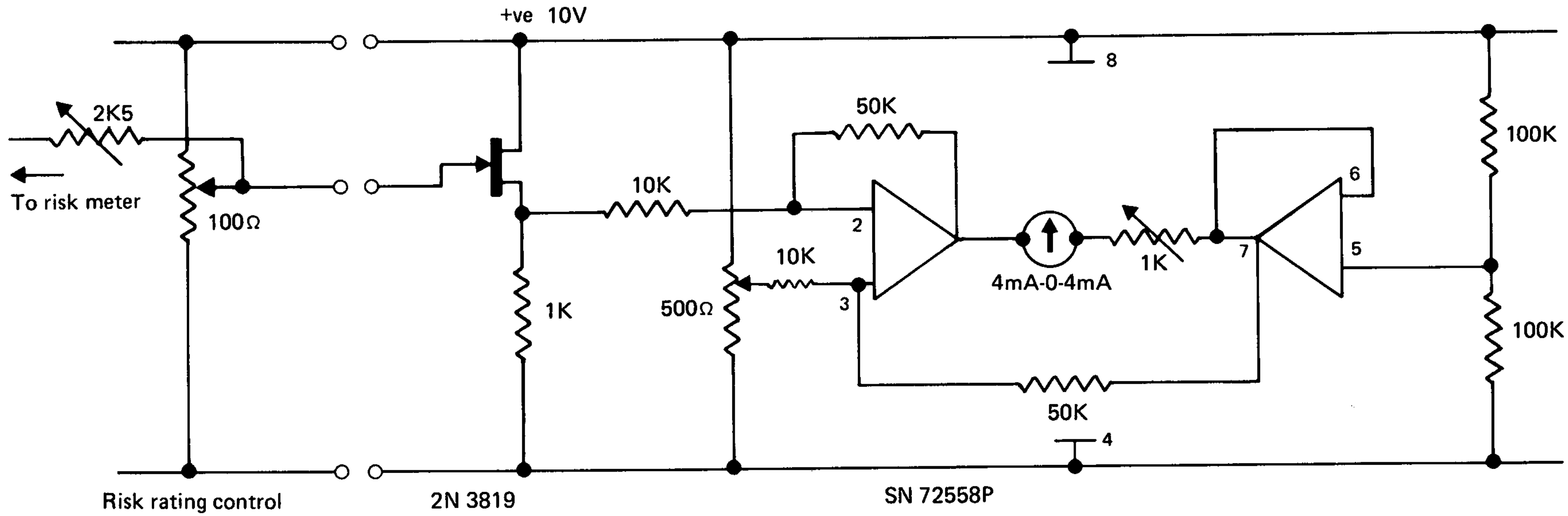



Fig. 2 BUFFER AMPLIFIER



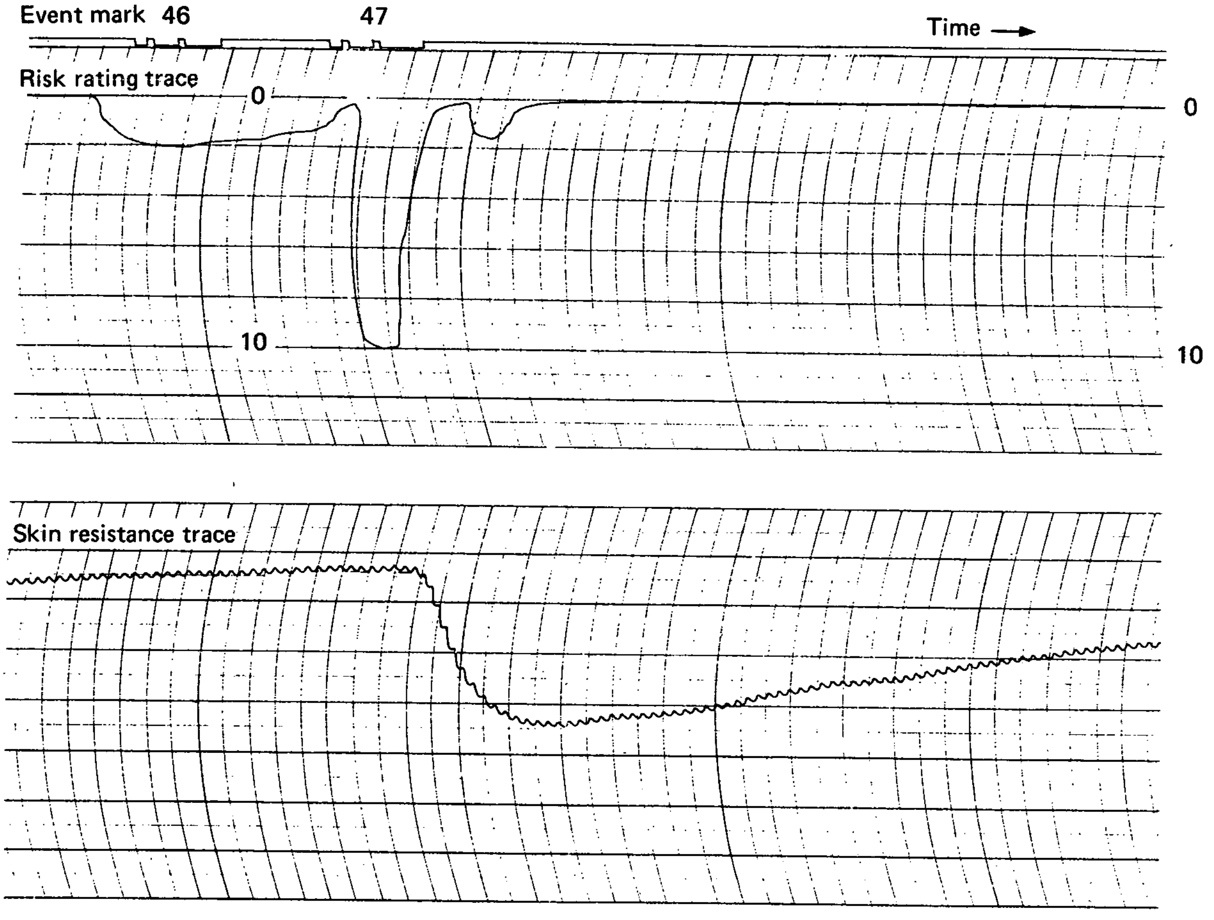

| Switch frequency in Hz | Capacitors in μF | Resistors in KΩ | | | Limits of frequency band in Hz | |
|---|---|---|---|---|---|---|
| | $C_o$ | $R_o$ | $R_1$ | $R_2$ | $f_1$ | $f_2$ |
| 300 | 1.0 | 51 | 36 | 36 | 422 | 209 |
| 1000 | .033 | 390 | 12 | 6.2 | 1204 | 801 |
| 3500 | 0.1 | 33 | 3.6 | 2.4 | 4665 | 2762 |

**Fig. 3 FREQUENCY SENSITIVE SWITCHES**




500Ω precision potentiometer is for achieving a null position on chart record

**Fig. 4 AMPLIFIER FOR RISK RATING SIGNALS**




N.B. Grid lines are 10mm apart

**Fig. 5 CHART RECORD OF A TYPICAL SUBJECT IN THE VICINITY OF HAZARDOUS INCIDENT (EVENT No. 47)**

## 10. APPENDIX 2

INSTRUCTIONS FOR DRIVE

On hearing the tone, estimate your chance of being involved in a near accident or accident situation in the road ahead using the rating scale below.

A near accident would involve rapid braking or swerving on your part in order to avoid other vehicles, pedestrians, or stationary objects *or* would involve severe action on the part of other road users in avoiding your car.

After giving your rating list very briefly any events, features or actions you have considered important in making your ranking. Such things as actual or possible traffic events, features of the road, or roadside, or actions which you should or should not have taken could be included in the list.

Please drive at the speed and in the manner you are accustomed to. This is not a test of your driving ability.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No chance | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Good chance |

## 11. APPENDIX 3

INSTRUCTIONS FOR SIMULATOR TEST

The purpose of the driving simulator is to measure how 'risky' or 'dangerous' *you* consider driving to be in a variety of road and traffic situations.

During the experiment you should imagine that the simulator is a *real* car which you are driving along a *real* road. You will be asked to make a continuous assessment or judgement of the amount of risk or danger you see in the road and traffic situation ahead of you and behind you. Thus, you should attempt to estimate the possibility of being involved in a near accident (a 'close shave') or accident situation that would involve rapid braking or swerving on your part to avoid other vehicles, pedestrians or stationary objects *or* would involve severe action on the part of other road users in avoiding your car. You should also consider the possibility of mechanical failure (such as a puncture) in your assessment. In short, you should be trying to judge the amount of danger or degree of risk you see, as the driver, at any particular moment while 'driving' the car.

You make this assessment by simply moving the lever you see in the door pocket on your right. The lever is lightly sprung and will always return to the resting position (away from you) if you release it – there is also a limit to its movement towards you. You should consider these two extreme positions of the lever to correspond to the two possible extremes of your risk or danger assessment. You should position the lever away from you, to its full extent, when you consider there is *no* risk of an accident (for example, you might consider this to apply if you were parked in your own driveway), and at such times the dial in front of you would register 0. On the other hand you should position the lever at its extreme position towards you when you consider there to be a high degree of risk or danger (for example, when you consider there is an extremely high chance of being involved in a near accident or accident) and in this case the dial would register 10.

You may choose never to use these two extremes, but you should always try to position the lever *as quickly* and *as accurately* as you can, such that its position, and thus the dial's reading, correspond to the amount of risk or danger you see in the road and traffic situation ahead of you and behind you.

Remember – low risk conditions are signified by moving the lever away from you and by low numbers on the dial and high risk conditions are signified by moving the lever towards you and by high numbers on the dial. From time to time you should look at the dial to ensure that for similar risk levels you have positioned the lever to register similar dial readings.

Please note that the simulator is equipped with an interior rear view mirror, plus a wing mirror so you can include the traffic situation behind you in your estimate. Please use these mirrors as often as you do while driving your own car. The car is not equipped with a working speedometer so you should assess your speed as best you can. If you think the 'car' is travelling too fast or too slow for safety you should adjust your estimate accordingly.

You cannot control the speed or direction of the car and you should always assume you are going straight ahead unless the right or left indicator lights flash to signify you are changing lane or turning at the next junction.

Throughout the experiment you should keep your left hand as still as possible because any moving or flexing of the fingers will influence the signal recorded by the electrodes on your fingers. You may find it restful to keep your left hand resting in your lap throughout the experiment.

There will be two 'drives'. The first 'drive' will last approximately 5 minutes and is designed to familiarise you with the range of traffic and road conditions you will meet in the second 'drive' and to give you practice at the risk assessment task.

After you have completed the first 'drive' you will have a short break before starting the second 'drive' which will last about 30 minutes.

If you have any questions or need advice please raise them during this break otherwise any interruption of the second 'drive' will interfere with the experiment.

However, if at any point during the two 'drives' a serious problem arises please let the experimenter know – he will always be within earshot.

Finally, if there are any initial questions please raise them now.



(1834) Dd0536361 1,500 9/79 HPLtd So'ton G1915
PRINTED IN ENGLAND

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**Design and validation of a driving simulator for use in perceptual studies:** G R WATTS AND A R QUIMBY: Department of the Environment Department of Transport, TRRL Laboratory Report 907: Crowthorne, 1979 (Transport and Road Research Laboratory). A simulator is described that can be used to investigate a variety of perceptual factors concerned with driving. It employs a back projection system for presenting a driver's eye view film, in colour, to subjects sitting in a modified car body. The impression of being in a real moving car is increased by providing suitable auditory and vibratory inputs.

Studies designed to validate the use of the simulator as an acceptable research tool are described. It was demonstrated that similar results were obtained in an experiment requiring assessments of risk, irrespective of whether subjects made their ratings while driving around a test route in their own cars or while viewing a film of the route while in the simulator. It was also shown that emotional responses to traffic events in the simulator, obtained by measuring skin conductance changes, were typical of those found in the road situation. The results of a questionnaire completed by the drivers revealed that the simulator provides an acceptably realistic simulation of the driver's perceptual environment.

Possible improvements are discussed and finally a variety of potential uses of the simulator, as a research tool, are given.

ISSN 0305–1293

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