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SPEED PERCEPTION 2: Drivers' judgements of safety and speed on rural straight and curved roads and for different following distances.

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Abstract

This project was a continuation of a previous study in speed perception that evaluated the role of the type of road and road width, roadside development, travel speed, driving experience and the sex of the driver on estimates of safety and travel speed (Fildes, Fletcher & Corrigan, 1987). In the first experiment, the effect of night driving and time of testing on a driver's perception of speed on straight rural roads was assessed using the previous methodology. A validation study was performed to test whether the laboratory assessment technique was suitable for assessing speed perception at rural curves. A multi-factorial experiment followed that assessed the role of the previous road, environment, and driver variables (as well as curve radius and curve direction) on drivers' estimates of safety and travel speed on flat rural curves. The last experiment was a preliminary study to see whether the speed perception methodology was also suited to testing perceptions of following distance in rural areas. The final chapter reviewed the literature on road treatments that would be suitable for use as speed perception countermeasures. A number of treatments were identified and a programme of research necessary to evaluate their effectiveness and potential road safety costs and benefits was outlined.

Keywords

SPEED, PERCEPTION, HIGHWAY, CARRIAGEWAY, PAVEMENT, ENVIRONMENT, MAN, WOMAN, EXPERIENCE(HUMAN), RECENTLY QUALIFIED DRIVER, LABORATORY, SAFETY, RURAL AREA, RISK TAKING, HEADWAY, VEHICLE SPACING

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EXECUTIVE SUMMARY

Rural road curves tend to be over-represented in road crash statistics and perceptual cues are often claimed to be responsible.

This study set out to examine the perception of speed on horizontal and vertical curved roads in rural settings and was an extension of a previous project on the perception of speed for urban and rural straight roads (Fildes, Fletcher and Corrigan, 1987).

The Research Project

The role of type of road, roadside development, travel speed, driving experience and the sex of the driver for speed perception on rural curved roads was assessed experimentally. The effect of night vision on straight road speed perception was also evaluated.

In addition, the study examined the possibility of adapting the speed perception methodology to test unsafe driver actions on the road. A range of perceptual countermeasures for speed is also discussed, including additional research required to facilitate their use on the road.

Day and Night Vision Experiment

The first experiment involved the perception of speed on rural straight roads during the day and at night. Twelve rural straight road sites were filmed from the driving position of an automobile, simulating both normal daylight and high beam night driving conditions.

The independent variables included road type, travel speed, roadside environment, illumination level, sex of the driver, driving experience, and time of testing.

Forty eight licensed drivers were recruited and tested individually in a single laboratory sitting using both day and night stimulus scenes. Half of the subjects were tested during the day and the other half at night.

Free speed measures at each road site were taken during the day and at night.

The results showed that travel speed had the strongest effect on the subjects' responses. Speeds 15 percent above the posted speed limit, were judged to be ideal, while those 15 percent below the posted speed limit were assessed to be too slow. Speed estimate errors were greater for fast than slow speeds.

These results support the previous findings of the need for moving stimulus materials when assessing the perception of speed.

Speeds on divided roads were judged to be more safe than on 2-lane roads, but travel speeds were under-estimated more on these high quality roads. Gravel road speeds were generally assessed to be quite safe, although again, travel speeds were grossly under-estimated. Free speeds on the road tended to increase as the type of road improved.

Speed perceptions were generally less safe at night (and subjects made greater errors in estimating travel speed) than during the day. However, responses overall were not unsafe for either day or night scenes. There were no differences observed in free speed during either the day or night.

The level of perceived safety for daytime "spacious" sites was similarly reduced by both a "walled" roadside environment and darkness. However, trees on the side of the road had no influence at night, consistent with the lack of visual information available to drivers at this time.

Night testing had practically no influence on the subjects' responses, indicating that biological rhythms play very little part in speed perception.

The amount of driving experience had no reliable effect on either the safety of travel speed estimates, although female estimates of safe operating speed were generally less safe than male estimates.

Curvature Validation Study

A validation study was undertaken to test whether the laboratory method used for testing speed perception on straight roads was also suitable for curved roads in rural settings.

A route was selected that comprised twelve rural road curves outside the Melbourne Metropolitan area encompassing a range of spacious (open farming) and walled (heavily treed) horizontal and vertical curves.

Front seat passengers were asked to make assessments of safe operating speed and travel speed at each site. Similar responses were also made by another group of subjects in an experimental laboratory, using movie film segments of the same sites taken from the driving position of an automobile.

For horizontal curves, the pattern of results in the laboratory was similar to those collected on the road, confirming the validity of the laboratory method for testing speed perception at these sites.

However, there was less consistency for vertical curved roads, suggesting that the simple visual presentation method in the laboratory is not sufficient for testing speed perception here.

Subsequent experimentation, therefore, only assessed speed perception for horizontal rural road curves.

Horizontal Curve Experiments

A multi-factorial laboratory experiment was undertaken to assess the effect of road type, roadside environment, curve radius and direction, travel speed, driver experience and the sex of the driver on judgements of safety and travel speed on rural road curves.

Movie film sequences were taken at 48 road curves that encompassed all the variable combinations of interest. Free speed measurements were also taken at each road curve site.

Seventy two licensed drivers with varying amounts of driving experience were recruited and tested in the laboratory.

Travel speed had the strongest effect in the safety estimate data. Speeds 15% above the speed limit were judged to be less safe than speeds 15% below the limit. Speed estimate errors were greater for slow than fast speeds.

For type of road, safety estimates varied from overly safe for divided road curves, "about right" for 2-lane road curves, to unsafe for gravel curves. Moreover, travel speeds were under-estimated much more on high quality sealed roads than on gravel curves. This finding confirms the importance of road structure and surface in the perception of speed on rural road curves.

Radius of curvature influenced both the safety and speed estimates and also interacted with type of road. Large radius curves were judged to be more safe (and travel speed was more under-estimated) than small radius curves. In addition, small radius, gravel road curves were judged to be especially unsafe.

While the range of radii do differ across these three types of roads, this finding nevertheless suggests that maintaining radius levels in the upper ranges of the standards is important for speed perception on rural curves.

There was an important interaction in the safety estimates between type of road, roadside environment and curve radius where small radius, walled, gravel curves were judged to be particularly unsafe. This result is in general accord with previous findings in curve perception and demonstrates further the need to ensure maximum sight distances in road curve design.

Curve direction had practically no effect whatsoever on both sets of data, or the speed measurements observed at the sites. This suggests that visual differences reported for different curve directions are not important in the perception of speed.

Male drivers assessed travel speed to be more safe than females. Furthermore, novice male driver responses in particular, were less conservative than either experienced male driver or all female estimates.

Following Too Close Validation Study

A second validation study examined the possibility of adapting the speed perception laboratory method to examine the potentially unsafe driver action of "following too close to the vehicle in front".

Using a similar method to that reported earlier, a travel route was selected outside the Melbourne Metropolitan area that comprised divided, two-lane, and gravel straight rural road sites in both spacious (open farming) and walled (heavily treed) settings.

Two vehicles were used in this study. Passengers in the trailing vehicle (who were all licenced drivers) made safe distance judgements relative to the leading vehicle, and estimated their travel speed at each site for a range of different following distances and vehicle speeds.

Similar responses were made by another group of subjects in an experimental laboratory, using the same distance and speed conditions but from movie film segments taken from the driving position of the trailing vehicle.

The results in the laboratory were similar for both the safe following distance judgement and speed estimate to those observed on the road. This suggests that laboratory testing is a satisfactory means of assessing drivers' perceptions of "following too close to the vehicle in front".

An overall mean safe following distance of between 0.5sec and 2.0sec was observed from these preliminary data. Moreover, the perception of safe following distance seemed to be markedly affected by the type of road, the roadside environment, the sex of the driver, and the amount of driving experience.

There is a need for further research into following too close to the vehicle in front. In particular, a detailed study is required to systematically assess drivers' perceptions of safe following distance for a range of different road and driving conditions. The relationship between following distance and road crashes also needs to be fully assessed.

Perceptual Countermeasures

The final stage of this research program set out to review whether there were perceptual road and environment countermeasures that could be used to reduce excessive speeding in particular hazardous locations.

These measures could be expected to influence vehicle speed behaviour because they attempt to change the fundamental sensory information available to drivers. In addition, their benefits are likely to be long-term because they are unobtrusive and less likely to offend or frustrate drivers.

However, the earlier research hinted that their effectiveness would be limited if speed perception in a particularly hazardous location is overly safe to begin with (drivers did not appear to change their on-road behaviour until they perceive a particular location to be unsafe).

Eight novel road and roadside treatments were identified that could be useful as perceptual countermeasures against speeding. A planned program is described to evaluate their effectiveness and road safety benefits fully.

1. INTRODUCTION

In April 1987, the Federal Office of Road Safety commissioned RACV Limited to undertake a further study of the effects of perceptual changes on drivers' speed estimates. This project was a continuation of a previous study by Fildes, Fletcher and Corrigan (1987) that highlighted the effects of certain road, environment and driver factors on the perception of speed.

The previous project successfully developed a suitable method for assessing a driver's perception of travel speed in the laboratory, and also identified several factors that affect the perception of speed. However, the project was primarily aimed at evaluating road and environment effects on rural, semi-rural and urban straight roads.

The Federal Office of Road Safety is currently concerned with safety in rural environments. This study aimed to build on the earlier findings by examining how the road and the environment effect a driver's perception of speed on rural road curves and on straight roads at night.

1.1 PROJECT OBJECTIVES

The objectives of this study, specified by the Federal Office of Road Safety, were:

- . To develop the work previously undertaken on drivers' perception of speed for additional rural driving conditions;
- . To provide recommendations on suitable engineering countermeasures against excessive speeds; and
- . To examine the feasibility of adopting the speed perception methodology to test unsafe behaviours on the road.

In addition, the project was to review a range of available road delineation treatments and to discuss their likely consequences in influencing drivers' perceptions of what is a safe operating speed on the road ahead.

1.2 THE PREVIOUS PROJECT

Speed Perception 1 was undertaken to evaluate drivers' judgements of safety and speed on urban and rural straight roads. The results of this project showed that the speed of travel had the strongest effect on the subjects' judgements. The type of road also influenced speed perception while roadside development effects were somewhat dependent upon the type of environment (urban or rural) and the road type. Driver experience did not unduly influence the results, although the sex of the driver had a slight influence.

Furthermore, the project identified additional research that is needed in road speed perception. In particular, the role of road alignment and day versus night vision were nominated as other variables likely to influence the perception of speed on rural highways.

1.3 ROAD ALIGNMENT

The literature review from the earlier project suggested that road alignment is a critical factor in road crashes. Sanderson and Fildes (1984) also reported several studies that implicated increased crash risk with road geometry, and in particular, horizontal and vertical curvature.

1.3.1 Horizontal Curves

Road crash statistics have consistently shown an over-representation of single vehicle rural crashes at, or near, road curves (cf., Cowl and Fairlie, 1970; Witt and Hoyos, 1976; McLean, 1977a; Johnston, 1981, 1982a,b, 1983). The causes of the abnormally high frequency of such crashes are not yet fully understood, although investigators reporting on road safety claimed that perceptual factors play a significant role (Moore, 1968; Allen, 1969; Good and Joubert, 1973; Ross, 1974; Gordon and Schwab, 1979; Riemersma, 1982, 1984).

Research into curve perception suggests that the visual cues used by drivers in negotiating right-hand (RH) and left-hand (LH) road curves are quite different (Gordon 1966; Blaauw and Riemersma, 1975; Cohen and Studach, 1977; Shinar, McDowell and Rockwell, 1977; Stewart, 1977; Zwahlen, 1982). Triggs, Harris and Fildes (1979), Triggs, Meehan and Harris (1982) and Fildes and Triggs (1984) reported a performance superiority for RH curves in curve perception experiments. **This was subsequently explained in terms** of enhanced curvature information available for RH curves when viewed from the left side of the road (Fildes, 1986)

Differences in driving performance have also been reported for LH and RH road curves. Good and Joubert (1977) in Australia found that drivers tolerated higher deviations from a design course when negotiating RH curves, compared to similar LH curves. They explained this result in terms of perceptual advantage. This evidence clearly supports the need for any investigations into speed perception to consider the role of horizontal curvature and curve direction.

1.3.2 Vertical Curvature

There is also evidence that vertical curvature differences contribute to road crashes. Agent and Deen (1975) reported a disproportionate number of crashes on graded sections of roads than on flat roads, although the incidence of crashes at curve crests was surprisingly low. Cooper (1980) found a similar relationship and suggested that "increased vehicular speeds on downgrades may be the culprit". Wright and Zador (1981) and Hall and Zador (1981) also reported an increased risk of single-vehicle fatal roll-over crashes on downhill slopes than along level or uphill sections. Kostyniuk and Cleveland (1986) further argued that there were significantly fewer crashes at sites where vertical curvatures were of larger radii than design standards.

The perceptual evidence on vertical curvature relates more to the effects of reduced sight distance on performance, rather than vertical curvature per se. Gibson and Crooke (1938), Ives and Kissam (1964), the American Association of State Highway Officials (1965), NAASRA (1980) and McGee (1979) all argued that sight distance was the critical variable in defining a driver's performance on the road. Furthermore, Michaels and Van der Heijden, (1978) and Kadiyali, Viswanathan, and Jain and Gupta (1981) proposed models in which sight distance was the prime factor for determining the free speed of vehicles in curves on two-lane rural highways. These results, though, were not particularly convincing, given the small sample of roads and the severe restrictions imposed on the numbers of geometric variables that were investigated.

Other researchers, however, found no statistical relationship between sight distance and driving performance in curves (Babkov, 1970; Waldram, 1976; McLean, 1977a; Stockton, Brackett and Mounce 1981; Farber 1982). This lack of effect led McGee (1979) to propose that sight distance based on physical constraints alone provides an unsatisfactory basis for road design. He argued that the effect of reducing sight distance on driving performance needs to take into account a driver's ability criterion or a "decision sight distance". Thus, restricted preview on the road may only have an effect on driving performance below some minimum distance required for a driver to make travel decisions. In this respect then, it might be expected that severe restriction in sight distance of road crests would unduly influence a driver's speed perception on the road.

1.4 DAY AND NIGHT VISION

Night and day driving conditions represent extremes in a driver's visual information continuum. The illumination levels at night are some 200 times less under headlamps than daylight conditions, and background information is almost completely absent (Fildes, 1979). Interestingly though, driving speeds tend to be higher at night (Organization for Economic Co-operation and Development, 1980). This may help to explain the high number of fatal and serious injury crashes during darkness (OECD, 1980; Joscelyn, Jones & Elston, 1970), and especially those involving young drivers during night-time hours (Drummond, 1985).

A number of factors have been associated with different driving performance during night conditions. OECD (1980) reported abnormally large speed differences at night in bad weather.

Triggs and Berenyi (1982) found that subjects made more accurate judgements of rural road travel speed at night. They attributed this to the increased angular speed of elements visible to the driver which, under headlights, are much closer than normal and form visual streaming patterns on the retina of the eyes produced by reflectorized road delineators. **Although not a robust** finding, Sanderson (1985) reported no difference in crashes on freeways in Melbourne comprising both lit and unlit sections, supporting the notion of perceptual narrowing at night.

Elliot (1981) surveyed various groups of Australian drivers to formulate hypotheses regarding their speeding behaviour. He found that drivers were actually encouraged to travel at higher speeds at night because the road somehow seemed safer. **However,** verbal reports are inherently unreliable for perception studies as many of these influences occur without the driver's knowledge.

The role of night driving in the perception of speed clearly requires further investigation.

1.4.1 Time Of The Day Of Testing

Past research has shown that many physiological changes occur daily, weekly and monthly in animals and humans in cycles or circadian rhythms. Diurnal or daily variations in human physiology include changes in metabolic rate, blood-sugar level, haemoglobin level, and body temperature (Orme, 1969).

Other studies have also shown that circadian rhythms affect human performance on various tasks. As early as 1916, Gates reported that children's performance on mental tasks tended to peak in the afternoon, whereas their performance on motor tasks showed a more

continuous increase throughout the day (cited in Colquhuon, 1982). Performance on tasks with a clear perceptual component, such as rifle aiming and nut and bolt assembly, have also been shown to peak later in the day (Colquhuon, 1982).

Vigilance studies over 24 hours, often using military and naval personnel, have reported performance decrements for tasks involving immediate information processing during night hours. Shift worker research, too, has demonstrated a clear performance decrement at night (Colquhuon, 1982). These results lead Colquhuon to conclude that "the existence of systematic variations in relatively simple performance with time of day that appear to reflect circadian rhythms in 'mental' processes similar to those exhibited by physiological functions" (pages 68-69).

This evidence suggests that the time of the day of driving may well influence the perception of speed independently from any effect that day or night vision may have on a driver's judgement of safety and travel speed, and should also be evaluated.

1.5 FOLLOWING DISTANCE

Following too close to the vehicle in front is a particularly unsafe driving action and one that is over-represented in road crash statistics. In Victoria during 1983-85 for instance, there were 4,062 rear end mid-block casualty collisions, many of which were the result of insufficient headway (RTA, 1987). During this time period, this particular road user movement was the single most common form of casualty road crash in this State.

Drivers, too, rated this action as particularly unsafe. In a recent survey of automobile club members (Royalauto, 1988), it

was reported that drivers classified "following too close to the vehicle in front" as the most dangerous action of 16 possible unsafe driving actions. This action also rated highly in terms of what annoys drivers the most in an earlier survey (Royalauto, 1983) and was well represented in actions that drivers rated as particularly risky (Cairney, 1981; Quimby, 1988).

1.5.1 Recommended Following Distances

As a general rule of thumb, a two second gap behind the vehicle in front is recommended as a suitable safe following distance for drivers to adopt (RACV, 1986; RTA, 1987). Moreover, it is advisable to increase this figure at night, during bad weather, and for elderly drivers (Marsh, 1985; Royalauto, 1987).

Unfortunately, it is very difficult to maintain a three or four second gap in peak traffic conditions without inviting other motorists to enter the space.

In setting out the guidelines for the design of rural roads, the National Association of Australian State Road Authorities (NAASRA, 1980) recommended a 2.5sec minimum sight distance for road design incorporating allowances for reaction time and braking distance. A single figure of this magnitude has been criticized as being too general and inappropriate for many normal driving situations (McLean, 1977b; Olsen, Cleveland, Fander and Schneider, 1984). Nevertheless, a single rule of thumb approach is more likely to be understood and adopted as a general principle by the majority of drivers. The question remains what this recommended following distance should be?

1.5.2 Research Required

Further research is required to determine the relationship between following distance and road crashes, and what constitutes a suitable following distance for motorists to adopt in their driving habits. The laboratory method could be a safe and useful means of generating following distance data, providing it can be shown to be a valid and reliable technique.

1.6 RESEARCH STRATEGY

A similar research strategy to that of the previous project was adopted again to ensure research continuity and enable direct comparisons to be made with the previous findings. The strategy used is briefly described below.

1.6.1 Laboratory Experimentation

Laboratory experimentation was shown to be effective for assessing the perception of speed on urban and rural straight roads. Hence, further testing in this environment (day/night comparisons) can be carried out with the assurance of real world validity of this approach.

The perception of speed on horizontal and vertical curves, however, is noticeably different in terms of visual image and gravitational or kinesthetic feedback. Thus, the validity of the laboratory environment for this form of speed perception needs to be established prior to detailed experimentation.

Similarly, the suitability of the laboratory for testing unsafe driving actions also needs to be validated before further research is contemplated.

1.6.2 Stimulus Presentations

Moving road scenes were generated in the previous experiments by using 16mm film images back projected onto a large projection screen in front of the subjects. The distance between the screen and the subject ensured that the visual image was roughly equivalent to that seen while driving on the road itself. This procedure was also adopted here.

Movie films of road scenes were generated from a camera mounted close to the driving position of an Australian automobile. This was from the right-hand side of the car positioned left of the centreline of the road.

1.6.3 Free Vehicle Speed Data

To compare perceptual responses with driving behaviour on the road, free speeds of vehicles were collected at every possible site. Free speeds were measured using a Gatso Mini (across the road) radar gun or a Kustom hand held radar gun (HR4). These two units were shown to yield identical results for this purpose. Procedures for collecting and presenting the data were compatible with that recommended by the Advisory Committee on Road User Performance and Traffic Codes (ACRUPTC) and the previous project.

1.6.4 Independent Variables

The prime independent variables evaluated in this research included horizontal and vertical curvature and day/night vision. These factors formed the basis of two major experiments (Chapters 2 and 4 in this report). In addition, other variables were also evaluated **within** each experiment, namely driver experience and sex, type of road, roadside environment, and presentation speed.

Test time (time of the day when the tests were conducted) as well as Film time (time of the day of filming) were both evaluated in the day and night vision experiment (Chapter 2). Following distance was also initially evaluated in a laboratory validation study in this research programme (Chapter 5). Two replications of each site combination were again used to reduce the chance of any site bias in the results.

1.6.5 Controlled Factors

Every effort was made to ensure that the effects of additional factors not manipulated in this study were controlled for. These factors included a consistent road alignment and surrounding terrain (except where specified by the independent variable treatments), maximum sight distances (at least as much again as the film presentation time except where manipulated), minimal traffic density (zero whenever possible) to ensure other vehicles did not influence subjects' responses in this project, no parked vehicles or pedestrians, good light and weather conditions, and as consistent road delineation treatments as possible.

2. DAY AND NIGHT VISION EXPERIMENT

A factorial experiment was designed to test the effect of day and night vision on speed perception on straight rural roads. Some of the rural sites from the previous study (Fildes et al 1987) were used again with film segments including both day-time and night-time road illumination conditions.

2.1 STIMULUS MATERIALS

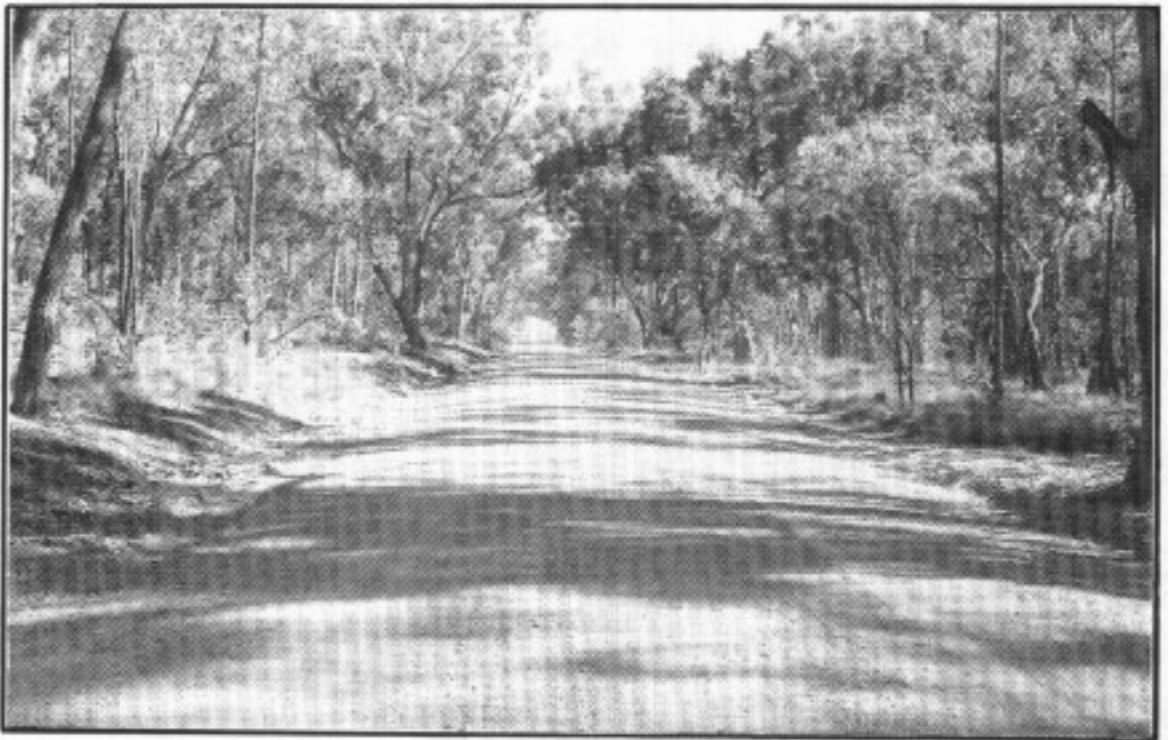
Twelve rural road sites were selected which encompassed the range of road and environment factors of interest. Details of each road site are shown in Appendices A-1 and A-2, while Figure 2.1 shows some typical sites used in this experiment.

The independent variables included three road types (divided, 2-lane undivided and gravel roads), two illumination levels (daylight and darkness), two roadside environments (spacious and walled settings), two repetitions (different road sites with the same characteristics), and two travel speeds (15 per cent above and below the posted limit). In total, 48 road scenes were used in a fully crossed factorial design experiment.

A suitable road segment was identified at each of the sites that ensured a minimum of five seconds film time with constant sight distance requirements. Each site was filmed four times from the research vehicle (at 15 per cent above and below the posted speed limit during both day and night light conditions). Sites were filmed using a Bolex H16 reflex movie camera with 16mm Kodak colour negative 100 ASA daylight film and 320 ASA night film.



Site 2 — Divided, 2-lane, spacious road.



Site 12 — Undivided, 2-laned walled gravel road.

FIGURE 2.1 — Two examples of straight road rural sites used in the day and night vision experiment.

For night filming, the research vehicle was mounted with six Hella Rallye 2000 pencil beam spotlights¹ as shown in the photograph in Figure 2.2. The spotlights were positioned to augment a standard headlight projection pattern and to produce at least five seconds or 150m sight distance on film. Pilot testing showed that these illumination levels and sight distances were roughly equivalent to what a driver normally has available at night from standard headlights on hi-beam. The films were processed into workprints (night scenes needed to be force processed 1 stop to increase the film's light sensitivity). Workprints were subsequently edited into 5sec film segments.

Four experimental films were then produced, each comprising 12 randomly selected day and night road scenes. Each 5sec road scene was followed by 10sec of blank film. Care was taken to ensure that road scenes with similar characteristics (repetition sites or the same site at different speeds) were on different film reels or spaced as far apart as possible. The presentation order of the films was structured across subjects to ensure that each film was presented equally in each serial position. A practice film, comprising 12 novel 5sec day and night road scenes, each separated by 10sec of blank film, was also provided to allow subjects practice at making speed and safety estimates in the laboratory.

1. The authors are indebted to Mr. Heinz Schulte, Design Engineering Manager of Hella Manufacturing Co. Pty. Ltd. for his assistance in selecting suitable lights for night filming and to Mr. Don Wells for arranging the loan of the units used in the project.



FIGURE 2.2 — Research vehicle with the 6-hella Rally-e 2000 spotlights and Bolex H16 movie camera in position.

2.2 APPARATUS

The laboratory had no windows or natural light and access was restricted to a single door only (see Figure 2.3 for details of the laboratory arrangement). Each subject was provided with a response booklet containing personal detail information sheets as well as several slash-line pages for practice and test responses. On each response page, there was a continuous line with end points marked as too slow and too fast. Subjects were asked to place a slash along the line to indicate their judgement of safety relative to their ideal safe operating speed. On the right hand top corner of each page, subjects were asked to estimate the travel speed to the nearest 5km/h. Figure 2.4 shows a sample page taken from the response booklet.

A Kustom-HR4 hand held radar gun was used to measure the free speed of 100 vehicles at 8 of the road sites in both day and night-time conditions (the gravel sites were not measured due to low traffic volumes). Measurements were taken by an observer seated unobtrusively in an unmarked vehicle at the side of the road.

2.3 EXPERIMENTAL PROCEDURE

Forty-eight licensed drivers who were unfamiliar with the task were recruited as subjects. Twelve subjects were allocated to each of four groups (male experienced, female experienced, male first year and female first year drivers) to test for experience and sex effects. Half of the subjects in each group were tested during daylight hours (9am - 5pm) and the remaining half at night (7pm - 12pm).

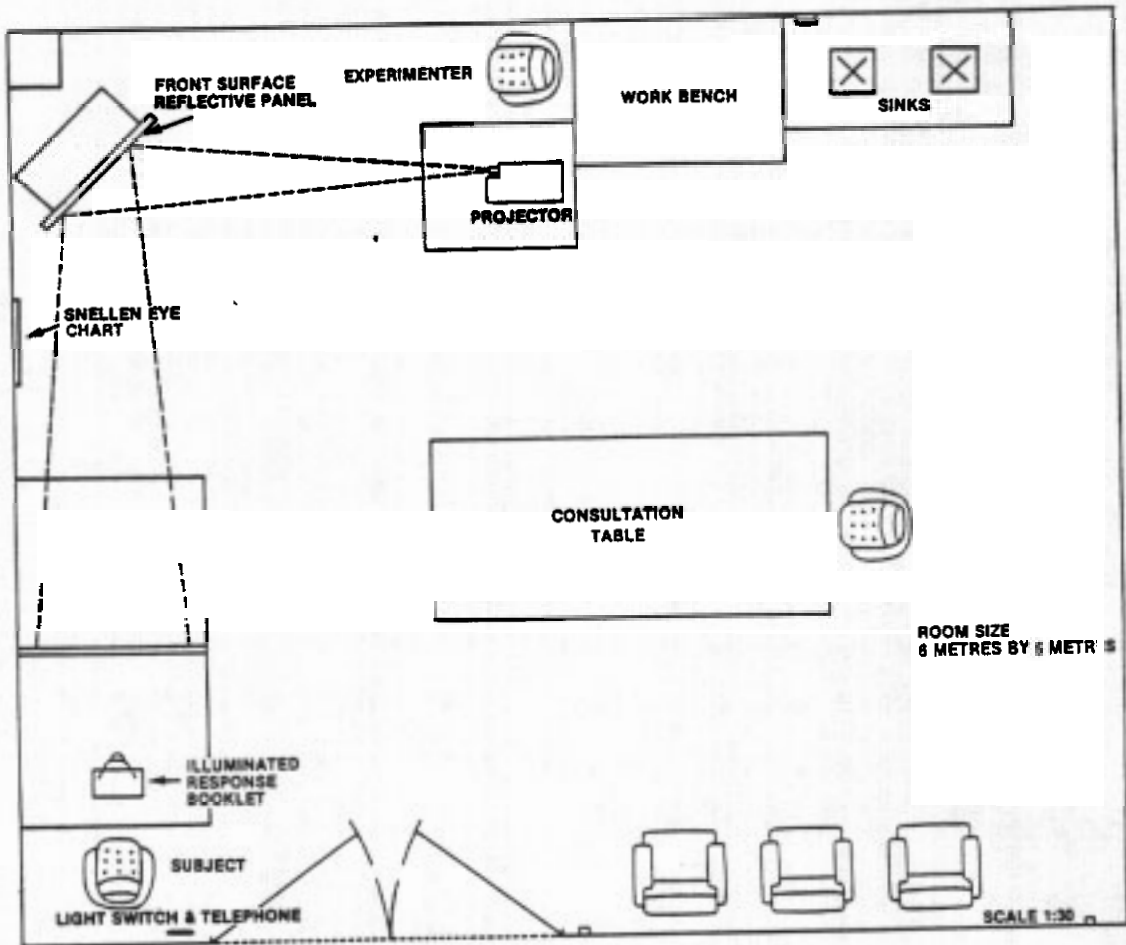


FIGURE 2.3 — Details of laboratory arrangement.

SITE NUMBER _____	SPEED ESTIMATE
TOO SLOW	TOO FAST




FIGURE 2.4 — Sample page from the response booklet.

Subjects were tested individually in a session lasting 40 minutes approximately and were paid for their participation. Each subject was seated in front of the back projection screen and listened to a pre-recorded tape of experimental instructions at the start of the session (see Appendix B-2). Any questions related to the task were then answered and the subject commenced with the practice film, followed by the four experimental films in a pre-determined order. The subjects made their assessments of safety and travel speed in the response booklet provided during the blank sequences between each road scene.

2.4 RESULTS

Safe operating speed responses for each site were converted to a measurement in millimeters (mm) representing the distance from the left-hand end of the 150mm long response scale. Thus, any number between 0 and 75 represented a "too slow" judgement, while numbers between 75 and 150 indicated a "too fast" response. Speed estimates were converted into error scores (positive or negative integers) by subtracting the subject's estimate of travel speed in km/h from the actual travel speed. Free speed measurements in km/h were read directly off the radar gun.

The safe operating speed responses and speed error scores were structured into separate data bases and analyzed using the BMDP P4V program for analysis of variance and omega-squared statistics. Once again, only those effects that attracted omega-squared (w^2) values greater than .002 were considered noteworthy effects in these analyses and are reported in order of their strength of effect (Fildes et al 1987).

The mean, standard deviation and 85th percentile of the free speed measurements were also computed and are listed in the site description sheets in Appendix A-1 and A-2. Speed measurements could not be collected at all sites for a number of reasons (e.g., some sites were modified between filming and free speed measurement, and other sites lacked sufficient traffic movements). This resulted in different sample sizes at many of the sites, and hence, a full statistical analysis of these data was not possible. Therefore, a descriptive analysis of the free speed measurements was only attempted here.

2.4.1 Safe Operating Speed Responses

Appendix C-1 lists the summary table of the 7-way analysis of variance of the safe operating speed data while Figures 2.5 and 2.6 show the results of particular interest. There were six main effects and four interactions that were statistically significant with w^2 values greater than .002 and these are described in order of their strength of effect.

Presentation speed shown in Figure 2.5a was a significant effect ($F(1,40)=104.5$, $p<.001$, $w^2=.0918$). **Subjects estimated slow** speeds to be too slow while fast travel speeds were judged to be safe. This variable was the strongest effect observed ($w^2=.0918$) and accounted for almost half the variance due to the independent variable manipulations.

Type of road in Figure 2.5b was also significant ($F(2,80)=23.8$, $p<.001$, $w^2=.0229$). **Subjects' estimates systematically varied** from too slow for major arterial roads through to "safe" for gravel roads. This variable had the second strongest effect, accounting for 12 per cent of the treatment variance.

E OPERATING SPEED JUDGEMENT

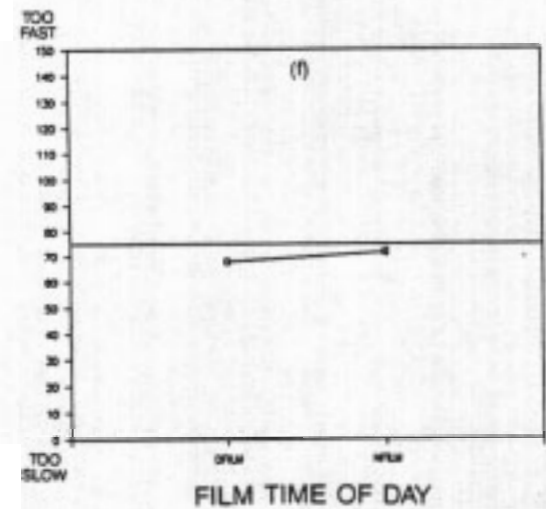
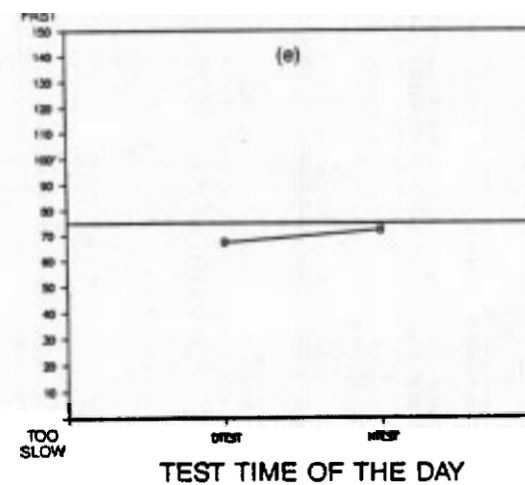
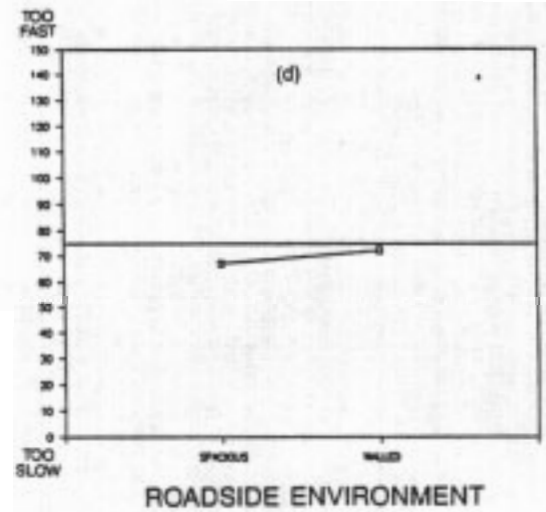
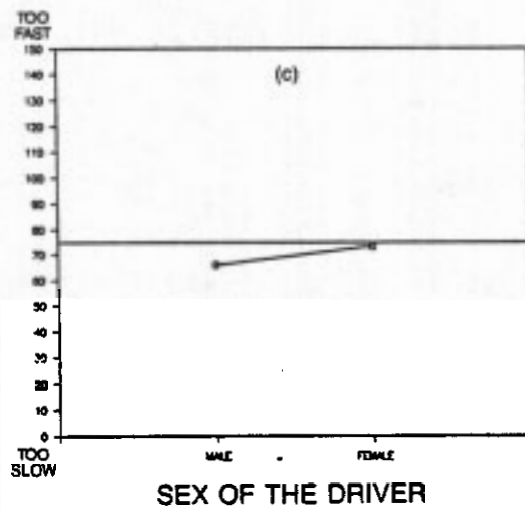
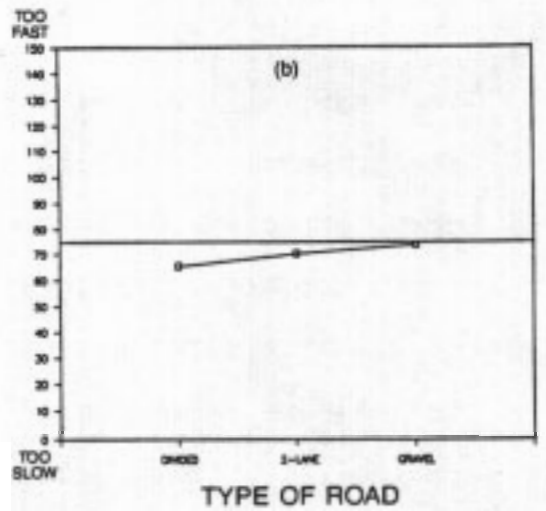
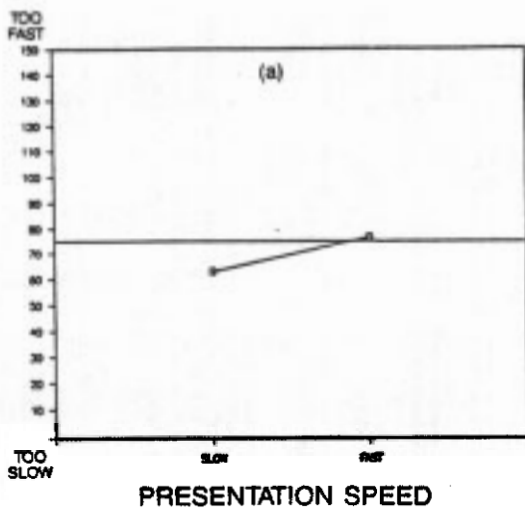


FIGURE 2.5 — Safe operating speed main effects of interest for the day/night experiment.

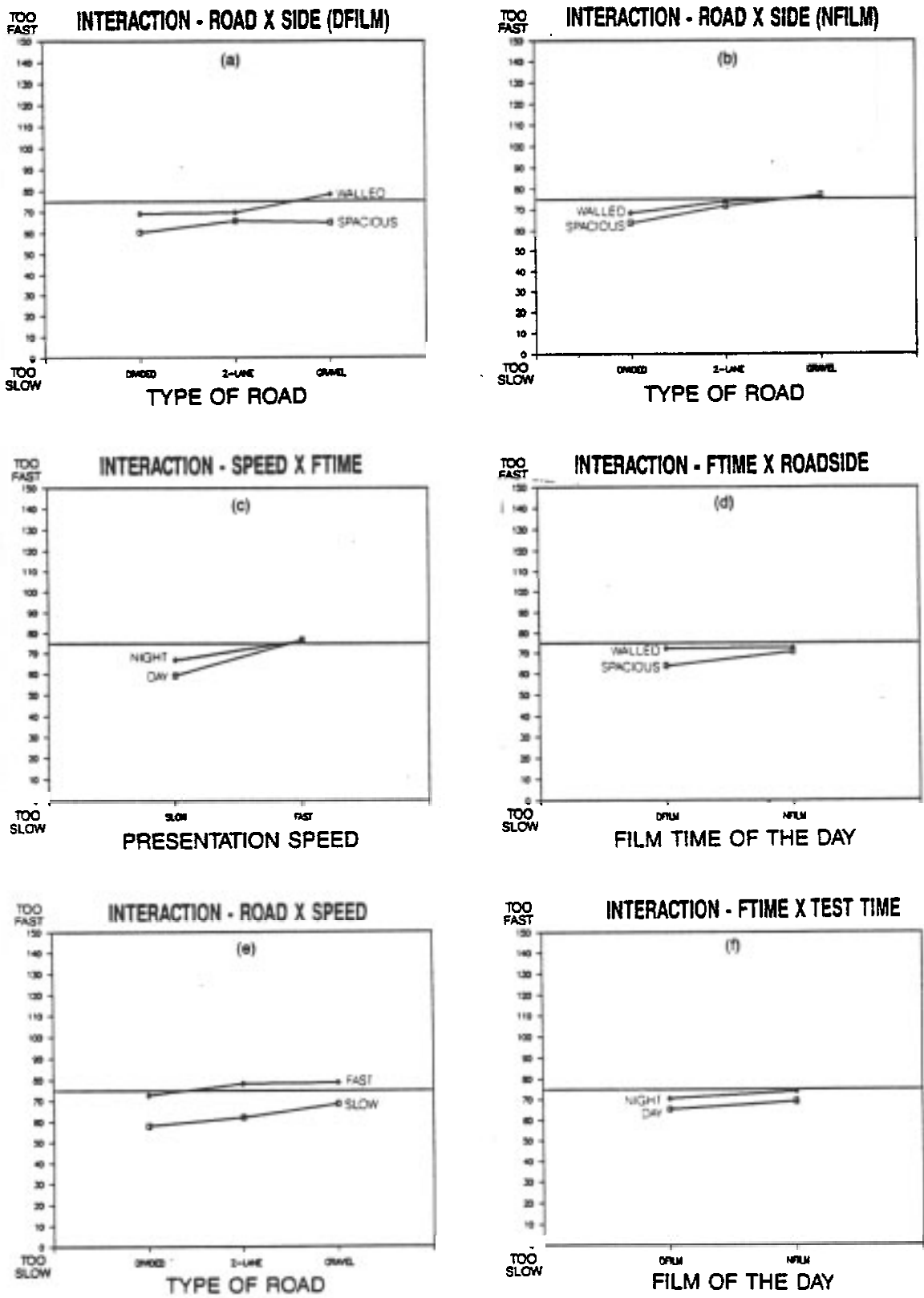


FIGURE 2.6 — Safe operating speed interactions of interest for the day/night experiment.

The sex of the subject shown in Figure 2.5c had the third strongest effect (10 percent of the treatment variance) and almost reached significance at the 5 per cent level ($F(1,40)=3.7$, $p=.060$, $w^2=.0199$). Males tended to estimate speeds generally to be too slow while female estimates were generally "about right".

Roadside environment shown in Figure 2.5d was also significant ($F(1,40)=72.3$, $p<.001$, $w^2=.0137$). Speed in spacious environments was judged to be too slow, whereas walled environment speeds were assessed as safe. With $w^2=.0137$, this variable was ranked fourth, although only one-seventh as strong an effect as presentation speed.

The interaction between presentation speed and film time, shown in Figure 2.6c was significant ($F(1,40)=46.9$, $p<.001$, $w^2=.0079$). Differences between slow and fast presentations were judged to be less for night films than for day films. This variable combination accounted for 4 per cent of the treatment variance.

The main effect for film time alone, shown in Figure 2.5f, was also significant ($F(1,40)=8.8$, $p<.01$, $w^2=.006$). Subjects assessed daylight scenes to be more safe than night scenes, although no scenes were judged to be unsafe. This variable accounted for 3 per cent of the treatment variance.

The interaction between film time and roadside environment shown in Figure 2.6d was significant ($F(1,40)=31.2$, $p<.001$, $w^2=.0055$). Speeds in spacious sites under daylight conditions were judged to be considerably more safe than in all other conditions (the safety of speeds at walled sites (day or night) and at spacious sites at night was assessed to be roughly equal by the subjects).

The time of testing in Figure 2.5e was not a significant effect ($F(1,40)=1.7$, $p=0.20$, $w^2=.005$), although it did have a noteworthy omega-squared value ($w^2=.005$ or 3 per cent of the total treatment variance). It should be noted that this variable was a between-subject factor in this analysis.

The triple interaction between type of road, film time and roadside environment shown in Figure 2.6a,b was significant ($F(2,80)=15.6$, $p<.001$, $w^2=.004$). Differences in perceived safety between spacious and walled sites were more apparent for day- than night-films. Moreover, gravel walled sites were the only locations where speeds were judged to be unsafe and were assessed quite differently to their spacious counterpart.

The interaction between speed and road shown in Figure 2.6e was the last significant effect of noteworthy strength ($F(2,80)=13.1$, $p<.001$, $w^2=.0031$). Slow presentation speeds were judged generally to be much too slow compared with fast presentation speed results, although the difference on sealed roads appeared to be greater than for gravel roads. This effect only accounted for 2 per cent of the treatment variance in this experiment.

There was no interaction observed between film time and test time shown in Figure 2.6f ($F(1,40)=<1$, $p=0.83$, $w^2=0$). The difference between the subjects' estimates of safety for day and night films was the same, irrespective of whether the subject was tested during the day or night.

2.4.2 Speed Estimation Errors

To provide a meaningful and comparable analysis of the travel speed estimates, the raw data were converted into error scores by

subtracting the actual speed level from each estimate. Appendix 3-2 lists the analysis of variance summary table of the effects that were significant with w^2 values greater than .002, while Figures 2.7 and 2.8 show these results. There were five main effects and six interactions of interest here and they are described in order of their strength of effect.

Presentation speed, shown in Figure 2.7a was again the strongest significant effect in this analysis ($F(1,40)=118.4$, $p<.001$, $w^2=.0809$). While all speeds were under-estimated, those for slow presentations (15 per cent below the speed limit) were judged much less accurately than those for fast presentations. This variable manipulation accounted for over one-third of all the treatment variance in this analysis.

Type of road in Figure 2.7b was also significant ($F(2,80)=56.3$, $p<.001$, $w^2=.0458$). Errors in estimating travel speed were roughly the same for divided and 2-lane roads but were much greater for gravel roads. This variable was the second strongest effect, accounting for 21 per cent of the treatment variance.

The third strongest significant effect shown in Figure 2.7c was film time ($F(1,40)=59.5$, $p<.001$, $w^2=.0398$), where subjects under-estimated travel speed much more for night-time scenes than for day-time sequences. This variable accounted for 18 per cent of the treatment variance.

Sex of the driver and time of test in Figure 2.8a was not significant but did account for 8 per cent of the treatment variance ($F(1,40)=2.5$, $p=0.12$, $w^2=.0170$). Males appeared to under-estimate speeds more during the day than at night, while female errors were roughly the same and equal to male night errors.

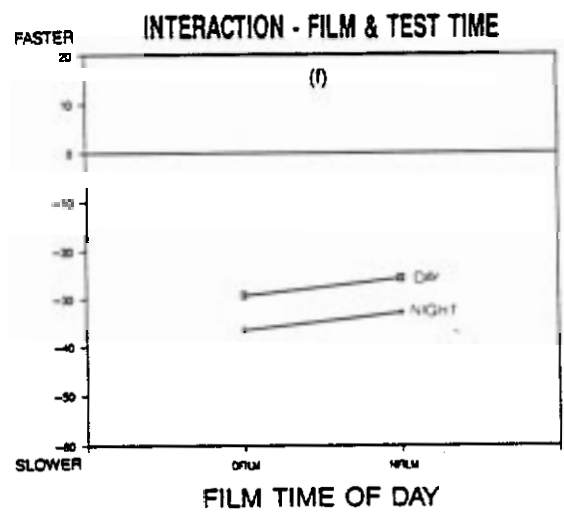
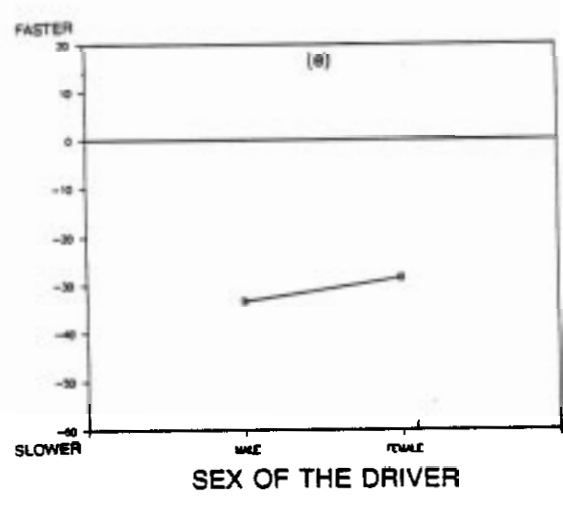
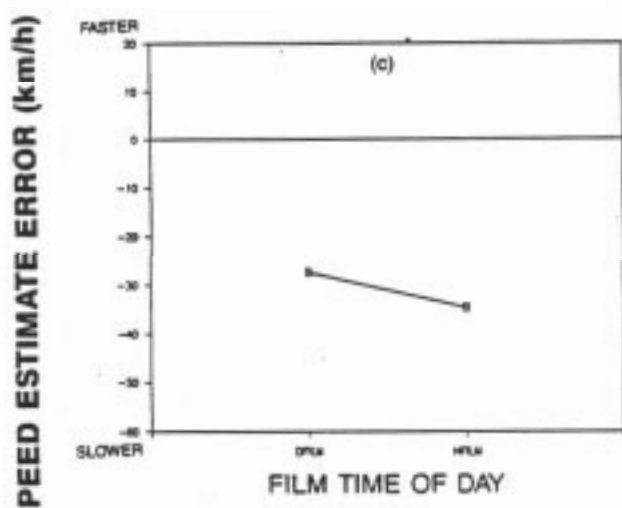
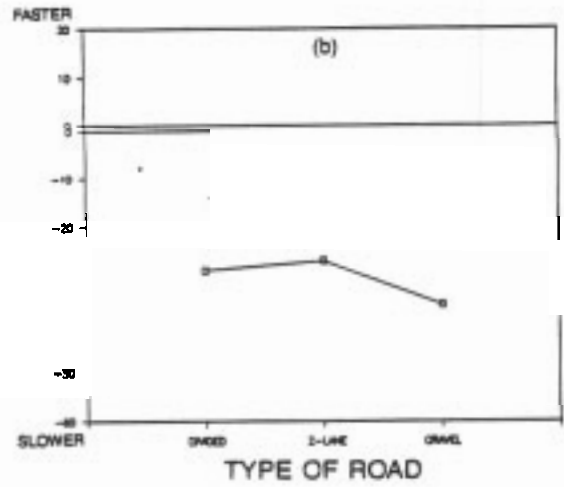
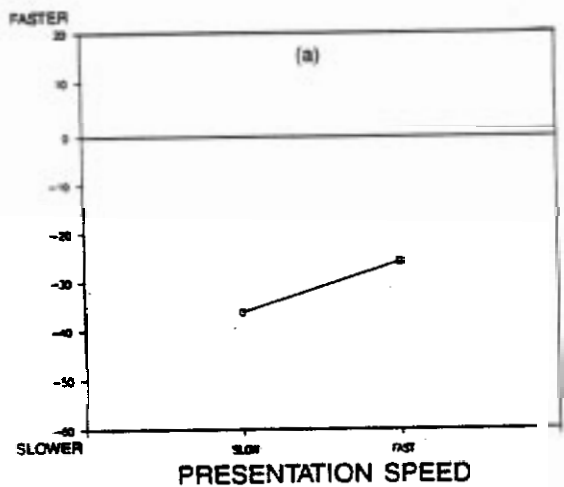


FIGURE 2.7 — Speed estimate error main effects and one interaction of interest in the day/night experiment.

SPEED ESTIMATE ERROR (km/h)

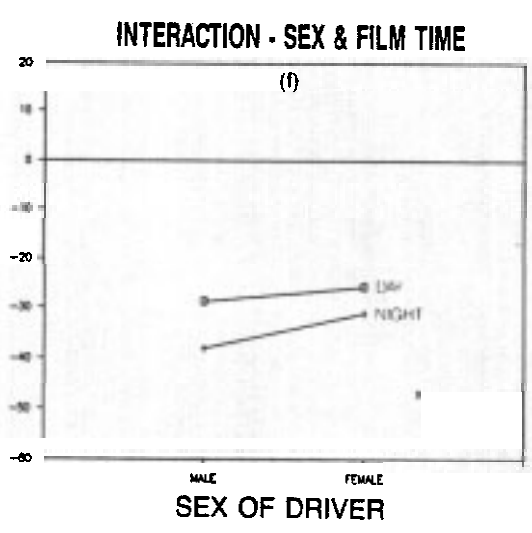
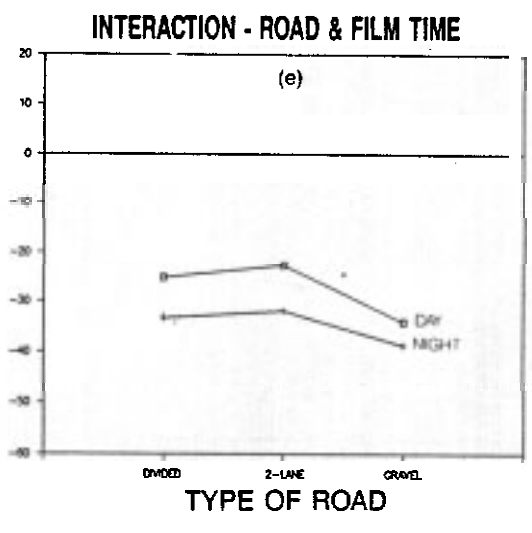
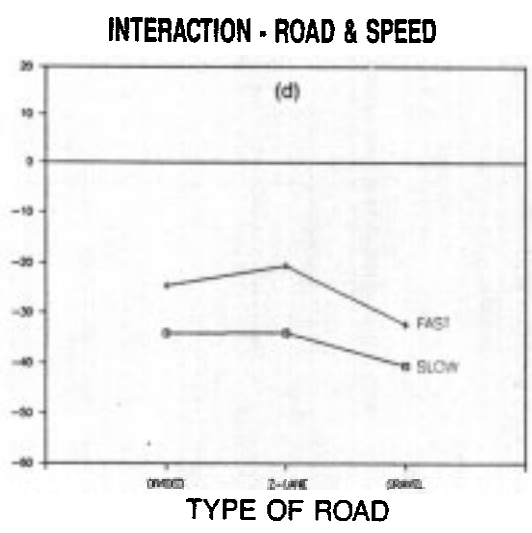
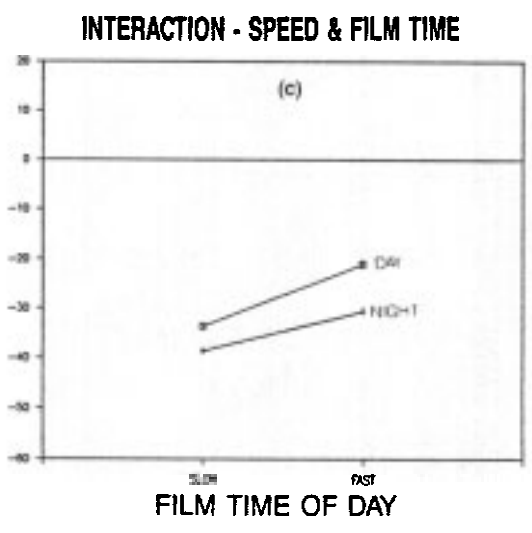
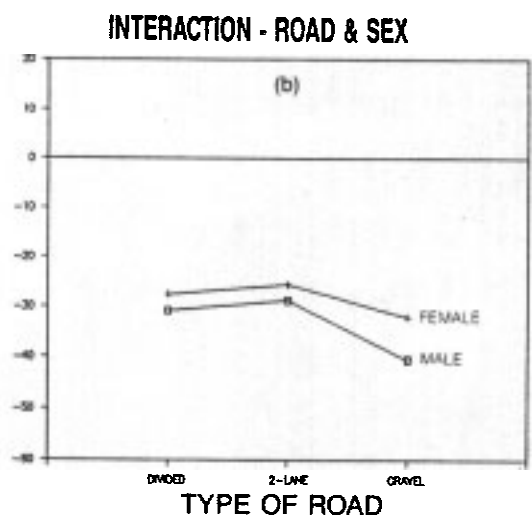
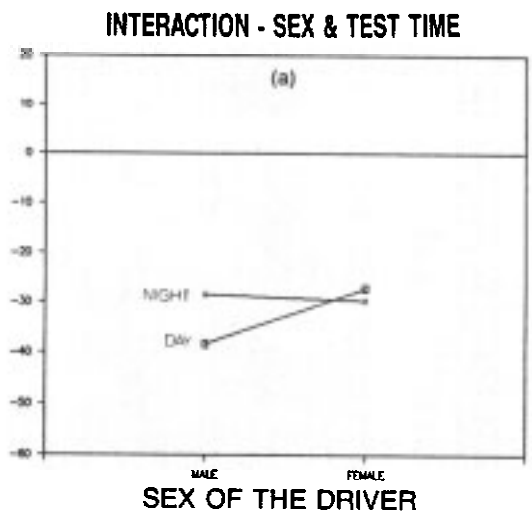


FIGURE 2.8 — Speed estimate error interactions of interest in the day/night experiment.

The main effects for driver experience (Figure 2.7d) and sex of the driver (Figure 2.7e) were also not significant but of noteworthy strength ($F(1,40)=1.7$ and 1.6 , $p=0.20$ and 0.21 , $w^2=.0078$ and $.0071$ respectively). These results suggest that males and novice drivers made greater speed estimate errors than experienced drivers and females. All of these variables were between subject manipulations in this experiment.

The interaction between type of road and the sex of the driver shown in Figure 2.8b, however, was significant ($F(2,80)=5.5$, $p<.01$, $w^2=.0037$). Male travel speed errors were much greater on gravel roads, compared to both sealed roads and to female errors. This effect accounted for 2 per cent of the treatment variance.

A significant interaction was observed between presentation speed and film time shown in Figure 2.8c ($F(1,40)=20.9$, $p<.002$, $w^2=.0036$). The error difference between slow and fast presentations was much greater for day films than night films.

The interaction between presentation speed and type of road shown in Figure 2.8d was also significant ($F(2,80)=13.8$, $p<.001$, $w^2=.0034$). The error difference between slow and fast presentations also appears disproportionate for 2-lane roads than for either divided or gravel roads. This effect accounted for 1.5 per cent of the treatment variance.

The interaction between type of road and film time in Figure 2.8e was significant ($F(2,80)=7.1$, $p<.01$, $w^2=.0025$), where the error difference between day and night film sequences was less on gravel roads than on comparable sealed roads. This interaction accounted for 1 per cent of the treatment variance.

A significant film time and sex of the driver interaction was observed in Figure 2.8f ($F(1,40)=4.5$, $p<.05$, $w^2=.0023$). Speed errors between male and female subjects were less for day than night tests. This interaction accounted for 1 percent of the total treatment variance.

As in the safe operating speed data, there was again no significant interaction observed in the subjects' speed estimates between test time and film time, shown in Figure 2.7f ($F(1,40)=<1$, $p=0.96$, $w^2=0$).

2.4.3 Free Speed Data

Free speed data were collected at 8 of the 12 sites used in the experiment (there were insufficient vehicles on the gravel roads to obtain meaningful samples). These sites were measured during the day and night, yielding a total of 16 sets of data (the means, standard deviations and 85th percentile values obtained are listed in Tables A-1 and A-2 in the Appendix of this report). The mean free speed for all sites was 99.5 km/h or approximately 4 km/h less than the average posted speed, while the average standard deviation for all sites was 11.4. The 85th percentile speed was 111 km/h or 7 km/h above the mean posted speed.

Figure 2.9 shows the speed variation plots for time of day, type of road and roadside environment. There was practically no difference observed in the mean or 85th percentile speeds during the day or night as shown in Figure 2.9a. The apparent interaction between time of day and roadside environment in Figure 2.9b, however, might suggest that speeds were faster at spacious sites and slower at walled sites during the day compared to those observed after dark.

SPEED LIMIT VARIATION (km/h)

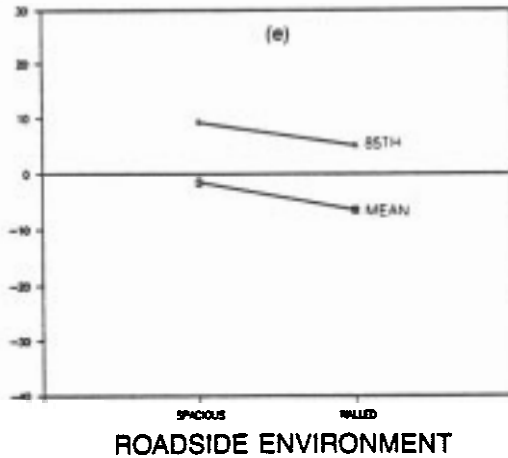
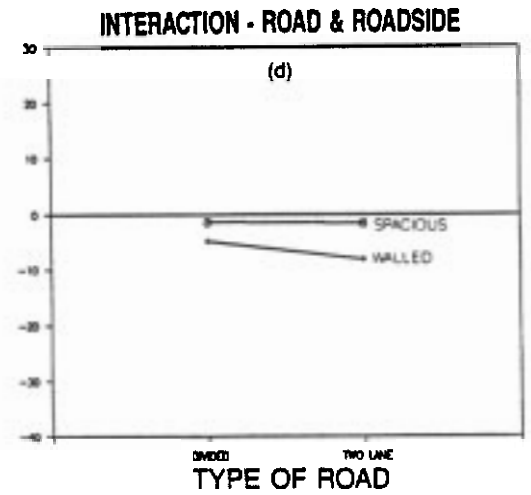
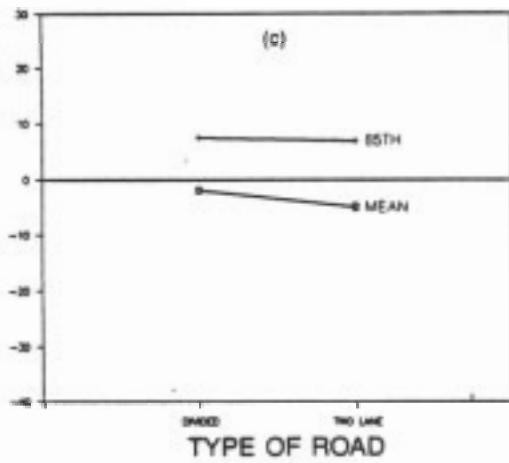
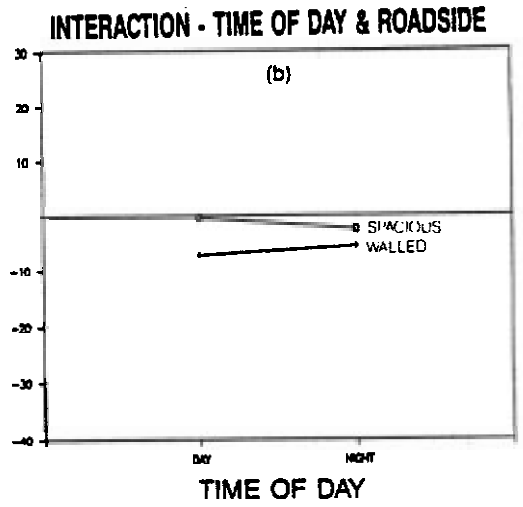
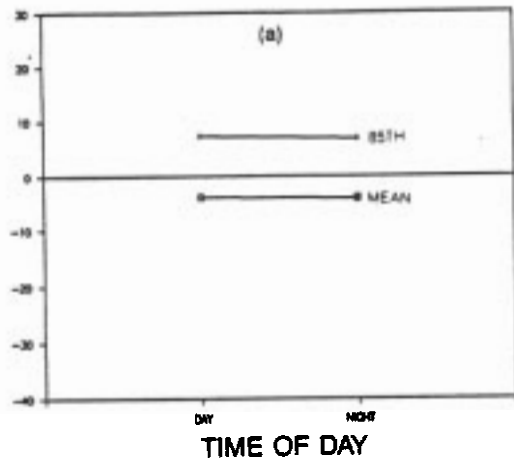


FIGURE 2.9 — Free speed variations around the speed limit in km/h for the variables of interest in the day and night vision experiment.

Figure 2.9c shows that the mean speeds on 2-lane roads appeared to be much less than the posted speed limit, compared to those observed on divided roads. However, there were larger speed variations recorded on the undivided roads, such that the 85th percentile speeds for both road types were roughly the same amount over the speed limit. It should be noted that three of the four divided road sites had 110 km/h speed limits, while all four of the 2-lane road sites were limited to 100 km/h, and this would help explain some of the variance differences observed.

Figure 2.9d reveals an apparent interaction between type of road and roadside environment, where mean speeds at spacious sites were close to the speed limit for both divided and 2-lane highways, but was disproportionately slower on 2-lane walled roads than on divided walled roads.

The apparent main effect for roadside environment in Figure 2.9e was further confirmation that free speed mean and 85th percentile values were generally slower at walled than at spacious sites.

2.5 DISCUSSION

The results from this experiment are best discussed in terms of the independent variables that were tested. The findings from the three sets of data provide a comprehensive account of the role of each factor in a driver's perception of speed on the road during day and night illumination conditions.

2.5.1 Presentation Speed

Presentation speed had the strongest effect on the results observed for both the safe operating speed and travel speed estimates. Subjects responded to travel speeds 15 per cent

below the posted speed limit as too slow relative to their ideal safe operating speed, while speeds 15 per cent faster than the posted speed limit were judged to be about right. In addition, they under-estimated travel speed much more for slow than for fast travel speeds.

This result is generally consistent with the findings for this variable in the previous project (Fildes, Fletcher and Corrigan, 1987) and is further confirmation of the success of the experimental technique and the need for moving, rather than static, stimulus materials when assessing speed perception.

Presentation speed was also seen to interact with type of road and film time in both analyses. For the former, this suggests that speed differences are not so apparent on gravel roads than those which are sealed, especially at night. This result is not so surprising as gravel surfaces are quite irregular and uneven (motion cues would be less systematic on streaming patterns arriving at the eye for these roads) and there is no centreline delineation on these roads to further enhance the perception of speed. The reduction in available light at night, too, would represent a sizable reduction in available motion information, particularly at slow travel speeds.

2.5.2 Type of Road

As in the previous project, this variable manipulation had the second strongest effect in both analyses confirming the importance that subjects placed on the road surface in their perception of speed. Responses systematically reduced from that considered an ideal safe operating speed on gravel roads to an

overly safe response on divided roads, even though the pavement width was approximately the same. Errors in estimating travel speed, too, were much larger on gravel roads than for the equivalent sealed surfaces, while free speeds tended to increase as the road surface improved.

This is further support for the notion that drivers' perceptions of safety are enhanced on high quality road surfaces such as freeways, compared to those on major undivided arterials or local rural highways. The divided road advantage was especially evident for fast presentation speeds.

Type of road only interacted with time of day of the filming in the error analysis where subjects made relatively larger speed estimate errors for sealed roads at night compared to gravel roads. While this might have minor ramifications for the effectiveness of delineation treatments, it is reassuring to know that speed perceptions are not unduly affected by darkness on any particular type of road.

2.5.3 Day and Night Driving

This experiment was principally concerned with testing the effect of daylight and darkness on speed perception. While drivers' responses to day and night scenes were of primary interest, the time of day of testing was also studied to examine whether biological rhythms had any influence on speed perception.

Regarding the former, the results show that perceptions of speed were less safe at night than during the day, all other things equal. Moreover, errors in estimating travel speed were also greater at night than during the day. While these findings may

seem intuitive because of the large reductions in the amount of visibility information available after dark, they do, however, differ from previous findings.

Elliot (1981) reported that drivers felt more safe at night, presumably because of lack of environmental information (the "devil you don't know can't hurt you" phenomenon). The results from this experiment clearly disprove Elliot's enhanced safety hypothesis and reaffirm the fallacy of relying too much on verbal reports in perceptual studies.

The findings also contradict the claim of Triggs and Berenyi (1982) that drivers judge road speed more accurately at night than during the day. It could be that the higher travel speeds adopted in this project somehow reverse the pattern of responses they reported, although it would be difficult to explain why this might be so.

Alternatively, the sites used in this experiment generally had minimum levels of road delineation, compared to the high level reflectorized road markers and other delineation treatments used in the earlier study. Thus, there were less high contrast, systematic indicators of travel speed in this study to that of Triggs and Berenyi. If this is true, it reinforces the need for high quality delineation systems on roadways at night to offset the severe degradation in road information.

There was no main effect for time of day of testing, although it did account for a sizable share of the experimental variance. Given that there were 24 subjects in each group, it would not seem to be a function of a lack of data. More likely, any differences in biological cycles between 9am and midnight do not

substantially influence the perception of speed on the road. This is further supported by the lack of an interaction between film time and test time.

2.5.4 Roadside Environment

The type of roadside environment again influenced judgements of speed. Spacious environments were perceived to be much safer than walled environments, although neither were judged here to be particularly unsafe. This effect, however, was only evident during the day as there was no difference in perceived safety between spacious and walled environments at night. In addition, walled sites had slower free speeds during the day than spacious sites during the day or all sites at night.

This result is not too surprising as differences in roadside environments are not so apparent at night under headlight illumination. The lack of peripheral visual information at these times may lead to less uncertainty in the perception of what is a safe operating speed. This suggests that peripheral vision and streaming effects are most important in the perception of speed (Gibson 1950, 1958, 1968; Calvert 1954; Gordon 1966; Moore 1968).

Unlike the earlier speed estimate finding for this variable in rural environments (Fildes et al 1987), there were no differences observed in this experiment in travel speed errors. This suggests further that the lack of roadside information has severely degraded speed perception at night.

2.5.5 Driver Variables

The subjects recruited in this experiment comprised equal numbers of experienced (full drivers licence) and inexperienced (first year provisional licence) drivers as well as males and females to evaluate the effects of driver experience and sex on the perception of speed at night. The results showed that the amount of driver experience had no significant effect on the results of this experiment. Both groups of drivers responded essentially the same in their judgements of safety and travel speed during both day and night conditions. **This confirms the earlier claim** that differences in driving behaviour between novice and experienced drivers are not due to any fundamental difference in the way they perceive the environment.

Unlike the previous experiment, though, the sex of the driver was a significant effect in the safe operating speed judgements and also interacted significantly with the type of road in the travel speed estimates. These results showed that females judged travel speed around the posted speed limit to be ideal, whereas male perceptions tended to be too slow in these environments. The earlier study did report similar results, even though they were not statistically reliable (Fildes et al 1987). In this experiment, however, the extra number of subjects in each sex category seems to have resulted in statistical significance.

The previous project speculated that this difference may reflect the lack of rural driving by females as it is quite common for males in our society to do most of the driving in country areas. While experience per se did not appear to be a significant factor in speed perception, this does not preclude the possibility that

a particular sub-group of drivers, namely females, may still perceive speed differently to others (the overall lack of an experience effect would still be expected as there were male subjects in both the experienced and inexperienced conditions). In short, the influence of driver experience in speed perception may be more dependent on the type of driving undertaken, rather than the absolute amount of driving exposure. This result warrants further investigation.

Importantly, however, there was no difference in the way males and females perceived speed during the day to that at night. This is reassuring as it shows that there is no perceptual vulnerability for one sex over the other at night in rural areas.

2.5.6 Speed Behaviour and Perception

The free speed data generally showed that the majority of vehicles studied chose to travel at or below the posted speed limits at the sites studied in this experiment. These included both major divided roads and 2-lane rural highways.

Of particular note, though, was the fact that the observed speeds at night were not substantially different to those recorded during the day, even though the laboratory results showed that the subjects' perceptions of safety reduced markedly at night. As judgements of safe operating speed were generally towards the very safe end of the scale during the day, this might suggest that reductions in perceived safety are less likely to influence travel speed directly when drivers judged the situation to be particularly safe. This was reported earlier in Fildes, Fletcher and Corrigan (1987) who argued that perceptual modifications would only induce speed reductions in perceived hazardous areas.

3. LABORATORY VALIDATION STUDY

The validation study in the previous project (Fildes et al, 1987) showed that speed perception on urban and rural straight roads could be simulated effectively in a relatively simple laboratory environment. While there was some sign of a reduction in overall sensitivity to safety and speed in the laboratory, the pattern of results between the variables was essentially the same across all conditions. Thus, the validity of testing the relative effects of the geometric factors of interest on straight roads in the laboratory was established.

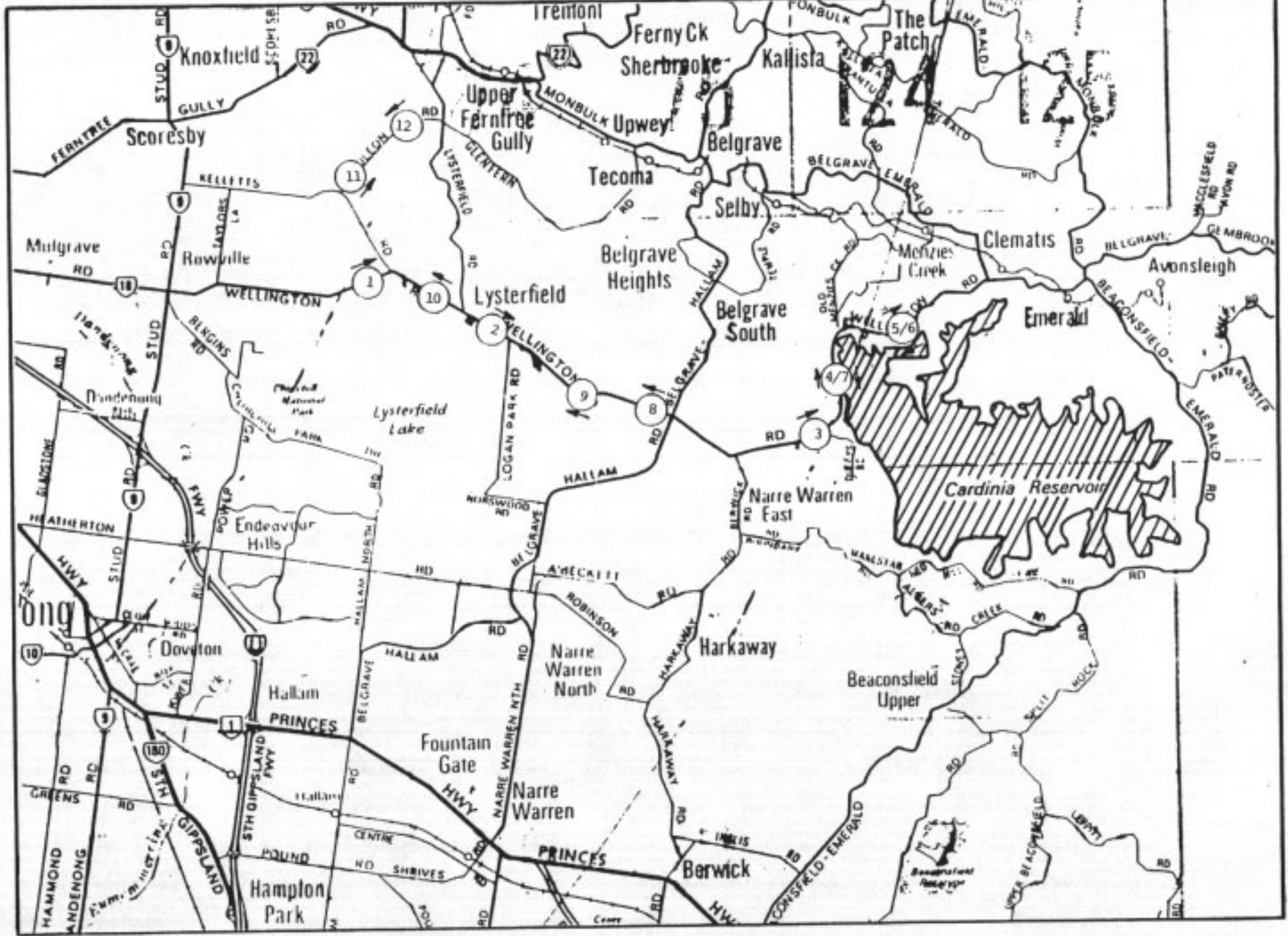
However, a further validation study is necessary to assess the suitability of the laboratory presentation method for testing speed perception on horizontal and vertical curved rural roads.

3.1 STIMULUS MATERIALS

Twelve rural road sites on the outskirts of the Melbourne Metropolitan area were selected as typical examples of the range of road sites to be used in the main experiment (see Figure 3.1 and Appendix A for full details of the pilot sites and travel route used).

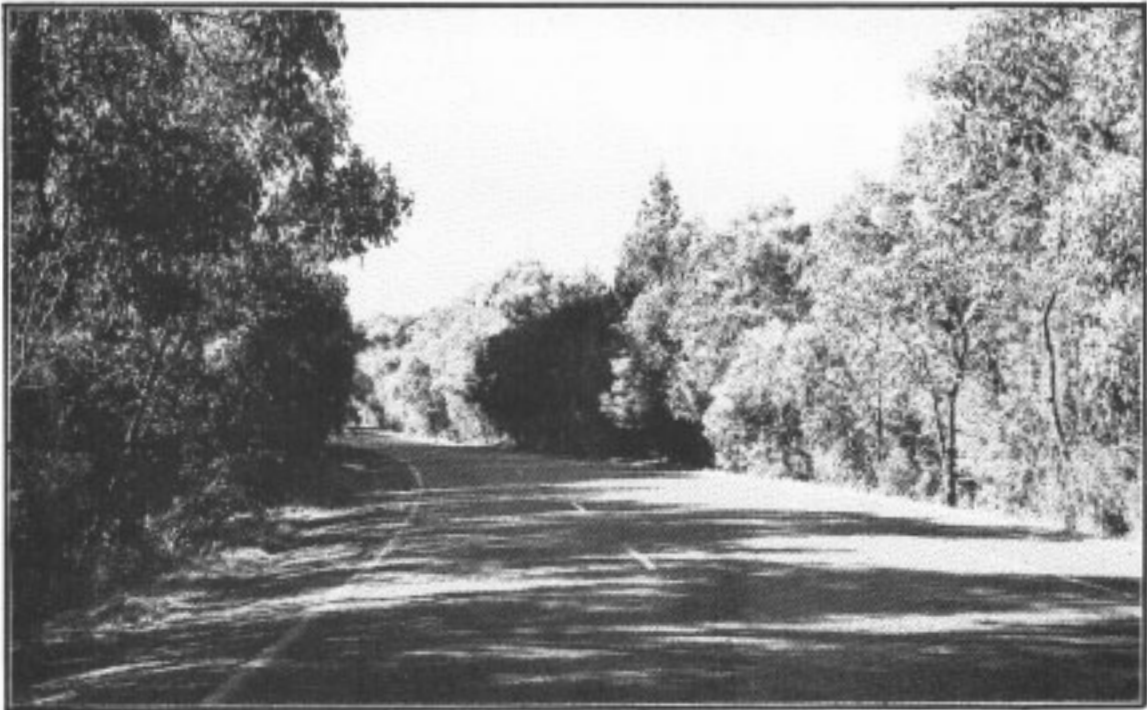
The selected sites offered a range of horizontal and vertical curves and rural roadside environments as shown in Figure 3.2. At each chosen road site, the road distance travelled in 5sec at 100 km/h was discreetly marked. These road segments constituted the stimulus materials for road and laboratory testing, as well as for free speed measurement of vehicles using the road.

FIGURE 3.1 — Test sites and travel route used in the curvature validation study.





Site 8 — Undivided, 2-lane, walled crest in road



Site 3 — Undivided, 2-lane, walled, left hand curve.

FIGURE 3.2 — Typical road sites used in the curvature validation study.

3.1.1 Movie Film Sequences

Movie road scenes were generated using 16mm colour films taken from close to the driving position of a typical Australian automobile. The movie film technique allowed for a large film presentation, resolution of fine road details, and an accurate perspective image size.

Each road section at the 12 selected sites was filmed for 5sec using a 16mm camera mounted near the driver position of the car. The 12 film segments were structured into a fixed sequence, each separated by 10sec of blank film. A practice film, comprising six novel road sites separated again with blank film, was also provided to allow subjects practice at making speed and safety estimates in the laboratory.

3.1.2 Free Speed Measurement

Free speed data for 100 vehicles were collected at the midpoint of each section of road to highlight perceptual and behavioural differences (see Appendix A for full details of the free speed data). Measurements were made by an observer seated in an unmarked car fitted with a Gatso mini (across the road) or a Kustom HR4 (hand held) radar unit.

3.2 APPARATUS

The purpose of the laboratory trials was to determine whether subjects' responses to the filmed road sites would be similar to responses made by subjects viewing the same scenes from the passenger seat of a car driven by an experimenter. The same laboratory and equipment from the previous experiment was again used for the off-road trials (see Chapter 2 for full details of

the laboratory arrangement). The road trials were conducted in the research vehicle (Ford Falcon sedan) with the subject seated in the front passenger seat. Speed and safety judgements were recorded in response booklets as before.

3.3 SUBJECTS

Eighteen subjects with varying degrees of driving experience and no prior knowledge of the present project were recruited. Nine subjects were assigned to the on-road experiment and nine to the laboratory experiment; each group comprised 5 females and 4 males. Experimental instructions for the on-road and laboratory experiments were recorded on a cassette tape (text described in Appendix B) to provide each subject with consistent information about the experimental task.

3.4 EXPERIMENTAL PROCEDURE

A similar experimental procedure was developed for the road and laboratory trials to ensure both sets of data could be directly compared.

3.4.1 Road Trials

The on-road experiment involved driving each subject individually along a pre-determined course encompassing practice sites and 12 test road sites (see Figure 3.1). All road trials were conducted during off-peak traffic conditions, on dry roads, and in good light conditions.

Subjects were given a response booklet and sat in the front passenger seat of the experimental vehicle. One experimenter was assigned to drive the car, while another sat in the rear seat and

conducted the experimental trial. Prior to arriving at the test course, the subject listened to the recorded instructions and any doubts about the required task were clarified. On arriving at the practice site, the driver shielded the car speedometer from the subject's view by placing a cloth over the dashboard and played white noise through the car's stereo system. The practice trial was then carried out.

At the start of each trial, the subject was asked to look down at the response booklet on his or her lap and to look up only when instructed. As each test site approached, the driver adjusted the speed of the experimental car to 100 km/h and positioned the vehicle to maximize headway (as a rule, a 5sec free headway was adopted as a minimum trial requirement, although no traffic was always aimed for at each site). In between sites, the driver varied the speed of the vehicle to ensure that vehicle speed was both increased or decreased on the approach to sites. As the vehicle entered the site, the subject was asked to look up and view straight ahead. After 5sec of viewing time, the subject was then asked to look down again and make his or her assessments of safety and travel speed. The experimenter stressed on the subject that they should try and make their responses as spontaneous as possible. After each test trial, the experimenter instructed the subject to relax and engaged him or her in casual conversation to distract attention from the road and traffic.

3.4.2 Laboratory Experiment

The procedure used for off-road testing was similar to the road trial method described above. Each subject was seated in the laboratory in the correct position in front of the projection

screen and listened to the recorded instruction. The subject was then shown the practice film comprising both urban and rural road scenes. The film of the 12 pre-determined road sites was then run in the same order as the road trials. During the 10sec of blank film between each road scene, subjects looked down and made their assessments of safety and travel speed. At the conclusion of the experiment, subjects were questioned about their impressions of the task and what strategies they used in their judgements.

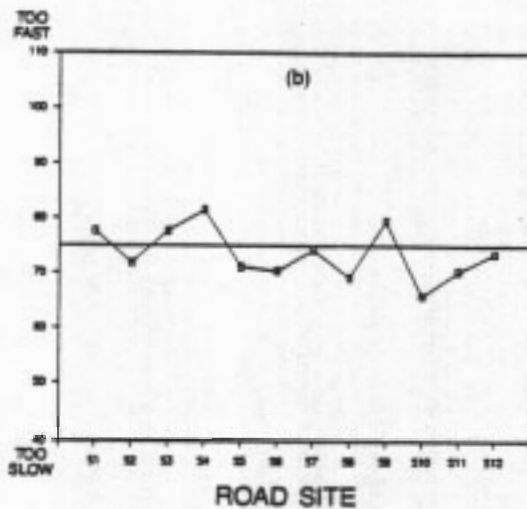
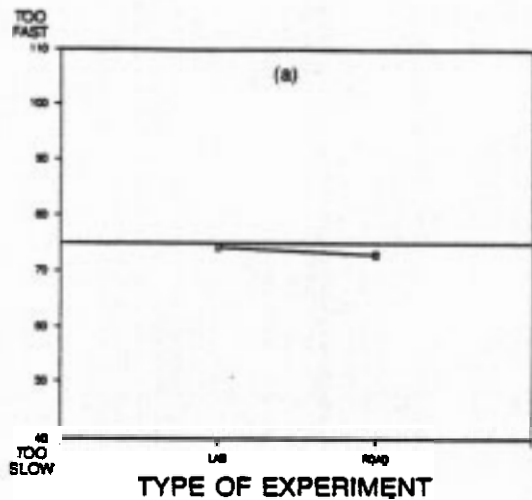
3.5 RESULTS

The safe operating speed responses for each site in both the road and laboratory experiment were converted into millimeters and the speed estimates were transformed into error scores as before. These data were then analyzed using the BMDP P4V program for analysis of variance and omega-squared statistics were also computed. The 2-way analyses comprised 12 values of a within-subject variable for "road site" and two values of a between-subject variable for "experiment". The analysis of variance summary tables are shown in Appendices C-3 and C-4.

The free speed data means, 85th percentile values and standard deviations are listed in the Site Detail Tables in Appendix A-3. No formal statistical analysis was carried out on these data, and hence, the results are interpreted in terms of general trends only. All three sets of data have been reported separately.

3.5.1 Safe Operating Speed Responses

The safe operating speed results are listed in Appendix C-3 and are shown in Figure 3.3. There was a significant main effect for road site, shown in Figure 3.3b ($F(11,176)=3.7$, $p<.001$, $w^2=.066$).



INTERACTION - ROAD SITE & EXPERIMENT

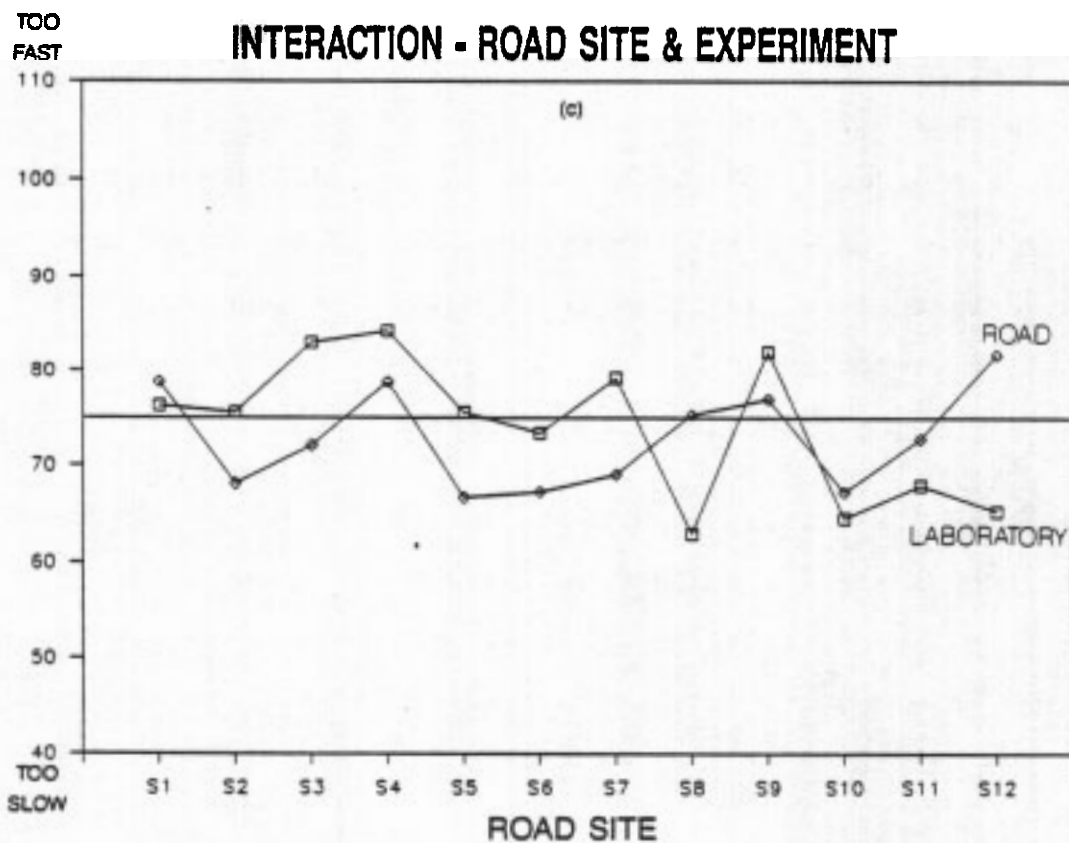


FIGURE 3.3 — Safe operating speed results of interest in the curvature validation study.

SAFE OPERATING SPEED JUDGEMENT

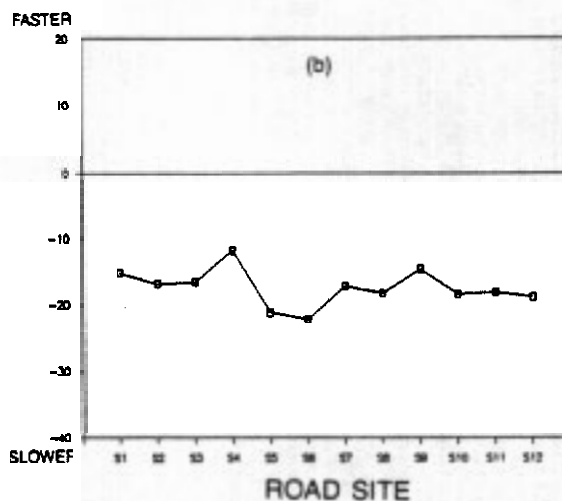
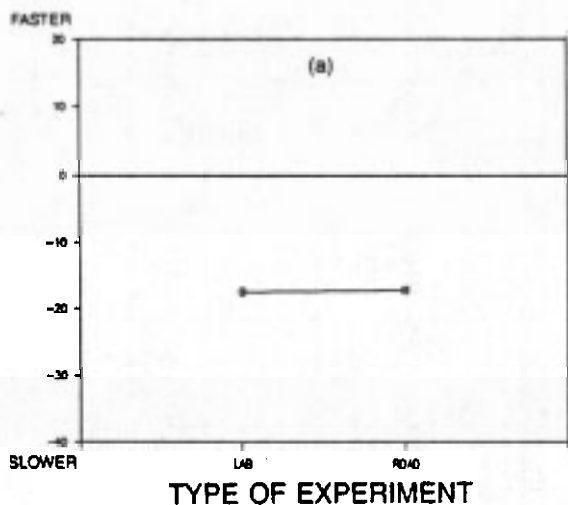
Subjects expressed considerable differences in their judgements of safety across the 12 road sites used in this experiment. This manipulation was the strongest effect observed, accounting for more than one-half of the total treatment variance in these data.

A significant interaction was also observed between experiment and site, shown in Figure 3.3c ($F(11,176)=3.4$, $p<.001$, $w^2=.059$). The source of this interaction appears to be the reversal in the pattern of responses between the road and laboratory trials for sites 1, 8, 10, 11 and 12. For all other sites, the laboratory responses were judged similar to the road responses (albeit at a higher overall level of safety) and consistent with that reported in Fildes, Fletcher and Corrigan, 1987). The main effect for experiment, shown in Figure 3.3a was not significant ($F(1,88)=<1$, $p>.05$, $w^2=0$).

3.5.2 Speed Estimation Errors

There were no significant effects apparent in the analysis of the speed estimate errors in this experiment, detailed in Appendix C-4 and plotted in Figure 3.4.

While the interaction between experiment and site (Figure 3.4c) attracted the highest omega-squared value, it was not a significant effect ($F(11,176)=1.2$, $p>.05$, $w^2=0$). The main effect for site, shown in Figure 3.4a, was also not significant ($F(11,176)=1.1$, $p>.05$, $w^2=.003$) and neither, too, was experiment, shown in Figure 3.4b ($F(1,11)=<1$, $p>.05$, $w^2=0$). None of the apparent differences in the speed estimate data, therefore, were statistically reliable.



SPEED ESTIMATE ERROR (km/h)

INTERACTION - ROAD SITE & EXPERIMENT

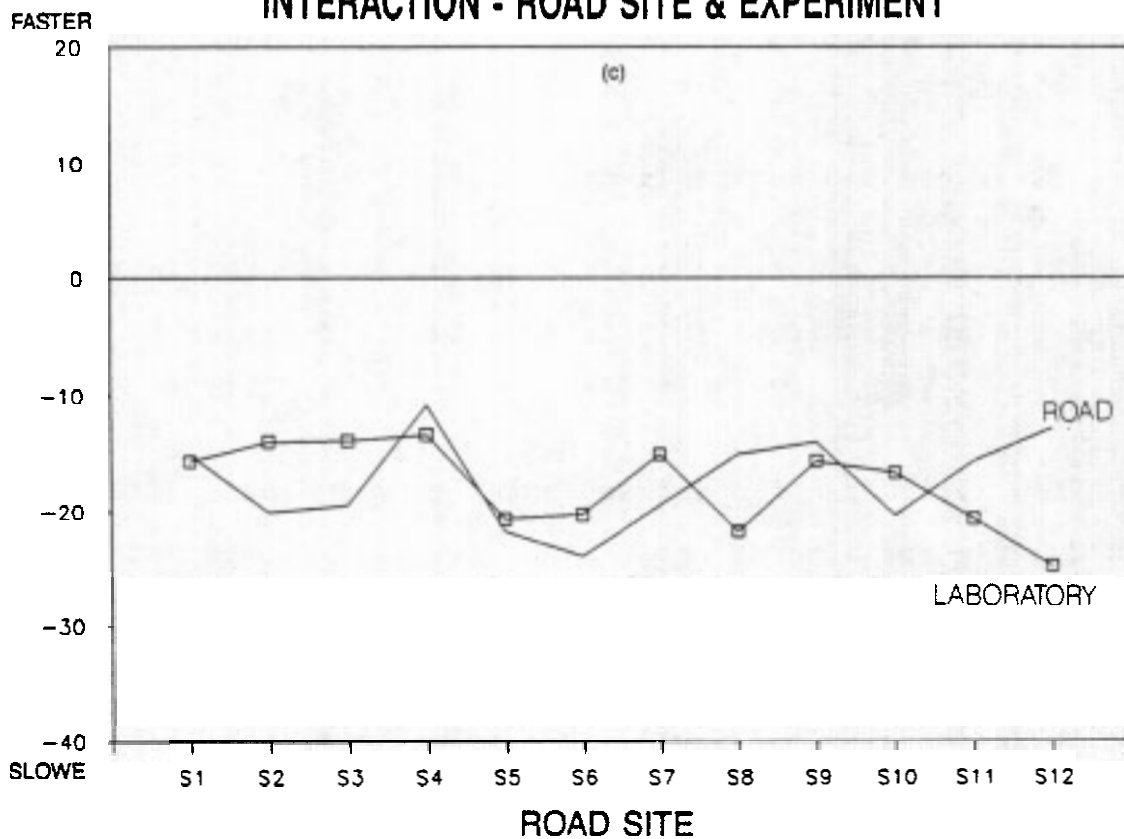


FIGURE 3.4 — Speed estimate error results of interest in the curvature validation study.

3.5.3 Free Speed Data

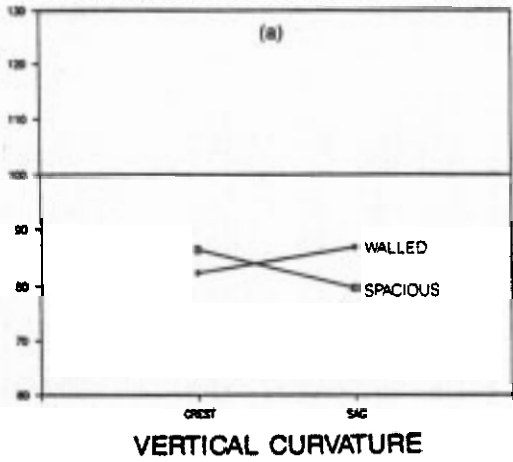
Free speed data were collected at the 12 test sites and are summarized in Appendix A-3 with the site definition information. In addition, the mean speed values observed at each site, along with the posted speed limits, are plotted in Figure 3.5. For reasons previously explained, no formal analysis was performed on these data. Hence, the report of these results will be confined to a descriptive analysis only.

The mean travel speed was approximately 12 km/h below the posted speed limit across all sites while the overall 85th percentile value was -3km/h. In general, the free speeds observed at the horizontal curve sites (numbers 3,4,5,6,7 and 9) were noticeably higher than at the vertical curve sites (sites 1,2,8,10,11 and 12). However, further breakdown by curve direction or roadside environment is not possible from these data.

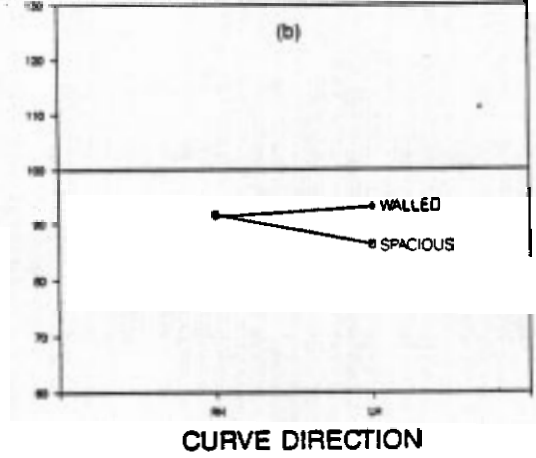
3.5.4 Road & Environment Effects

The main purpose of the validation study was to test the suitability of the laboratory for eliciting road speed judgements. A restricted range of road and environment variables were used here and the variable combinations were not exhaustive. Nevertheless, a preliminary evaluation of these effects was still possible, providing care was taken not to interpret too much from these results. Figure 3.6 shows the plots of the safe operating speed estimates for the road and environment factors. Several points can be made from these figures.

INTERACTION - VERTICAL CURVE & ROADSIDE



INTERACTION - DIRECTION & ROADSIDE



FREE SPEED (km/h)

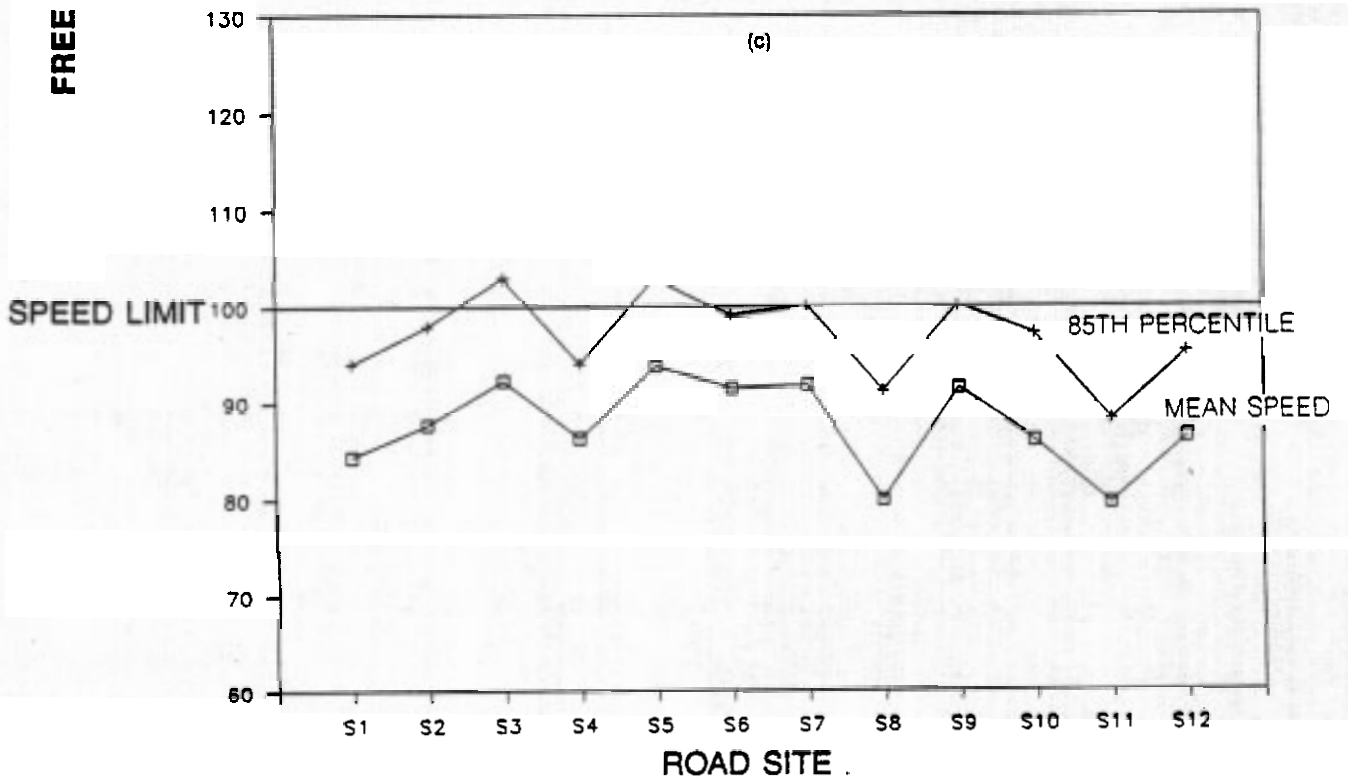


FIGURE 3.5 — Free speed measurements in km/h taken at the 12 test sites used in the curvature validation study.

SAFE OPERATING SPEED JUDGEMENT

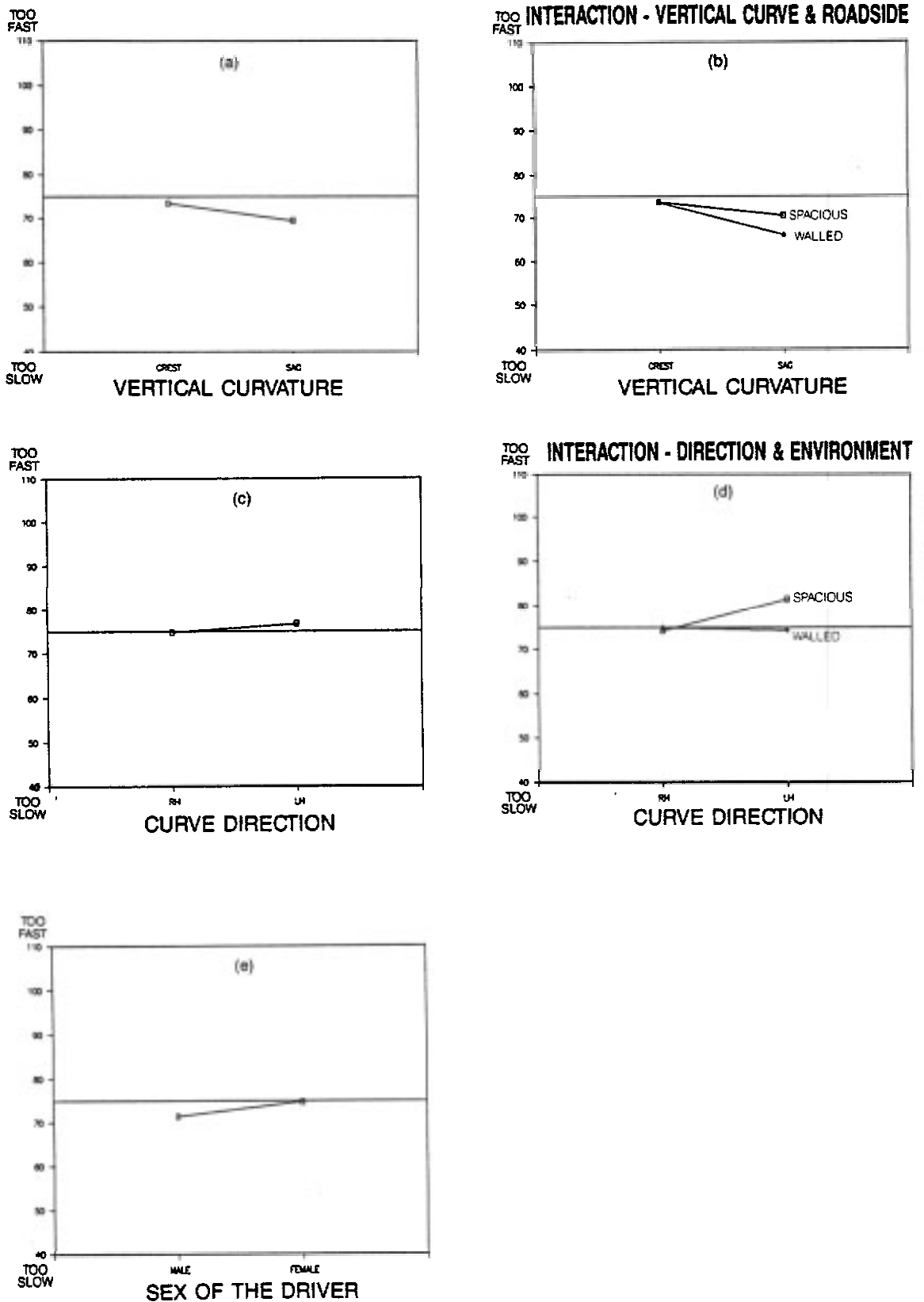


FIGURE 3.6 — Safe operating speed judgements for a range of road and driver factors in the curvature validation study.

First, the pattern of responses for vertical curves in Figure 3.6a suggests that crests were assessed as less safe than sags. This was expected because of the large differences that exist in sight distance between these two configurations. However, walled sites were judged to be more safe than spacious sites in Figures 3.6b and 3.6c. This result is opposite to that expected, although it is difficult to be too definitive about this finding because of the minimum number of sites involved in this study. There was also some suggestion of an interaction between vertical curvature and road environment shown in Figure 3.6b, where a walled environment degraded the safe operating response for sag curves alone. This can be explained in terms of available sight distance and visual streaming effects.

The results shown in Figure 3.6c indicate a marginal decrease in perceived safety for LH over RH curves. While this finding was not particularly convincing here, it was predicted from earlier curve perception research (Stewart, 1977; Triggs, Harris & Fildes, 1979; Fildes and Triggs, 1984; Fildes, 1987).

There was also an apparent interaction between curve direction and environment, shown in Figure 3.6d, where speeds on LH spacious environments were judged to be less safe than on either LH walled curves or all RH curves. While this result is difficult to interpret in terms of increased sight distance, it should be treated with some caution, given that these data include both horizontal and vertical road curvatures and only one road site in each condition.

Male drivers in Figure 3.6e appeared to judge travel speeds at the posted speed limit to be much slower than what they considered to be their ideal travel speed for these environments, whereas female assessments were about right.

3.6 DISCUSSION

The results of the validation study have again confirmed the appropriateness of using laboratory simulation for eliciting road speed perceptions at horizontal curve sites. While the safe operating speed responses were generally higher (less safe) in the laboratory than on the road, the pattern of results obtained between test sites was similar in form for both the safe operating speed judgements and the travel speed estimates.

In other words, while there appears to have been some loss of reality from off-road testing, the laboratory method is still capable of eliciting similar relative effects when experimentally manipulating the variables of interest. This result is consistent with that reported previously for flat straight roads (Fildes, Fletcher & Corrigan, 1987).

The results for vertical curve sites, however, were contrary to those reported for horizontal curved roads. Estimates of travel speed on the road were judged to be **less safe** overall than in the laboratory, and errors in estimating travel speed were quite inconsistent across both the experimental methods. This seems to suggest that the absence of non-visual cues (ie, gravitation forces) in these vertically curved environments may have had a marked effect on the subjects' perceptions of speed.

Whether this suggests that the laboratory method is not suitable for testing vertical curvature, however, is not clear. Figure 3.7 is a re-plot of the earlier Figure 3.3c, only this time with the results for horizontal and vertical curves separated. This shows that while the absolute level of response to what was considered safe in the road and the laboratory trials was reversed between the vertical and horizontal curvature sites, the pattern of responses was, nevertheless, reasonably consistent within both sets of results. In other words, the results may still suggest validation for both types of curvatures, albeit of a different (reversed) form for these roads. There is clearly a need for additional validation testing of vertical road curves.

The lack of any strong effect in the estimates of travel speed is rather puzzling, given the previous findings in Fildes et al (1987). However, while the pattern of responses was not significantly different in this validation analysis, it did tend to follow the same form as the pattern of safe operating speed responses. More subjects may be required, therefore, to obtain statistical significance with these responses.

The free speed data showed that the speeds that motorists tended to travel at at these 12 road sites was appropriate for the prevailing speed limits in rural Victoria. The mean speed was approximately 12 km/h below the posted speed limit while the 85th percentile speed was around or just below it (Joscelyn and Elston 1970 argued that the 85th percentile value is the preferred approach for establishing rural speed limits). This result is consistent with that reported for 2-lane straight rural roads in Fildes, Fletcher and Corrigan (1987).

SAFETY JUDGEMENTS — HORIZ. & VERT. CURVES

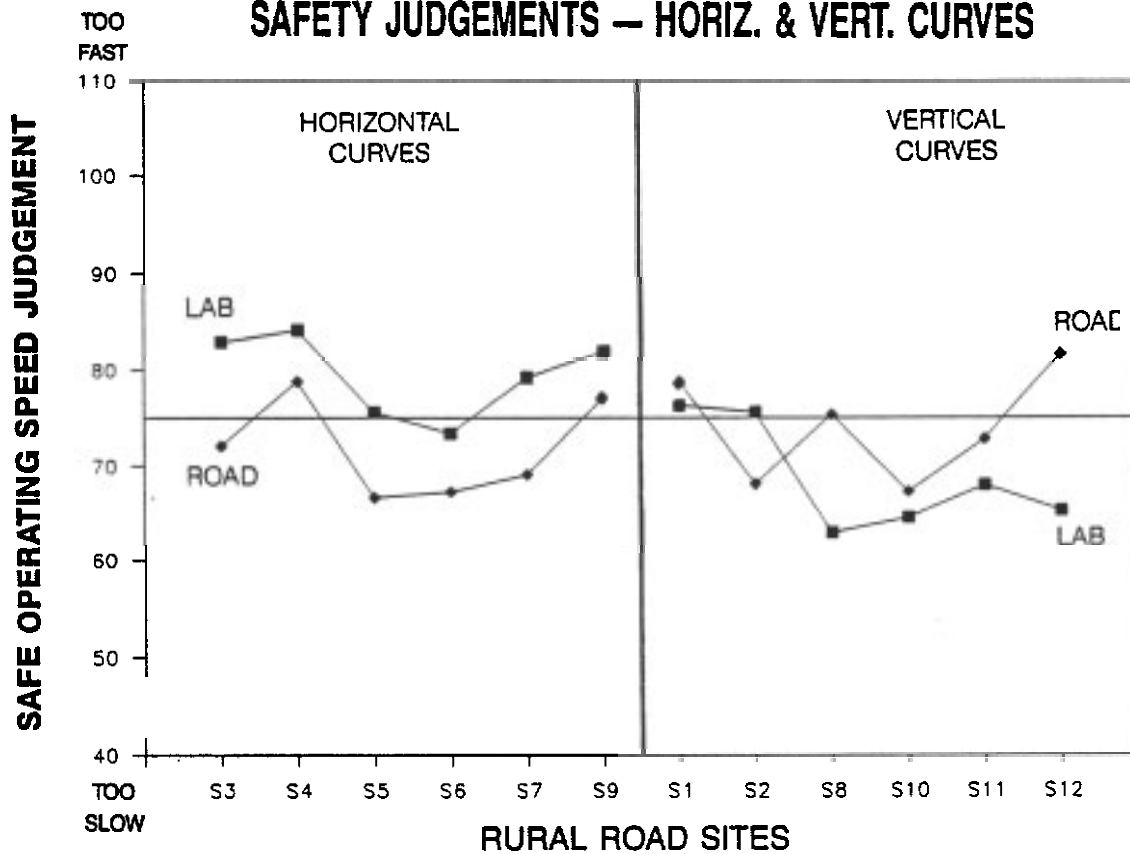


FIGURE 3.7 — Re-plot of the earlier safe operating speed interactions between road site and experiment only this time with horizontal and vertical curve results segregated.

The preliminary examination of road and environment factors highlighted some interesting findings. Without placing too much emphasis on these results, they nevertheless suggest that a systematic and thorough evaluation of these variables is likely to uncover new and important information about drivers' perceptions of speed on horizontally curved rural highways.

4. HORIZONTAL CURVATURE EXPERIMENT

The results of the laboratory validation study in Chapter 3 were most interesting. While further research is required to establish the validity of testing vertical curvature in an off-road simulator, it is clear from these data that horizontal curvature can be simulated accurately in a relatively simple laboratory environment.

The laboratory method used for testing speed perception on urban and rural straight roads (Fildes et al 1987) was again adopted to assess the effects of the road, roadside environment, driver experience and sex of the driver on subjects' estimates of safety and travel speed for rural horizontal road curves.

4.1 STIMULUS MATERIALS

Forty-eight road sites were located that encompassed the range of road and environment factors of interest. Details of the road sites are shown in Appendices A-4 to A-9, while Figure 4.1 shows some typical horizontal curves used in the experiment.

The independent variables included three road types (divided, 2-lane and gravel), two roadside environments (spacious and walled), two curve directions (left-hand and right-hand), two curve radii (large radius and small radius), two repetitions (different sites with the same characteristics), and two travel speeds (15 per cent above or below the posted limit). In total there were 96 road scenes in a fully crossed factorial design experiment.



Site 9 — Divided, 2-lane, spacious, left hand curve with small radius.



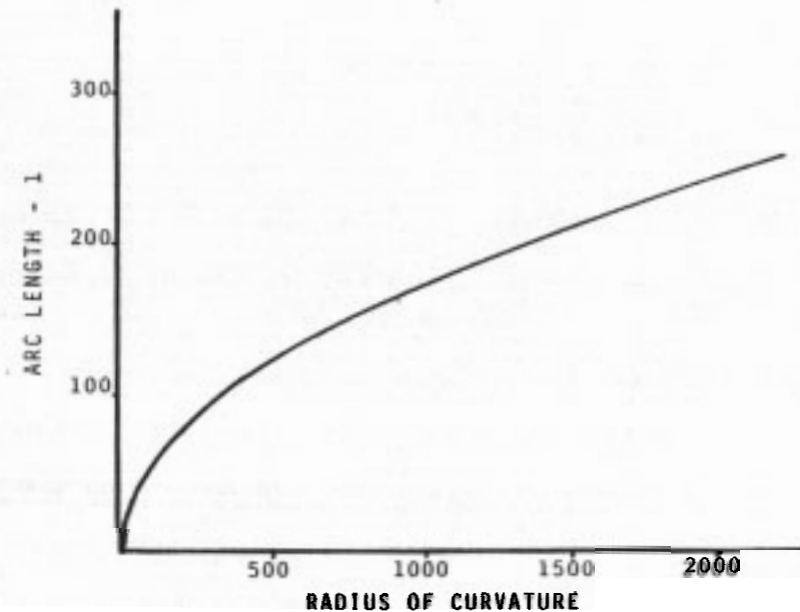
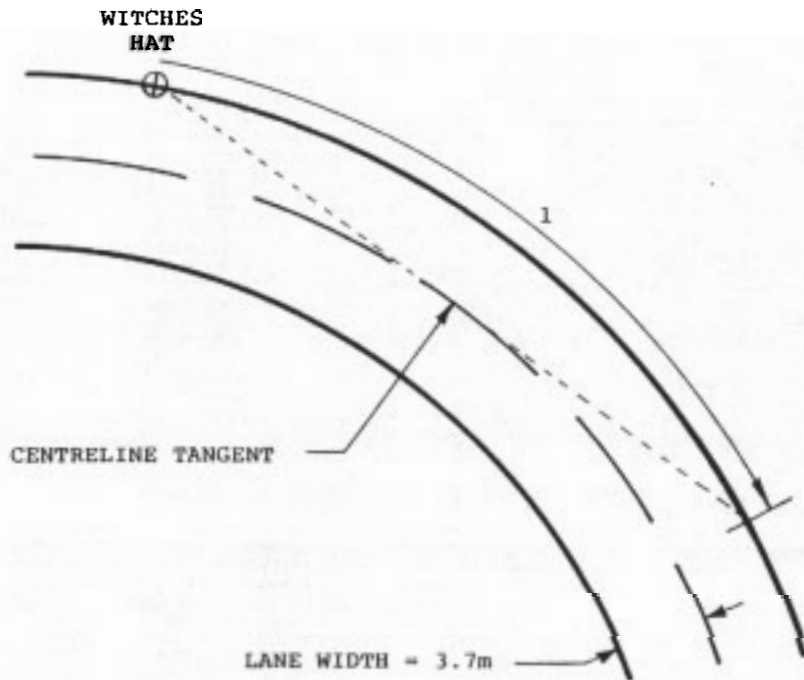
Site 40 — Undivided, 2-lane walled, right hand gravel curve with large radius.

FIGURE 4.1 — Typical rural curves used in the horizontal curvature experiment.

The two levels of radius were pre-determined from design standards of minimum and maximum values specified for each type of road curve (National Association of Australian State Road Authorities, 1972; 1980). For divided roads, a 1000m cut-off was adopted; a large radius curve was one with a radius greater than 1000m, while small radius curves had values less than 1000m. A 500m cut-off was adopted for 2-lane rural roads and a 250m cut-off applied to gravel roads. These cut-offs subsequently proved to be realistic values for the range of rural roads measured in Victoria. The method adopted for measuring the radius of curvature on-site is shown in Figure 4.2.

A suitable road segment was identified at each of the 48 road curves to ensure a minimum of 5sec film time within the curve with similar sight distance conditions. Each site was filmed at 15 per cent above and below the posted speed limit using the Bolex H16 reflex camera with 16mm Kodak colour negative 100ASA film. Films were processed into workprints and subsequently edited into 5sec film segments.

Six experimental films were produced, each comprising 16 randomly selected road curve scenes. Each scene was 5sec duration followed by 10sec of blank film. Road scenes with similar characteristics were placed on different film reels or as far apart in the sequence as possible. The presentation order of the films was also structured across subjects to ensure that each film was presented roughly equally in every serial position.



METHOD OF MEASUREMENT

On arrival at the site for measurement, a "witches hat" was placed on the outside edge of the road, roughly in the centre of the curve. Using a measuring wheel, the observer tracked around the outer edge of the road surface to a point where his line of sight to the witches hat was tangent to the centreline of the road. This enabled the arc length (l) to be determined which could then be translated into a radius value using the relationship shown above. Where the curve appeared to be a "transitional curve", radius was always calculated in the centre of the bend and checked on either side for apparent differences; the *minimum* value obtained was always assumed to be the actual radius level of that curve.

FIGURE 4.2 - Method used to measure the radius of curvature of the road curve sites.

A practice film comprising 12 novel horizontal road curves, each separated by 10sec of blank film, was provided to allow subjects practice at making speed and safety estimates in the laboratory. Subjects' estimates were again recorded in response booklets similar to those previously described.

A Kustom-HR4 hand held radar gun was used to measure the free speed of 100 vehicles at 34 of the 48 road sites (the gravel road sites could not be measured due to their low traffic volumes). Measurements were taken by an observer seated in an unmarked vehicle at the side of the road.

4.2 EXPERIMENTAL PROCEDURE

Seventy-two licensed drivers were recruited as subjects. Eighteen subjects were allocated to each of four driver groups (male-experienced, female-experienced, male-first year and female-first year) to test for experience and sex effects. Subjects were tested individually in a session lasting approximately one hour and were paid for their participation. The laboratory set up was identical to that used earlier.

Each subject was seated in front of the back-projection screen and was played a pre-recorded tape of the experimental instructions at the start of the session (see Appendix B-2). Any questions were then answered and the subject commenced the task with the practice film, followed by the six experimental films in their pre-determined order. During the 10sec of blank film between each road scene, subjects made their assessments of safety and travel speed in the response booklet provided.

4.3 RESULTS

The safe operating speed results were again scored in millimeters from the zero (too slow) end of the scale, while speed estimates were converted into speed estimate errors (+ or - km/h) from the actual travel speed. Both data sets were analyzed using the BMDP P4V program for analysis of variance and omega-squared statistics. The statistical summary tables for the significant and noteworthy effects (F values $>.05$ & w^2 values $>.002$) are shown in Appendices C-5 and C-6. The mean, standard deviation, and 85th percentile of the free speed measurements were computed and are listed in the site summary tables in Appendices A-4 to A-9. The results for each data set are again described separately.

4.3.1 Safe Operating Speed Responses

Appendix C-5 lists the statistical summary table of this analysis while Figures 4.3 to 4.5 show the effects of interest. There were four main effects and five interactions that warrant close attention and these are described in order of their omega-squared value.

The speed of presentation shown in Figure 4.3a was the strongest effect observed in this analysis ($F(1,68)=310.5$, $p<.001$, $w^2=.2380$). Slow speeds (15 per cent below the posted speed limit) were judged to be too slow, while speeds 15 per cent above the speed limit were assessed as too fast. This variable manipulation accounted for one-half of the treatment variance in this analysis.

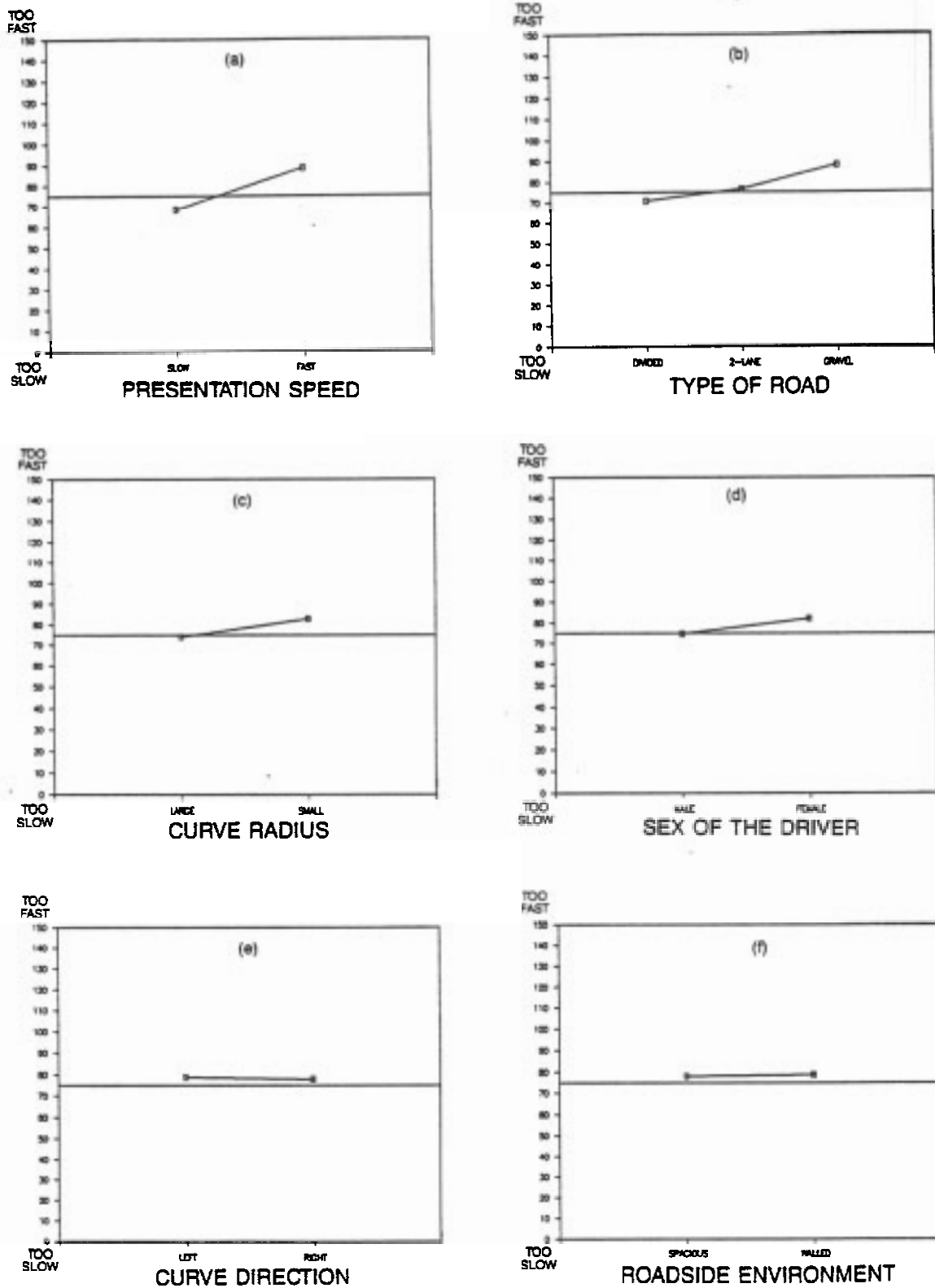


FIGURE 4.3 — Safe operating speed main effects of interest for the horizontal curvature experiment

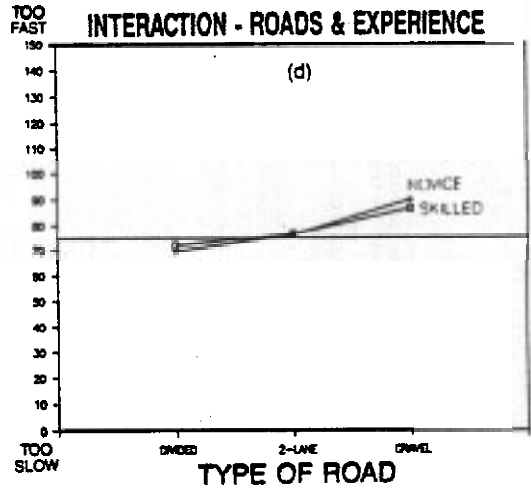
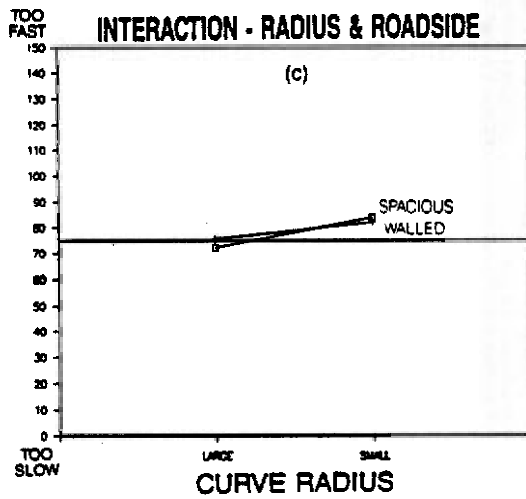
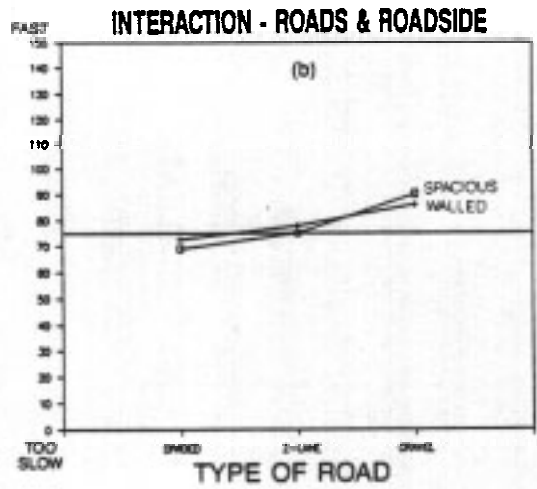
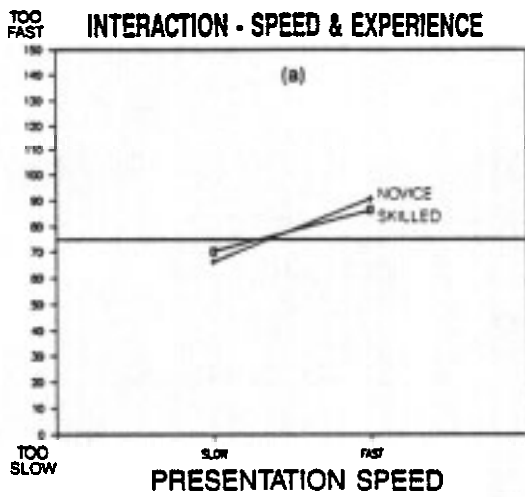


FIGURE 4.4 — Safe operating speed interactions of interest for the horizontal curvature experiment.

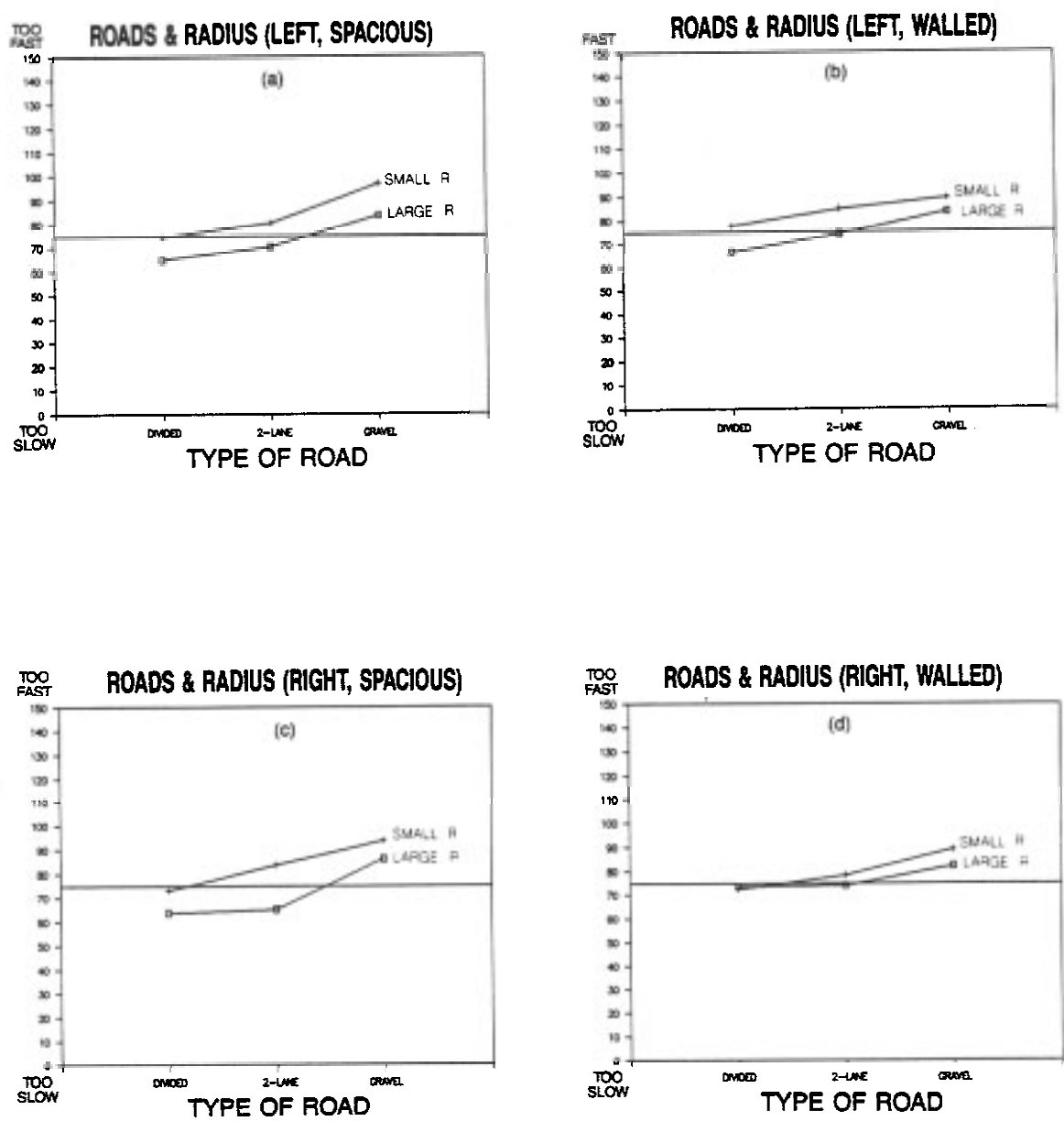


FIGURE 4.5 — Safe operating speed interactions of interest for the horizontal curvature experiment.

Type of road in Figure 4.3b was the second strongest effect ($F(2,136)=104.1, p<.001, w^2=.1199$). Subjects assessed travel speed to be too slow on divided road curves, about right on 2-lane roads, and too fast on gravel road curves. This variable accounted for 25 per cent of the treatment variance.

Radius of curvature in Figure 4.3c was also significant ($F(1,68)=232.0, p<.001, w^2=.0451$). Speed was judged to be safe on large radius curves but unsafe on small radius curves. With $w^2=.0451$, radius accounted for 10 per cent of the treatment variance.

The sex of the driver shown in Figure 4.3d was the next noteworthy significant effect ($F(1,68)=10.2, p<.01, w^2=.0297$). Presentation speed was judged to be safe by males, but too fast by females. This between-subject manipulation accounted for 6 per cent of the treatment variance in this experiment.

There was a significant interaction between presentation speed and driving experience of the subject, shown in Figure 4.4a ($F(1,68)=13.6, p<.001, w^2=.0097$). Drivers with more than 3 years driving experience responded more conservatively to differences in presentation speed than novice drivers. These variables accounted for 2 per cent of the treatment variance.

Type of road and roadside environment in Figure 4.4b was also significant ($F(2,136)=41.1, p<.001, w^2=.0068$). While speeds on divided and 2-lane walled road curves were assessed to be less safe than their spacious counterparts, the reverse was true for gravel road curves. This effect accounted for 2 per cent of the treatment variance.

The interaction between radius of curvature and roadside environment in Figure 4.4c was significant ($F(1,68)=42.5$, $p<.001$, $w^2=.0037$). Speeds at large radius spacious curves were judged to be more safe than speeds on either large radius walled curves or all small radius curves. This interaction accounted for 1 per cent of the treatment variance.

The four-way interaction between type of road, curve radius, roadside environment and curve direction in Figure 4.5 was also significant ($F(2,136)=33.6$, $p<.001$, $w^2=.003$). The difference between small and large radius curves was generally greater for spacious than walled sites. However, for 2-lane, right-hand spacious curves, speeds were judged to be safe at large radius sites but unsafe at small radius sites (refer Figure 4.5c). This interaction, however, accounted for less than 1 per cent of the total treatment variance in this analysis.

Curve direction in Figure 4.3e was also a significant main effect in the analysis ($F(1,68)=4.3$, $p<.05$, $w^2=.0003$), but had very little power. Roadside environment in Figure 4.3f ($F(1,68)=2.64$, $p=.10$, $w^2=0$) and driver experience (not illustrated, $F(1,68)=.01$, $p=.94$, $w^2=0$), however, were neither significant, nor noteworthy, effects in this analysis.

4.3.2 Speed Estimation Errors

Appendix C-6 lists the statistical summary table while Figures 4.6 and 4.7 show the significant and noteworthy effects in these data. There were five main effects and four interactions that warranted close attention.

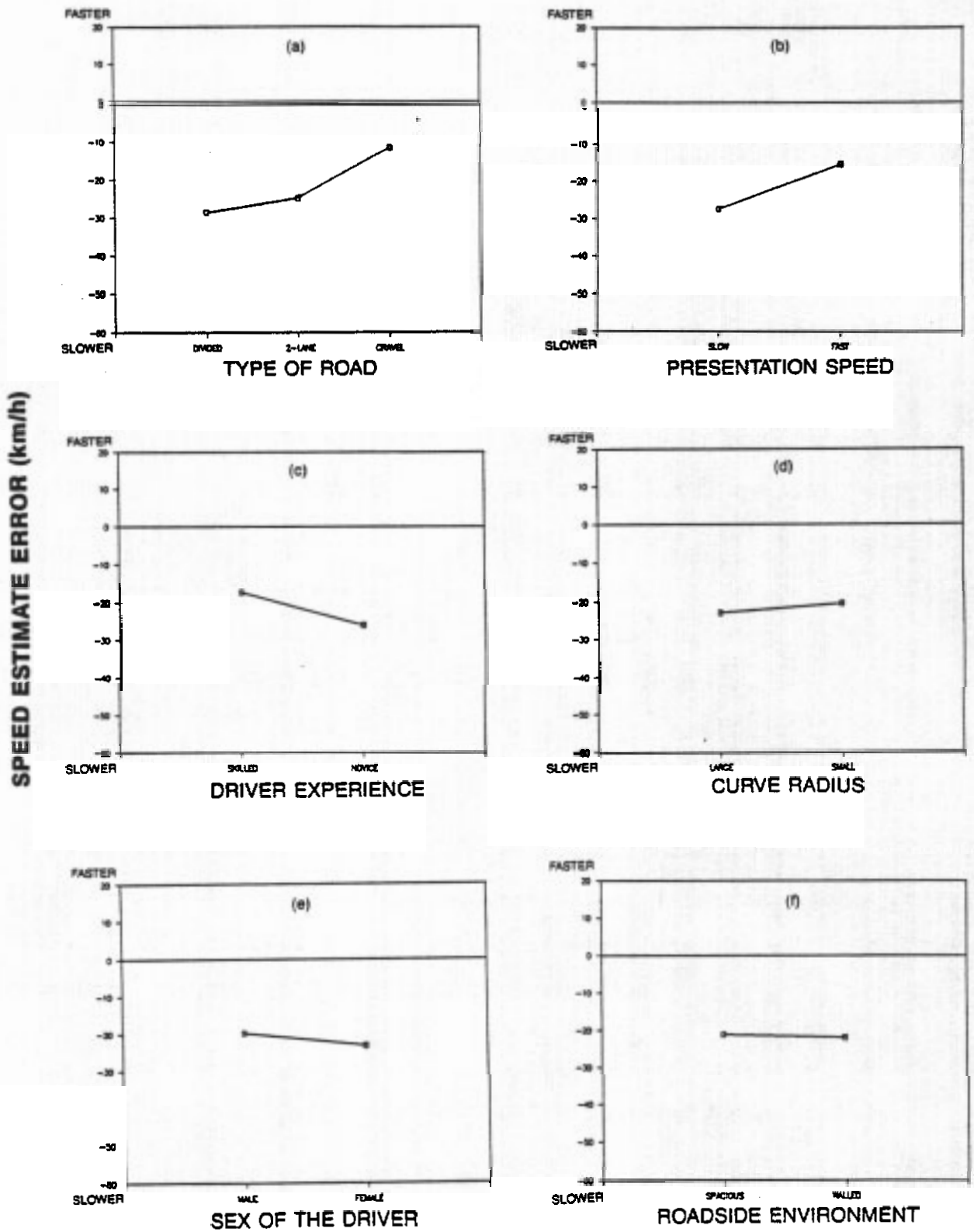


FIGURE 4.6 — Travel speed estimate error main effects of interest for the horizontal curvature experiment.

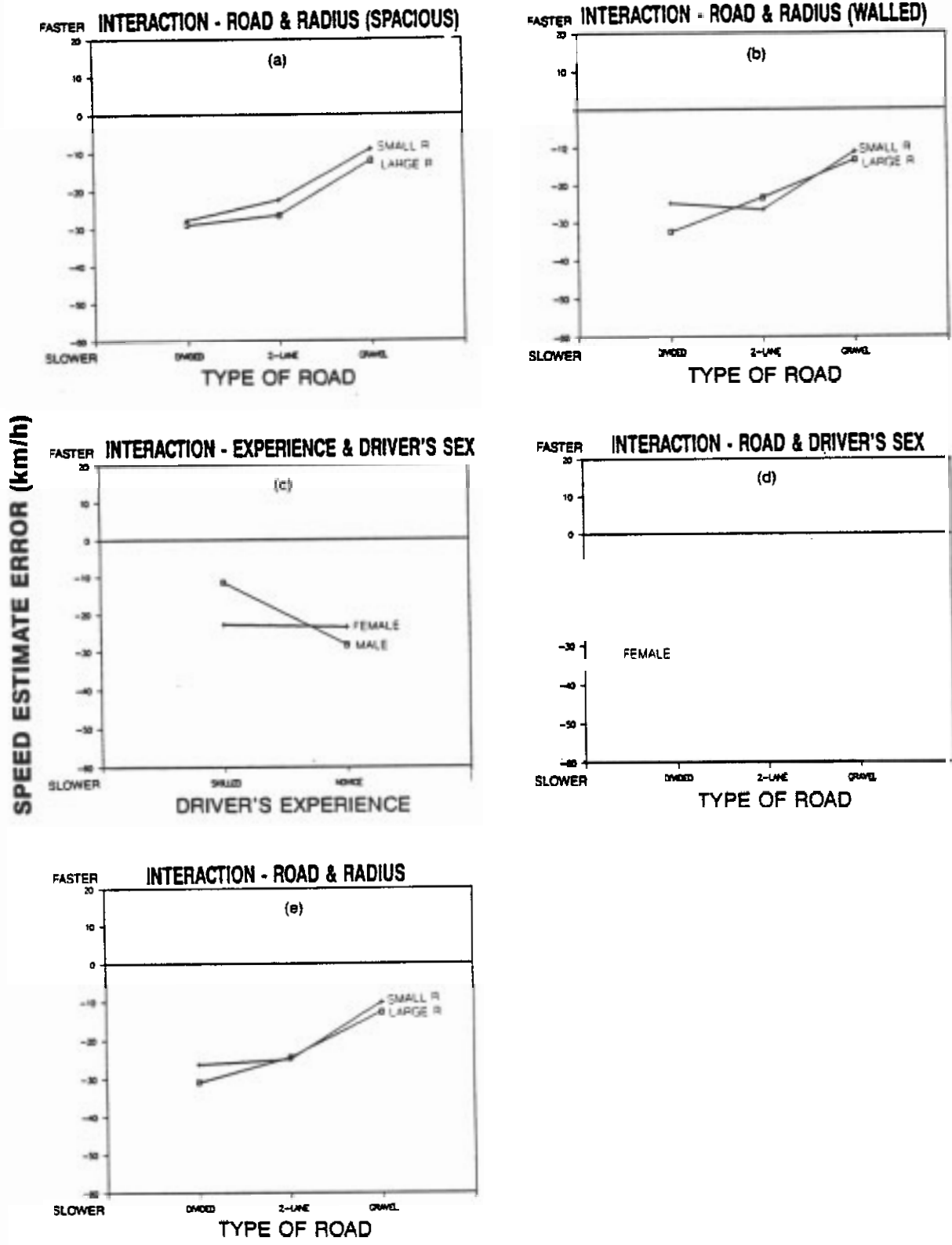


FIGURE 4.7 — Travel speed estimate error interactions of interest for the horizontal curvature experiment.

In contrast to the safe operating speed results, type of road shown in Figure 4.6a was the strongest significant effect observed in the speed estimate error analysis ($F(2,136)=228.9$, $p<.001$, $w^2=.1598$). Speeds for divided roads were under-estimated much more than for 2-lane roads, while both sealed road speeds were under-estimated more than gravel road speeds. This variable accounted for more than 40 per cent of the treatment variance.

Presentation speed shown in Figure 4.6b was the second strongest effect in this analysis ($F(1,68)=533.1$, $p<.001$, $w^2=.1063$). Speed was under-estimated much more for slow than for fast presentation speeds. This variable accounted for 27 per cent of the treatment variance.

Driver experience in Figure 4.6c was the next strongest, significant effect ($F(1,68)=9.8$, $p<.01$, $w^2=.0522$). Novice drivers (those in their first year of driving) under-estimated vehicle speed much more than drivers with more than three years driving experience. This variable attracted 13 percent of the total treatment variance in this analysis.

There was a significant interaction between the sex and amount of experience of the driver, shown in Figure 4.7c ($F(1,68)=8.2$, $p<.01$, $w^2=.0426$). The difference observed between novice and experienced drivers (reported above) was essentially a male driver effect, as female estimates between novice and experienced drivers were much the same. This interaction accounted for 11 per cent of the treatment variance.

The interaction between sex of the driver and type of road in Figure 4.7d was also significant ($F(2,136)=9.8$, $p<.001$, $w^2=.0062$). Females under-estimated speed much more than males on divided and

2-lane roads, although errors were roughly the same for both sexes on gravel roads. This interaction accounted for 2 per cent of the total treatment variance.

The triple interaction between type of road, radius of curvature, and roadside environment, shown in Figure 4.7a and 4.7b was significant ($F(2,136)=73.9$, $p<.001$, $w^2=.0057$). Errors in estimating speed between small and large radius curves were essentially the same for each spacious road type (Figure 4.7a). However, speeds on large radius divided road curves in walled environments, shown in Figure 4.7b, were more under-estimated than any other road or environment condition. Speeds on small radius divided road curves, on the other hand, were judged more accurately in both environments. This variable combination accounted for less than 2 percent of the treatment variance.

Radius of curvature in Figure 4.6d was a significant (although not particularly strong) effect ($F(1,68)=43.8$, $p<.001$, $w^2=.0046$). Vehicle speed for all large radius curves was under-estimated more than for all small radius curves. This variable, however, only accounted for 1 per cent of the treatment variance.

Type of road and radius of curvature in Figure 4.7e was the last significant interaction of noteworthy strength of effect ($F(2,136)=21.4$, $p<.001$, $w^2=.002$). Errors in estimating vehicle speed were less for small radius curves than large radius curves for both divided and gravel roads, but roughly the same for 2-lane roads. This variable combination accounted for less than one-half of one per cent of the total treatment variance.

While slightly above the .002 omega-squared cut-off, sex of the driver, shown in Figure 4.6e, was not significant ($F(1,68)=1.4$, $p=0.24$, $w^2=.0025$). Roadside environment in Figure 4.6f was significant, although of little strength ($F(1,68)=7.2$, $p<.01$, $w^2=.0004$) and curve direction (not illustrated) was neither significant, nor noteworthy ($F(1,68)=0.6$, $p=.43$, $w^2=0$).

4.3.3 Free Speed Data

Free speed measurements were collected at 30 of the 48 sites used in this experiment (free speed could not be collected on the 16 gravel road sites because of low traffic volumes and on two of the small radius undivided road curves that were modified between filming and free speed measurement). The mean, standard deviation and 85th percentile values are listed in Tables A-4 to A-9 in the Appendix of this report. Figures 4.8 and 4.9 show the apparent trends in the data recorded (no formal analysis was carried out on these data for reasons explained earlier).

The mean free speed for all sites was 93.1km/h (10km/h below) the average posted speed, while the 85th percentile speed of 105.3 km/h was roughly 2.5km/h above the average posted speed. Figure 4.8a show that the free speeds were much lower than the posted speeds for divided road curves, compared to undivided road curves, and opposite to that observed for similar straight road conditions (see Chapter 2).

The apparent interaction between type of road and environment in Figure 4.9a suggests that free speeds on divided road curves were not affected by the type of environment, whereas on undivided roads, free speeds were higher for spacious than for walled curves.

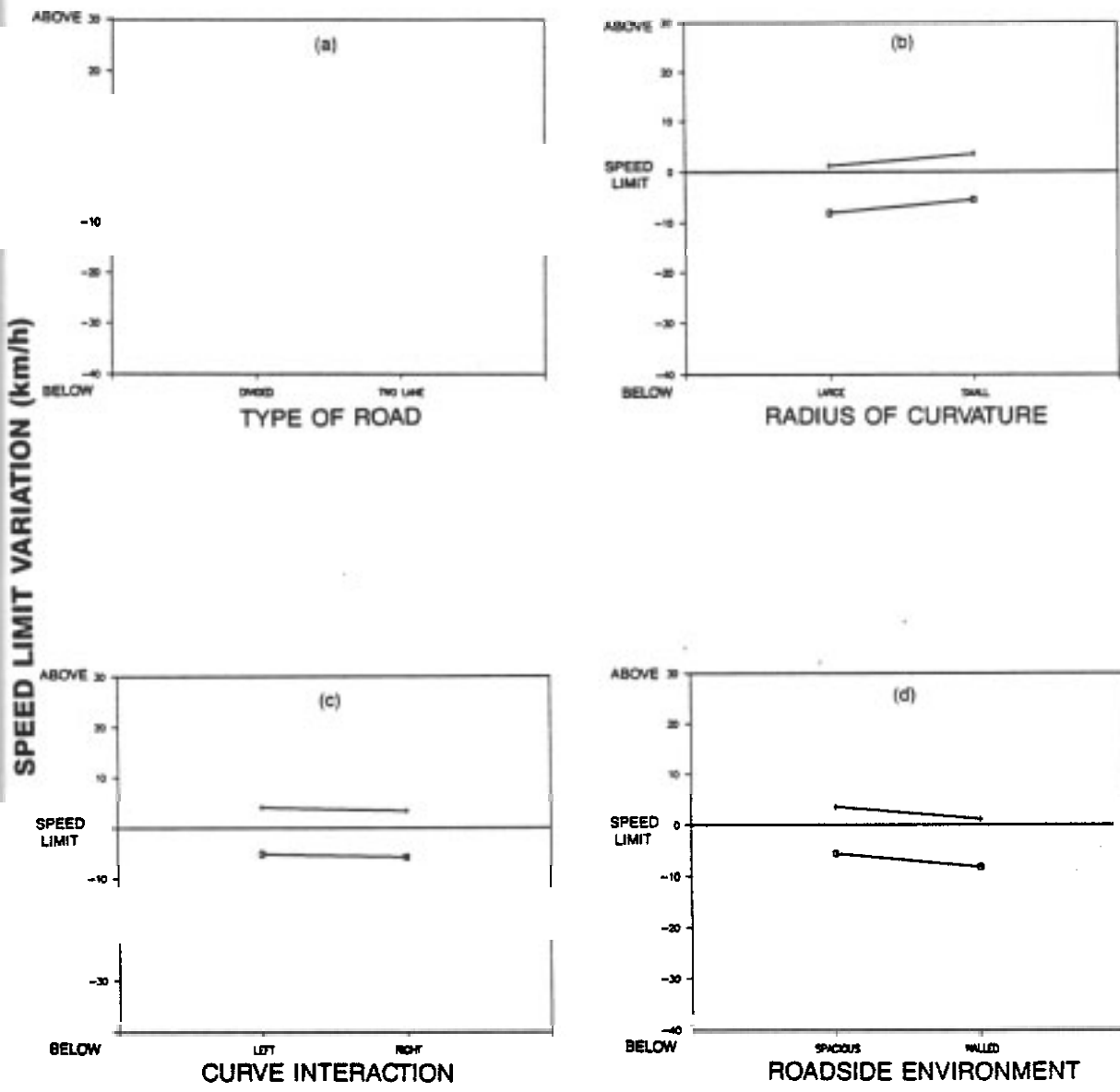


FIGURE 4.8 — Free speed variations in km/h around the speed limit for the main effects of interest in the horizontal curvature experiment.

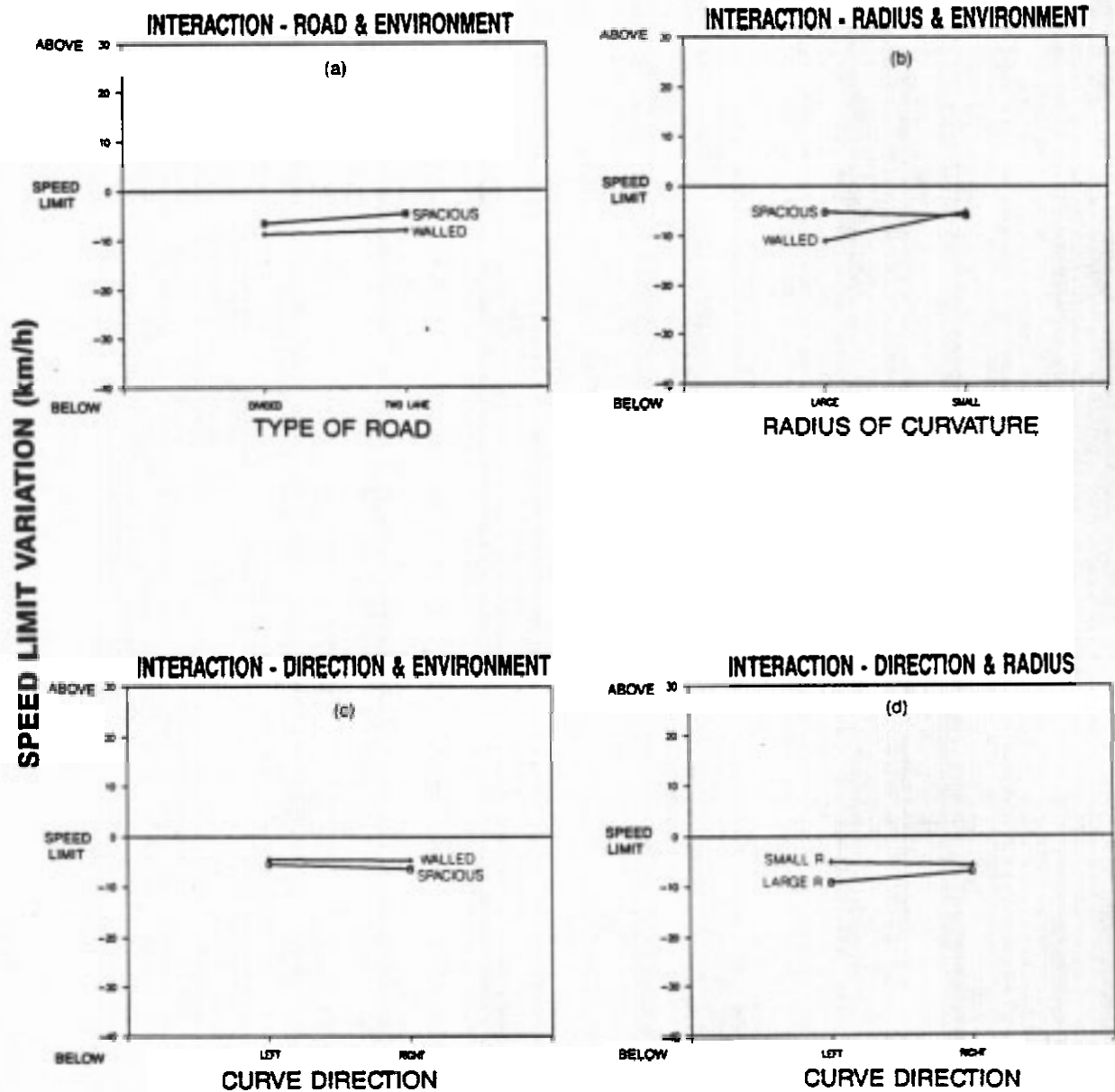


FIGURE 4.9 — Free speed variations in km/h around the speed limit for the interactions apparent in the horizontal curvature experiment.

Free speeds on large radius curves appeared to be further below the posted speed limit than on small radius curves, shown in Figure 4.8b. However, the actual mean free speed was only 1.5km/h greater for large than small radius road curves (there was also a difference of +2.0km/h in the average posted speed limit between large and small curves). Furthermore, the apparent interaction between curve radius and roadside environment in Figure 4.9b suggests that the source of the free speed difference was predominantly confined to large radius walled curves.

The results for curve direction in Figure 4.8c suggest that free speeds were similar for both right-hand and left-hand curves. The interaction between curve direction and roadside environment in Figure 4.9c further indicates that the environment did not unduly affect curve direction. However, large radius, left-hand curves were transversed particularly slowly, shown by an apparent interaction between curve direction and radius in Figure 4.9d.

4.4 DISCUSSION

As in the previous experiment, it is more fruitful to discuss the results obtained from the three sets of data here in terms of the independent variables that were tested.

4.4.1 Presentation Speed

In both the safety and travel speed analyses, the speed of presentation was shown to be an important factor in the experiment. This is not surprising as it has consistently been the strongest effect observed in previous speed perception analyses. In this experiment, however, presentation speed was only the second strongest effect in the speed estimate error

analysis and this is a novel finding. There are at least two possible explanations for this.

First, it may be nothing more than a statistical aberration, a minor chance finding as a result of the number of analyses performed with essentially the same variable combinations. Ferguson (1971) and Keppel (1982) discuss the possibility of such a chance finding from multiple testing in commenting on Type I and Type II errors of inference. However, these multiple findings were all separate experiments with substantial numbers of subjects, and presentation speed was always highly significant (what has been observed here is a change in order of omega-squared ranking or the degree of correlation of the variance with the variables tested). Thus, it seems unlikely that this result was simply a chance statistical finding.

More likely, the type of road has a stronger influence on a driver's ability to estimate speed in these curved rural environments than the level of speed itself. This does not seem unreasonable, given the perceptual differences that exist between gravel and sealed roads and the vast differences in curvature incorporated both in the stimulus materials and in rural highway design. Thus, it could be argued that the minimal amounts of sight distance available in these scenes has had an overwhelming influence on the ability to estimate travel speed here.

4.4.2 Type of Road

This factor had been shown to have a strong influence on a driver's perception of speed on rural and urban straight roads (Fildes, Fletcher and Corrigan, 1987). The results here have shown that this factor, similarly, has had a major influence on

the perception of speed on rural curved roads, too. Subjects judged travel speeds around the posted speed limit to be too slow on good quality divided road curves, about right on 2-lane, 2-way rural bends, and too fast on gravel curves. In addition, subjects under-estimated travel speed much more on sealed than gravel surfaces.

This finding was influenced significantly by the curve's radius and surrounding roadside environment. More will be said of the role of these factors later on. However, the type of road alone had the greatest impact on the subjects' responses and especially more than any other road factor or combination of road factors. This, again, indicates the necessity for good quality road surfaces to improve the perception of speed on rural highways.

The reason for the reduction in travel speed on divided road curves, though, is not clear. If drivers perceive these bends to be safer than undivided curves, one would expect travel speeds to be greater, not less. This might suggest that other factors may be influencing on-road behaviour in these settings (ie, the likelihood of being stopped by the police) and needs to be investigated further.

The safe operating speed judgements in this experiment were distributed roughly evenly around the centre of the response scale, which suggests that at least some of the behavioural responses involved factors apart from sensory perceptual inputs. Small radius curves on 2-lane undivided roads may, for instance, evoke more of a thrill for drivers travelling at, or above, the speed limit, than larger radius divided road curves do. The higher geometric standards (including the use of "transitional

curves") currently adopted for divided road design may remove the "challenge" for some drivers who attempt to negotiate these curves without reducing travel speed. This finding warrants further investigation, and in particular, whether experienced and inexperienced drivers are affected differently.

4.4.3 Curve Radius and Roadside Environment

The effects of these two variables need to be discussed together because of the nature of the findings. Speeds for large radius curves were assessed to be more safe than speeds for small radius curves, and travel speed was under-estimated much more for large, than for small, radius curves. While roadside environment was not a significant main effect in either analysis, it did interact with both curve radius and type of road.

Speeds at small radius walled curves (especially on gravel roads) were judged to be particularly unsafe. Spacious gravel road curve speeds, too, were assessed as unsafe, but good examples of these types of roads were difficult to find as they are fairly rare in this State and even small amounts of roadside vegetation is sufficient to destroy preview in much the same manner as trees and shrubs.

It should be remembered that the curve radius values were different for the three road types. Large radius values varied from 1000m to 1500m for divided roads, compared to 250m to 500m on gravel roads (these values are typical of the range of radius values recommended and used in Victoria for each different type of road). Thus, it is not really possible to compare the curve radius results for each of the different road types.

On a positive note, though, these data do confirm that sight distance had a strong influence on drivers' speed perceptions at curves. As the available sight distance is reduced (the visibility at the curve is restricted by the vegetation on the side of the road), the perceptions of speed became less safe and vehicle speed estimates increased. Fildes (1986) reported that the angle of curvature was a more salient feature than radius in a driver's perception of curvature of an approaching bend in the road. He showed that judgements of road curvature became less curved as curve angle (the amount of sight distance available) reduced. The results obtained here support this contention.

This suggests, therefore, that small radius walled road curves are particularly unsafe on rural roads. Drivers are not provided with an adequate preview of the road ahead and this interferes with their perception of what constitutes a safe travel speed. Hence, they are likely to misperceive the curvature of these bends and enter the curve at an inappropriate speed and travel path for safe negotiation.

4.4.4 Curve Direction

The direction of the curve had practically no effect whatsoever on the safe operating speed and travel speed estimates, as well as on the free speeds observed at the sites.

This result was a little puzzling as curve direction has been shown to have some influence on a driver's perception of curvature (Triggs, Harris & Fildes, 1979; Fildes 1979; Triggs, Meehan & Harris, 1982; Nemeth, Rockwell & Smith, 1986), the angle of curvature (Shinar, McDowell & Rockwell, 1974, 1977; Fildes, 1986), and crashes on curves (Stewart, 1977; Wright & Zador,

1981; Hall & Zador, 1981; Fildes & Triggs, 1982; Sanderson & Fildes, 1984).

Many of the earlier findings for curve direction, however, involved static stimulus materials, where subjects made assessments of photographs of curves or curve outlines. Thus, the introduction of motion may nullify any perceptual advantage for curve direction (this has been suggested elsewhere by Triggs and Fildes, 1985). Interestingly, the road crash direction asymmetry is actually the reverse of the perceptual asymmetry (in Australia where vehicles travel left of the centreline, there is a left-hand crash advantage and a right-hand perceptual advantage). Fildes (1986) argued that these differing effects have different causation mechanisms. The lack of a direction finding here confirms this hypothesis.

4.4.5 Driver Variables

The sex of the driver was a significant main effect in the safe operating speed responses. Male assessments of travel speed across all sites were judged to be safe, while female assessments overall were less safe. Moreover, this was a strong effect where the variable manipulation accounted for a sizable proportion of the treatment variance in the safe operating speed analysis.

A similar finding was reported for this variable in the day and night vision experiment reported in Chapter 2. It was suggested here that the increased number of subjects tested in this project explained the lack of significance that was observed for this variable in the previous project (Fildes, Fletcher & Corrigan, 1986). The results obtained here concur with this explanation.

More importantly, however, it does suggest that males and females perceive speed in rural settings quite differently. As was explained earlier, this may simply be a function of the amount of female exposure to rural driving.

Driving experience was a significant main effect in the speed estimate error analysis and, furthermore, interacted with presentation speed, type of road and the sex of the driver on occasions. Novice drivers tended to be less conservative and more varied in judging what was a safe operating speed compared with experienced drivers, and this appears to be solely a male phenomenon (male inexperienced drivers under-estimated travel speed on rural curves much more than either experienced males or all females).

While it is tempting to conclude that this might help to explain performance differences observed between these separate groups of drivers and their relative levels of experience, it must be stressed that this is the first sign of any substantial experience effect in all the speed perception research to date. Nevertheless, it does show that novice male drivers may be particularly at risk in assessing speed on rural curves.

5. LABORATORY VALIDATION STUDY - CLOSE FOLLOWING

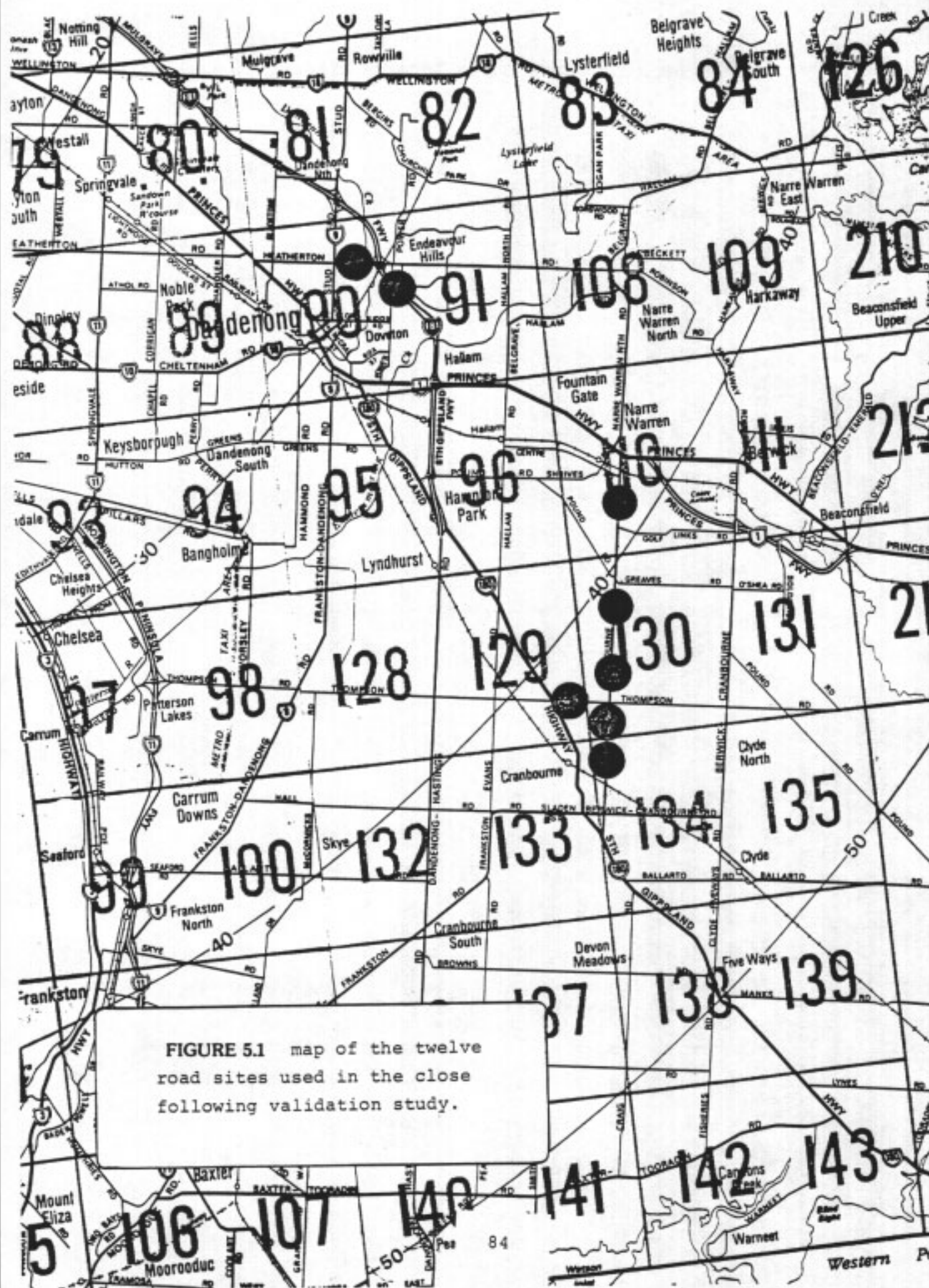
The need for further research into the relationship between following distance and road crashes was discussed in the introduction. While traveling too close to the vehicle in front appears to be a particularly dangerous action on the road, very little is known about why drivers adopt such practices. As a preliminary step towards better understanding, it would be useful to undertake a study of drivers' perceptions of what constitutes a safe following distance for a variety of different roads, environments and speeds.

The laboratory environment would be a convenient means of testing following distance without endangering subjects unnecessarily. The speed perception technique might be a suitable candidate for assessing drivers' perceptions of following distance on the road. However, a validation study would be required first to assess its suitability for this task.

5.1 STIMULUS MATERIALS

Twelve rural road sites on the outskirts of the Melbourne metropolitan area were located that encompassed a range of road and environment factors. Details of each road site are shown in Appendix A-10 and in Figure 5.1, while Figure 5.2 shows some typical sites used in the close following validation study.

The independent variables included three road types (divided, 2-lane undivided and gravel), two roadside environments (walled and spacious), and two following distances (half-sec and two-sec). In total, there were twelve road scenes in a fully crossed factorial design experiment.





Site 2 — Divided, 2-lane, walled urban freeway (speed limit 110k)



Site 4 — Undivided, 2-lane, spacious gravel road.

FIGURE 5.2 — Typical road sites used in the close following validation study.

First, it was necessary to develop a method of maintaining a one-half and a two second following distance between two experimental vehicles travelling at 75km/h and 100km/h. A "following distance" indicator was developed comprising a 24cm long vertical steel rod, approximately 0.5cm in diameter, along which there were four different coloured markings calibrated to represent the two following distances at both speed levels (see Figure 5.3 showing the rod and following distance scale).

The scale was mounted vertically on the rear test vehicle in the driver's line of sight to the lead vehicle. **As a test site** approached, the driver of the lead vehicle adjusted his speed to the posted speed limit (75km/h or 100km/h). **The driver of the** second vehicle then selected the appropriate coloured mark on the scale corresponding to the desired following distance and lined up this marker on the rear bumper of the lead vehicle at the appropriate speed. **This rather simple procedure ensured that the** correct following distance was achieved at each test site.

A suitable road segment was identified at each of the 12 selected sites that guaranteed a minimum of 5sec film time with specified sight distance requirements. The entrance point for these sites was marked and noted.

For the laboratory trials, each site was filmed once using the Bolex H16 reflex movie camera with 16mm Kodak colour negative 100 ASA film. **Films were processed into workprints and edited into** 5sec film segments. **A single experimental film was produced,** comprising the 12 road scenes in a fixed presentation order with 3 additional and novel practice sites. **Each road scene was of** 5sec duration and was followed by 10sec of blank film as before.



FIGURE 5.3 — The “following distance scale” in place on the trailing research vehicle. The driver of this vehicle aligned the correct graduation mark on the scale with the bumper bar of the leading vehicle with both cars stabilised at the same travel speed. This ensured that the two vehicles were correctly spaced apart during a particular road trial.

A response booklet, similar to those used in the day/night and curvature experiments, was employed for recording the subjects' speed and safety estimates on the road and in the laboratory. The endpoints of the slash-line response scale for this task were labeled "very safe" and "very unsafe". The subjects indicated how safe they perceived the distance to be between their vehicle and the vehicle in front by slashing across the response line.

A Kustom HR4 hand held radar gun was used to measure the free speed of 100 vehicles at the 12 road sites. Measurements were again taken by an observer seated in an unmarked vehicle at the side of the road.

5.2 ROAD TRIALS

Twelve subjects (three male and three female, first year drivers, and three male and three female full licence holders) were recruited. Each subject was driven individually along the pre-determined course encompassing three practice sites and the 12 chosen road sites. All road trials were conducted during off-peak traffic conditions, on dry roads and in good light and weather conditions.

Two experimenters were assigned to drive the first and second experimental vehicles. Both drivers underwent considerable training at maintaining following distances and how to avoid dangerous situations on the road. In addition, a third experimenter sat in the rear seat of the following vehicle to control the experimental procedure.

Each subject was given a response booklet and sat in the front passenger seat of the second (trailing) vehicle. Prior to

arriving at the course, the subject listened to the pre-recorded experimental instructions (see appendix B-3) and any doubts about the task were clarified. The driver then shielded the car speedometer from the subject's view by placing a cloth over the dashboard and played white noise through the car's stereo system.

Upon reaching a site, the subject was asked to look down at the response booklet on his or her lap, while the drivers of both vehicles adjusted their speed to the posted speed limit for that site (either 100km/h or 75km/h). The driver of the second vehicle maintained the pre-chosen following distance as described previously in Section 5.2. When the vehicle entered the site, the subject was asked to look up and view straight ahead. After 5sec of viewing time, the subject looked down and made his or her assessments of safety and travel speed.

The experimenter stressed that subjects should try and make their responses as spontaneously as possible. After each trial, the experimenter engaged the subject in casual conversation to distract attention from the road and task. In between sites, both drivers varied their speeds and following distances to reduce familiarization and ensure that speed was sometimes increased or decreased on the approach to each site.

5.3 LABORATORY TRIALS

A further twelve subjects, consisting of three male and three female first year drivers and three male and three female experienced drivers, were recruited for the laboratory trials. The procedure used was similar to that used for the road and previous laboratory trials.

Each subject was seated in front of the back-projection screen and listened to the recorded instructions (see Appendix B-4). The subject was then shown the first part of the film comprising three practice sites and any doubts about the task were clarified. The film was then re-started and the 12 test sites were presented in the same order as the road trials. Subjects made their assessments of safety and speed during the 10sec of blank film between each 5sec test sequence.

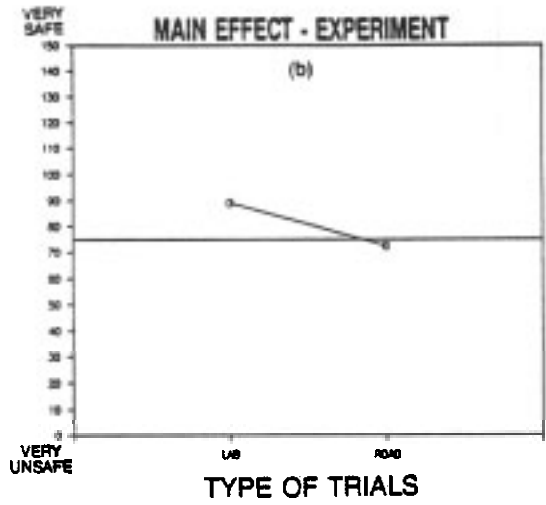
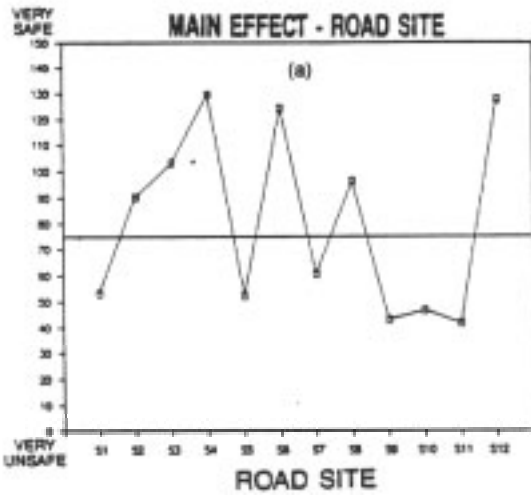
5.4 RESULTS

While a full factorial analysis of the data was possible in this study with the structured format adopted, there were, however, only three subjects employed in each driver condition and the presentation order was the same for each subject. This was quite appropriate as the study was only intended to be for validation of the technique. Thus, a simple two factor analysis was undertaken, including type of experiment and road site, similar to that adopted in the previous validation study. The stricter design format, however, enabled a more thorough examination of the effects of the factors of interest than before. Free speed measures were collected once more to compare the perceptual responses with on-road driver behaviour at the 12 sites.

5.4.1 Safe Operating Distance Responses

Appendix C-7 lists the statistical summary table of these data and Figure 5.4 shows the effects of interest in this experiment.

The main effect for road site shown in Figure 5.4a was significant ($F(11,242)=54.2, p<.001, w^2=.6235$). Subjects' responses across the 12 road sites used in this study were quite



SAFE OPERATING DISTANCE JUDGEMENT

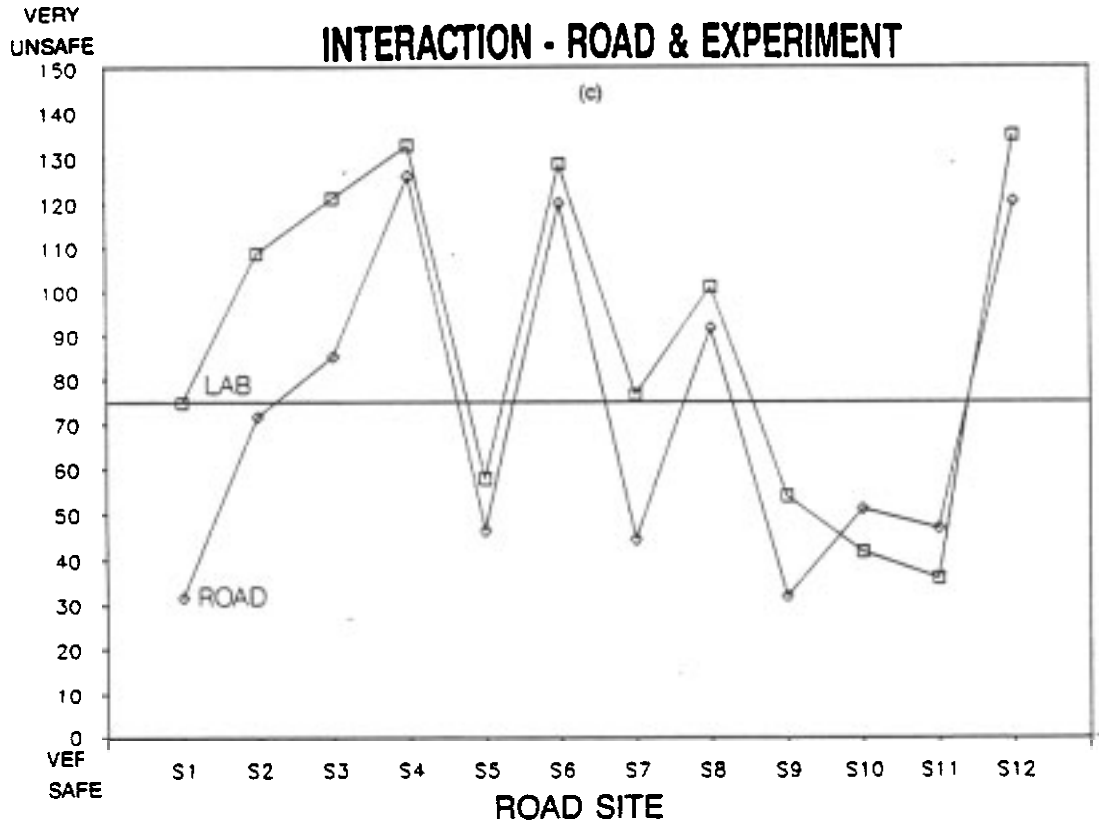


FIGURE 5.4 — Safe operating distance effects of interest in the close following validation study.

different and distributed quite evenly around the centre of the scale. This variable manipulation accounted for more than 90 per cent of the total treatment variance.

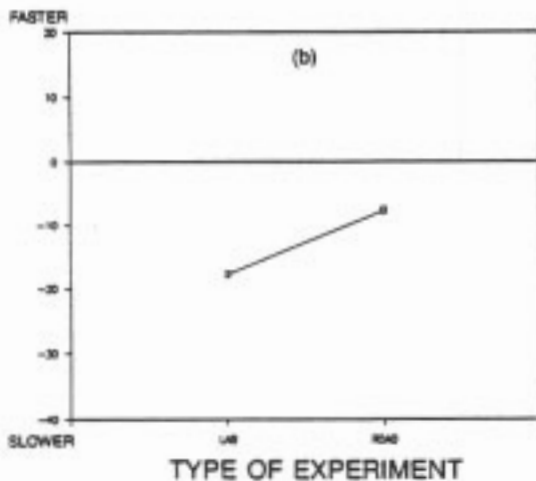
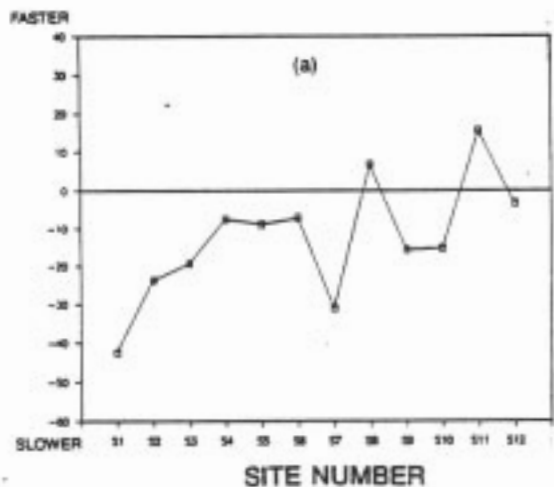
There was also a significant main effect for experiment, shown in Figure 5.4b ($F(1,22)=4.9$, $p<.05$, $w^2=.0315$). Subjects' following distance responses in the laboratory were less safe overall than those collected on the road. This variable, however, only accounted for 5 per cent of the total treatment variance and was considerably less powerful than road site.

There was also a significant interaction observed between road site and experiment in Figure 5.4c ($F(11,242)=3.5$, $p<.001$, $w^2.0290$). The source of this interaction appears to be the cross-over in the level of responding between the laboratory and road trials for sites 10 and 11. Apart from this discrepancy, the pattern of responses is quite similar for all other sites. This interaction attracted 4 per cent of the treatment variance.

5.4.2 Speed Estimation Errors

These results are listed in Appendix C-8 and are shown graphically in Figure 5.5. Road site in Figure 5.5a was again the strongest, significant effect observed in this analysis ($F(11,242)=74.0$, $p<.001$, $w^2=.5581$). Errors in estimating travel speed were noticeably different across the 12 sites and in most cases were under-estimates of travel speed. This variable accounted for 87 per cent of the total treatment variance.

The main effect for experiment in Figure 5.5b was significant ($F(1,22)=8.7$, $p<.01$, $w^2=.0564$). Vehicle speed was underestimated much more in the laboratory than on the road. This effect accounted for 9 per cent of the treatment variance.



SPEED ESTIMATE ERROR (km/h)

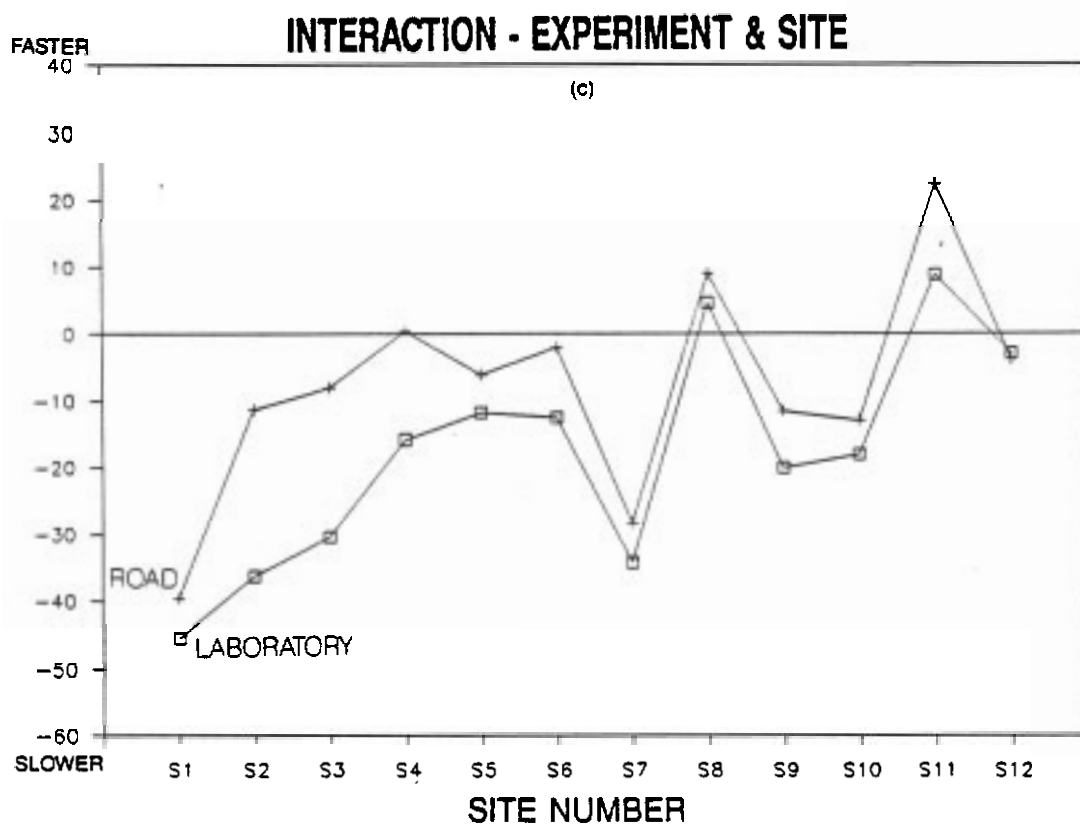


FIGURE 5.5 — Speed estimate error effects of interest in the close following validation study.

The interaction between experiment and road site in Figure 5.5c was also significant ($F(11,242)=4.4$, $p<.001$, $w^2=.0262$). The divergent trends in speed estimates taken in the laboratory to those collected on the road for sites 2 to 6 would be sufficient to generate this result. This variable combination, however, only captured 5 per cent of the treatment variance in the experiment.

5.4.3 Free Speed Data

For consistency, free speed measurements were collected at each of the 12 sites used in the close following study. Appendix Table A-10 lists the actual results, while Figure 5.6 shows the plot for road site and other variable combinations of interest. These data, however, were of less interest in this study because of the nature of the task (close following does not necessarily translate directly to speed behaviour on the road). Thus, apparent differences by type of road and roadside environment are not described any further here.

5.4.4 Other Variable Effects

The factorial design adopted in this study enabled a preliminary evaluation of the road, roadside environment and driver effects. These factors were not tested statistically for reasons previously explained and care should be taken not to interpret too much from these data. Figure 5.7 shows the main effects observed for these factors.

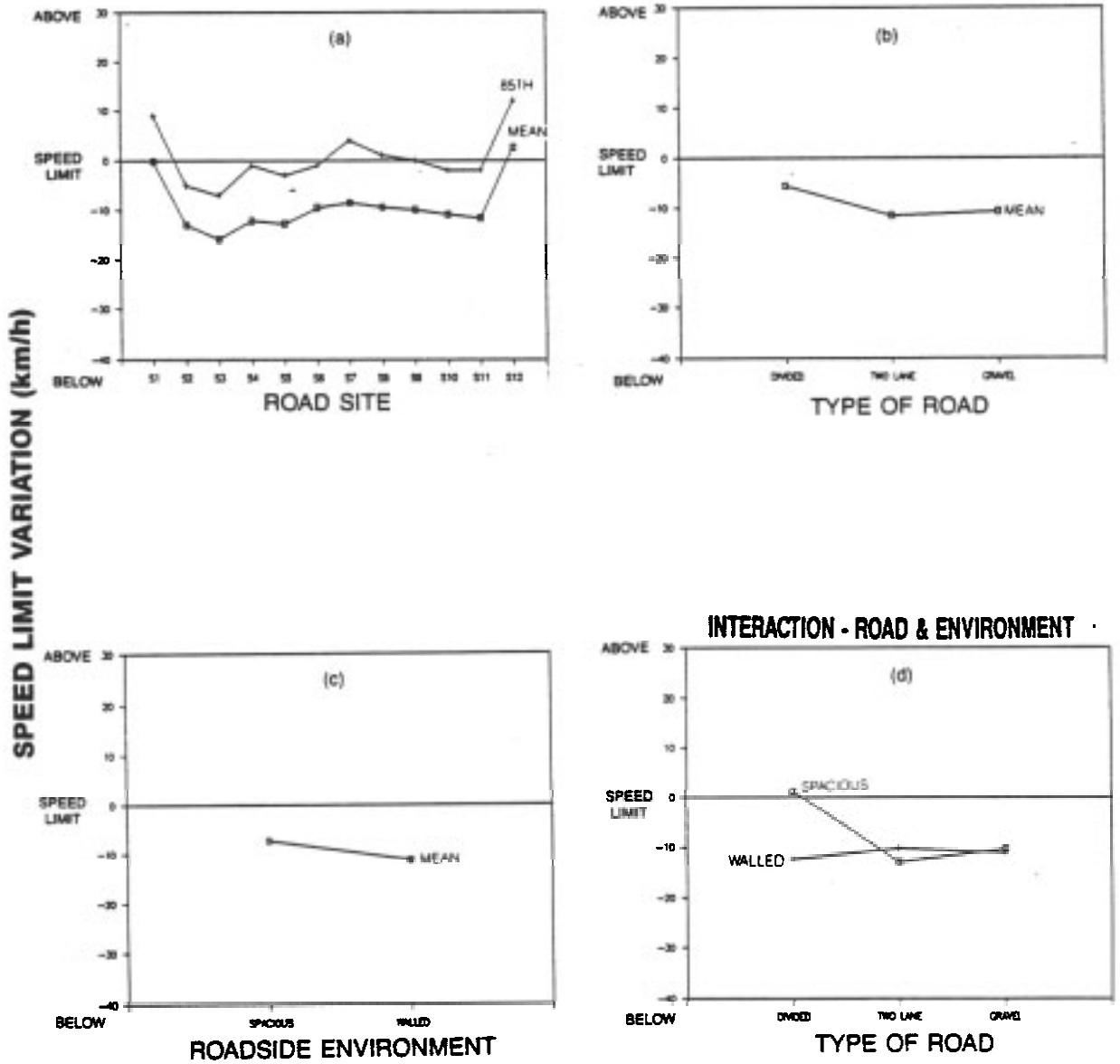


FIGURE 5.6 — Free speed variations around the speed limit in km/h for the variables of interest in the close following validation study.

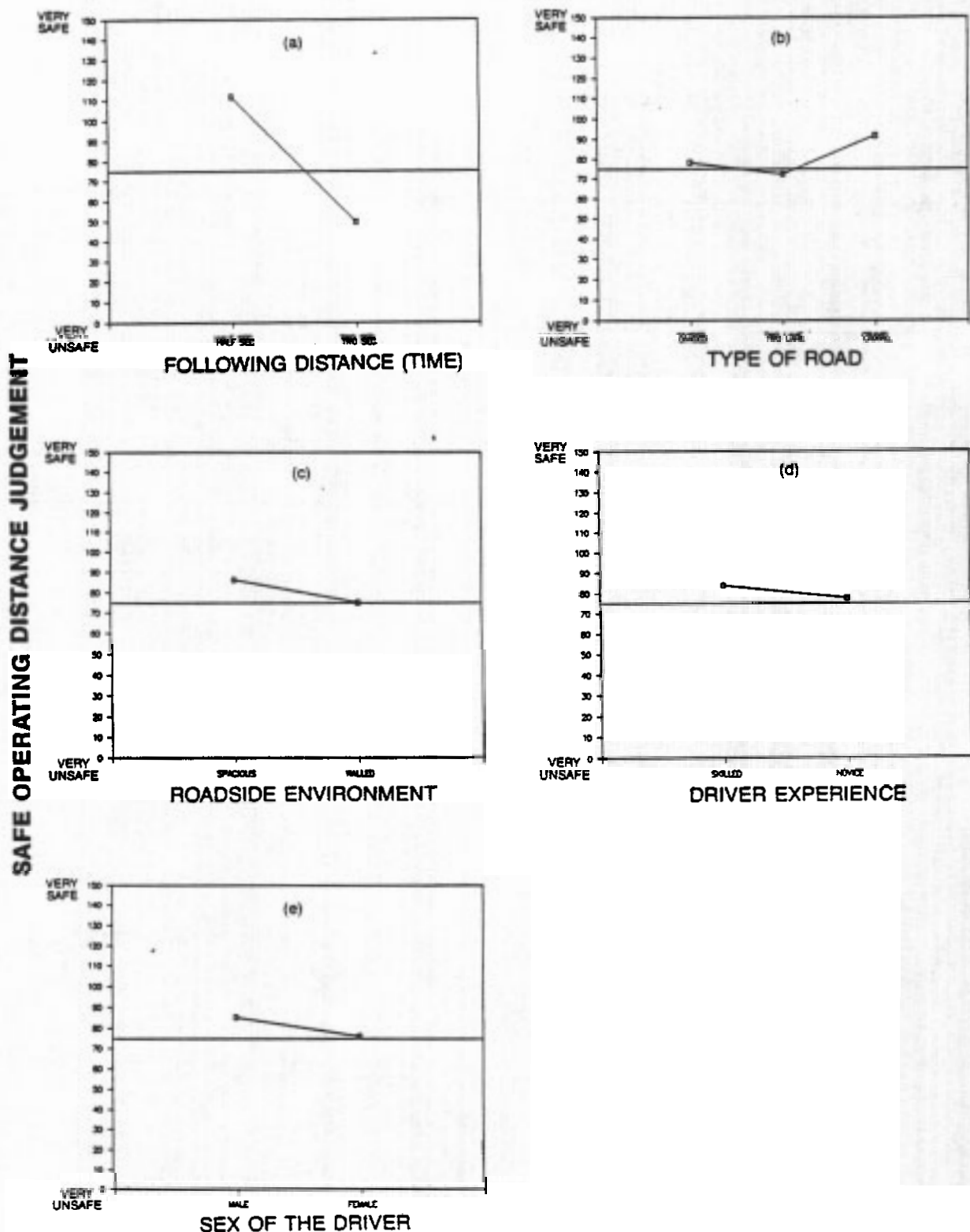


FIGURE 5.7 — Safe operating distance effects for a range of factors included in the close following validation study.

First, the results for following distance, shown in Figure 5.7a suggest that the one-half second distances were judged to be too close, while the two second distances were assessed very safe. This result suggests that a driver's ideal following distance on rural roads lies somewhere between these two values.

The type of road, shown in Figure 5.7b, indicates that perceptions of safe following distances can be influenced by the type of road surface. Gravel roads, in particular, seem to have evoked much less safe following distance responses than either divided or 2-lane undivided roads. Figure 5.7c also illustrates that following distances in walled environments were assessed to be safer than spacious road environments.

Two driver variables were included in the subject sample. The trend for driver experience in Figure 5.7d indicates that experienced drivers assessed the two following distances as safer overall than did the novice drivers. Furthermore, female drivers seem to have judged following distance to be more safe than male drivers did (Figure 5.7e).

5.5 DISCUSSION

The main purpose of the validation study was to assess the suitability of the laboratory for eliciting close following responses from the road. The results conclusively show that the laboratory method is suited for this task.

Figures 5.4c and 5.5c showed the interaction between experiment and road site for both sets of perceptual data and demonstrated a similar pattern of responses between the road and the laboratory trials. While these interactions were statistically significant

effects in both analysis (the pattern for both the laboratory and road responses were not perfect mirror images of each other), the minor differences that appear to have caused these interactions do not really detract from experimental validity.

It could be that one or two sites used in this study may not have been particularly well chosen; the practicalities of conducting road studies means that sites are occasionally included because they are the best available in the area, rather than ideal choices. Moreover, the prevailing conditions for the 12 road trials may not have been perfectly consistent or similar to the laboratory trials and six subjects in each condition is not really sufficient. These are, of course, the very reasons for conducting laboratory experiments in perception and the consistency in form of both sets of responses is sufficient to support further laboratory testing.

The main effect observed for experiment in both data sets also suggests that the overall level of sensitivity was different in the laboratory to the road. This was also experienced in the speed perception research where it was argued that reductions in other information normally available to drivers (sound, gravitational forces, vibrations, lateral forces, etc.) decreased the subjects' perceptions of safety off-road. This decrease in safety, however, is of little consequence here where the relative effects of the independent variables are being tested, rather than their overall effects on the road. What must be stressed, however, is that subjects demonstrated considerable differences in their responses to the 12 sites and, for the most part, responded similarly in both the laboratory and road tests.

Without making too much of the other variable findings, it is worth noting that there appeared to be substantial differences in the level of safety for most of the factors included in the trials. The finding that subjects' ideal following distances appears to be somewhere between 0.5sec and 2.0sec on rural roads is especially interesting. If this is robust, it may help to explain some of the rear end crashes that occur on Australian roads. A 2.5sec following distance, as specified by the National Association of Australian State Road Authorities, (NAASRA, 1980) allows time for the driver to respond to a danger signal on the road and for the vehicle to come to a complete stop. With less than a 2.0sec gap between vehicles, the following vehicle could not avoid skidding, swerving, or colliding with the leading vehicle in the event of it stopping abruptly. This would be potentially dangerous in many driving situations.

In many instances, of course, the leading vehicle also has to brake in which case the gap between vehicles theoretically needs only to be equivalent to the time to respond. This assumes that the system is "perfectly calibrated" in that a driver's attention is not distracted, his response mechanisms are not dulled by drugs, tiredness, emotions or even old age, or that vehicle braking systems and road surfaces do not have different braking characteristics and effects. In short, the greater the following distance, the greater the margin for error on the road, vehicle and driver systems and the less likelihood there is of a crash. A following distance of less than two seconds does not seem to be an adequate margin for error in many circumstances.

It should be noted that the subject in this experiment was always the front seat passenger and not the driver. This was necessary

to ensure that the subject's response was purely perceptual and free of any driving performance influence. Nevertheless, the results obtained may have been biased in that a passenger's perception of what constitutes a safe following distance may be quite different to that of a driver. The authors are not aware of any research that shows that a passenger's sensory perception on the road differs markedly from that of the driver. While it would be difficult to design an experiment to test solely for sensory perceptual effects between drivers and passengers, it is, nevertheless, an empirical question.

Further testing is clearly warranted here to test the robustness of these findings and to examine further the perceptual relationship between a driver's following distance, the road and environment influences, and the likely crash consequences.

6. GENERAL DISCUSSION AND FINDINGS

The findings from the road validation studies and the two laboratory experiments enable several conclusions and general principles to be drawn about the perception of speed in rural areas.

6.1 DAY AND NIGHT VISION

The first experiment conducted in this research programme was aimed at evaluating the effects of night vision on the previous findings of Fildes, Fletcher and Corrigan (1987) regarding drivers' judgements of safety and speed on rural straight roads during day-light hours. In addition, the time of testing during the day was also studied to see if biological cycles influence speed perception.

The results confirmed the previous day-light findings for presentation speed, type of road and roadside environment. However, the reduction in illumination to night-vision levels did influence the previous results.

Speeds at night were perceived to be less safe overall than speeds during the day and subjects made greater errors in estimating how fast they were travelling during night presentations. This was explained in terms of "perceptual narrowing" where the visual streaming patterns in the periphery of the eye of a driver during the day are markedly reduced at night. The speed estimation finding contrasted with that reported earlier by Triggs and Berenyi (1982) but this was explained by the differences in the amounts of night delineation treatments between the two studies.

Night vision interacted with the type of road and roadside environment. The perceptual advantage for walled sites during the day almost completely disappeared at night as roadside environment differences became less apparent. Unexpectedly though, speeds on walled, gravel, roads during the day were perceived to be much less safe than speeds at spacious gravel sites, suggesting that drivers seem to experience substantial reductions in perceived safety on these unsealed surfaces, even during day-light hours.

Night testing did not influence the results of the experiment. The only evidence of any night testing effect was an interaction between the sex of the driver when estimating travel speed (males made greater errors during the day than at night, and also made more errors than females did). It appears that this may have been a chance finding in the data.

If this is true, then it would appear that different biological cycles do not have much influence on a driver's perception of speed. Thus, differences in speed performance between day and night driving are more likely the result of fatigue or adaptation effects at night, rather than a fundamental difference in biological ability at this time. It could be argued that this result was a function of the relatively short testing times that applied to the trials and that the effects of fatigue or adaptation were not tested thoroughly in this experiment. Furthermore, there is reason to expect sensory perceptions to change with the level of alertness. Hence, it would be worth examining the effects of day and night testing further in any future perceptual studies, particularly those involving continuous testing over long periods of time.

6.2 THE VALIDITY OF CURVATURE TESTING

A study was undertaken to assess the validity of testing horizontal and vertical curvature effects in speed perception in the laboratory. A previous study by Fildes et al (1987) had shown that speed perception on rural straight roads could be tested in a laboratory using moving stimulus materials with controlled visual images.

Responses collected on the road were compared with those collected in a laboratory for a range of different curved road and environment conditions. The results confirmed the validity of using laboratory simulation for eliciting road speed perceptions for **horizontal** curves. However, the vertical curve results were ambiguous, suggesting that non-visual cues (gravitational force, sound, car movement and other forces) play a much larger role in speed perception in these undulating environments. Further testing is required to establish the effectiveness and degree of simulation necessary for testing **vertical** curvature effects off-road.

6.3 HORIZONTAL CURVES

A factorial experiment was undertaken to test the effects of a range of road, environment and driver factors on the perception of speed at horizontal rural curves.

While speed of presentation was still a strong effect in the subjects' judgements of safety and travel speed, the road and environment effects had considerably more influence here than previously reported for straight rural roads (Fildes et al, 1987). It was argued that the combined effects of type of road,

curve radius, and roadside environment indicated that available sight distance was a crucial factor in curve perception.

Differences were noted between the sex of the driver and the amount of driving experience in this experiment. **Male subjects** assessed travel speeds on rural curves to be generally more safe than females, while male inexperienced drivers under-estimated travel speed much more than either the experienced males or all females. It was argued that these differences may have been a function of the different exposure rates between these groups of drivers on the road. The inexperience effect between novice and experienced drivers was only marginal and care should be taken not to infer too much from this result.

Curve direction had practically no effect on the subjects' judgements of safety and speed. This suggests that perceptual asymmetries previously reported for bends in the road by Gordon (1966), Stewart (1977), Fildes (1979), Triggs and Fildes (1986) and Fildes (1986) are essentially a static perceptual phenomenon. The introduction of motion appears to alleviate these effects.

The free speed results suggested that motorists' behaviour on 2-lane rural road curves under certain circumstances involves other factors apart from the sensory perception of speed. Further research is warranted here to investigate possible reasons why drivers negotiate small radius, 2-lane, undivided, road curves much faster than similar large radius curves.

6.3.1 Implications For Curve Safety

The results obtained here and elsewhere (Fildes 1986) suggest that there are several critical geometric aspects that should be addressed to improve road safety on rural curves:

1. Hazardous road curves should be upgraded to improve the quality of the road surface and increase the curve radius (the results here suggest that curve radii below 500 metres are undesirable for safe speed perception on rural road curves).
2. Trees and shrubs close to the edge of the curve should be cleared back from the road sufficiently far enough to ensure adequate vision around the curve. Fildes (1986) found that a curve angle of 30deg was a minimum requirement for veridical curve perception. Moreover, on some spacious curves, tall grass on the side of the road can be as detrimental for the safe perception of curvature as other major visual restrictions such as cliffs, trees and shrubs.
3. Road delineation treatments need to emphasize the change in direction of the road surface. Road markings, reflectorized guide posts and reflectorized pavement markers have all been shown to be efficient treatments for improving a driver's perception of an approaching road curve (Triggs, Harris & Fildes, 1979; Triggs, Meehan & Harris, 1982; Johnston, 1982, 1983; Jackson, 1983; Nemeth, Rockwell & Smith, 1985).
4. Speed zoning at hazardous curve locations may also be required in difficult geometric locations. However, advisory speed signs are often disregarded by motorists because they are inconsistent and unreliable (advisory speed signing really needs to be in terms of driver perceptions, rather than geometric parameters).

6.4 CLOSE FOLLOWING

Driving too close to the vehicle in front (not providing sufficient headway) has been shown to be a particularly dangerous action on the road (Cairney 1981; Quimby 1987; Royalauto 1988).

To test whether the speed perception technique would be suitable for studying the perceptual effects of these aspects of driving, a validation study was performed on drivers' perceptions of safe following distance. Subjects were asked to judge how safe they felt about the distance between them and the vehicle in front for a range of different road, environment, speed, and headway conditions, involving both on-road and laboratory trials.

The results demonstrated that close following responses can be simulated effectively in the laboratory. The pattern of responses on the road was similar to that collected in the laboratory, confirming the suitability of the technique for assessing the relative effects of the likely factors of interest. Moreover, subjects appeared sensitive to these factors as there were considerable differences expressed in safe following distance for the range of road, environment and driver factors employed in this study.

The data also suggested that a driver's safe following distance from the vehicle in front lies somewhere between 0.5sec and 2.0 sec. It was argued that this is less than ideal to avoid road crashes. Further research is warranted to establish safe following distances precisely for a range of road and roadside conditions, as well as its role in road crashes.

6.5 SPEED BEHAVIOUR IN RURAL AREAS

Free speed measurements were collected at 58 straight and curved rural road sites during the course of this research. Overall, these data show that the majority of motorists tend to travel at speeds close to or below the posted speed limits on rural roads in this state. In addition, while 85th percentile values were

generally slightly above the posted speed limits, they were not excessively so. While there was a tendency for divided straight roads during the day to be perceived as extremely safe, this effect disappeared on curves and after dark.

It is difficult to argue that speed perceptions alone are responsible for motorists' speed behaviour on the road. The previous project (Fildes et al 1987) demonstrated a direct link between observed speed and **unsafe** speed perceptions (vehicle speeds reduced proportionally when unsafe speed perceptions in particular areas became more unsafe). However, the reverse was not true when safe speed perceptions became more safe; the authors claimed that other factors (eg, enforcement) seemed to set a ceiling limit on maximum speeds that most motorists were willing to travel at. The data collected here appeared to confirm this hypothesis.

What this means for perceptual countermeasures against speeding is taken up further in the next section of this report. However, on the evidence collected here for free speeds, it would be difficult to argue that the current speed limits in Victoria (100km/h on 2-lane rural highways and 110km/h on rural freeways) are in need of review.

6.6 FUTURE RESEARCH IN SPEED PERCEPTION

The results from this project and the previous speed perception research (Fildes et al 1987) have thrown considerable light on the role of a number of road, environment and driver variables in a driver's perception of speed. However, there a number of research questions raised during the course of this research

program that still need to be answered in this area. These are listed below:

- . What are the effect of travel lane on speed perception for multi-lane divided and undivided roads.
- . What influence does different grades of road delineation have on speed perception at night (this is currently unknown and potentially useful for highway design and maintenance).
- . Why were speeds on small radius, 2-lane, 2-way road curves relatively faster than on much larger divided road curves.
- . What is the relationship between small radius, small visible angle road curves and rural crashes.
- . What effects do driver experience and sex of the driver have on vehicle free speeds for straight and curved rural highways in Australia.

6.6.1 Variables Not Tested To Date

While these two projects evaluated many of the factors identified from a review of the literature as likely to be important for speed perception (Fildes et al 1987), a number of other variables could not be evaluated for a number of reasons, namely:

- . Traffic density and mix (these factors are likely to have considerable influence on speed perception, although it would be difficult to test the effects of these variables using the method adopted here).

- . Weather, too, would be expected to play a major role in speed perception but it is extremely difficult to simulate different weather conditions accurately on film.
- . The effect of parked vehicles and pedestrians on speed perception is potentially testable using the laboratory technique. However, these effects tend not to have the same impact on a driver off-road and it would be difficult to nominate perceptual countermeasures likely to offset these influences.

Vertical curvature influences, however, are potentially manageable using perceptual countermeasures. However, the lack of a robust finding in the validation study in Chapter 3 suggests that this variable may also be difficult to test using the laboratory technique.

It would seem important, therefore, that an alternative method of evaluating the perception of speed on the road be developed before many of these other variables can be properly tested.

5.6.2 **The Next Step**

The long-term aim of this research programme was to discover perceptual countermeasures against speeding that could be applied to suitable locations to reduce road crashes. The last Chapter in this report lists a number of particular road and roadside treatments that may have potential benefits. However, many of these treatments need to be evaluated first to establish their potential costs and benefits.

In the first instance, a laboratory test of these countermeasures would be desirable to demonstrate their effectiveness and to

identify any undesirable side effects. If these results were encouraging, performance testing could then be undertaken at specific hazardous road locations to assess their potential crash benefits. Finally, a detailed cost-benefit analysis should be carried out to rank these treatments in order of their potential road safety effectiveness.

6.6.3 New Directions

The close following validation study showed that the film and laboratory simulation technique could be used for evaluating the effects of the road and environment on particular driver actions on the road. Given the relative lack of knowledge about what constitutes unsafe driving actions on the road, research into drivers' perceptions of road user behaviours (in association with the risk of crash involvement) would be useful and ultimately lead to countermeasures against unsafe driving actions.

7. PERCEPTUAL COUNTERMEASURES

The project objectives outlined in Chapter 1 required a discussion of perceptual countermeasures against excessive speeding in hazardous rural locations. That is, treatments to the road or its surrounds that will influence a driver's perception of speed without introducing physical barriers or restrictions. These are sometimes referred to as perceptual illusion or trickery effects.

The results from both this study and the earlier study of speed perception on urban and rural straight roads (Fildes, Fletcher and Corrigan, 1987) showed that there is potential for manipulating the environment to produce changes in speed behaviour. In particular, it was argued that changes to the road surface have the greatest potential for influencing a driver's perception of speed, although roadside environment effects can also influence speed perception. The effectiveness of the treatment, however, is likely to be a function of the overall level of safety in a driver's perception of speed for a particular road and environment location.

This chapter is structured into 4 sections. First, it includes a brief discussion of traditional approaches to speed control and their successes and failures. Second, it proposes perceptual countermeasures as a viable alternative (or additional) approach to speed control and argues why these measures are likely to influence vehicle speed, drawing from the limited amount of evidence and theory available in this area. Third, an inventory of potential perceptual countermeasures is presented from a range of relevant sources (including literature reviews in this area,

other studies that have evaluated the effectiveness of particular perceptual treatments on speed or driving performance, and local knowledge of measures that have been or are being contemplated for use in this country). The chapter concludes with a discussion of the need for a full evaluation of these treatments so that their black spot effectiveness (including their potential cost effectiveness at reducing road crashes) can be established.

7.1 TRADITIONAL APPROACHES TO SPEED CONTROL

Traditional approaches to speed control have emphasized the role of police enforcement (McMenomy, 1984; Vulcan, 1986; Road Traffic Authority, 1987). While this will always be an important and necessary approach to controlling vehicle speed in hazardous locations, the fact that a large number of motorists continually drive above the current speed limit suggests that it is not a totally sufficient means of speed control (cf., Mostyn and Sheppard, 1980; Cowley, 1980; Elliot, 1981; Sanderson and Corrigan, 1984; 1986; and Stiebel 1986). Moreover, findings by Hauer, Ahlin and Bowser (1982), Armour (1986) and Shinar and Stiebel (1986) have questioned the extent to which police enforcement generalizes much beyond the area of police presence.

Other researchers, therefore, have argued for alternative forms of speed enforcement (Klein and Waller, 1971; McLean, 1977; Hogg, 1977; Sabey, 1980; Elliot, 1981). Engineering the road and its immediate environment has been shown to have long-term effects on changing driving behaviour (Russam, 1979; Silcock and Walker, 1982; Parker and Tsuchiyama, 1985; Wright and Boyle, 1987). Thus, engineering countermeasures too have been introduced to make drivers slow down in particular hazardous locations.

7.1.1 Local Area Traffic Management

Engineering countermeasures against speed in residential streets and heavy traffic areas have tended to focus on Local Area Traffic Management devices (LATM). These measures usually employ a physical restriction on the road or in the travel path to force motorists to slow down or adopt a more desirable track. Examples of LATM devices include road humps, roundabouts, deviations and "neckings" in the travel lane, planter boxes, etc.

In many situations, these countermeasures have met with a degree of success. Webster and Schnerring (1986), for instance, reported a significant reduction in mean speed of 5km/h compared to a control precinct after installation of LATM devices on two residential streets in New South Wales.

The exact nature of the success of LATM devices, however, is not always immediately apparent. While measurements may reveal a drop in mean speed or an increase in travel time for a particular location after installation, they do not show the real reason for this effect. It may have occurred because of an overall reduction in speed by all vehicle users, or simply because the previous high speed deviant vehicles chose to use another route through that neighborhood after LATM was introduced (i.e., in statistical terms, a truncation rather than a downward shift in the overall speed distribution).

Some would argue that it really doesn't matter what caused the speed reduction at a particular location as the hazard has been eliminated for whatever reason. From a road system perspective, however, it is important to know whether the treatment has been effective or whether "accident migration" has occurred (where the

problem at one hazardous location is shifted somewhere else in the road network). Moreover, the installation of physical barriers on the road can introduce an additional road hazards, where one type of crash is traded for another.

The introduction of any countermeasure can only be beneficial if it can be shown that there has been a resultant reduction in injury or damage for the total road network. Unfortunately, this evaluation procedure is often overlooked once the LATM device is installed.

7.2 PERCEPTUAL COUNTERMEASURES

More recently, there has been interest in developing road treatments aimed at changing undesirable travel behaviour that do not require building obstructions or barriers. These measures attempt to create perceptual conditions that will induce a particular desired change in behaviour by the driver (i.e., a speed reduction in this context), and are referred to as "perceptual countermeasures".

7.2.1 The Unobtrusive Nature of Perceptual Countermeasures

Unlike either of the other two methods of speed control discussed previously, perceptual countermeasures attempt to bring about a change in behaviour unobtrusively (i.e., without the driver being aware necessarily of any change in his or her behaviour).

This more subtle approach to speed control has several advantages over the traditional methods. First, by influencing the visual information on display to the driver, it is attempting to address

the root of the problem. If drivers subconsciously perceive a particular road situation to be safe, then cognitive restrictions (involving conscious thought processes) are only likely to have a marginal effect on their behaviour. This is evident from the fact that police enforcement is only effective in "safe environments", for the most part, as long as the deterrent is obvious to the driver.

In addition, modifying the perceptual environment is less likely to annoy or frustrate the driver and, therefore, is more likely to be a long-term benefit. A change in the visual input to create an illusion of "less safe" will probably go by unnoticed and, therefore, not lead to "accident migration" by forcing speed deviants onto other roads. It could be argued that subtle changes to the road or the environment may be the only effective long-term means of influencing drivers who blatantly refuse to obey the law by driving at excessive speeds. In any event, removing restraints which people believe to be unnecessary should result in safer driving for the total driving population.

Finally, perceptual countermeasures, by definition, do not involve introducing additional hazards on the roads in the same way as LATM devices have in the past. Most of these treatments simply involve painted lines or additional plastic or gravel surfaces applied to the road surface to create the desired effect. Apart from the obvious road safety benefit, perceptual countermeasures are also likely to be relatively inexpensive, may be easier to justify in terms of cost/benefit effectiveness, and enable more treatments per budget than other methods.

7.2.2 The Effectiveness of Perceptual Countermeasures

It was argued that perceptual countermeasures are likely to be effective because they are aimed at modifying the relatively subconscious visual information arriving at the driver's eyes. While the evidence about visual perception processes is far from complete, it is worthwhile reviewing what is known about the perception of speed in humans.

There are only a limited number of studies that have attempted to explain how drivers perceive sensory information about speed from their environment. Early studies by Gibson (1950, 1958, 1968) and Calvert (1954) argued that a moving environment is coded on the retina of the eye as a pattern of blurred images, varying from zero blurring at the fovea (area of visual fixation) to maximum blurring at the extremities of the eye. The perception of speed, they claimed, is interpreted from analyzing the differences in relative velocity across the surface of the retina.

Other researchers, however, have criticized this rather simple direct account of speed perception (e.g., Johnston, White and Cummings, 1973; Regan and Beverley, 1978; 1982). These papers reported findings that could not be explained solely in terms of retinal streaming from a fixed point of expansion. They claimed that the visual processes associated with motion perception are more complex than those postulated earlier by Gibson.

Most authors reporting on visual perception in driving do agree that relative coding on the retinal surface of the eye is an extremely important cue for the perception of speed (Gibson and Crook, 1938; Gordon, 1966; Moore, 1968; Lee and Lishman, 1977; Harrington and Wilkins, 1980). It is the extent of the retinal

streaming explanation, rather than the concept itself, that seems to be contentious.

Salvatore (1972) and Triggs (1986) suggested that the way velocity is sensed may be dependent upon the absolute level of speed. They proposed that slow speeds are perceived from successive static observations of changes in position, while fast speeds seem to be assessed relatively directly. This hypothesis is intuitively attractive but needs further development before it can be tested empirically. Moreover, a simple static/dynamic distinction has been criticized by other researchers interested in explaining the perception of movement in humans (Johansson, 1977; 1985; 1986; Warren & Shaw, 1985; Mace, 1985).

In any event, while retinal streaming may not be a totally sufficient explanation of the perception of speed, it does seem to explain many of the effects reported in this programme of research. In particular, it helps explain why the road surface is a primary cue for speed perception and how the immediate roadside environment can influence a driver's perception of speed.

7.2.3 Limitations With Perceptual Countermeasures

While perceptual countermeasures may have several advantages over other forms of speed control, it would be unrealistic to expect these treatments to solve all speeding problems on the road. The different findings between the perceptual results and the free speed measurements in Fildes et al (1987), as well as the study reported here, show the subtle relationships that exist between speed perception and behaviour and the likely limitations in the effectiveness of perceptual countermeasures. When drivers' perceptions of speed at particular road sites were in the "too

slow" range of the response scale (i.e., drivers generally felt quite safe), free speeds at these road sites tended to be above the speed limit, but the pattern of the results was generally less sensitive to the effects of the independent variables. However, when perceptions were less safe (responses were in the "too fast" range of the scale), free speed differences almost mirrored the perceptual effects. This suggests that countermeasures aimed at reducing perception of safety may only be effective in reducing travel speed in environments that drivers' perceive to be unsafe.

7.3 SPEED PERCEPTION COUNTERMEASURES

In arriving at a list of potential perceptual countermeasures for speed, evidence was drawn from a range of sources including relevant literature reviews in this area, other studies that have evaluated the effectiveness of particular perceptual treatments on speed or driving performance, and local knowledge of measures that have been or are being contemplated for use in this country.

7.3.1 Transverse Road Markings

Perhaps the most well known and widely used perceptual road treatment to reduce vehicle speed at roundabouts and other intersections is the transverse line treatment used extensively in the U.K. Denton (1973) described the treatment as a series of contrasting lines painted across the road on the approach to a hazard that increase in frequency as the hazard approaches. The lines provide a systematic perceptual aid for drivers as they decelerate on approach to the roundabout or intersection (Denton, 1971). Figures 7.1 and 7.2 show some examples of this particular road treatment in the U.K. and more recently in Australia.

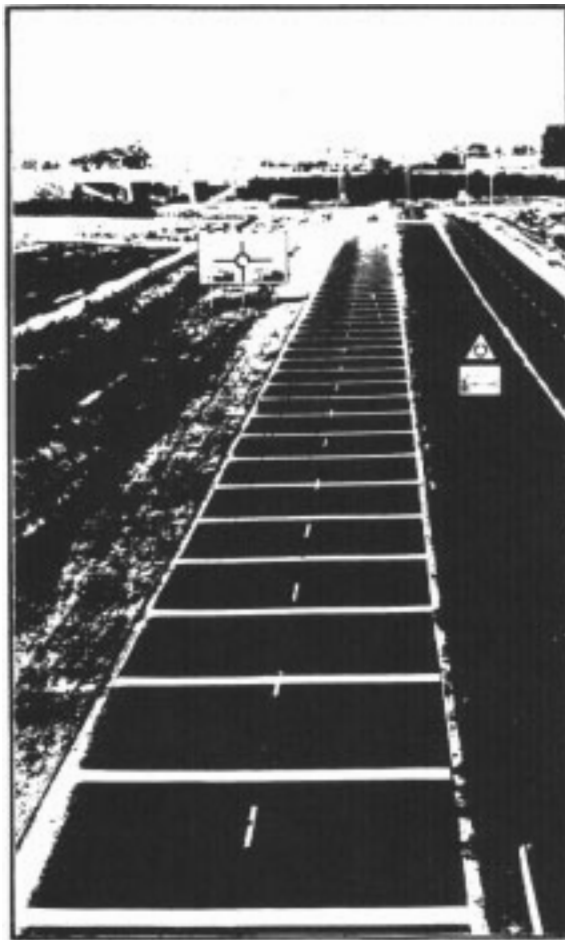


FIGURE 7.1 — Transverse line treatment at the approach to Windsor, England (Denton, 1973).



FIGURE 7.2 — Transverse line treatment using different road metal on the Northern Hwy., Victoria.

Several authors have attempted to evaluate the speed and crash consequences of these treatments. Denton (1973) reported reductions in mean travel speed of 23 percent and a 37 percent reduction in speed variance immediately after installation of the treatment. However, mean speed reductions subsequently fell to only 8 percent one year later, presumably because of a "novelty effect" with this treatment (Rutley, 1975).

Agent (1980) also found a large decrease in vehicle speed after transverse lines were installed at several hazardous locations in the USA, but he noted a subsequent increase in speed one year later (crashes, however, remained consistently lower, although he commented on interpretation problems due to central tendency effects and other statistical difficulties).

Havell (1983) reported a 10 percent reduction in mean vehicle speed one year after installation of transverse bars in the approach zone of a roundabout at Fountains Circle in Pretoria, South Africa. Unfortunately, though, none of these authors have followed up to test for speed reduction effects beyond 12 months.

Helliar-Symons (1981) examined the crash consequences of 42 transverse bar installations in the U.K. and claimed a decrease in speed related crashes of 57 percent over 4 years. Furthermore, he showed this treatment to be highly cost-beneficial. Silcock and Walker (1982) argued that crash reduction from bar markings was more apparent in the U.K. for access roads than in local streets. This finding, however, was deduced from other studies and did not involve collecting any new data.

7.3.2 Transverse Markings with Rumble Bars

More recently, visual treatments have been "enhanced" with rumble effects from the vehicles crossing these bars through the use of raised markers, varying grades of road metal, or road scoring procedures (Figure 7.2 shows one such combined treatment installation on the approach to a dangerous tee-intersection in rural Victoria).

Enustun (1972) evaluated a combination line and rumble bar installation on the approach to a freeway interchange in Michigan, USA. Using a series of contrasting plastic strips adhered to the road surface to provide the required visual and rumble effects, he reported an immediate drop in mean speed of 12km/h (-15%) which subsequently moderated to only 8km/h (-10%) one month after installation, without any change in before and after speed variation. He further claimed that this process was extremely durable to wear and tear (including snow plowing operations, with special precautions). Interestingly, though, when compared with the research reported earlier, this combination road treatment does not seem to have produced any additional speed reduction benefit over that of the lines alone.

7.3.3 Lane Width Reductions

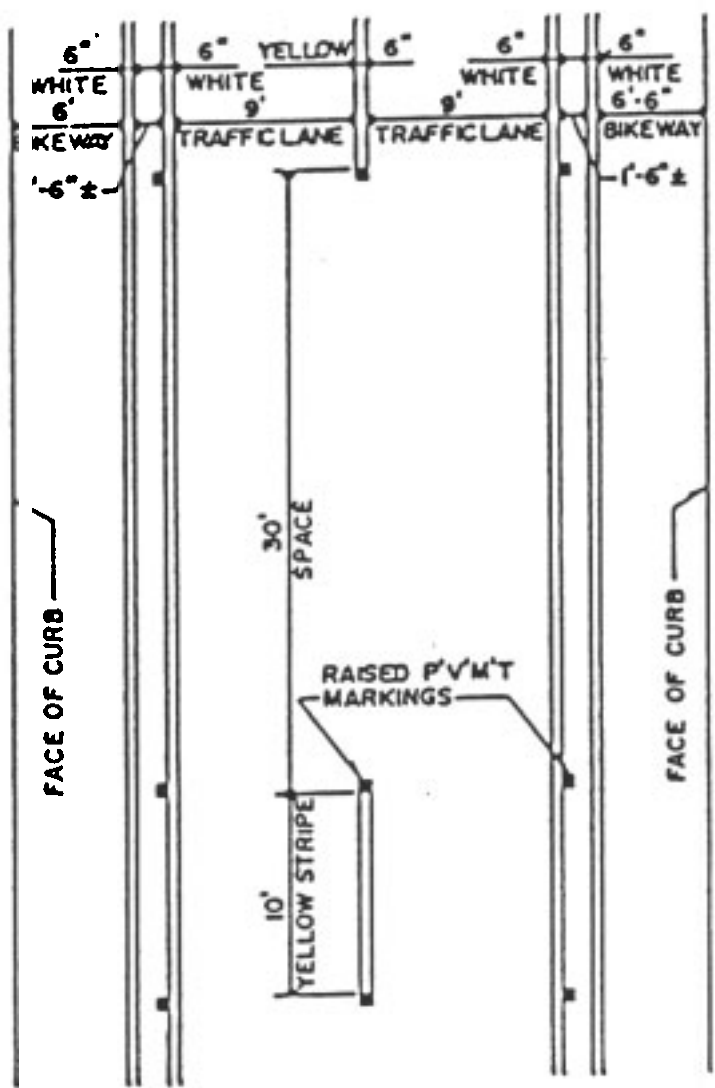
If road surface has a primary role in drivers' perceptions of speed (as found in this programme of research), it seems logical to expect the width of the travel lane to have a strong influence on perception and travel speed. Indeed, the first stage of this speed perception research (Fildes, Fletcher and Corrigan, 1987) demonstrated that reduced lane width and number of lanes were generally associated with lower safe operating speed responses on

urban and rural straight roads (and in some instances actual lower free speeds), although this result was often confounded with different classes of roads and varying speed limits.

McLean and Hoffman (1972) reported a change in driver steering behaviour from wide lanes (3.7m) at low speeds (42km/h) to narrow lanes (2.5m) at high speeds (80km/h) that they attributed to a perceptual difference in vehicle control for straight road driving for these different lane widths and vehicle speeds. In addition, they reported that shoulder width also influenced steering strategy (through perceptual differences apparently), although this was never evaluated in their research. There was some suggestion in Fildes et al (1987) that speed on wide divided urban and rural road pavements was perceived differently from that on equivalent narrow surfaces, although opposite to that predicted by McLean and Hoffman (1972).

Lum (1984) showed that duplicate longitudinal pavement markings with raised pavement markers set between them and the original lines to create an impression of a narrower residential street, had no effect on vehicle speed (see figure 7.3). They did, however, report a tendency for drivers to stay within narrow lanes (2.7m), but their conclusion that drivers' perceptions of road width remained unchanged was, at best, speculative using their methodology. It would be interesting to test this particular treatment more fully, especially its effect without a plain, wide verge area on the side of the road.

Vey and Ferreri (1968) reported lower speeds for 3m compared to 3.4m lane widths on two bridges in the USA. DeLuca (1985) also examined the effect of reducing lane width on an urban freeway in



NOTES:
DIMENSIONS ARE NOT TO SCALE.
1-FOOT = .305 METERS

FIGURE 7.3 — Duplicate longitudinal pavement markings used at one residential road site by Lum (1984).

Miami from 3.7m to 3.4m. He reported no significant difference in vehicle capacity (presumably this meant similar vehicle speeds), but he did find subsequent crash improvements. Neither of these studies, though, assessed perceptual consequences directly.

7.3.4 Longitudinal Edgeline Treatments

Several studies have attempted to assess the effect of the presence or absence of standard edgeline treatments on the side of the road on vehicle speed, performance and road crashes. Witt and Hoyos (1976) found that edgelines in the approach zones of rural road curves resulted in drivers adopting a more suitable curve entry speed and travel path in a driving simulator. This difference, however, was dependent on the type of treatment, and the speed findings were not particularly robust. They noted that:

"The question remains open as to whether the effect was due to the fact that the advance information directly influenced speed perception or whether the driver decoded the information and consciously selected a more appropriate speed."

Triggs and Wisdom (1979) and Triggs (1988) reported reliable differences in the pattern of lane-keeping and lateral position behaviour between matched road sections with and without centreline and edgeline treatments. Lines enabled drivers to maintain a more consistent travel path and safer travel strategy, especially at higher speeds. However, they did not test for observable differences in travel speeds across contrasting road conditions directly (travel speed was a control, rather than an independent, variable in this study).

Potter Industries (1981) argued that wide edgelines in the USA, W. Germany and England systematically reduced road crashes in

these countries, particularly those crashes involving drinking drivers. However, most of their evidence was derived from other studies, some of which are unavailable. Johnston (1983) also reported a perceptual advantage for wide edgelines in conjunction with chevron signs on rural curves for drinking drivers. However, neither of these two studies reported specifically on the speed consequences of variable edgeline types.

Willis, Scott and Barnes (1984) applied solid and broken edgelines on two hazardous sections of roads in south-west England. They found a significant reduction in the number of single vehicle loss of control crashes (especially in dry weather) but less impressive reductions in other crash types. Unfortunately, they didn't evaluate the perceptual or performance effects of these treatments in their study either.

7.3.5 Lateral Edgeline Treatments

A number of investigators have examined the effects of novel painted treatments to the edges and shoulders of straight and curved roads.

Parker and Tsuchiyama (1985) reported on the effects of several edge-of-the-road treatment evaluations by other researchers. In particular, they noted the use of a herringbone pavement marking pattern of decreasing frequency in the approach to a roadside hazard which they claimed resulted in a reduction of mean travel speed (although no reduction in speed variance). Figure 7.4 illustrates the herringbone pavement marking system listed in this report (unfortunately, the reference to the original source of this treatment is not clear from this report).

Rockwell, Malecki and Shinar (1975) applied a painted line treatment to the inside edge of a rural road curve to increase apparent curvature by increasing the inside perspective angle presented to drivers on their approach to the curve (see Figure 7.5). This treatment resulted in speed reductions in the approach zone of the curve but not in the curve itself. However, they did note significant reductions in speed variance for all vehicles negotiating the curve as a result of this treatment. Their evaluation unfortunately did not extend beyond 30 days after the treatment was applied.

In a later report, Rockwell and Hungerford (1979) also reported the effects of applying a modified form of transverse striping to the outside lane only of a two-way rural road curve for up to 30 days after application (see Figure 7.6). They found that this treatment caused a marked reduction in approach speed and curve negotiation speed for the full evaluation period and attribute this to a modification in curve perception.

Emmerson and West (1985) applied shoulder rumble strips on the approach zone of a number of bridges on two Oklahoma turnpikes. This treatment consisted of 3m long, high contrast concrete bars, 15cm x 3cm sections, applied to the sealed shoulder region of the road surface to provide a visual and auditory warning for drivers as they approached these narrow bridges. They reported a reduction of up to 56 percent in the numbers of crashes at these sites over a 4 years before and 4 years after time period, which yielded an average benefit/cost ratio of between 29:1 and 73:1. Unfortunately, they failed to report speed differences before and after at these sites so it is difficult to know whether these crash improvements may have had a perceptual basis.

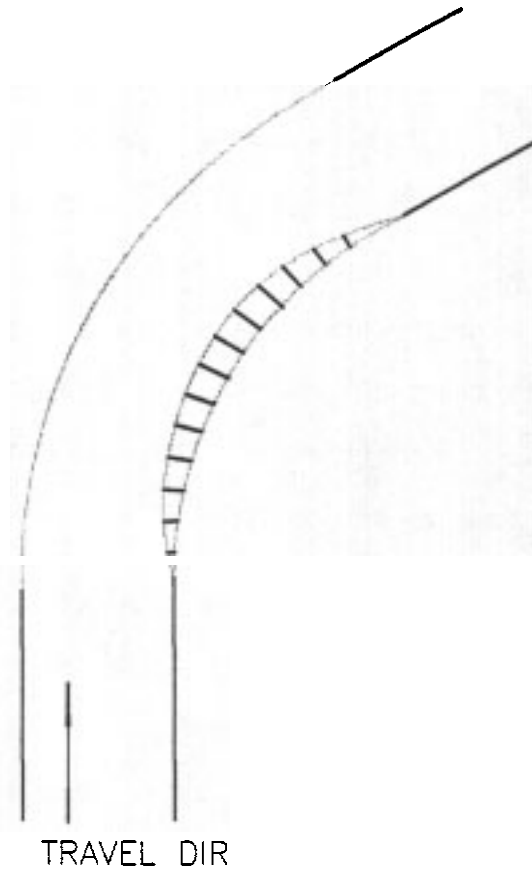


FIGURE 7.5 — Inside perspective angle treatment
 (Rockwell, Malecki and Shinar, 1975).

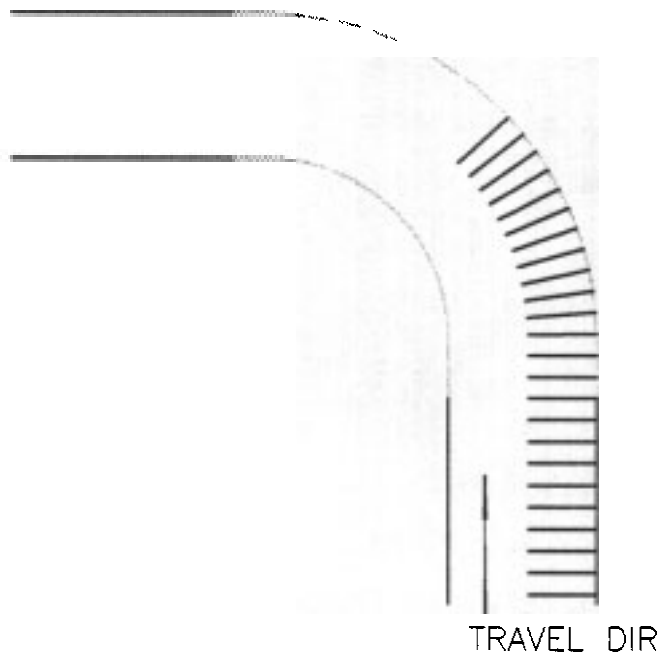


FIGURE 7.6 — Transverse striping of a rural road curve
 (Rockwell and Hungerford, 1979).

7.3.6 Guideposts and Chevron Signs

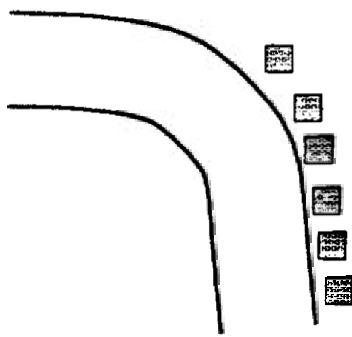
Hungerford and Rockwell (1980) attempted to modify drivers' behaviour at rural road curves by the use of novel guidepost and chevron sign delineation systems. At 2 rural road curves, they varied the height of post delineators from ground level to 10 feet high from the approach to the exit positions and also manipulated the perceived radius of the curve by relocating the guideposts to appear to give the appearance of a tighter radius road curve. Large chevrons were also applied at an additional 2 road curve sites (Figure 7.7 shows the various treatments adopted at these curves).

Their results showed reduced vehicle velocities (especially for high speed vehicles) for the the novel guidepost system at night immediately after installation, but there were no significant speed benefits for chevron signs. These speed differentials, however, were not apparent during the day and were not tested beyond 1 month after installation.

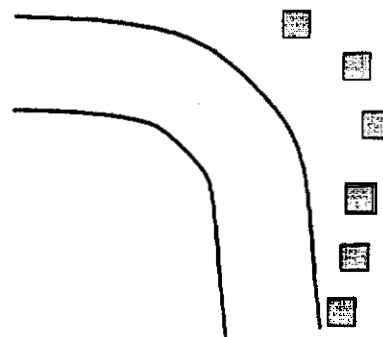
7.3.7 Special Road Treatments

The South Melbourne City Council in Victoria have recently been experimenting with various perceptual road treatments as an alternative crash countermeasure to L.A.T.M. devices.

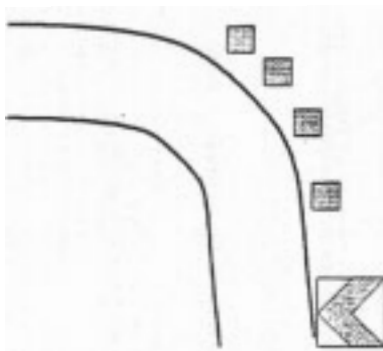
One measure that has been used in several locations, includes a road marking system comprising a white gravel median strip and a one metre hatched edgeline marking (in conjunction with solid edgelines) to create a perceptually narrow road surface and travel lane. Figure 7.8 shows an example of this particular treatment.



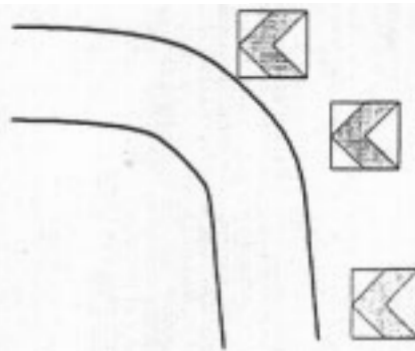
Six (6) standard delineators



Six (6) standard delineators arranged in increasing height & distance from berm



One (1) large chevron followed by four (4) carsonite delineators



Three (3) large chevron delineators

FIGURE 7.7 — Various guidepost and chevron arrangements evaluated by Hungerford and Rockwell (1980).

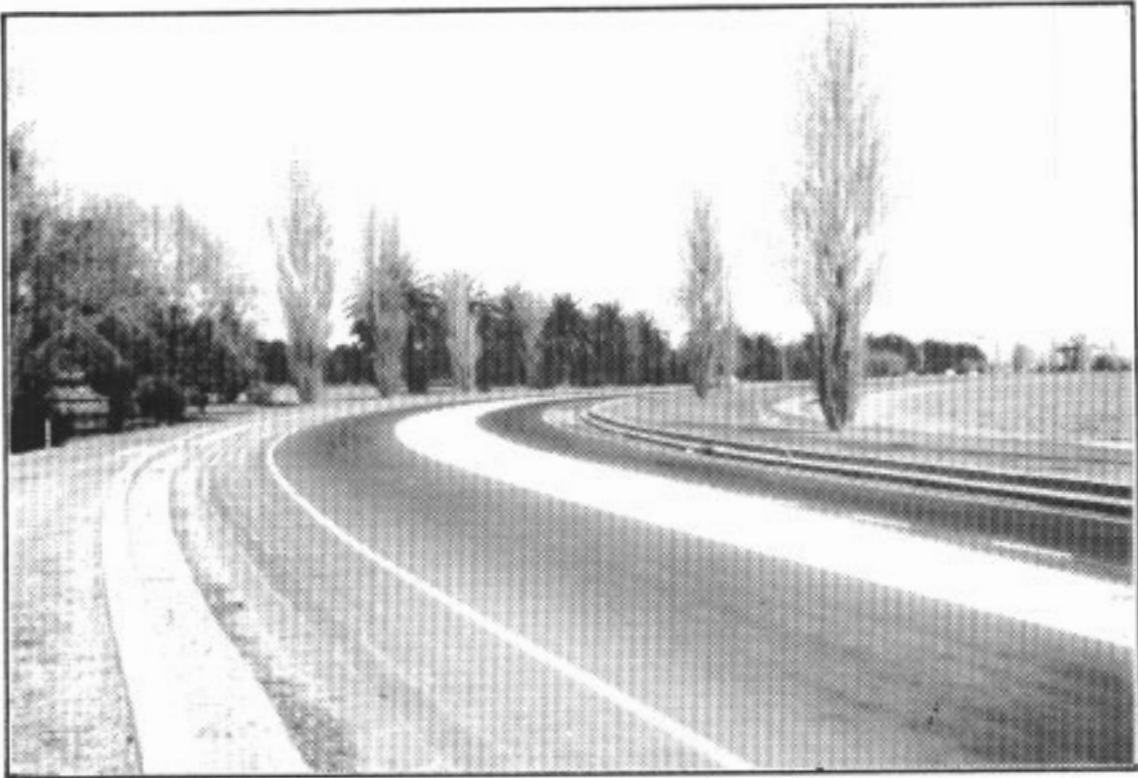


FIGURE 7.8 — Median and edge treatment on Lakeside Drive, Albert Park.



FIGURE 7.9 — Perceptual narrowing treatment applied on Kerford Road, South Melbourne.

As a part of this project in speed perception, a simple before and after speed study was performed recently at a new installation using a variation of this treatment on Kerford Road, South Melbourne, Victoria, and the results are listed in the Appendix D to this report. The treatment consisted of a white gravel perceptual separation strip and associated edgeline markings being applied between the moving and parked vehicles (which was also used as a bike path on occasions). This separation strip effectively reduced the travel lane width from 5.0m to 3.7m. Corner bollards and bluestone paving at the intersections were also added, subsequent to the after-installation speed observations (see Figure 7.9).

The major finding of this study was a reduction in free speeds of 3km/h after treatment installation with no appreciable change in traffic volume. Control sites had no reductions in free speeds over the same period. It was not possible to evaluate the perceptual effect of this road treatment on drivers' speed judgments, unfortunately, because of time constraints. This result, therefore, needs to be tested further to demonstrate its long-term speed perception and road crash effectiveness.

Nevertheless, this simple evaluation demonstrates the potential for this particular road treatment to reduce vehicle speed in these locations. Moreover, the results generally support many of the previous findings on lane width reductions and edge-of-the-road treatments. As the treatment cost is minimal compared to other physical speed management devices, it further suggests that reducing vehicle speeds through perceptual treatments at hazardous locations may be particularly cost-effective.

7.3.8 Road Signs

The final category of delineation treatments likely to induce a reduction in speed perception includes advisory speed signs and other dynamic sign systems. While some of these devices tend to require a deliberate conscious decision about travel speed rather than to influence speed perception automatically¹, they have been included here nevertheless for completeness.

Summala and Hietamaki (1984) reported on the speed consequences of an extensive experimental road curve sign programme, advising motorists of either impending danger, children crossing, or an advisory speed limit of 30km/h. They found reliable speed reductions to all signs, depending to some degree on the position of observation before the curve. However, they noted greater speed reductions for danger and children signs than speed reduction signs which they classified as "more significant" to the drivers involved.

They argued that the effectiveness of road signs at reducing speed was dependent, therefore, upon motivational factors of the drivers involved (Summala and Naatanen, 1974; Summala and Hietamaki, 1984), a view shared by other researchers in sign perception (e.g., Hughes and Cole, 1984).

Koziol and Mengert (1978) conducted a before and after study to evaluate the effectiveness of "dynamic sign systems" to alert motorists to the presence of narrow bridges on two lane rural highways in the USA. Of the four sign systems tested, they found

¹ This research programme here was confined to speed perception at a basic sensory level, excluding higher cognitive levels of human information processing (see Fildes et al 1987, pp 9-10).

that a strobe light sign combination reduced mean vehicle speed by 3km/h during the day while a flashing beacon sign combination had a similar effect on vehicle speeds at night. None of the other signs had a significant speed effect over the existing standard static sign and there were no appreciable differences in lateral position for any of the four signs tested.

While the precise nature of the perceptual influence they were measuring is unclear, they noted that signs were not as effective on driver behaviour in their study as the presence of opposing vehicles or roadway geometry.

7.3.9 Summary of Treatment Effects

The review of the effects of potential speed perception countermeasures is summarized in Table 7.1 and the following discussion:

1. Transverse road markings appear to have had a significant long-lasting influence on driver's perceptions of speed and road crashes at hazardous intersections and roundabouts. The addition of rumble bar effects at these locations does not appear to have any additional perceptual or behavioral benefit over just the lines themselves.
2. There seems to be some evidence of speed and crash reductions benefits from reduced travel lane widths, but the effects may be dependent upon the lane widths and class of road involved. It seems that travel lanes of 3.0m or less are necessary to induce sufficient perceptual effects to ensure free speed reductions on the road.

TABLE 7.1
SUMMARY OF REPORTED EFFECTS
SPEED PERCEPTION COUNTERMEASURES

TREATMENT	INSTALLATIONS	REPORTED PERFORMANCE EFFECTS	REPORTED SAFETY EFFECTS
1. Transverse lines	urban & rural roundabouts, curves, dangerous bridges	speed reductions & improved lane travel	crash reductions
2. Trans. lines + bars	rural intersection and a freeway interchange	speed reduction	unknown
3. Lane width reductions	urban & rural straight roads, residential streets, bridges	speed reduction ? better lane keeping improved steering	crash reductions
4. Longitudinal edgelines	rural curves & straight roads	minor speed reductions better lane keeping	crash reductions (esp. drink drivers)
5. Lateral edgeline treat.	approaching road hazards, dangerous curves, bridges	speed reductions (before & during curve) bridges unknown	crash reductions at bridges.
6. Guideposts & chevrons	rural curves	speed reductions for posts at night but no effect for chevrons	unknown
7. Special treatments	urban residential streets and arterials	speed reductions	crash reductions ?
8. Road signs	residential streets, rural highways & bridges	some speed reductions	unknown

3. A slight perceptual advantage in speed perception may be gained from the presence of both centreline and edgeline treatments on the road. Standard edgelines, however, seem less likely to produce significant reductions in travel speed and road crashes than other kinds of road surface treatments.
4. Transverse striping on the edges and shoulder regions of the road may have a positive influence on vehicle speeds at specific hazardous locations. The approach zones of dangerous curves seem especially suited for this treatment. Rumble bars may have an added advantage in some cases, although their full effects need to be established further in the perception of speed on the road.
5. There seems to be potential for novel guidepost arrangements to influence speed perception and road crashes on rural curves that are particularly hazardous at night.
6. Special road treatments, such as the white gravel median with edgeline marking, have potential for reducing travel speed in some locations. The full perceptual effects of this treatment, however, need to be tested further.
7. While signs may have a marginal effect at reducing vehicle speeds in some locations, they seem dependent on a driver's motivation and expectation and the 'element of surprise'. These are hardly desirable characteristics for any long-term benefits in the perception of speed.
8. There was some evidence that reducing vehicle speeds through perceptual treatments at hazardous locations may be particularly cost-beneficial.

7.4 IMPLEMENTATION AND EVALUATION

So far, the discussion has centered on perceptual countermeasures as an alternative means of speed control. A range of countermeasures likely to influence speed perception in certain locations was also compiled. The final section in this chapter deals with the need for these treatments to be installed and tested, including the need for a full evaluation of their potential cost-effectiveness.

7.4.1 Countermeasure Selection

In discussing the identification of hazardous road locations, Sanderson, Cameron and Fildes (1985) pointed out that there is a general lack of definitive documents on how to treat hazardous locations. The reports that are currently available tend to be derivatives of each other and there is little evidence of a single accepted procedure for implementing and evaluating hazardous countermeasures in general.

Moreover, they found that many of the authorities in Australia responsible for implementing hazardous countermeasures, tend to rely on "professional judgment" and "past experience" in the selection of suitable countermeasures. This was not meant as a criticism of engineers responsible for reducing roadside hazards, but rather to highlight the lack of objective information available to them when making their judgments.

What is required then, they argued, is a formalized research programme, listing suitable countermeasures that are available for treating particular hazardous road situations, computations on the potential cost effectiveness of each countermeasure (in

terms of benefit cost ratios), and a method for evaluating the effectiveness of countermeasures employed at various locations. In particular, evaluation criteria and implementation priorities would be most helpful for practitioners in the field.

7.4.2 The Next Step For Perceptual Countermeasures

To help satisfy this need and show the desirability of perceptual countermeasures for reducing speed and road crashes, a range of measures could be installed at suitable hazardous locations to test their potential for black spot improvement. These sites would need to be matched with control sites and several different before- and after-installation evaluations would need to be carried out to test these effects fully. A methodology for this research is detailed below.

1. Perceptual Measurement - an assessment of the perceptual consequences of these treatments at these sites would need to be carried out initially to ensure that the proposed measures do influence speed perception at the installations nominated and that there are no negative side effects from these treatment/site combinations. The method of testing drivers' perceptions developed in this program of research would be suitable for this first stage evaluation.

2. Performance Measurement - an assessment of the performance effects would also be required 'before' and 'after' installation. This should include a range of measures such as vehicle speeds and lateral position (at several critical site positions), and volumes and type of vehicles using the sites. Traffic movements throughout a particular region would also need to be monitored for changes in the pattern of vehicle movements, brought about by

the introduction of these measures. The evaluation period would need to be over 1 or 2 years with measurements immediately after installation, 1 month after, and then 12 months and 24 months later. Even longer effects would be desirable but not practical.

3. Road Crash Consequences - a 'before' and 'after' crash analysis would also be necessary to show the potential road safety benefits from the introduction of these measures. As there is a general tendency for "regression to the mean" at high accident locations, several control and experimental sites would be preferable and this analysis should extend over a considerably longer time period than that required for the other evaluations.

4. Cost & Benefit Analysis - a detailed cost/benefit analysis of the potential savings from the introduction of these treatments would be the final stage of the evaluation. The benefits could be determined from the potential savings in road crashes from the previous analysis, while costs would need to cover installation, maintenance, and any other intangible charges over the same period used to measure crash benefits.

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SITE NUMBER	SITE DESCRIPTION	AREA	ROAD CATEGORY	SPEED LIMIT	FREE SPEED (kph) (mean / 85%)	FREE SPEED (std dev)	SEAL WIDTH (m)	LANE WIDTH (m)	ROADSIDE ENVIRONMENT	SHOULDER WIDTH	SIGHT DISTANCE
1	Western Freeway, Ballan 255 D1*	rural	4-lane Divided, (Freeway)	110kph	107.2/ 112	9.3	7.4	3.7	spacious - open farming	4.0m	>800m
2	South Gippsland Hwy., Kooweerup 256 R7	rural	4-lane Divided	100kph	102.3/ 115	12.3	7.3	3.65	spacious - open farming	16.0m	>800m
3	Princes Freeway, (Geelong Rd.) Werribee 255 H4	rural	4-lane Divided, (Freeway)	110kph	105.8/ 116.8	10.6	7.5	3.75	walled - treed	3.0m	>800m
4	Western Freeway, Pykes Creek 255 E1	rural	4-lane Divided, (Freeway)	110kph	101.1/ 114	12.4	7.4	3.7	walled - cutting	3.0m	>800m
5	Calder Highway, Kyneton 253 F9	rural	2-lane Undivided	100kph	100.8/ 111	9.9	7.4	3.7	spacious - open farming	3.0m	>800m
6	Ballan-Daylesford Rd. Ballan 253 D12	rural	2-lane Undivided	100kph	98.0/ 111	13.2	7.4	3.7	spacious - open farming	4.0m	>800m
7	South Gippsland Hwy., The Gurdies 256 R9	rural	2-lane Undivided	100kph	96.7/ 108	10.8	7.4	3.7	walled - treed	4.5m	>800m
8	Trentham Road, Daylesford 253 D10	rural	2-lane Undivided	100kph	87.1/ 101	13.9	7.4	3.7	walled - forest	2.0m	>800m
9	Kitty Millers Bay Rd. Phillip Is. 256 N11	rural	2-lane Gravel	75kph	-	-	7.4	3.7	spacious - open farming	3.0m	>600m
10	Hoppers Lane, Werribee 206 H5	rural	2-lane Gravel	75kph	67.2/ 80	11.8	7.5	3.75	spacious - open farming	6.0m	>600m
11	Kitty Millers Bay Rd. Phillip Is. 256 N11	rural	2-lane Gravel	75kph	-	-	7.4	3.7	walled - treed	3.0m	>600m
12	Reef Hills Road, Benalla 254 U1	rural	2-lane Gravel	75kph	-	-	7.4	3.7	walled - forest	1.4m	>600m

*Map references from MELWAY - GREATER MELBOURNE, edition N^o. 17, 1987.

DAY/NIGHT STUDY - 12 RURAL STRAIGHT ROADS - NIGHT VISION.

SITE NUMBER	SITE DESCRIPTION	AREA	ROAD CATEGORY	SPEED LIMIT	FREE SPEED (kph) (mean / 85%)	FREE SPEED (std dev)	SEAL WIDTH (m)	LANE WIDTH (m)	ROADSIDE ENVIRONMENT	SHOULDER WIDTH	SIGHT DISTANCE
1	Western Freeway, Ballan 255 D1*	rural	4-lane Divided, (Freeway)	110kph	104.1/ 116	11.09	7.4	3.7	spacious - open farming	4.0m	
2	South Gippsland Hwy., Kooweerup 256 R7	rural	4-lane Divided	100kph	100.7/ 112	11.88	7.3	3.65	spacious - open farming	16.0m	
3	Princes Freeway, (Geelong Rd.) Werribee 255 H4	rural	4-lane Divided (Freeway)	110kph	104.7/ 111	9.69	7.5	3.75	walled - treed	3.0m	
4	Western Freeway, Pykes Creek 255 E1	rural	4-lane Divided, (Freeway)	110kph	109.3/ 123	14.27	7.4	3.7	walled - cutting	3.0m	
5	Calder Highway, Kyneton 253 F9	rural	2-lane Undivided	100kph	99.0/ 112	10.82	7.4	3.7	spacious - open farming	3.0m	
6	Ballan-Daylesford Rd. Ballan 253 D12	rural	2-lane Undivided	100kph	95.9/ 105	11.06	7.4	3.7	spacious - open farming	4.0m	
7	South Gippsland Hwy., The Gurdies 256 R9	rural	2-lane Undivided	100kph	93.7/ 104	8.66	7.4	3.7	walled - treed	4.5m	
8	Trentham Road, Daylesford 253 D10	rural	2-lane Undivided	100kph	89.6/ 103	13.03	7.4	3.7	walled - forest	2.0m	
9	Kitty Millers Bay Rd Phillip Is. 256 N11	rural	2-lane Gravel	75kph	-	-	7.4	3.7	spacious - open farming	3.0m	
10	Hoppers Lane, Werribee 206 H5	rural	2-lane Gravel	75kph	-	-	7.5	3.75	spacious - open farming	6.0m	
11	Kitty Millers Bay Rd. Phillip Is. 256 N11	rural	2-lane Gravel	75kph	-	-	7.4	3.7	walled - treed	3.0m	
12	Reef Hills Road, Benalla 254 U1	rural	2-lane Gravel	75kph	-	-	7.4	3.7	walled - forest	1.4m	

*Map references from MELWAY - GREATER MELBOURNE, EDITION N^o. 17, 1987.

RURAL SITES USED IN THE CURVATURE VALIDATION STUDY.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROAD/LANE CATEGORY	ROADSIDE GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH	ROAD LANE WIDTH	SHOULDER WIDTH	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE 5 SEC INTO CURVE.	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
1	2-lane	vertical curve (crest)	LYSTERFIELD Wellington Road Before Cornish Rd. 82 J3*	7.4m	3.7m	3m	walled (treed)	50m	100	84.36	94	9.55
2	2-lane	vertical curve (sag)	LYSTERFIELD Wellington Road After Lysterfield Rd. 83 F5	7.4m	3.7m	4m	walled (treed)	800m	100	87.66	98	10.23
3	2-lane	horiz. LH-curve (flat)	NARRE WARREN EAST Wellington Road After Edebohls Rd. 84 K12	7.4m	3.7m	3m	walled (treed)	120m	100	92.29	103	9.96
4	2-lane	horiz. LH-curve (flat)	CARDINIA Reservoir Wellington Road 126 C10	7.4m	3.7m	4m	spacious	500m	100	86.29	94	8.54
5	2-lane	horiz. LH-curve (flat)	CARDINIA RESERVOIR Wellington Road. 126 E6 After Aura Vale Rd.	7.4m	3.7m	4m	walled (cutting)	200m	100	93.62	103	9.12
6	2-lane	horiz. RH-curve (flat)	CARDINIA RESERVOIR Wellington Road 126 E7 Before Aura Vale Rd.	7.4m	3.7m	4m	walled (cutting)	200m	100	91.34	99	9.91
7	2-lane	horiz. RH-curve (flat)	CARDINIA RESERVOIR Wellington Road After Aura Vale Rd. 126 B9	7.4m	3.7m	5m	spacious	500m	100	91.55	100	8.95
8	2-lane	vertical curve (crest)	NARRE WARREN EAST Wellington Road 84 D10 After Hallam-Belgrave Rd.	7.4m	3.7m	4m	walled (treed)	75m	100	79.94	91	8.86
9	2-lane	horiz. RH-curve (flat)	LYSTERFIELD Wellington Road After Ryans Rd. 83 J8	7.4m	3.7m	3m	walled (treed-cutting)	120m	100	91.32	100	8.66
10	2-lane	vertical curve (sag)	LYSTERFIELD Wellington Road Before Glen Rd. 73 H10/11	7.4m	3.7m	4m	walled (treed)	500m	100	86.03	97	11.97
11	2-lane	vertical curve (sag)	FERNTREE GULLY Napoleon Road 73 H10/11 After Kellelts Rd.	7.4m	3.7m	4m	spacious	500m	100	79.51	88	7.50
12	2-lane	vertical curve (crest)	FERNTREE GULLY Napoleon Road 73 K8/9 Before Blackwood Pk. Rd.	7.4m	3.7m	4m	spacious	50m	100	86.32	95	10.22

*Map references from HELMAY-GREATER MELBOURNE, EDITION N^O. 17, 1987.

LARGE RADIUS, DIVIDED ROADS - HORIZONTAL SITES.

SITE DESCRIPTION				SITE DETAILS				SPEED DETAILS				
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85 th kph)	STANDARD DEVIATION
1	spacious	LH R=1040	Sth. Gippsland Hwy., (Phillip Is. bound) Tooradin 144 E4*	7.4	3.7	10	ing tri	550	100	94.3	105	1.22
2	spacious	LH R=1720	Western Hwy., (Ballan bound) Ballan 253 D12	7.6	3.8	25	orchard	700	110	102.1	110	8.84
3	spacious	RH R=1160	Sth. Gippsland Hwy., (After Rawlins Rd.) Cranbourne 138 F3	7.4	3.7	5	open farming (median strip)	550	100	98.2	108	10.86
4	spacious	RH R=1720	Western Highway, (Melbourne bound) Ballan 253 D12	7.6	3.8	25	orchard	700	110	101.1	110	9.36
5	walled	LH R=1160	Princes Highway, East of Deep Crk., (Melbourne bound) Pakenham 256 R6	7.6	3.7	5	cutting	350	110	95.0	105	10.59
6	walled	LH R=1200	Hume Highway (M40) Wallan 254 L11	7.5	3.75		cutting	400	110	100.2	112	11.21
7	walled	RH R=1040	Hume Highway (M80) Broadford 254 M8	7.5	3.75	5	treed	350	110	101.6	109	8.60
8	walled	RH R=1040	Hume Highway (M107) Avenel 254 N5	7.5	3.75	3.5	shrubs/trees	350	110	99.5	109	8.81

SMALL RADIUS, DIVIDED ROADS- HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	S ULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
9	spacious	LH R=575	Sth. Gippsland Hwy., Before M Donalds Rd. (Phillip Is. bound) Koo Wee Rup 256 R7	7.4	3.7	10	open farming (median strip)	400	100	98.4	110	11.43
10	spacious	LH R= 750	Western Hwy. (M50) (Ballarat bound) Baccus Marsh 216A DI	7.6	3.8	20	crops/farming	450	110	97.5	106	8.94
11	spacious	RH R=720	Sth. Gippsland Hwy., (Dandenong bound) Koo Wee Rup 256 R7	7.4	3.7	10	open farming (median strip)	450	100	97.2	106	9.51
12	spacious	RH R= 760	Princes Hwy. (Melb. bound) W. of Morwell 252 A11	7.4	3.7	10	grazing	450	110	98.6	106	8.21
13	walled.	LH R=650	Princes Hwy. East of Gumscrub Crk. Officer 215 B5	7.4	3.7	5	treed	400	100	97.1	105	9.39
14	walled	LH R= 580	Princes Hwy. (Melb. bound) before Moe-Newbgh. 252 A11	7.4	3.7	4	cutting	400	110	97.4	105	9.00
15	walled	RH R= 480	Princes Hwy. (Melb. bound) East of Kennedy Crk. Pakenham 256 R6	7.4	3.7	3	treed	450	100	90.6	99	8.37
16	walled	RH R=500	Sth. Gippsland Hwy., btw. Abbotts-Knowles Rds. (Dand. bound) Lyndhurst 96 AB	7.4	3.7	5	treed	350	100	99.0	111	12.35

LARGE RADUIS, 2-LANE ROADS - HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
17	spacious	LH R=870	Midland Hwy. (South bound) Sth. of Morwell 252 All	7.6	3.8	20	grazing	200	100	98.0	106	11.76
18	spacious	LH R= 750	Northern Hwy. (M156) Near Belt Road Runnymede 253 H1	7.4	3.7	5	grazing	650	100	90.9	99	8.92
19	spacious	RH R= 1100	Midland Hwy. (South bound) South of Morwell 252 All	7.6	3.8	20	grazing	200	100	97.0	105	8.56
20	spacious	RH R= 870	Midland Hwy. (North bound) South of Morwell 252 All	7.6	3.8	20	grazing	200	100	96.6	109	11.86
21	walled	LH R= 720	Wellington Road After Aura Vale Rd. Menzies Crk. 126 F7	7.4	3.7	3.5	cutting	200	100	93.6	103	9.12
22	walled	LH R= 650	Bass Hwy. Before Ullathorne Rd. Inverloch 256 812	7.0	3.5	5.5	treed	200	100	82.5	92	1.83
23	walled	RH R= 720	Wellington Road Before Aura Vale Rd. Menzies Crk. 126 F7	7.4	3.7	3.5	cutting	200	100	91.3	99	1.91
24	walled	RH R=650	Bass Highway Before Ullathorne Rd. Inverloch 256 812	7.0	3.5	5.5	treed	200	100	88.5	98	9.00

SMALL RADIUS, 2-LANE ROADS - HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					SPEED DETAILS			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
25	spacious	LH R=400	Maroondah Hwy. Near Growlers Gully Rd Merton 254 T6	7.4	7	6	grazing	350	100	97.6	106	9.89
26	spacious	LH R=480	Melba Hwy. Near Devlins Bridge. Glenmore Prop. 254 Q10	7.4	3.7	8	grazing	400	100	94.5	104	9.02
27	spacious	RH R=400	Maroondah Hwy. Near Growlers Gully Rd. Merton 254 T6	7.4	3.7	6	grazing	350	100	96.6	103	9.53
28	spacious	RH R=450	Maroondah Hwy. Near Kubeils Road Woodfield 254 T6	7.4	3.7	5	grazing	400	100	92.1	102	9.85
29	walled	LH R=360	Melba Hwy. After Kinglake Road Mt. Slide 254 Q11	7.4	3.7	2.5	heavily treed	200	100	-	-	-
30	walled	LH R=450	Goulbourn Valley Hwy. Near Native Dog Crk. Yea 254 R8	7.4	3.7	3.5	cutting	250	100	102.0	112	9.39
31	walled	RH R=360	Melba Hwy. After Kinglake Road Mt. Slide 254 Q11	7.4	3.7	2.5	heavily treed	200	100	-	-	-
32	walled	RH R=450	Goulbourn Valley Hwy. Near Native Dog Crk. Yea 254 R8	7.4	3.7	3.5	cutting	250	100	94.2	106	9.43

APPENDIX A - 8

LARGE RADIUS, GRAVEL ROADS - HORIZONTAL CURVE SITES.

S I T E D E S C R I P T I O N				S I T E D E T A I L S					S P E E D D E T A I L S			
S I T E N U M B E R	R O A D S I D E C A T E G O R Y	R O A D G E O M E T R Y	S I T E D E S C R I P T I O N	R O A D S E A L W I D T H (m)	R O A D L A N E W I D T H (m)	S H O U L D E R W I D T H (m)	R O A D S I D E E N V I R O N M E N T	R E M A I N I N G S I G H T D I S T A N C E A F T E R T R A V E L L I N G 5 S E C I N T O C U R V E (m)	S P E E D L I M I T (k p h)	F R E E S P E E D (m e a n k p h)	F R E E S P E E D (8 5 % k p h)	S T A N D A R D D E V I A T I O N
33	spacious	LH R=300	EDE Track (2-way) Monegeeta 253 J10	8.5	4.25	10+	farming	300	75	-	-	-
34	spacious	LH R=260	Colbinabbin - Lake Cooper Road, Colbinabbin 253 J1	7.1	3.55	10	grazing	300	75	-	-	-
35	spacious	RH R=300	EDE Track (2-way) Monegeeta 253 J10	8.5	4.25	10+	farming	300	75	-	-	-
36	spacious	RH R=260	Colbinabbin - Lake Cooper Road, Colbinabbin 253 J1	7.1	3.55	10	grazing	300	75	-	-	-
37	walled	LH R=540	Whroo-Negambie Rd. Reedy Lake 254 M3	7.5	3.75	2	light forest	250	75	-	-	-
38	walled	LH R=250	Cumberland-Woods Pt. Road. (W59) Cumberland 254 V12	7.1	3.55	2	forest	150	75	-	-	-
39	walled	RH R=540	Whroo-Negambie Rd. Reedy Lake 254 M3	7.5	3.75	2	light forest	250	75	-	-	-
40	walled	RH R=250	Cumberland-Woods Pt. Road. (W59) Cumberland 254 V12	7.1	3.55	2	forest	150	75	-	-	-

SMALL RADIUS, GRAVEL ROADS - HORIZONTAL CURVE SITES.

SITE DESCRIPTION				SITE DETAILS					PERFORMANCE			
SITE NUMBER	ROADSIDE CATEGORY	ROAD GEOMETRY	SITE DESCRIPTION	ROAD SEAL WIDTH (m)	ROAD LANE WIDTH (m)	SHOULDER WIDTH (m)	ROADSIDE ENVIRONMENT	REMAINING SIGHT DISTANCE AFTER TRAVELLING 5 SEC INTO CURVE (m)	SPEED LIMIT (kph)	FREE SPEED (mean kph)	FREE SPEED (85% kph)	STANDARD DEVIATION
41	spacious	LH R=160	Colbinabbin-Lake Cooper Road Colbinabbin 253 J1	7.1	3.55	7	grazing	200	75	-	-	-
42	spacious	LH R=140	EDE Track (Riddells Rd) Monegeeta 253 J10	7.0	3.5	10+	grazing	200	75	-	-	-
43	spacious	RH R=160	Colbinabbin-Lake Cooper Road Colbinabbin 253 J1	7.1	3.55	7	grazing	200	75	-	-	-
44	spacious	RH R=140	EDE Track (Riddells Rd) Monegeeta 253 J10	7.0	3.5	10+	grazing	200	75	-	-	-
45	walled	LH R=180	Reef Hills Road Benalla 254 V1	7.4	3.7	3	forest	200	75	-	-	-
46	walled	LH R=190	Watta Rd. Off River-View Drive Shepparton 251 J6	7.5	3.75	2	forest	200	75	-	-	-
47	walled	RH R=180	Reef Hills Road Benalla 254 V1	7.4	3.7	3	fore t	200	75	-	-	-
48	walled	RH R=190	Watta Rd. Off River-View Drive Shepparton 251 J6	7.5	3.75	2	fore t	200	75	-	-	-

APPENDIX A - 10
LABORATORY VALIDATION STUDY
CLOSE FOLLOWING TEST SITES.

SITE NUMBER	SITE DESCRIPTION	AREA	ROAD CATEGORY	SPEED LIMIT (kph)	FREE SPEED (kph) (mean / 85%)	FREE SPEED (std dev)	SEAL WIDTH (m)	LANE WIDTH (m)	ROADSIDE ENVIRONMENT	SHOULDER WIDTH	SIGHT DISTANCE
1	Dandenong 90 H3	semi - rural	4-lane Divided Arterial.	75	74.8 / 84	9.5	7.4	3.7	spacious - grazing land	5.0m	500m
2	Mulgrave Freeway, Dandenong 91 A6	semi - rural	4-lane Urban Freeway.	110	97 / 105	8.0	7.4	3.7	walled - treed	3.0m	1000m
3	Thompson Road, Cranbourne 129 K1	Rural	2-lane Undivided Collector.	100	84.2 / 93	9.6	7.4	3.7	spacious - market gardens	2.5m	1000m
4	Narre Warren-Cranbourne Road, Cranbourne 130 B12	Rural	2-lane Gravel Collector.	75	62.9 / 74	10.3	7.2	3.6	spacious - open paddocks	5.0m	1000m
5	Narre Warren-Cranbourne Road, Cranbourne 134 B1	semi - rural	2-lane Gravel Collector.	75	62.3 / 72	10.4	7.2	3.6	walled - treed	2.5m	500m
6	Narre Warren-Cranbourne Road, Cranbourne 134 B1	semi - rural	2-lane Gravel Collector.	75	65.5 / 74	12.8	7.2	3.6	walled - treed	2.5m	500m
7	Narre Warren-Cranbourne Road, Cranbourne 130 B12	Rural	2-lane Gravel Collector.	75	66.5 / 79	12.2	7.2	3.6	spacious - open paddocks	5.0m	500m
8	Narre Warren-Cranbourne Road, Cranbourne 130 C7	Rural	2-lane Undivided Collector.	100	90.6 / 101	10.3	7.4	3.7	walled - treed	5.0m	750m
9	Narre Warren-Cranbourne Road, Narre Warren 130 C4	Rural	2-lane Undivided Collector.	100	90.1 / 100	10.9	7.4	3.7	spacious - open paddocks	5.0m	1000m
10	Narre Warren-Cranbourne Road, Narre Warren 110 D9	Rural	2-lane Undivided Collector.	100	89.1 / 98	9.7	7.4	3.7	walled - treed	2.5m	1000m
11	Mulgrave Freeway, Dandenong 91 A6	semi - rural	4-lane Urban Freeway.	110	98.4 / 108	9.3	7.4	3.7	walled - treed	3.0m	1000m
12	Heatherton Road, Dandenong 90 H3	semi - rural	4-lane Divided Arterial.	75	77.5 / 87	8.4	7.4	3.7	spacious - grazing land	5.0m	750m

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*Map references from MELWAY - GREATER MELBOURNE, Edition N^o. 17, 1987.

APPENDIX B - 1

INSTRUCTIONS FOR THE ROAD SPEED EXPERIMENT

The purpose of the driving test today is to measure how safe you consider driving to be in a variety of road and traffic situations. You will be asked to make a series of judgements about whether you feel the speed you are travelling at in a particular road situation is too fast or too slow. There is no need to be unduly concerned about your safety as you will not be put through any dangerous exercises. We are only interested in your perceptions of speeds over a range of different travel speeds and road environments.

The pad on your knees is for recording your responses. You will note that each page has a line on it marked at each end as either too fast or too slow. For each site, you make your speed assessment by simply scribing across the response line at a position indicating your judgement. You may not wish to use either of the two extreme positions. However, you should try to use a range of responses somewhere between them. There will be differences in travel speed and your feeling of safety, for each of the sites you will be tested on.

A second response is also required at each site. Immediately following the slash-line response, would you please estimate to the nearest 5 kilometres per hour what speed you think you are travelling at and record it in the box in the right-hand corner of the response page. Remember, however, that the slash-line response should always be your first response and that the speed estimate response is secondary.

The course we will be travelling on has 12 sites for assessment. In addition, we will give you some practice before we start the main experiment. There will be plenty of warning when a site is approaching. When instructed, look down at the response pad and only look up when asked to do so. You will be given 5 seconds to view the road and then instructed to look down again and make your response. Please do not respond until after the full 5 seconds of viewing time.

When viewing the road during a test trial, try to concentrate on looking straight ahead and not be distracted by objects in any of the side windows. Also, try not to use any car cues about travel speed but rely entirely on the road and the environment immediately ahead of you.

Are there any questions?

APPENDIX B - 2

INSTRUCTIONS FOR THE LABORATORY SPEED EXPERIMENT

The purpose of this experiment today is to measure how safe you consider driving is in a variety of road and traffic situations. You will be shown a series of road scenes as viewed from the driving position of a moving car. Your task is to judge whether the speed you are travelling at is too fast or too slow compared to what you consider is a safe operating speed. There is no need to be concerned about speed limits when making your judgements. We are not interested in knowing what speed limit is appropriate but rather what you believe is a safe operating speed for a range of different travel speeds and road environments.

The pad in front of you is for recording your responses. You will note that each page has a line on it marked at each end as either too fast or too slow. For each site, you make your speed assessment by simply scribing across the response line at a position indicating your judgement. You may not want to use either of the two extreme positions, however, you should try to use a range of responses somewhere between them. There will be differences in travel speed and your feelings of safety for each of the road scenes you will be tested on.

A second response is also required for each scene. Immediately following the slash-line response, would you please estimate to the nearest 5kph what speed you think you are travelling at and then record that in the box in the right hand corner of the response page. Remember, however, that the slash-line response should always be your first response and that the speed estimate response is secondary.

You will be shown a range of road scenes for assessment. **Each road scene** will be displayed on the screen in front of you for 5 seconds followed by 10 seconds of blank screen. During each road presentation, you should concentrate on looking only at the screen. When the road scene disappears, then look down at your response book and quickly make your assessments. **We will give you warning** when another scene is about to appear. In addition, you will also be given practice at making these judgements before we start the main experiment.

And finally, when viewing the road during a test trial, try to concentrate at looking straight ahead as you would if you were driving. **Try not to be distracted** by anything happening around you during a test trial.

Are there any questions?

"CLOSE FOLLOWING" STUDY - ONROAD INSTRUCTIONS

The purpose of the driving test today is to measure how safe you consider driving to be in a variety of road and traffic situations. You will be asked to make a series of judgements about how safe you feel about the distance between you and the vehicle in front. There is no need to be unduly concerned about your safety as you will not be put through any dangerous exercises. We are only interested in your feelings of safety for a range of different travel speeds and road environments.

The pad on your knees is for recording your responses. You will note that each page has a line on it marked at each end as either very safe or very unsafe. For each site, you make your safety assessment by simply scribing across the response line at a position indicating your judgement. You may not want to use either of the two extreme positions. However, you should try to use a range of responses somewhere between them. There will be differences in travel speed and your feelings of safety for each of the road sites you will be tested on.

A second response is also required for each site. Immediately following the slash line response would you please estimate to the nearest 5 kph what speed you think you are travelling at, and then record that in the box in the right hand corner of the response page. Remember, however, that the slash line response should always be your first response and that the speed estimate response is secondary.

The course we will be travelling on has 12 sites for assessment. In addition we will give you some practice before we start the main experiment. There will be plenty of warning when a site is approaching. When instructed, look down at the response pad and only look up when asked to do so. You will be given 5 seconds to view the road and then instructed to look down again and make your response. Please do not respond until after the full 5 seconds of viewing time.

When viewing the road during a test trial try to concentrate on looking straight ahead and not be distracted by any objects in any of the side windows. Also try not to use any car cues but rely entirely on the road and the environment immediately ahead of you.

Are there any questions?

APPENDIX - B4

"CLOSE FOLLOWING" STUDY - LABORATORY INSTRUCTIONS

The purpose of this experiment today is to measure how safe you consider driving is in a variety of road and traffic situations. You will be shown a series of road scenes as viewed from the driving position of a moving car. Your task is to judge how safe you feel about the distance between you and the vehicle in front for a range of different travel speeds and road environments.

The pad in front of you is for recording your responses. You will note that each page has a line on it marked at each end as either very safe or very unsafe. For each site you make your safety assessment by simply scribing across the response line at a position indicating your judgement. You may not want to use either of the two extreme positions. However, you should try to use a range of responses somewhere between them. There will be differences in travel speed and your feelings of safety for each of the road scenes you will be tested on.

A second response is also required for each scene. Immediately following the slash line response would you please estimate to the nearest 5 kph what speed you think you are travelling at, and then record that in the box in the right hand corner of the response page. Remember, however, that the slash line response should always be your first response and that the speed estimate response is secondary.

You will be shown 12 different road scenes for assessment. Each road scene will be displayed on the screen in front of you for 5 seconds, followed by 10 seconds of blank screen. When the road scene disappears, then look down at your response book and quickly make your assessments. We will give you warning when another road scene is about to appear. In addition you will also be given practice at making these judgements before we start the main experiment.

And finally, when viewing the road during a test trial, try to concentrate on looking straight ahead as you would if you were driving. Try not to be distracted by anything happening around you during the test trial.

Are there any questions?

TABLE C-1
 ANALYSIS OF VARIANCE SUMMARY TABLE
 DAY & NIGHT VISION EXPERIMENT
 SAFETY ESTIMATE DATA
 SIGNIFICANT & NOTEWORTHY EFFECTS

EFFECT	SS	df	MS	F	w ²
SPEED	52,400	1	52,400	104.5 ^{***}	.0918
TYPE OF ROAD	13,485	2	13,485	23.8 ^{***}	.0229
SEX OF THE DRIVER	15,425	1	15,425	3.7	.0199
ROADSIDE ENVIRONMENT	7,836	1	7,836	72.3 ^{***}	.0137
SPEED X FILMTIME	4,574	1	4,574	46.9 ^{***}	.0079
FILMTIME	3,817	1	3,817	8.8 ^{**}	.0060
FILMTIME X ROADSIDE	3,221	1	3,221	31.2 ^{***}	.0055
TESTTIME	7,018	1	7,018	1.7	.0055
ROAD X FTIME X SIDE	2,232	2	1,116	15.6 ^{***}	.0037
SPEED X ROAD	1,891	2	946	13.1 ^{***}	.0031

SPEED X ROAD X FTIME X SIDE	1,179	2	590	6.8 ^{**}	.0018
SPEED X ROAD X SIDE X SEX	1,025	2	512	6.4 ^{**}	.0015
SPEED X SIDE X EXP X SEX	826	1	826	9.1 ^{**}	.0013
SPEED X ROAD X FTIME X SIDE X EXP	875	2	438	5.1 ^{**}	.0012
SPEED X FTIME X EXP	656	1	656	6.7	.0010
ROAD X FILMTIME	795	2	397	3.6	.0010
SPEED X ROAD X EXP X TTIME	693	2	347	4.8	.0009
ROAD X ROADSIDE	758	2	379	3.4 [*]	.0009
SPEED X ROAD X SIDE	579	2	290	3.6	.0007
FTIME X SIDE X EXP X TTIME	424	1	424	4.1	.0006
FILMTIME X TESTTIME	20	1	20	<1	.0000

*** prob <.001

** prob <.01

* prob <.05

TABLE C-2
 ANALYSIS OF VARIANCE SUMMARY TABLE
 DAY & NIGHT VISION EXPERIMENT
 SPEED ESTIMATE ERROR DATA
 SIGNIFICANT & NOTEWORTHY EFFECTS

EFFECT	SS	df	MS	F	w ²
SPEED	30,876	1	30,876	118.4 ^{***}	.0809
ROAD	17,632	2	8,816	56.3 ^{***}	.0458
FILM TIME	15,334	1	15,334	59.5 ^{***}	.0398
SEX X TEST TIME	10,853	1	10,853	2.5	.0170
EXPERIENCE	7,386	1	7,386	1.7	.0078
SEX	7,100	1	7,100	1.6	.0071
ROAD X SEX	1,715	2	857	5.5 ^{**}	.0037
SPEED X FILM TIME	1,431	1	1,431	20.9 ^{***}	.0036
SPEED X ROAD	1,404	2	702	13.8 ^{***}	.0034
ROAD X FILM TIME	1,103	2	551	7.1 ^{**}	.0025
FILM TIME X SEX	1,160	1	1,160	4.5	.0023

SPEED X ROADSIDE	582	1	582	14.1 ^{***}	.0014
SPEED X ROAD X SIDE X EXP	498	2	249	5.8 ^{**}	.0010
SPEED X ROAD X FTIME X SIDE X EXP	516	2	258	3.7 [*]	.0010
ROADSIDE	369	1	369	7.4 ^{**}	.0008
ROADSIDE X SEX	354	1	354	7.1 [*]	.0008
ROAD X FTIME X SIDE	394	2	197	4.6	.0008
ROAD X FTIME X SIDE X EXP X SEX	350	2	175	4.1	.0007
SPEED X ROAD X SIDE X SEX	306	2	153	3.6	.0006
ROAD X FTIME X SIDE X SEX	300	2	150	3.5	.0006
SIDE X EXP X SEX X TTIME	209	1	209	4.2 [*]	.0000
TESTTIME X FILM TIME	1	1	1	<1	.0000

*** prob <.001

** prob <.01

prob <.05

TABLE C-3
ANALYSIS OF VARIANCE SUMMARY TABLE
CURVATURE VALIDATION STUDY
SAFETY ESTIMATE DATA

EFFECT	SS	df	MS	F	w^2
SITE	4,266	11	388	3.7**	.0657
EXPERIMENT X SITE	3,975	11	3,975	3.4**	.0595
EXPERIMENT	87	1	87	<1	.0000

*** prob <.001

** prob <.01

* prob <.05

TABLE C-4
ANALYSIS OF VARIANCE SUMMARY TABLE
CURVATURE VALIDATION STUDY
SPEED ESTIMATE ERROR DATA

EFFECT	SS	df	MS	F	w^2
EXPERIMENT X SITE	1,530	11	139	1.2	.0040
SITE	1,454	11	132	1.1	.0030
EXPERIMENT	5	1	5	<1	.0000

*** prob <.001

** prob <.01

* prob <.05

TABLE C-5
 ANALYSIS OF VARIANCE SUMMARY TABLE
 HORIZONTAL CURVATURE EXPERIMENT
 SAFETY ESTIMATE DATA
 SIGNIFICANT & NOTEWORTHY EFFECTS

EFFECT	SS	df	MS	F	2
SPEED	352.251	1	352.251	310.5 ^{***}	.2380
TYPE OF ROAD	178.670	2	89.335	104.1 ^{***}	.1199
RADIUS	66.781	1	66.781	232.0 ^{***}	.0451
SEX OF THE DRIVER	48.637	1	48.637	10.2 ^{**}	.0297
SPEED X EXPERIENCE	15.394	1	15.394	13.6 ^{***}	.0097
ROAD X ROADSIDE	10.354	2	5.177	41.1 ^{***}	.0068
RADIUS X ROADSIDE	5.658	1	5.658	42.5 ^{***}	.0037
ROAD X RADIUS X ROADSIDE X DIRECTION	4.630	2	2.315	33.6 ^{***}	.0030

ROAD X EXPERIENCE	4.938	2	2.468	2.9	.0020
SPEED X SEX X EXPERIENCE	3.661	1	3.661	3.2	.0017
RADIUS X ROADSIDE X DIRECTION	2.484	1	2.484	34.3 ^{***}	.0016
ROAD X RADIUS	2.076	2	1.038	9.2 ^{***}	.0013
SPEED X ROAD X RADIUS	2.030	2	1.015	9.7 ^{***}	.0012
ROAD X RADIUS X DIRECTION	1.990	2	995	8.3 ^{***}	.0012
ROAD X RADIUS X ROADSIDE X EXPERIENCE	1.590	2	795	7.8 ^{***}	.0010
RADIUS X EXPERIENCE	1.495	1	1.495	5.2 [*]	.0008
RADIUS X DIRECTION	1.259	1	1.259	13.4 ^{***}	.0008
SPEED X ROAD X ROADSIDE	1.356	2	678	9.9 ^{***}	.0008
ROAD X ROADSIDE X SEX	606	2	303	5.1 ^{**}	.0007
SPEED X ROAD	1.255	2	628	5.1 ^{**}	.0007
SPEED X RADIUS X ROADSIDE X DIRECTION	882	1	882	4.8 ^{**}	.0005
SPEED X DIRECTION X EXPERIENCE	752	1	752	5.8 [*]	.0004
ROADSIDE X DIRECTION X SEX X EXP	684	1	684	9.1 ^{**}	.0004
ROAD X RADIUS X SIDE X SEX X EXP	771	2	385	3.8 [*]	.0004
ROAD X ROADSIDE X DIRECTION	721	2	360	4.7 [*]	.0004
DIRECTION	763	1	763	4.3 [*]	.0003
SPEED X RADIUS X ROADSIDE	586	1	586	7.0 ^{**}	.0003
ROAD X RADIUS X ROADSIDE X SEX	695	2	347	3.4 [*]	.0003
SPEED X RADIUS	344	1	344	4.6 [*]	.0002
ROAD X DIRECTION	651	2	326	3.1 [*]	.0002
SPEED X ROADSIDE X EXPERIENCE	241	1	241	4.0 [*]	.0001

*** prob <.001

** prob <.01

* prob <.05

TABLE C-6
ANALYSIS OF VARIANCE SUMMARY TABLE
HORIZONTAL CURVATURE EXPERIMENT
SPEED ESTIMATE ERROR DATA
SIGNIFICANT & NOTEWORTHY EFFECTS

EFFECT	SS	df	MS	F	w ²
ROAD	185,753	2	92,876	228.9 ^{***}	.1598
SPEED	123,272	1	123,272	533.1 ^{***}	.1063
EXPERIENCE	67,261	1	67,261	9.76 ^{**}	.0522
SEX X EXPERIENCE	56,199	1	56,199	8.2 ^{**}	.0426
ROAD X SEX	7,976	2	3,988	9.8 ^{***}	.0062
ROAD X RADIUS X ROADSIDE	6,760	2	3,380	73.9 ^{***}	.0057
RADIUS	5,461	1	5,461	43.8 ^{***}	.0046
ROAD X RADIUS	2,456	2	1,228	21.4 ^{***}	.0020

DRIVER SEX	9,742	1	9,742	1.4	.0023
ROAD X RADIUS X DIRECTION	1,307	2	653	15.1 ^{***}	.0011
SPEED X ROAD	1,061	2	530	11.7 ^{***}	.0008
ROADSIDE X DIRECTION	921	1	921	38.1 ^{***}	.0008
ROAD X DIR X SEX X EXP	658	2	329	6.8 ^{**}	.0005
ROADSIDE	560	1	560	7.2 ^{**}	.0004
RADIUS X ROADSIDE X DIRECTION	547	1	547	15.6 ^{***}	.0004
ROAD X RADIUS X ROADSIDE X DIRECTION	517	2	258	6.9 ^{**}	.0004
DIRECTION X EXPERIENCE	420	1	420	5.9	.0003
ROADSIDE X DIRECTION X EXPERIENCE	326	1	326	13.5 ^{***}	.0003
SPEED X ROAD X ROADSIDE	471	2	235	6.3 ^{**}	.0003
SPEED X ROADSIDE X DIRECTION	427	1	427	12.8 ^{***}	.0003
SPEED X ROAD X RADIUS X ROADSIDE	366	2	183	5.6 ^{**}	.0003
ROAD X ROADSIDE	329	2	164	3.2 [*]	.0002
ROAD X DIRECTION	347	2	173	3.6 [*]	.0002
ROAD X RADIUS X ROADSIDE X EXPERIENCE	392	2	196	4.3 [*]	.0002
ROAD X ROADSIDE X DIRECTION	318	2	159	4.5 [*]	.0002
SPEED X ROAD X RADIUS X SIDE X DIR	247	2	123	3.1	.0002
SPEED X ROADSIDE	222	1	222	8.4 ^{**}	.0002

*** prob <.001

** prob <.01

* prob <.05

TABLE C-7
ANALYSIS OF VARIANCE SUMMARY TABLE
CLOSE FOLLOWING VALIDATION STUDY
SAFETY ESTIMATE DATA

EFFECT	SS	df	MS	F	w ²
SITE	322,113	11	29 283	54.2***	6235
EXPERIMENT	20 133	1	20,133	4 9*	0315
EXPERIMENT X SITE	20.677	11	1,879	3.5***	0290

*** prob < 001

prob < 01

* prob < 05

TABLE C-8
ANALYSIS OF VARIANCE SUMMARY TABLE
CLOSE FOLLOWING VALIDATION STUDY
SPEED ESTIMATE ERROR DATA

EFFECT	SS	df	MS	F	w^2
SITE	65,785	11	5,980	74.0***	.5581
EXPERIMENT	7,411	1	7,411	8.7**	.0564
EXPERIMENT X SITE	3,942	11	358	4.4***	.0262

*** prob <.001

** prob <.01

* prob <.05

APPENDIX D: FREE SPEEDS AND TRAFFIC VOLUMES BEFORE AND AFTER PERCEPTUAL ROAD TREATMENT ALONG KERFERD ROAD, SOUTH MELBOURNE.

SITE DESCRIPTION	AREA	ROAD CATEGORY	STAGE OF PERCEPTUAL ROAD TREATMENT	DATE	SPEED LIMIT km/h	FREE SPEED MEAN, STD. DEV, 15% (kph)	TRAFFIC VOLUME	SEAL WIDTH	LANE WIDTH	SHOULDER WIDTH	SIGHT DISTANCE	NOTES
Kerferd Rd. Mel. 2J-B8 South bound (between Herbert and Hamilton Streets)	residential	4-lane divided, secondary arterial road.	before treatment	22-9-87 p.m.	60	62.44 8.88 71	Kerferd Rd. between Danka & Page Sts. Nov. '84, 24 hrs. 5,858 vehicles	14m	5.0m (4m parking)	4m	>500m	valleyed-houses and treed median strip
" "	" "	" "	after 1st stage (gravel-strip, no line marking)	1-3-88 p.m.	60	59.34 9.24 68	Kerferd Rd. between Danka & Page Sts. 25-5-88 24 hrs. 5,579 vehicles	14m	3.7m (4m parking (2.5m bike path))	4m	>500m	" "
Kerferd Rd. Mel. 2J-B8 North bound (between Herbert and Hamilton Streets)	" "	" "	before treatment	22-9-87 p.m.	60	62.78 7.34 70	Kerferd Rd. between Danka & Page Sts. Nov. '84, 24 hrs. 5,622 vehicles	14m	5.0m	4m	>500m	" "
" "	" "	" "	after 1st stage (gravel-strip, no line marking)	1-3-88 p.m.	60	64.19 6.72 71	Kerferd Rd. between Danka & Page Sts. 25-5-88 24 hrs. 5,630 vehicles	14m	3.7m (4m parking (2.5m bike path))	4m	>500m	" "
" "	" "	" "	after 2nd stage (complete line marking & gravel)	22-3-88 p.m.	60	63.49 8.43 72	-----	14m	3.7m	4m	>500m	" "
Mason Street Altona Mel. 55 D3 eastbound	" "	" "	control site	17-2-84 p.m.	60	65.0 8.2 73	-----	7.4m	3.2m / 4.2m	4m	>500m	" "
" "	" "	" "	" "	3-6-88 p.m.	60	65.36 8.15 73	-----	7.4m	3.2m / 4.2m	4m	>500m	" "
Mason Street Altona Mel. 55 D3 westbound	" "	" "	" "	16-2-84 p.m.	60	66.3 6.8 72	-----	7.4m	3.2m / 4.2m	4m	>500m	" "
" "	" "	" "	" "	3-6-88 p.m.	60	65.17 8.43 72	-----	7.4m	3.2m / 4.2m	4m	>500m	" "