DEPARTMENT OF TRANSPORT
FEDERAL OFFICE OF ROAD SAFETY

DOCUMENT RETRIEVAL INFORMATION

Report No.	Date	Pages	ISBN	ISSN
CR60	June 1989	174	0 642 51402X	CR=0810-770X

Title and Subtitle

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

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Available from

Federal Office of Road Safety

Price/Availability/Format

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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 (b) reports of research conducted by other organisations on behalf of FORS are published in the CR series.

ACKNOWLEDGEMENTS

The authors are indebted to the Federal Office of Road Safety, Commonwealth Department of Transport and Communications, Australia, for their sponsorship, interest and assistance in this project.

A study of this magnitude could not have been undertaken without the help and co-operation of a large number of RACV staff. In particular, Mr. Ian Russell of the Traffic & Safety Department assisted in setting up the project, the Chief Engineer, Mr. John McKenzie, provided the research vehicle, Mr. Don Finegan assisted with the necessary vehicle modifications and associated equipment, and many other staff willingly agreed to participate in the experiments.

The authors are also indebted to Mr. Heinz Schulte and Mr. Don Wells of Hella Manufacturing Co. Pty. Ltd. who generously aided in the selection and supply of the Rallye 2000 spotlights used for night filming. The Victorian Police force also assisted in traffic control during the night filming sessions and we are grateful to Superintendent R. Stevens and his staff for their co-operation. Our thanks, too, to Major L. Morgan, Officer Commanding, EDE Proving Ground at Monegetta, Victoria and staff for assisting with site filming and testing.

Monash University generously contributed in the preparation of the stimulus materials. In particular, Mr. Ken Hall, Mr. Vladimar Kohout and Mr. Richard Hobbs of the Department of Psychology supplied and fitted the Bolex camera to the research vehicle, while Mr. Don Hausser and Mr. John Torrance of the Higher Education Research Unit kindly helped with film editing.

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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 and 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.

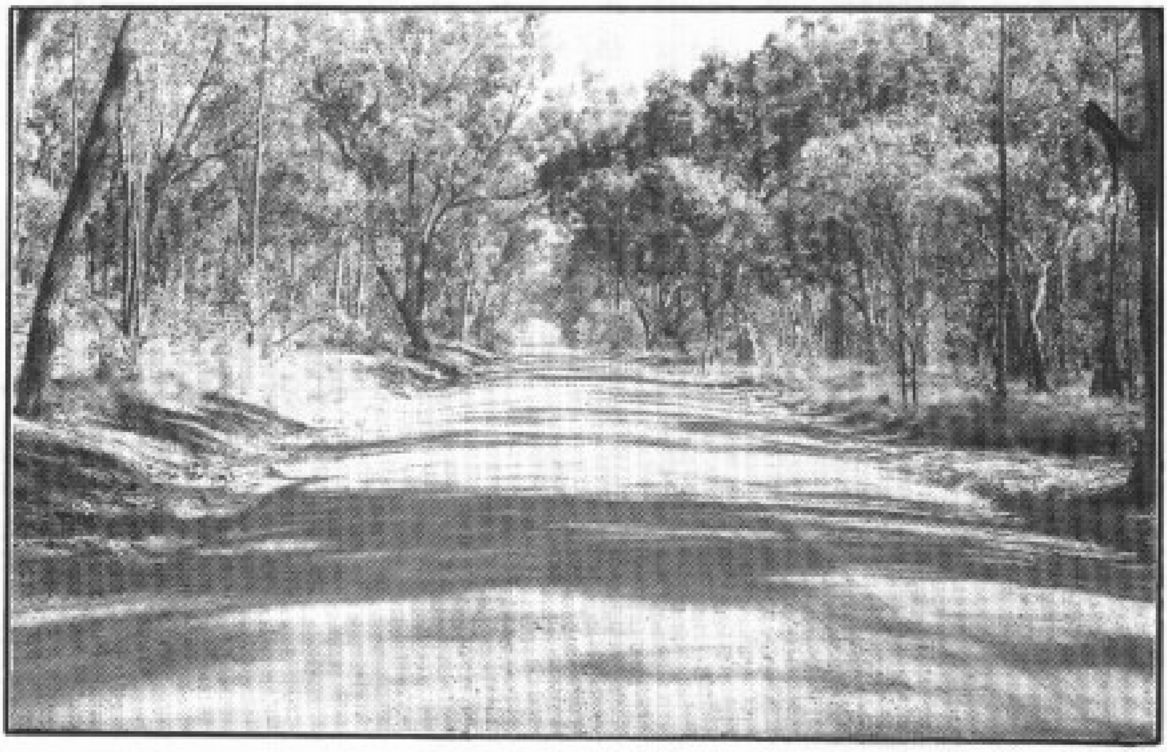
2.1 STIMULUS MATERIALS

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 (day-light 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 spotlights[1] 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.

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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).

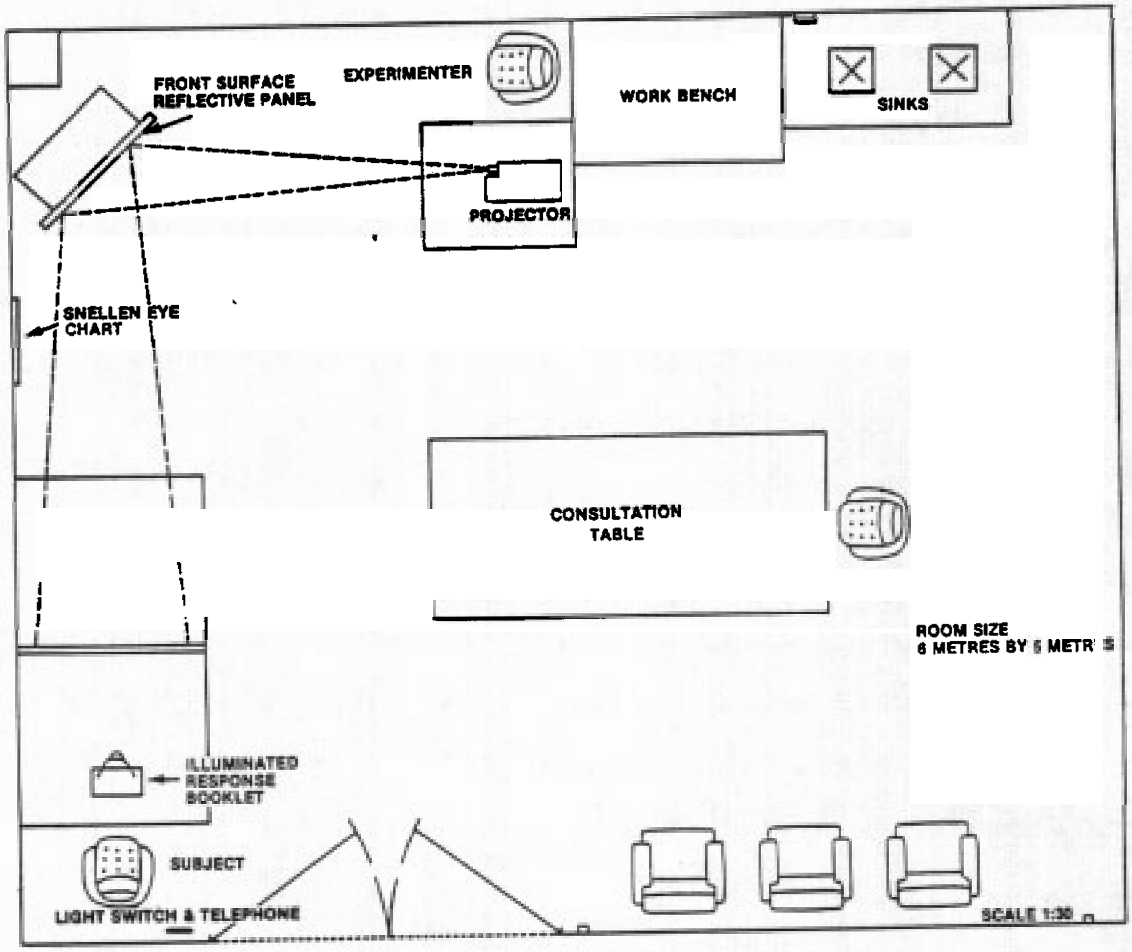


FIGURE 2.3 — Details of laboratory arrangement.

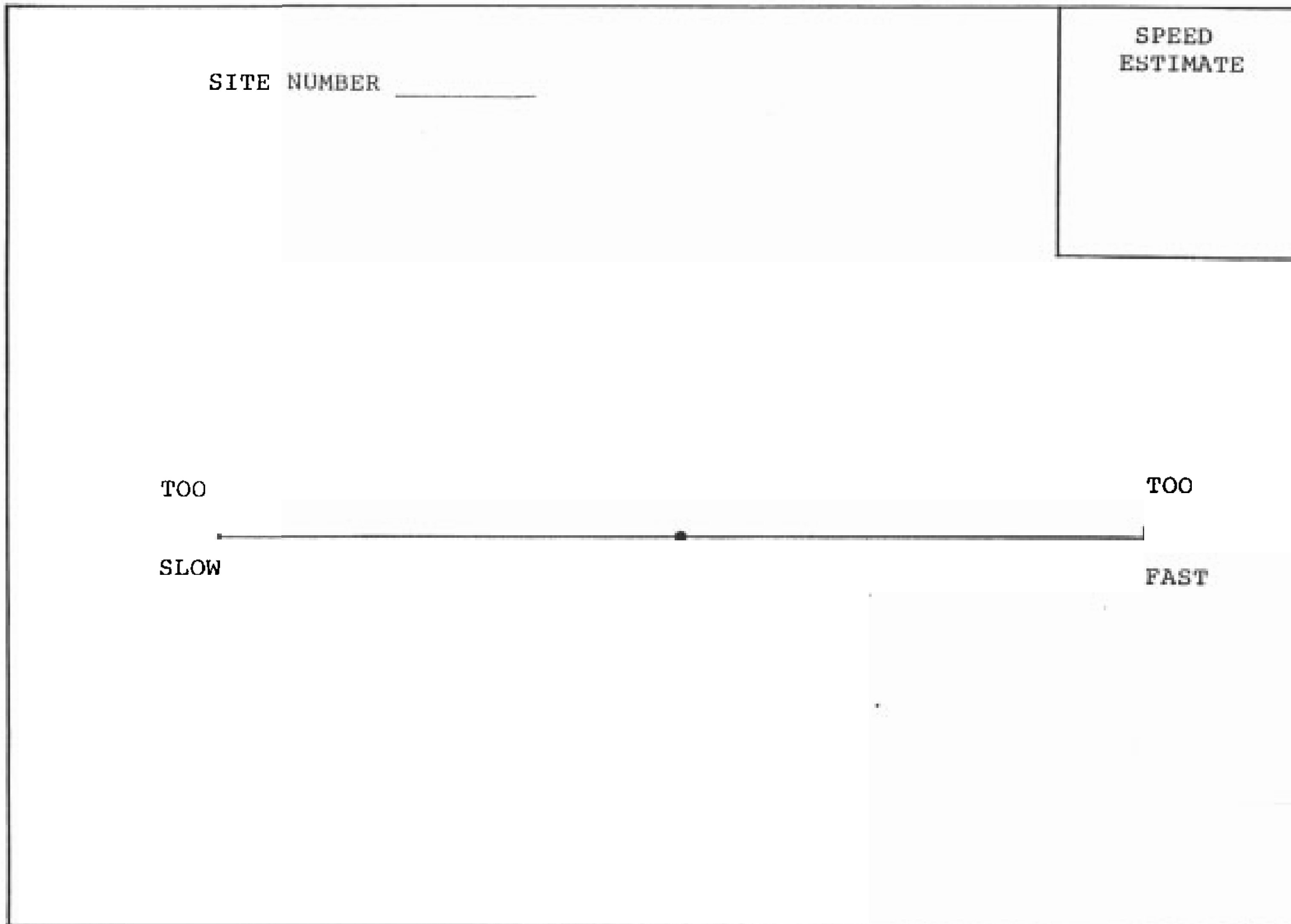


FIGURE 2.4 — Sample page from the response booklet.

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.

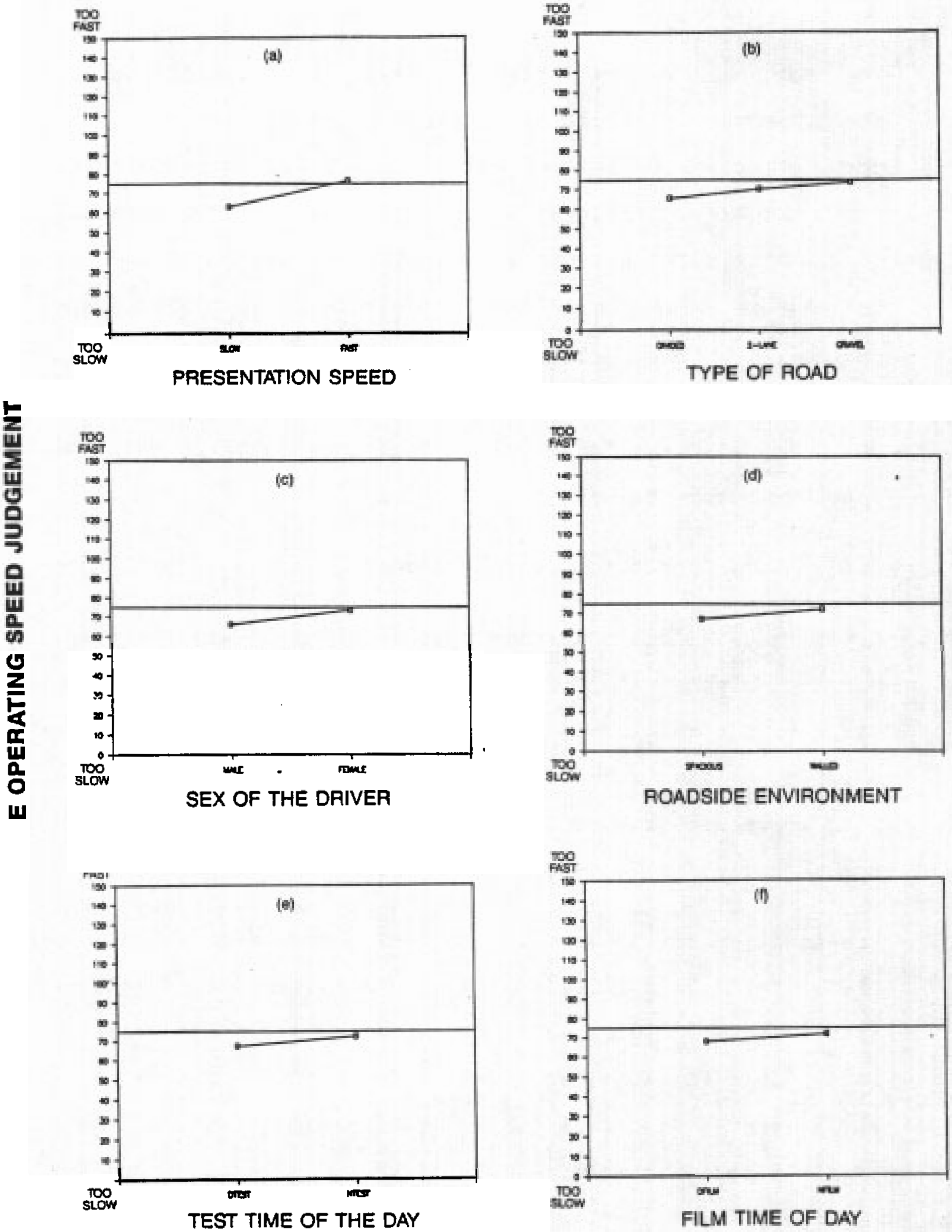


FIGURE 2.5 — Safe operating speed main effects of interest for the day/night experiment.

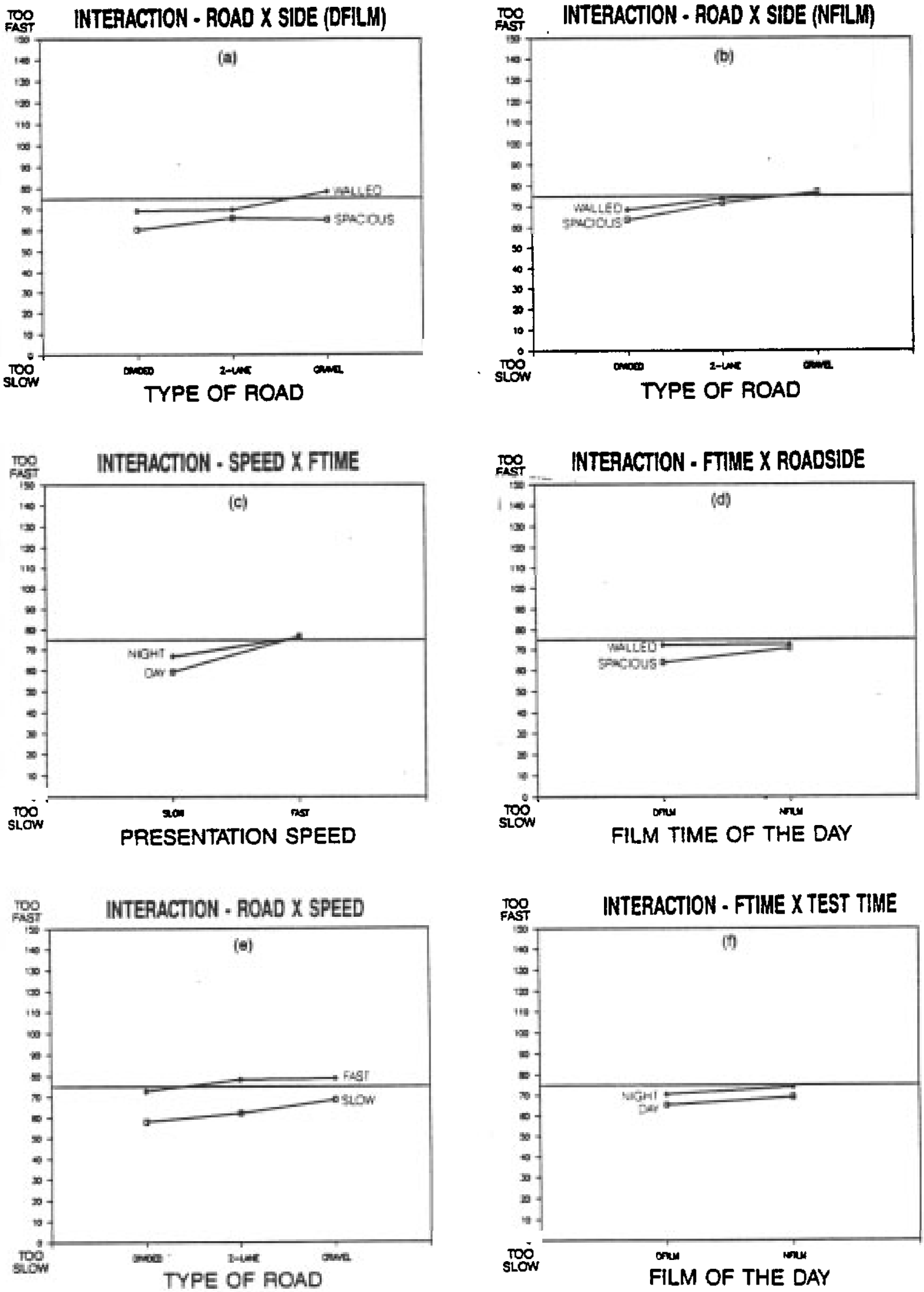


FIGURE 2.6 — Safe operating speed interactions of interest for the day/night experiment.

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** C-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.

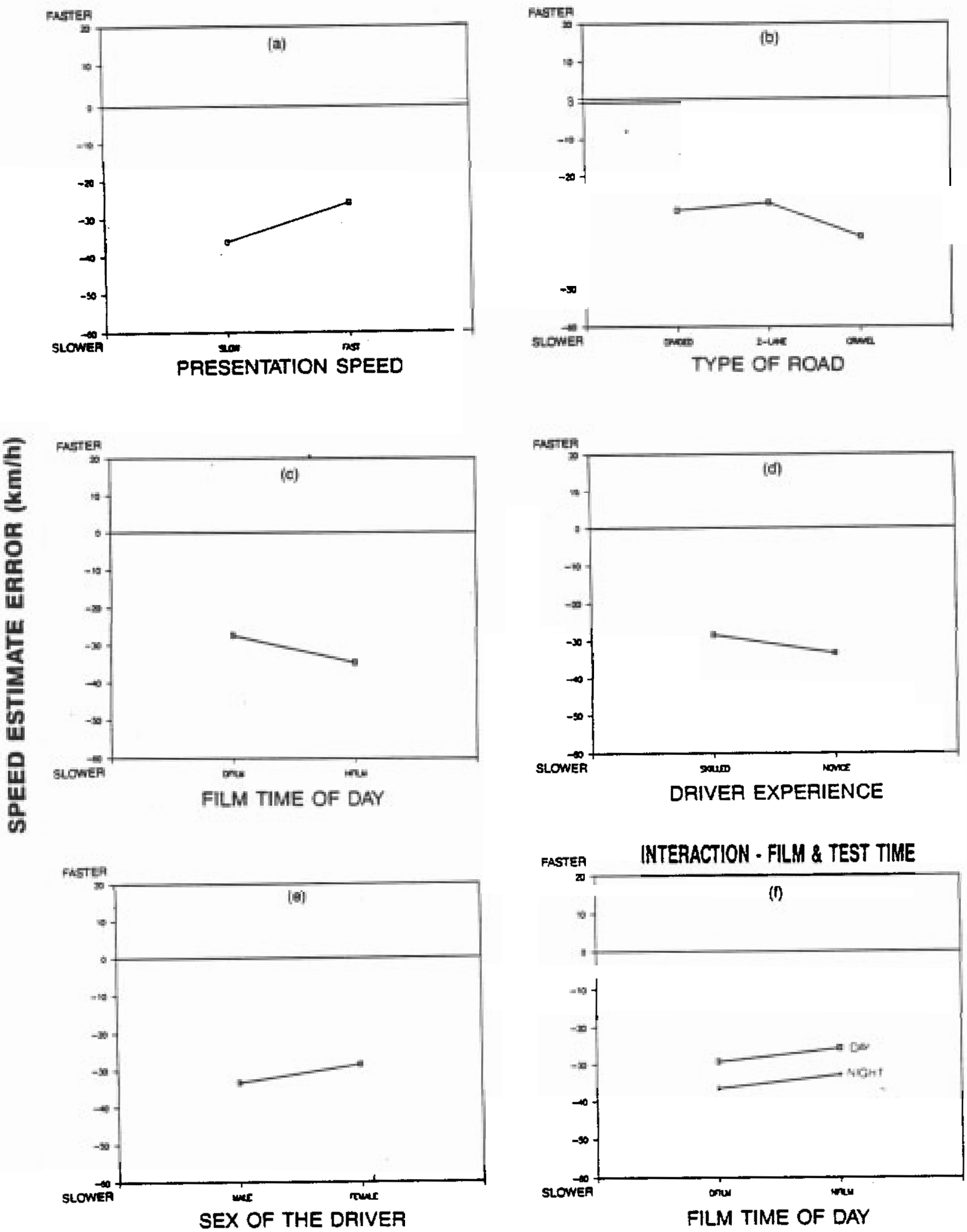


FIGURE 2.7 — Speed estimate error main effects and one interaction of interest in the day/night experiment.

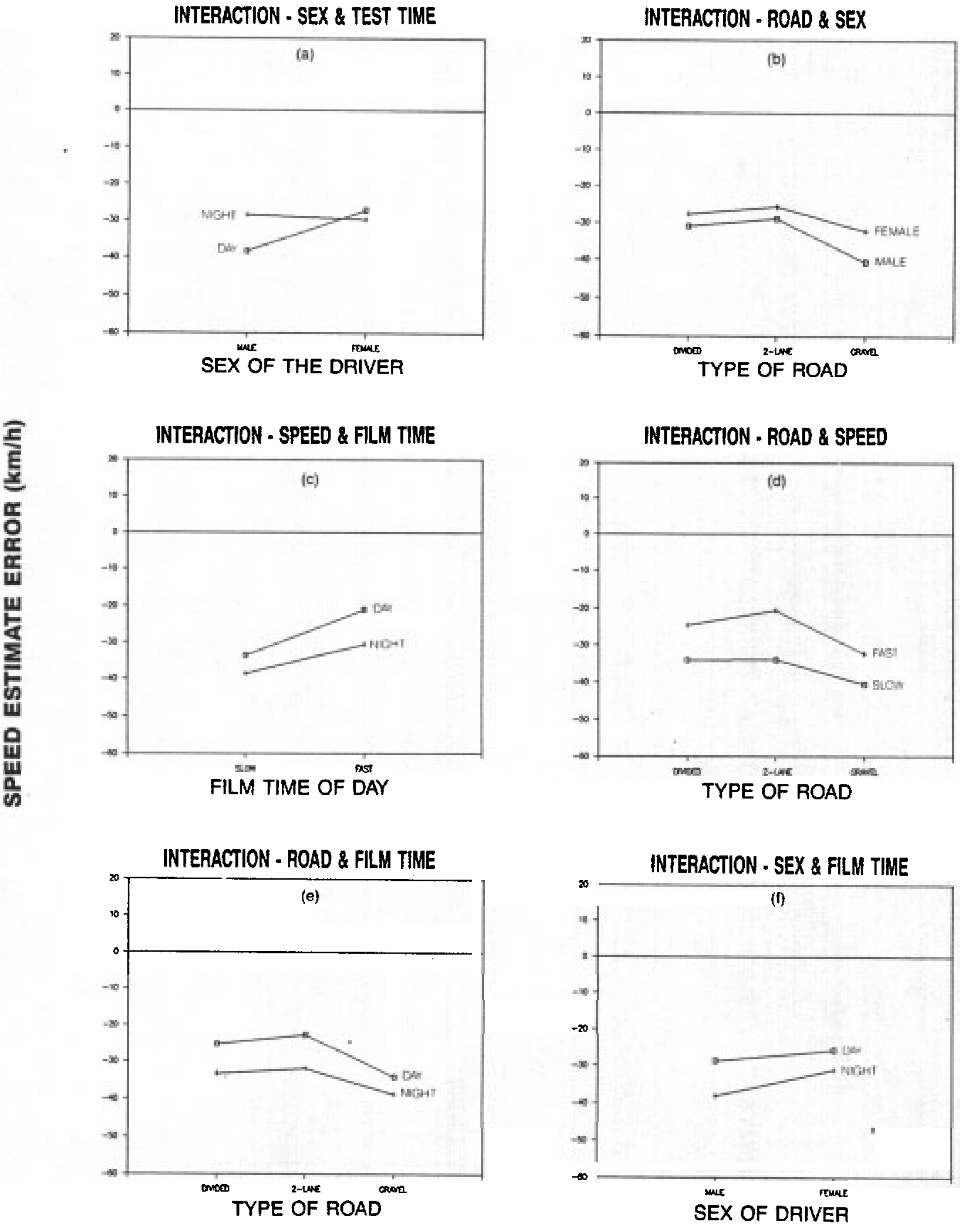


FIGURE 2.8 — Speed estimate error interactions of interest in the day/night experiment.

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.

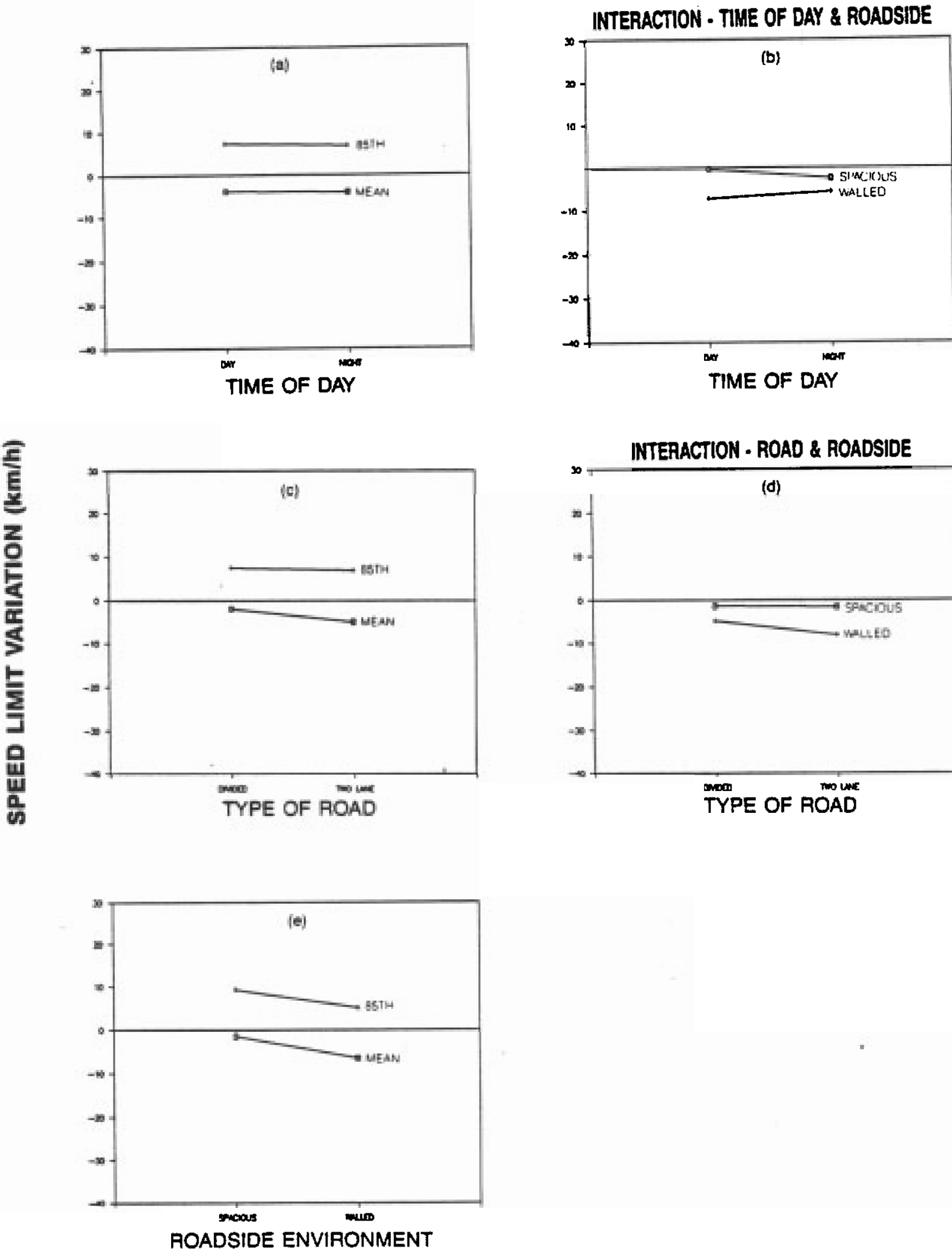


FIGURE 2.9 — Free speed variations around the speed limit in km/h for the variables of interest in the day and night vision experiment.

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 ststic, 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 at 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.

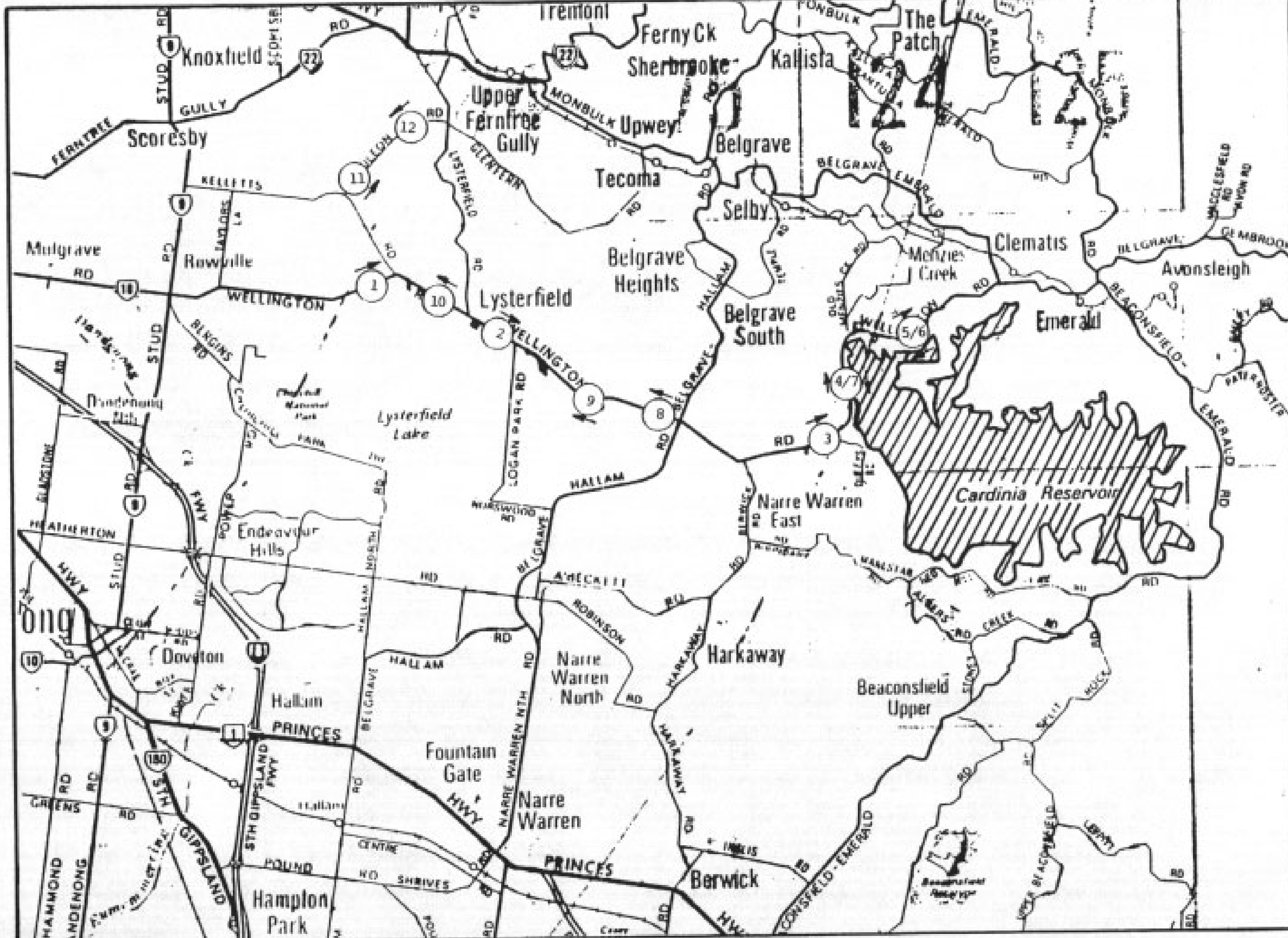
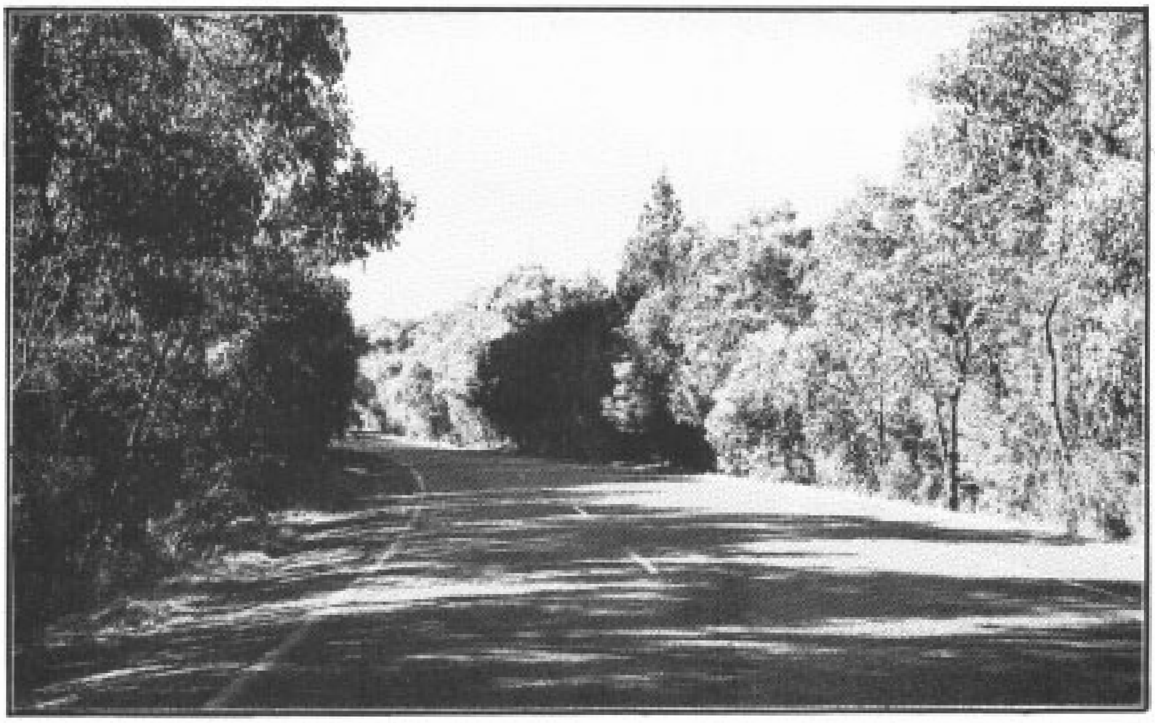


FIGURE 3.1 — Test sites and travel route used in the curvature validation study.

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 ($F(11,176)=3.7$, $p<.001$, $w^2=.066$).

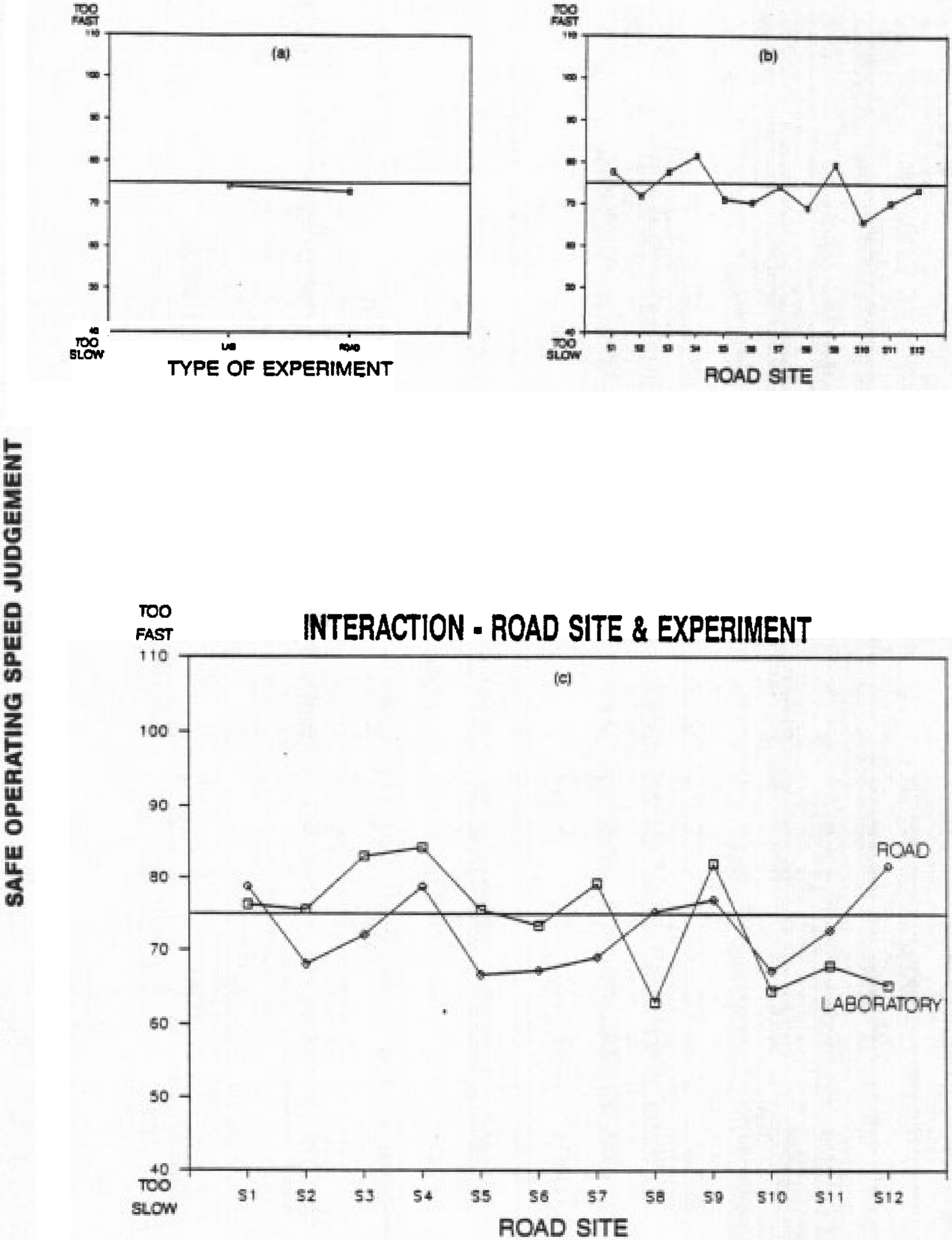


FIGURE 3.3 — Safe operating speed results of interest in the curvature validation study.

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.

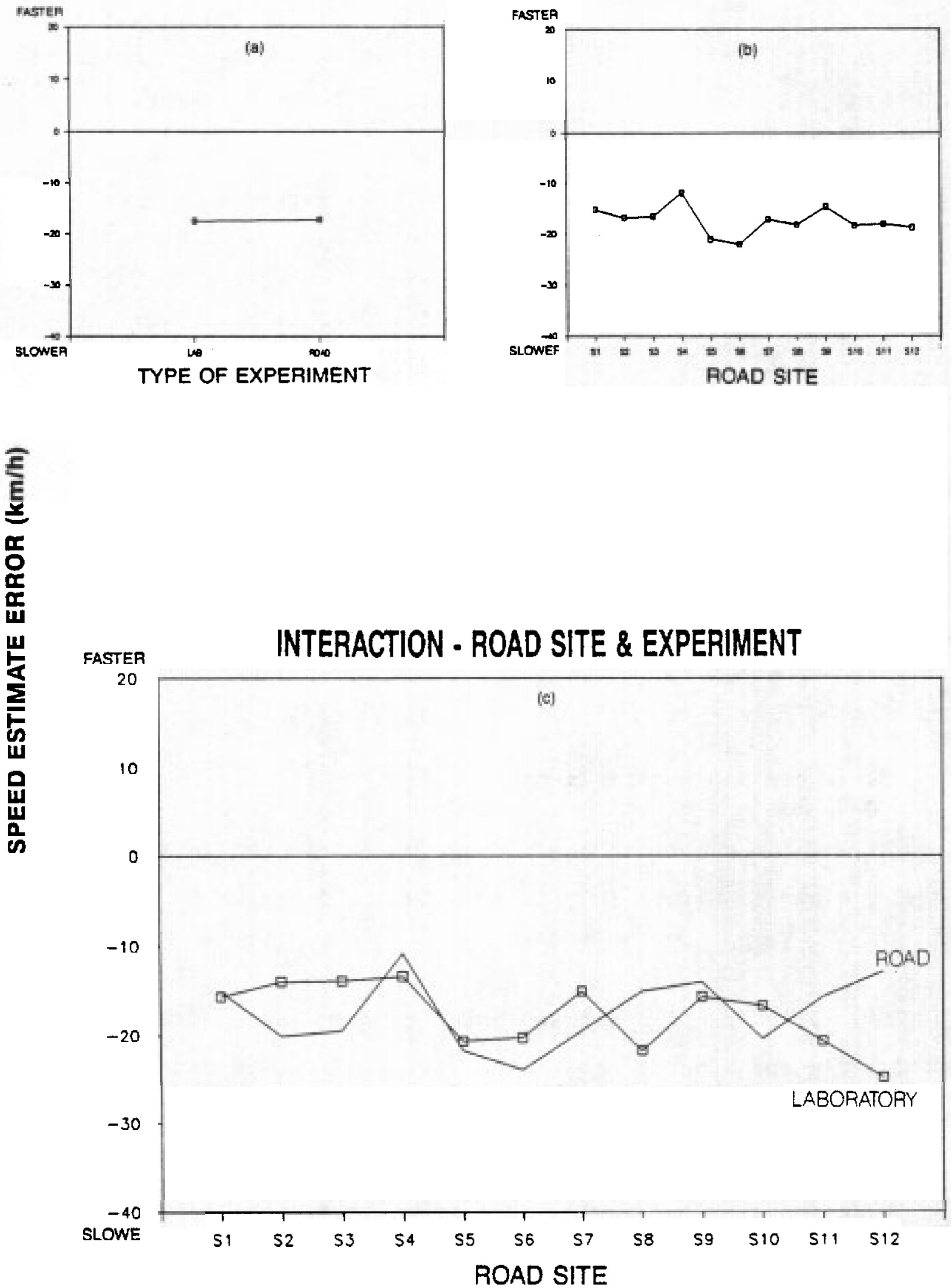


FIGURE 3.4 — Speed estimate error results of interest in the curvature validation study.

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.

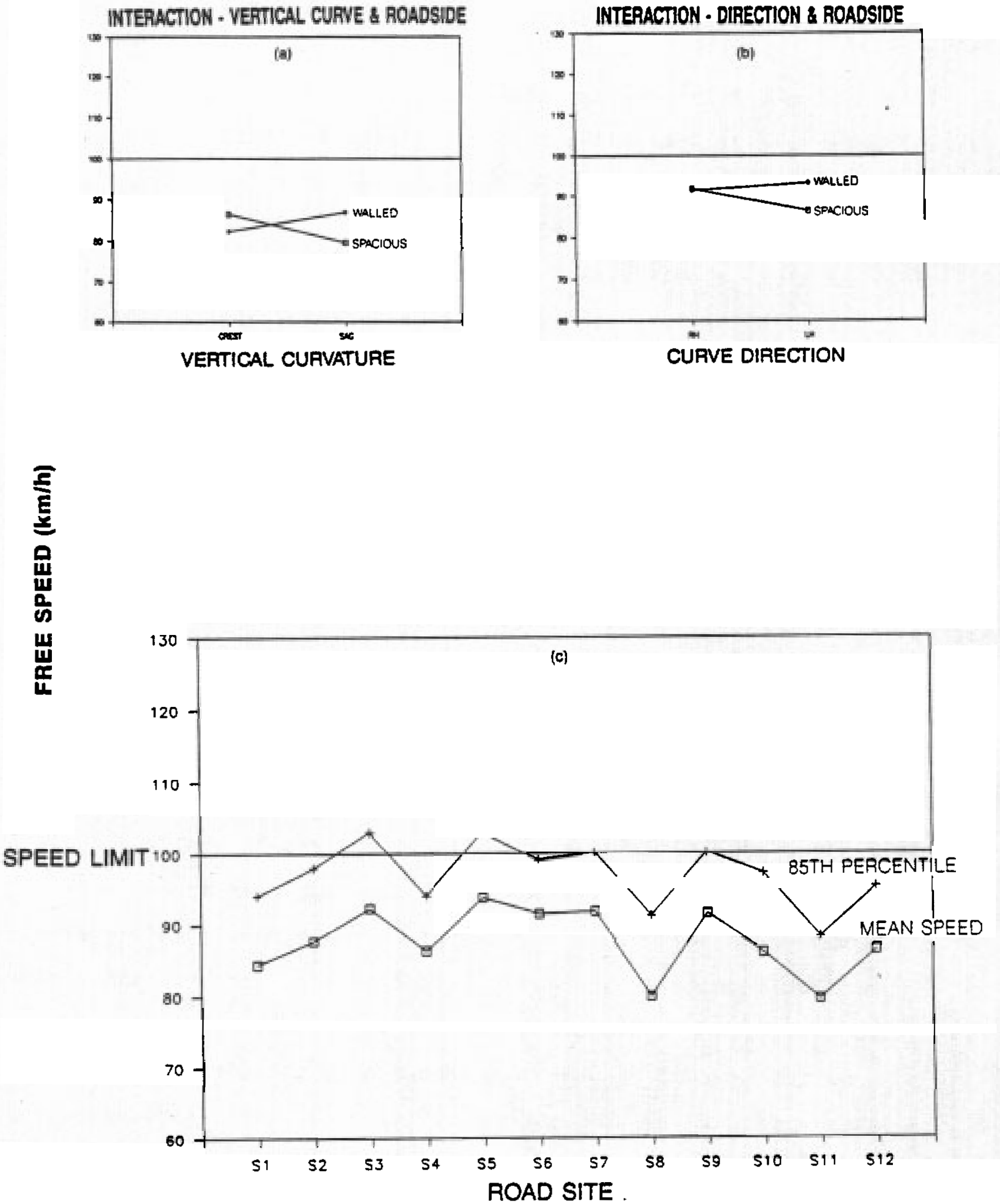


FIGURE 3.5 — Free speed measurements in km/h taken at the 12 test sites used in the curvature validation study.

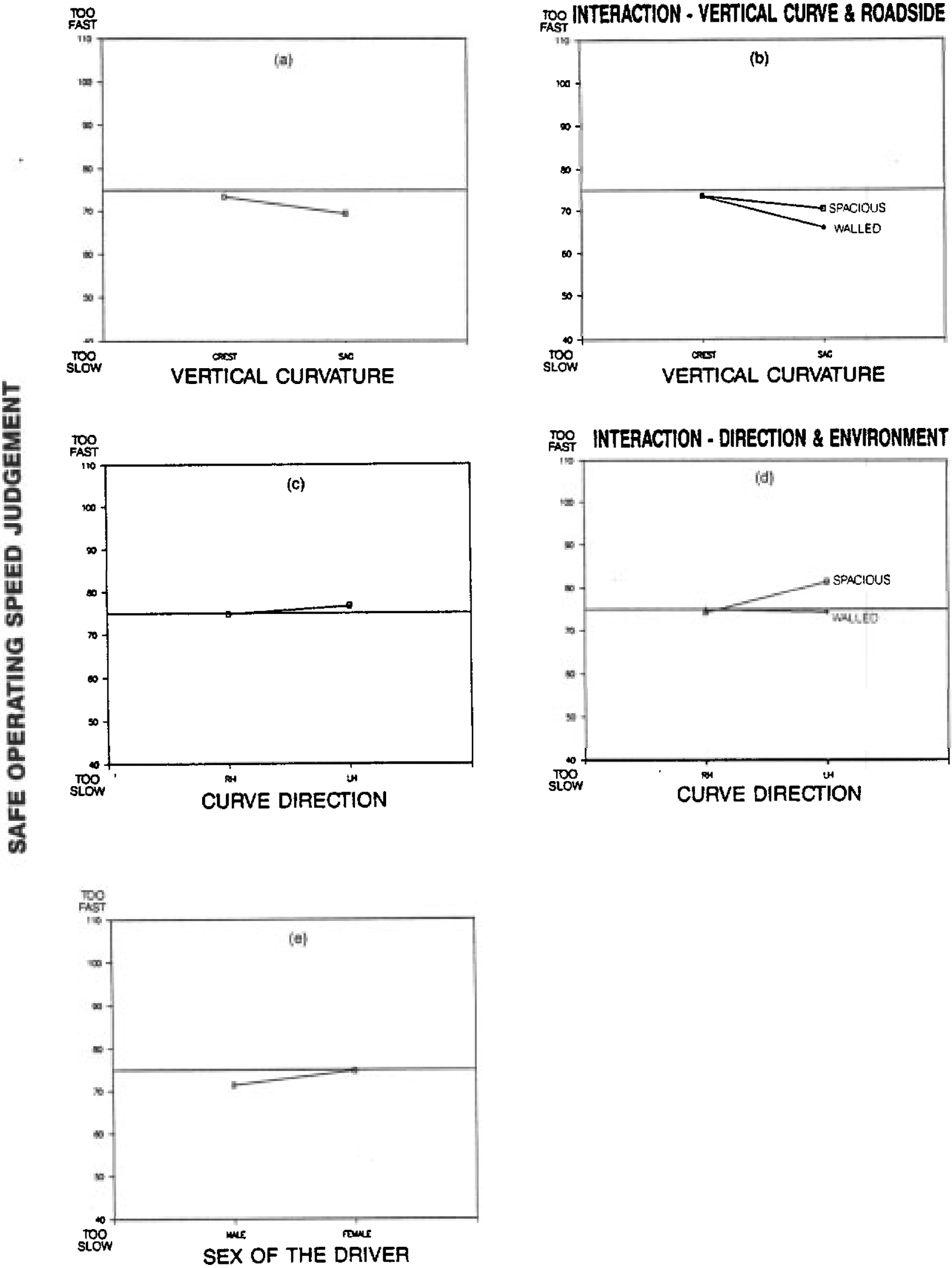


FIGURE 3.6 — Safe operating speed judgements for a range of road and driver factors in the curvature validation study.

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 judged 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).

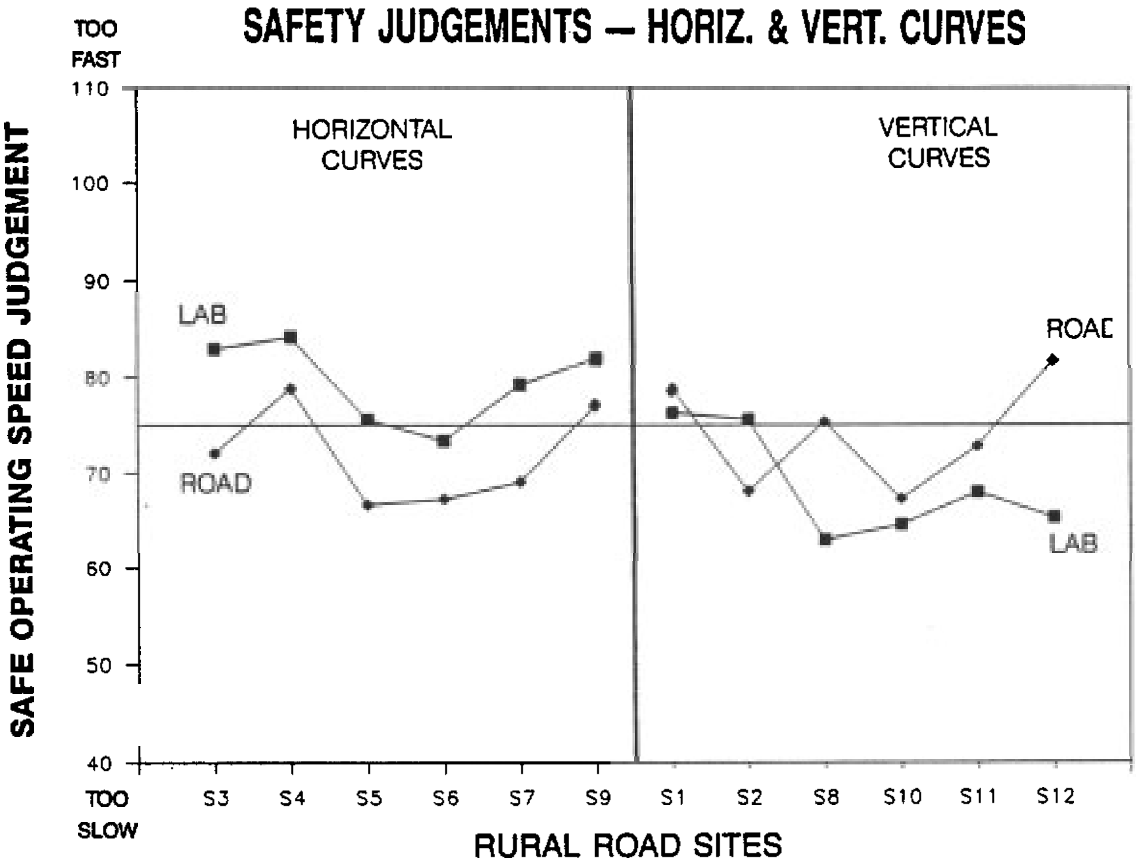


FIGURE 3.7 — Re-plot of the earlier safe operating speed interactions between road site and experiment only this time with horizontal and vertical curve results segregated.

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.

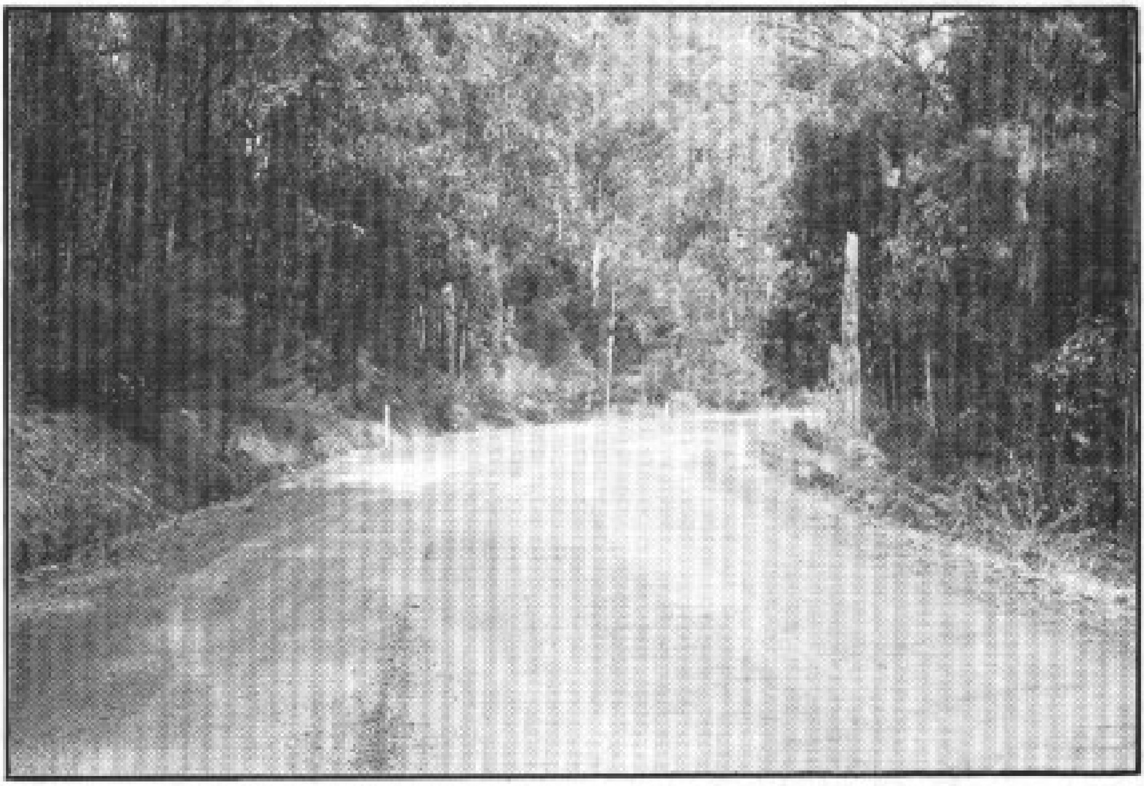
The laboratory method used for testing speed perception on urban and rural straight roads (Fildes et al 1987) was again adopted to assess the effects of the road, roadside environment, driver experience and sex of the driver on subjects' estimates of safety and travel speed for rural horizontal road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

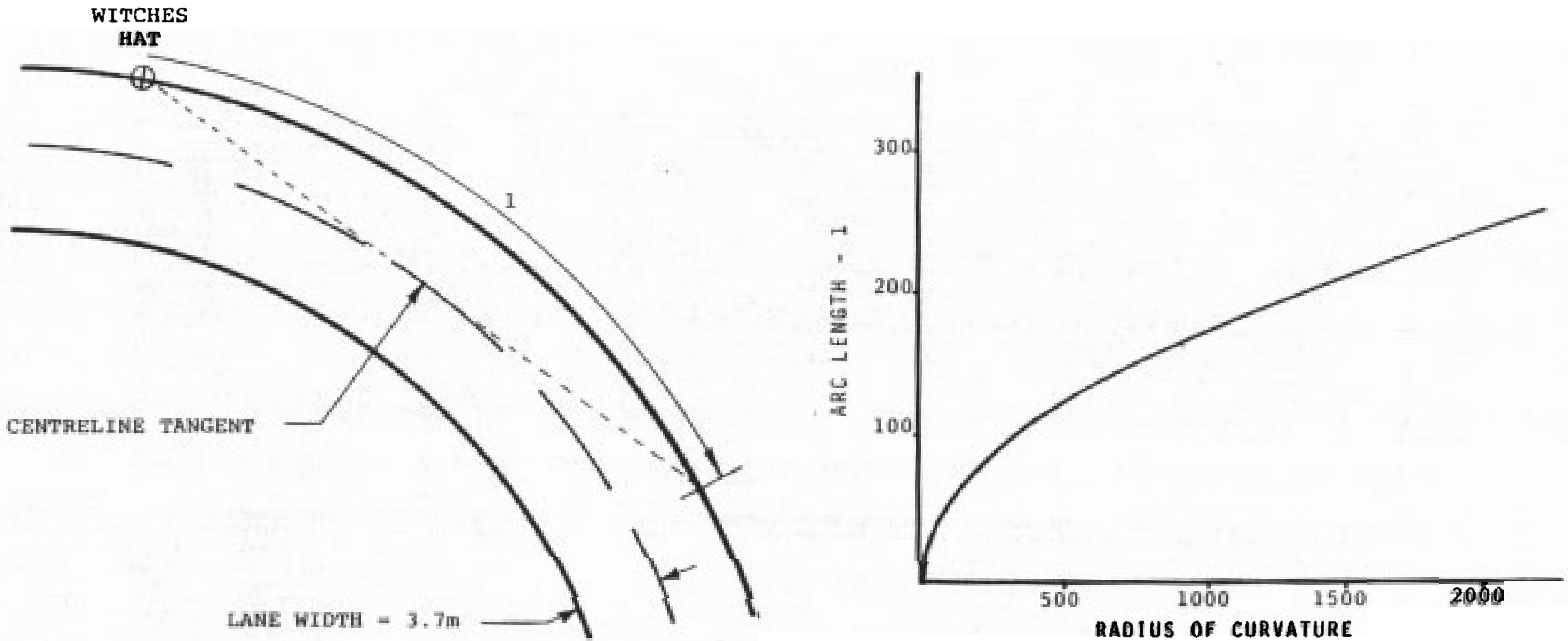


FIGURE 4.2 — Method used to measure the radius of curvature of the road curve sites.

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.**

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.

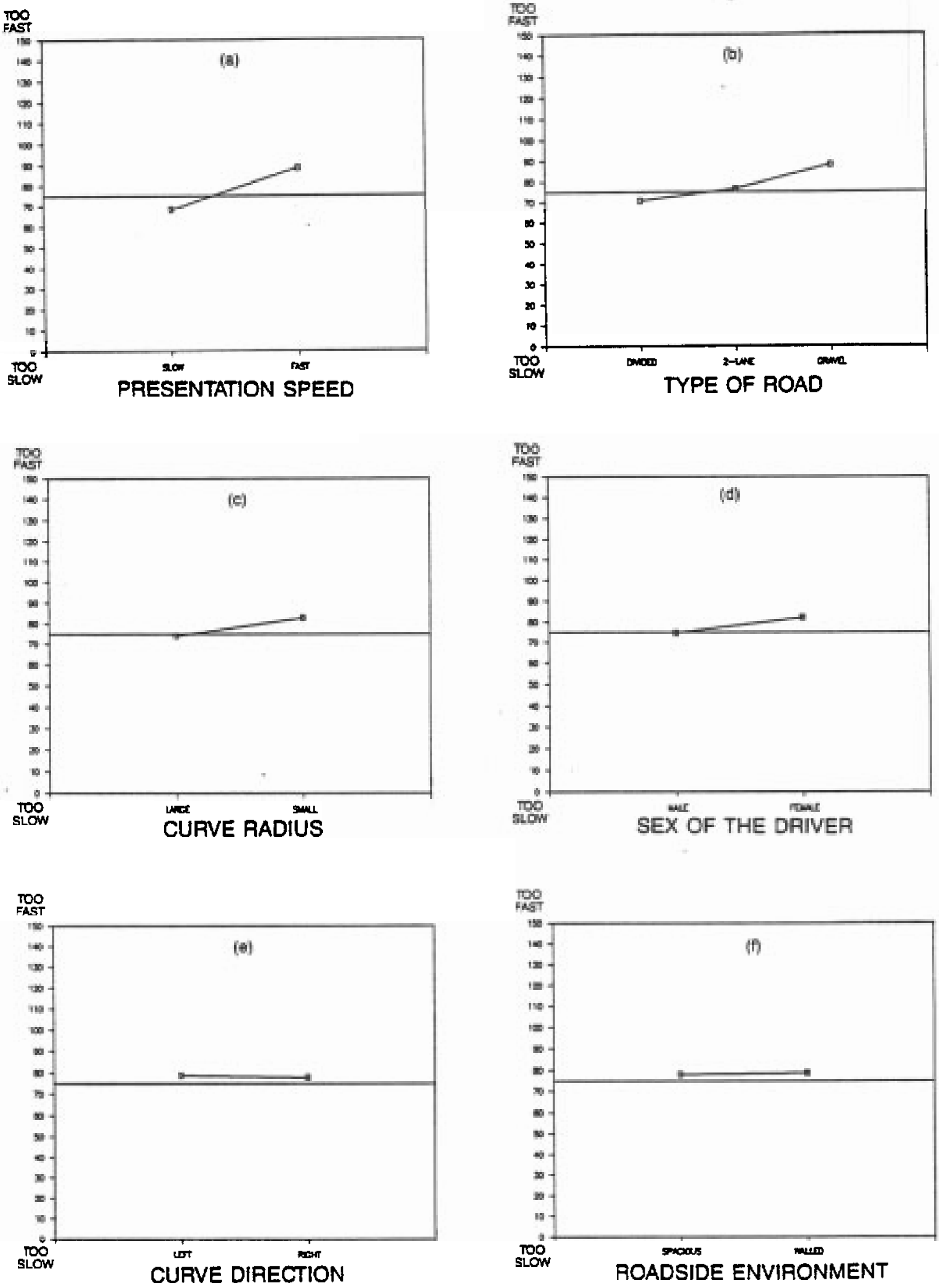


FIGURE 4.3 — Safe operating speed main effects of interest for the horizontal curvature experiment

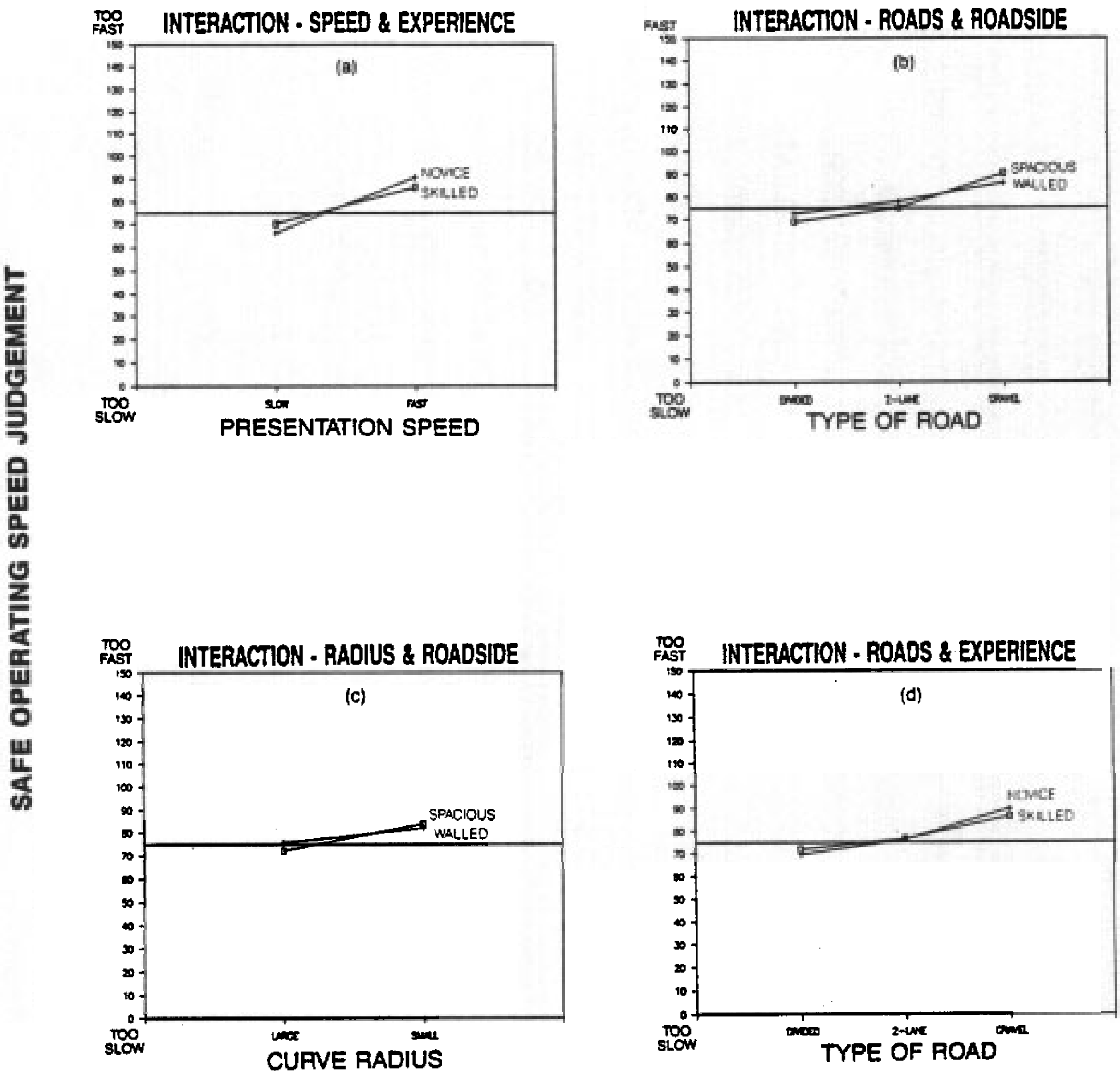


FIGURE 4.4 — Safe operating speed interactions of interest for the horizontal curvature experiment.

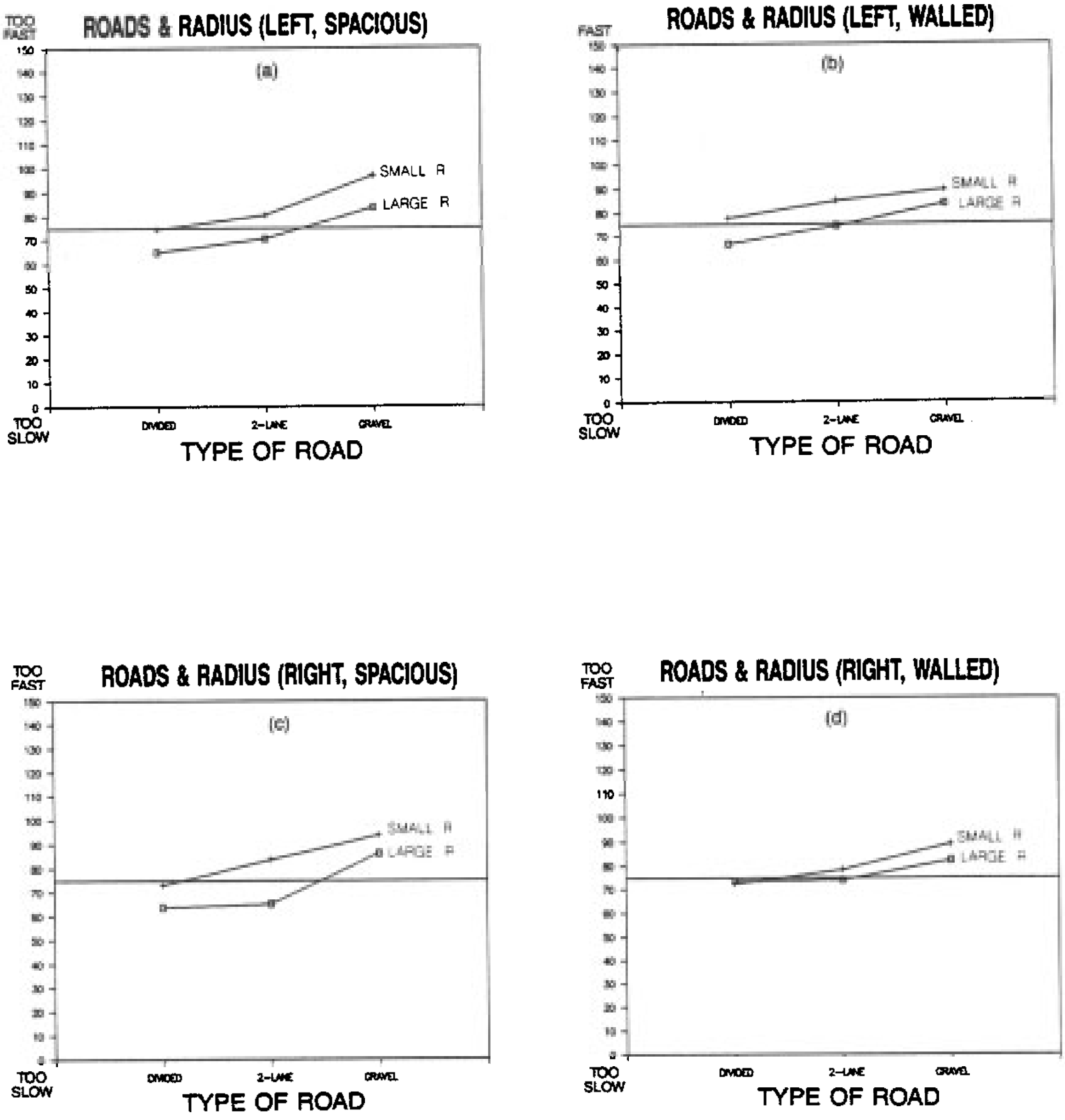


FIGURE 4.5 — Safe operating speed interactions of interest for the horizontal curvature experiment.

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.

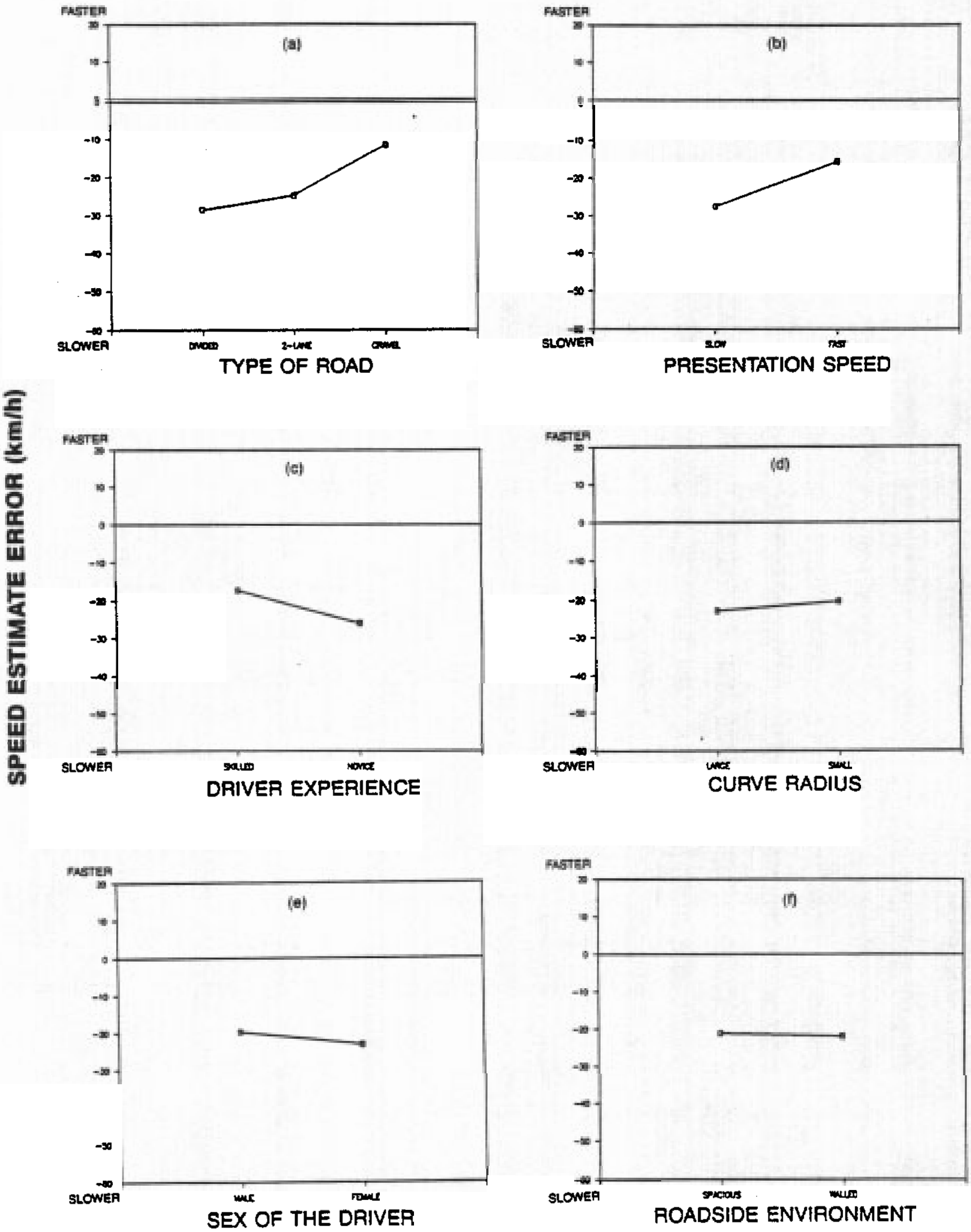


FIGURE 4.6 — Travel speed estimate error main effects of interest for the horizonatal curvature experiment.

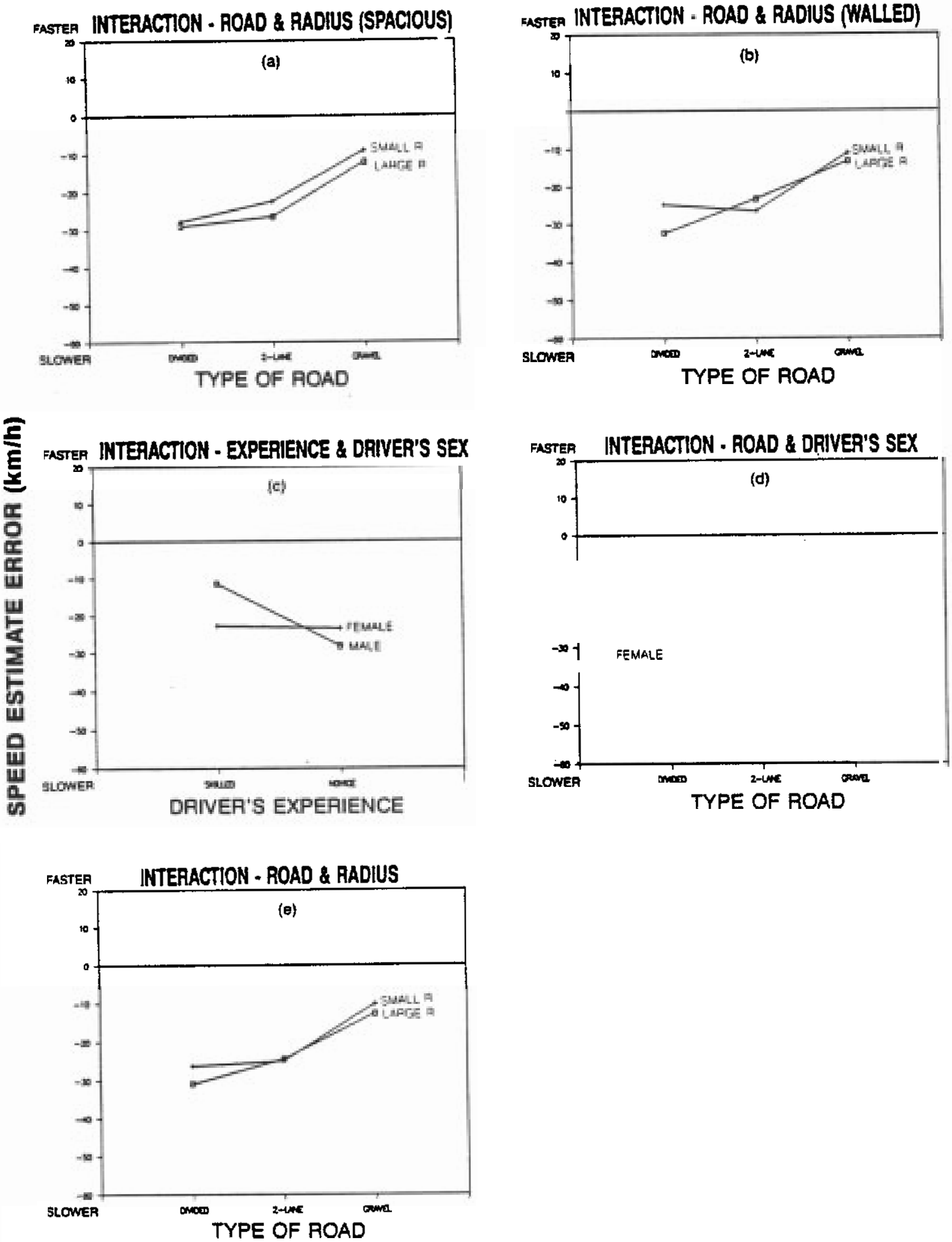


FIGURE 4.7 — Travel speed estimate error interactions of interest for the horizontal curvature experiment.

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.

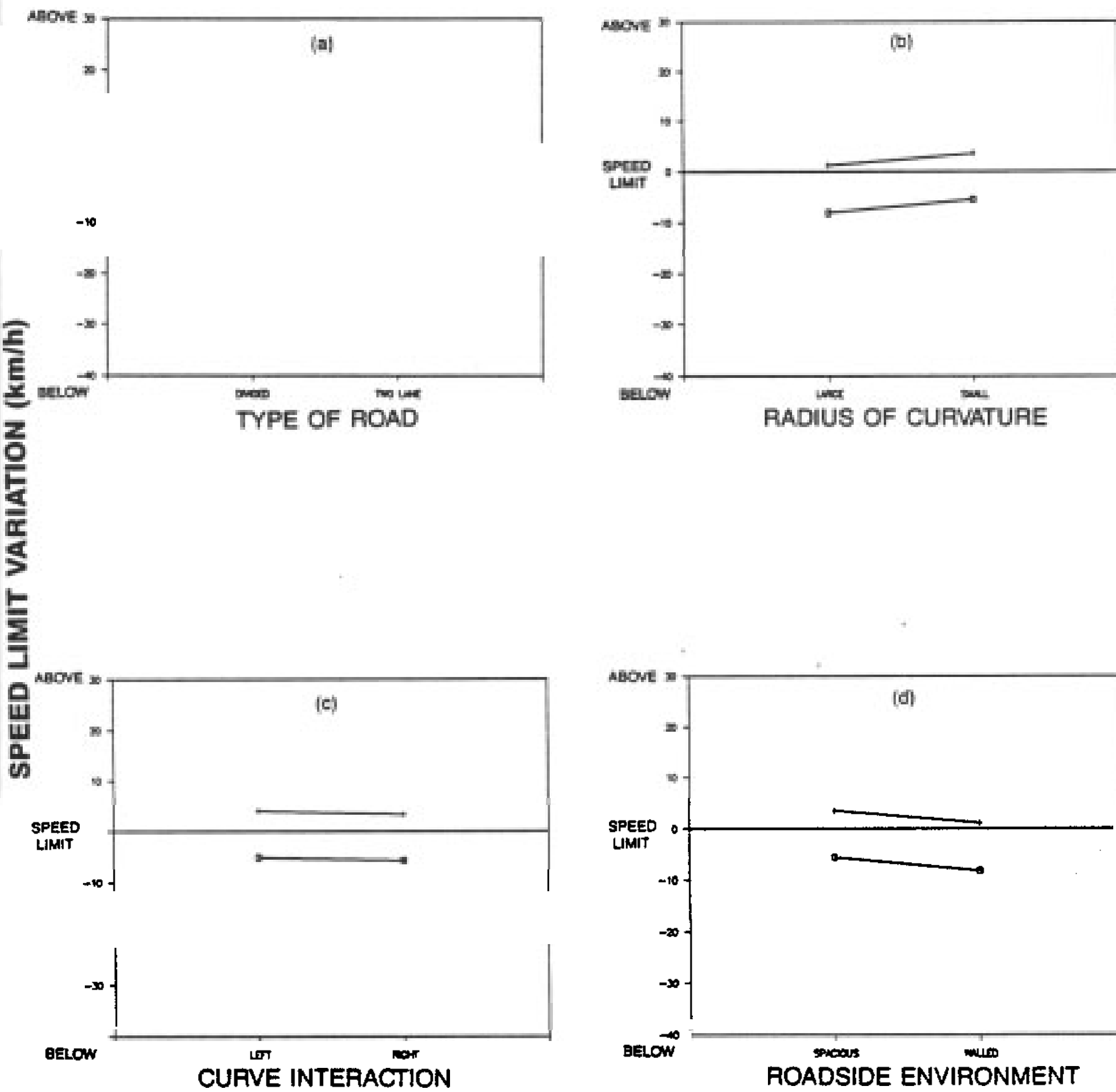


FIGURE 4.8 — Free speed variations in km/h around the speed limit for the main effects of interest in the horizontal curvature experiment.

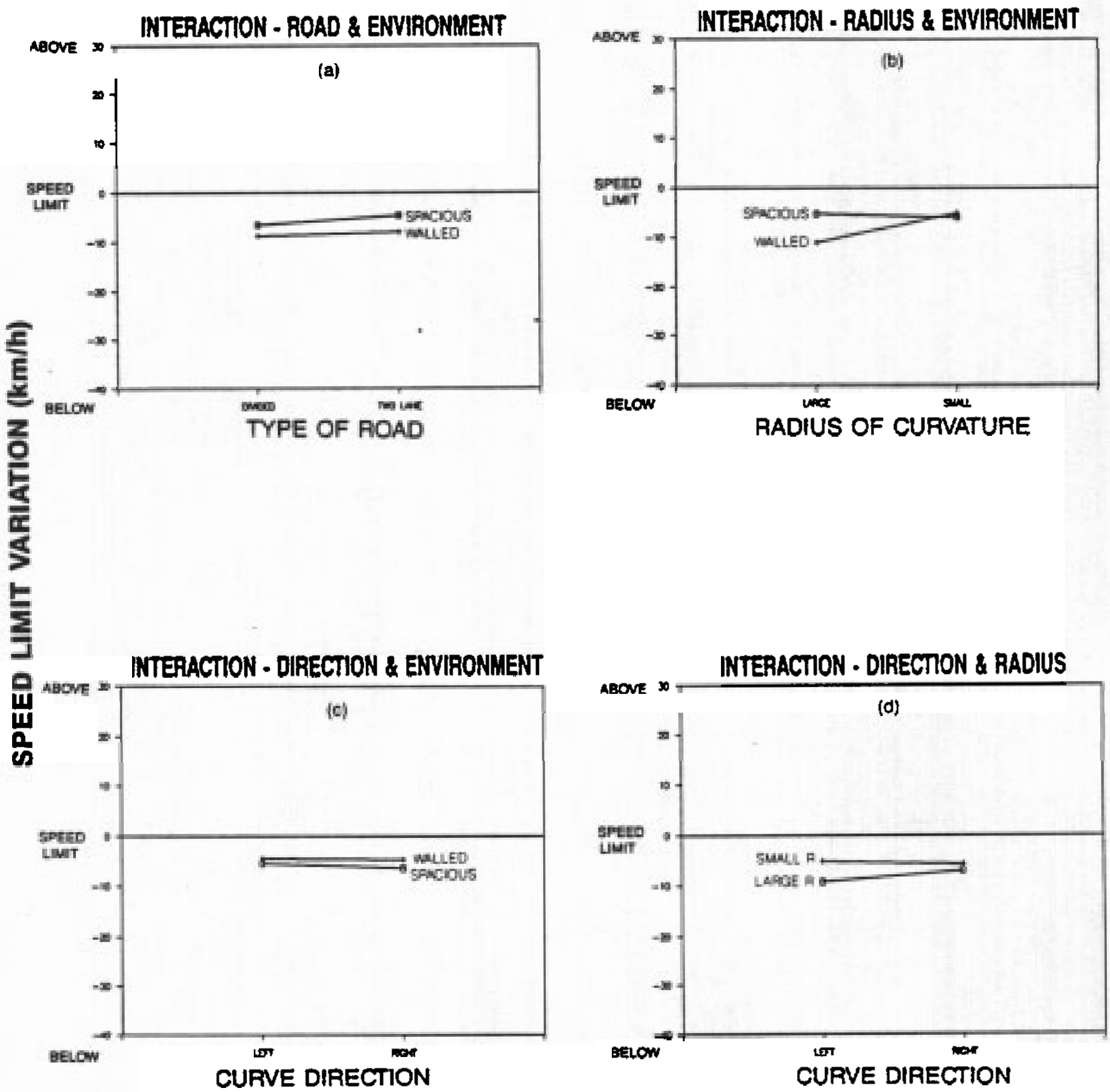


FIGURE 4.9 — Free speed variations in km/h around the speed limit for the interactions apparent in the horizontal curvature experiment.

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 interfers 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.