5. LABORATORY VALIDATION STUDY

A preliminary study was undertaken to validate the method proposed of measuring speed perception in the laboratory. As well as helping to establish a valid experimental procedure, this study would also provide valuable insight and practice in testing drivers' perceptions of speed.

5.1 STIMULUS MATERIALS

Twelve urban road sites in the Melbourne Metropolitan area were selected as typical examples of a range of road sites to be used in the main experiment (see Appendix A-1 and Figures 5.0 and 5.1 for complete details of the sites selected for the validation study). These sites offered a variety of road categories, speed limits and road environments and in all cases, there was a minimum of 30 seconds unobstructed sight distance.

A 5 second road segment was selected at each site for the study and free speed measurements were made at each of these 12 experimental segments (details are listed in Appendix A-1). A film sequence at the posted speed limit was taken at each site and subsequently spliced into a 5 second segment as described earlier. This film sequence was later used for the laboratory assessment. Road trials were conducted at the same road site.

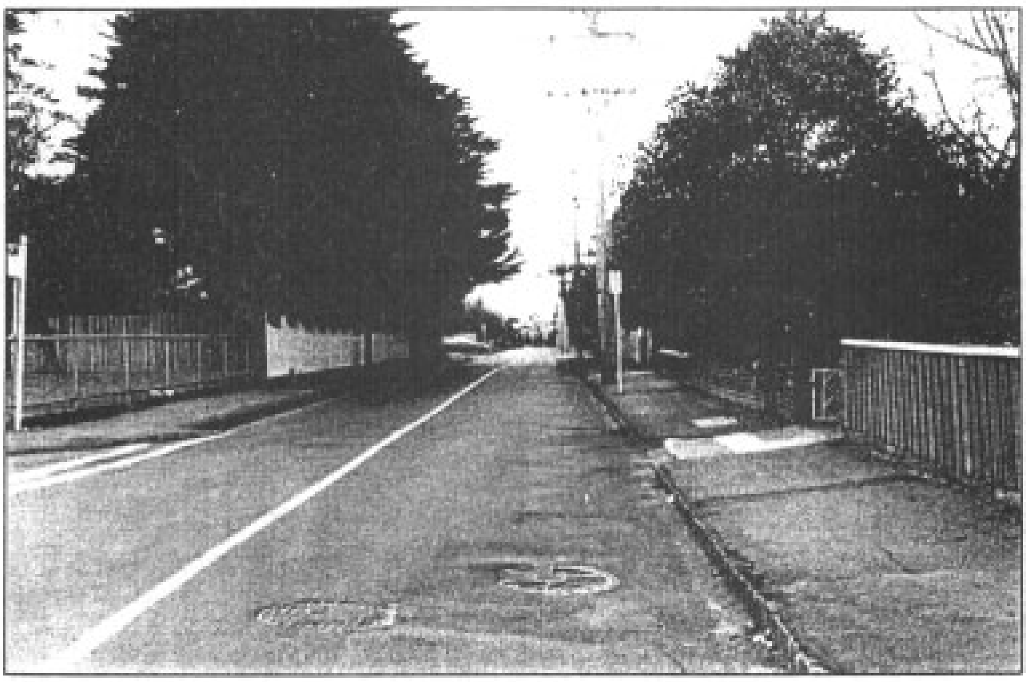
5.2 ROAD TRIALS

Six fully licensed drivers (3 male and 3 female) with no prior knowledge of the project were recruited from within RACV staff and driven around a pre-determined course encompassing the 12 chosen road sites (see Figure 5.1). Each subject sat in the passenger side front seat and was instructed in the experimental procedure from a cassette tape, prior to arrival at the first site (Appendix B-1 lists the experimental instructions used for the road experiment).

FIGURE 5.1
PILOT ROAD SITES.
(MELB. METROPOLITAN AREA)
5.6.86.

FIGURE 5.0
LABORATORY VALIDATION SITES

Pilot Site 7 - Undivided, 4-Lane, Spacious road



Pilot Site 10 - Undivided, 2-Lane, Narrow, Walled road

As each site approached, the driver of the experimental car adjusted his speed to the posted speed limit and positioned the vehicle to maximise free headway (as a rule, a 5 second free headway was adopted as a <u>minimum</u> trial requirement, although no traffic was always aimed for at each site). The subject was asked to look down at the response booklet on his or her knees and to look up only when instructed by the experimenter seated in the back seat. The speedometer of the experimental vehicle was shielded from the subject's view and loud white noise was played through the vehicle's stereo system to mask engine and wind noises.

As the vehicle entered each experimental site, the subject was asked to look up and view straight ahead until instructed otherwise. After 5 seconds of viewing time, the subject was then asked to look down again and make his or her assessments of safety and estimated travel speed. After 10 seconds, the experimenter instructed the subject to relax and engaged him or her in casual conversation to distract attention from the road and traffic.

Practice was given before the first experimental trial to familiarise the subject with the task. Because of the minimum number of subjects involved in this study, a fixed route was used for the experimental trials (a fixed presentation order was also adopted for the laboratory presentation of the 12 movie film segments). All road trials were conducted during off-peak traffic conditions and with dry roads and good light conditions.

5.3 LABORATORY TRIALS

The procedure used for off-road testing was a close replication of the road trial method. A laboratory was established at the Noble Park Headquarters of the RACV in a isolated and relatively quiet works area (the room was without windows and natural light and only had one access door). Details of the laboratory arrangement are shown in Figure 5.2.

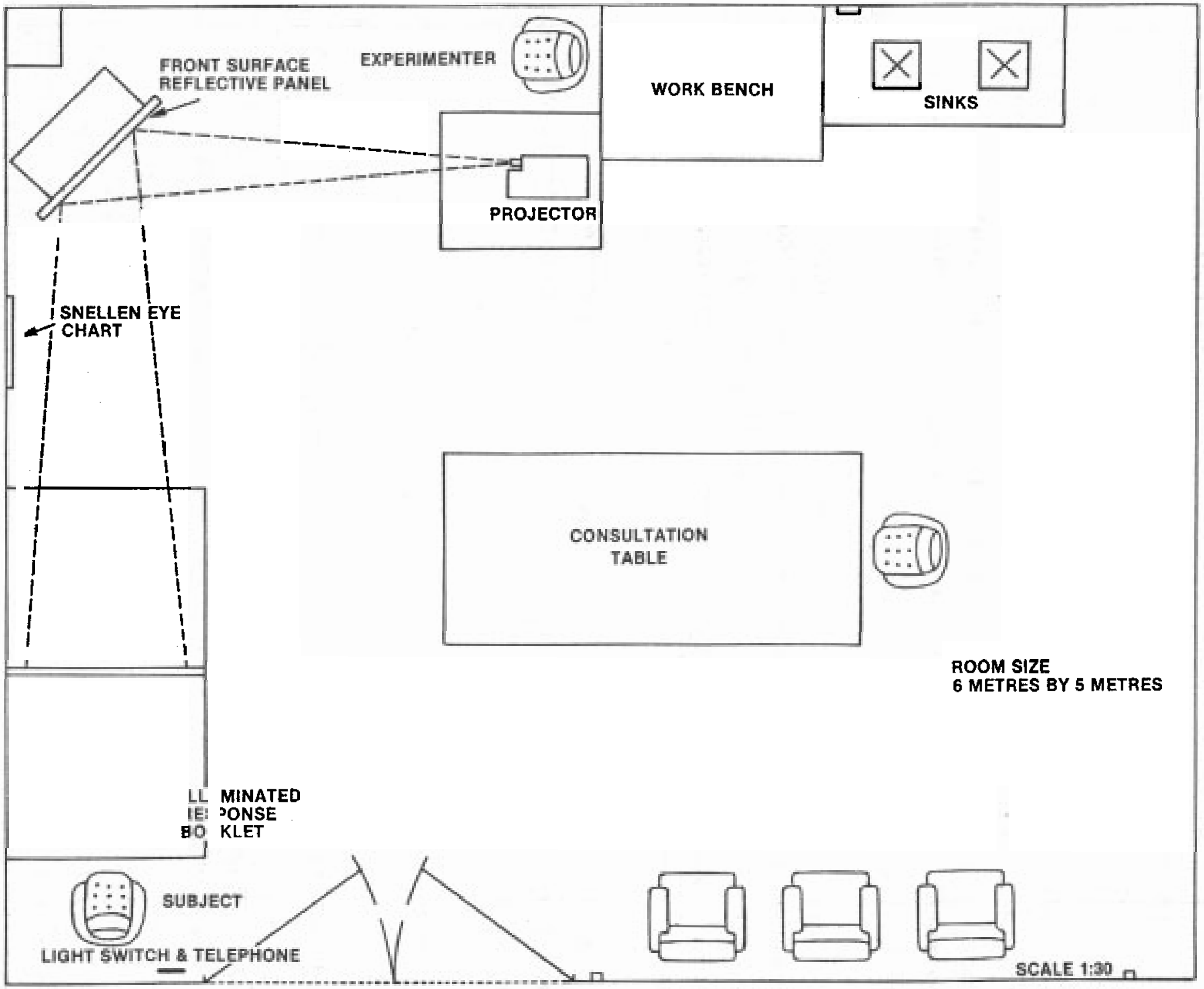


FIGURE 5.2 DETAILS OF LABORATORY ARRANGEMENT

An experimental film sequence of the 12 road sites was constructed, along with another film of 6 additional and novel sites for practice. Six new subjects (3 male and 3 female) were recruited from within RACV headquarters and were individually tested in the laboratory.

Each subject listened to a tape recording describing the experimental instructions (see Appendix B-2 for details). The practice film was then loaded and the subject was given practice at making responses. The practice film was identical with the experimental sequence but used different sites and different speeds to prevent learning.

The experimental film was then run. Each road site was presented in the same manner as the road trials. Subjects viewed the road scene until the onset of the 10 second blank, then looked down and made their assessments of safety and estimated travel speed as previously.

At the conclusion of the experiment, subjects were questioned about their impressions of the task and strategies they used when making their estimates.

5.4 RESULTS

The safe operating speed responses for each site in both the road and laboratory experiment were measured and converted to a distance in millimetres from the left hand "Too Slow" anchor point. Thus, any number between 0 and 75 represented a slow response while numbers between 75 and 150 indicated a fast response.

The response numbers were then structured into a data base and analysed using the ANOVALEE program for analysis of variance and omega-squared statistics (Fildes, 1987). The analysis assumed 12 values of a within-subject variable for "road site" and 2 values of a between-subject variable for "experiment". The analysis of variance summary tables are shown in Appendix C-1.

The speed estimate responses were subsequently converted into error scores (positive or negative differences in km/h between the estimate and the actual travel speed) and also analysed using analysis of variance and omega-squared. The statistical summary of these results is also shown in Table 1 of Appendix C-1.

5.4.1 Safe Operating Speed Data

The main effect for road site shown in Figure 5.3b was significant ($F(11,110)=9.7$, $p<.001$, $\omega^2=.292$). Subjects expressed considerable differences in their judgements of safety across the 12 road sites used in this experiment. This variable manipulation was the strongest effect observed in this experiment, accounting for almost one-third of the total treatment variance in this experiment.

There was also a significant main effect observed in this analysis, shown in Figure 5.3a ($F(1,10)=21.1$, $p<.001$, $\omega^2=.165$). The mean estimates of safety in the laboratory were approximately equal to the mean scale value, whereas the road estimates were significantly slower. This variable accounted for approximately 17 per cent of the experimental variance, but even so, was only one-half the strength of statistical association as that of road site.

A significant interaction was observed between the experiment and site variables, shown in Figure 5.3c ($F(11,110)= 2.3$, $p<.05$, $\omega^2=.042$). The pattern of responses in the laboratory was practical identical to that of the road responses (albeit at a higher overall level of safety) except for the reversal that occurred in the results for site 2.

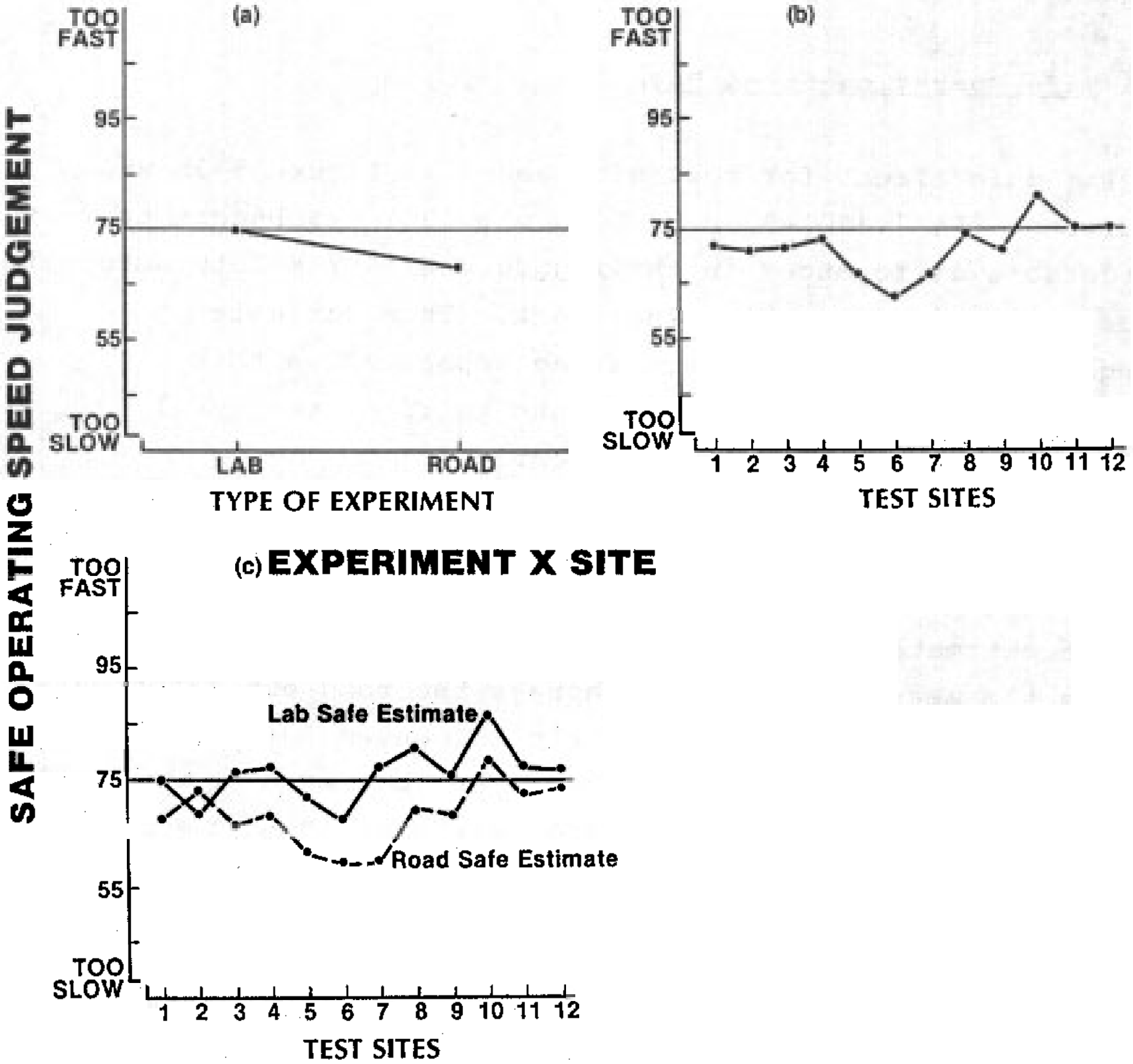


FIGURE 5.3 Safe operating speed responses obtained in the laboratory validation study.

5.4.2 Speed Estimation Data

A significant main effect for site was observed as shown in Figure 5.4b ($F(11,110)=2.8$, $p<.01$, $\omega^2=.007$). The accuracy of the subjects' speed estimates was dependent on the particular site tested. This variable was again the strongest effect observed in this analysis, capturing almost eight per cent of the total variance.

There was also a significant interaction observed between type of experiment and site shown in Figure 5.4c ($F(11,110)=2.3$, $p<.05$, $\omega^2=.005$). A simple main effects analysis performed on these data shows that the only significant differences were at sites 5 and 7 ($F(1,10)=6.6$, $p<.05$ and 9.8, $p<.01$, respectively). None of the other sites were significant at the 5 per cent level of probability.

There was no significant main effect for experiment in this analysis, shown in Figure 5.4a ($F(1,10)=<1$, $p>.25$, $\omega^2 = 0$). Subjects' speed estimates were not noticeably different in the laboratory to those made during the road experiment, even though the trend was similar to that observed for the safe operating speed data (Figure 5.3a). Moreover, the lack of a significant main effect for site for either laboratory or road testing confirms the uniformity in the response pattern for both types of speed estimates.

5.4.3 Free Speed Data

Free speed data was collected at 8 of the test sites and is summarised in Appendix B-1 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 5.5. 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.

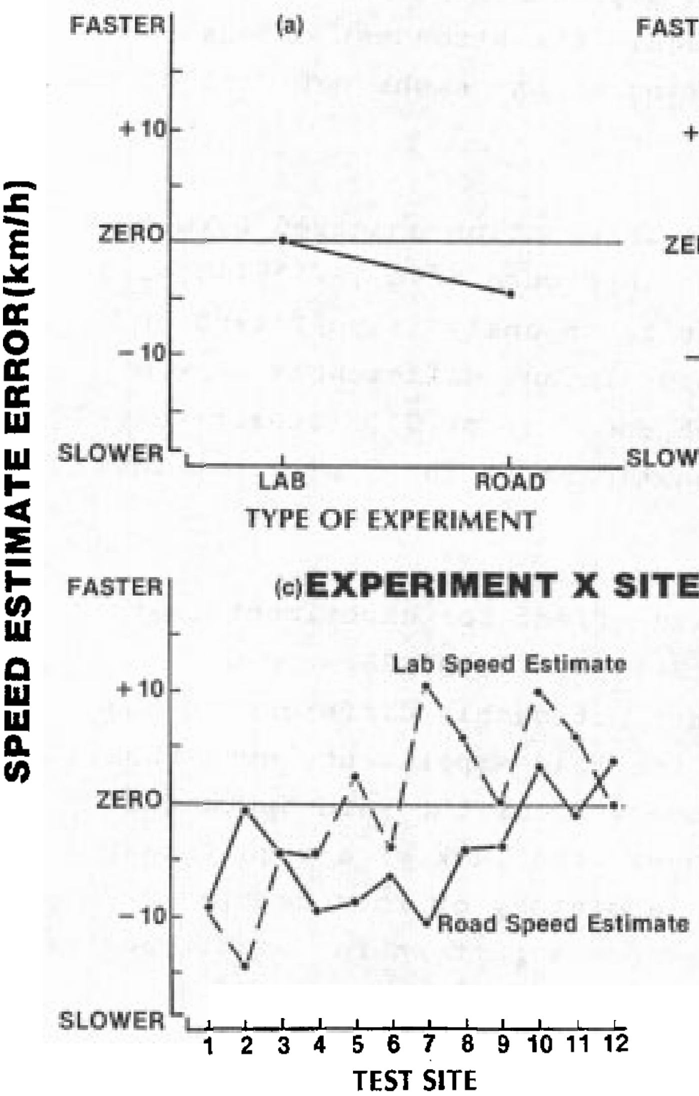


FIGURE 5.4 Errors in the travel speed estimate results from the laboratory validation study.

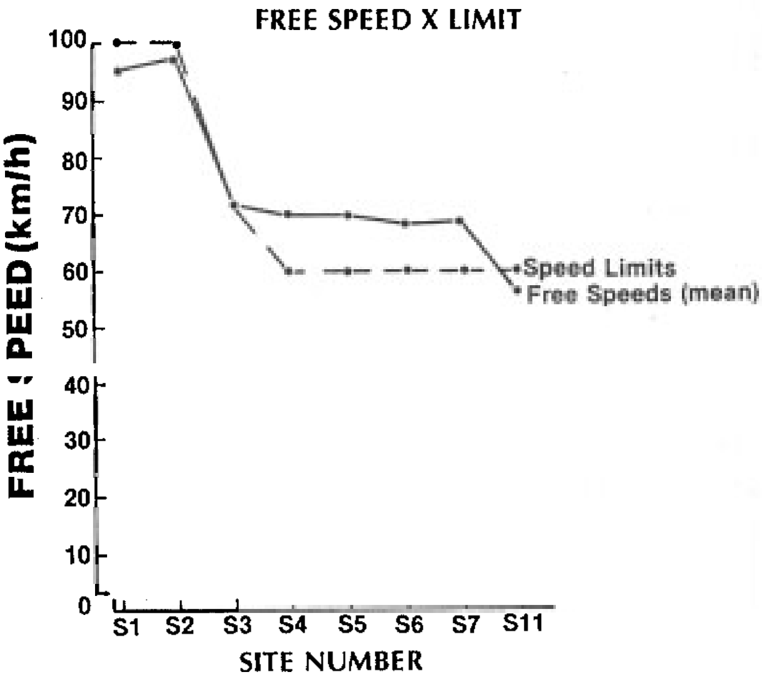


FIGURE 5.5 Free speed measurements in km/h taken at 8 of the 12 test sites in the laboratory validation study.

The mean travel speed was approximately equal to the posted speed limit at sites 1, 2, 3 and 11. These sites encompassed speed limits ranging from 60 to 100 km/h. However, the mean travel speeds at sites 4, 5, 6 and 7 were all approximately 10 km/h faster than the 60 km/h posted speed limit.

In addition, the 85th percentile speed at each of these 12 sites was between 5 and 38 per cent greater than the posted speed limit, depending on the posted speed level and type of roadside environment.

5.4.4 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 environmental variables was used here compared to the main experiments 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 5.6 shows the plots of the safe operating speed estimates for the road and environment factors included. Several points can be made from these figures.

First, all roads were judged slower than that normally considered to be a safe operating speed when the data was collapsed across experiment. Undivided roads were generally assessed slower than divided roads, while for divided roads, 8-lanes were judged slower than 6-lanes and 6-lanes were judged slower than 4-lanes. This result was independent of whether the road was a major arterial or a freeway. On undivided roads, 4-lanes were assessed much slower than 2-lanes . The main reason for this, strangely enough, appears to be 4-lane collector and local roads, rather than similar arterials.

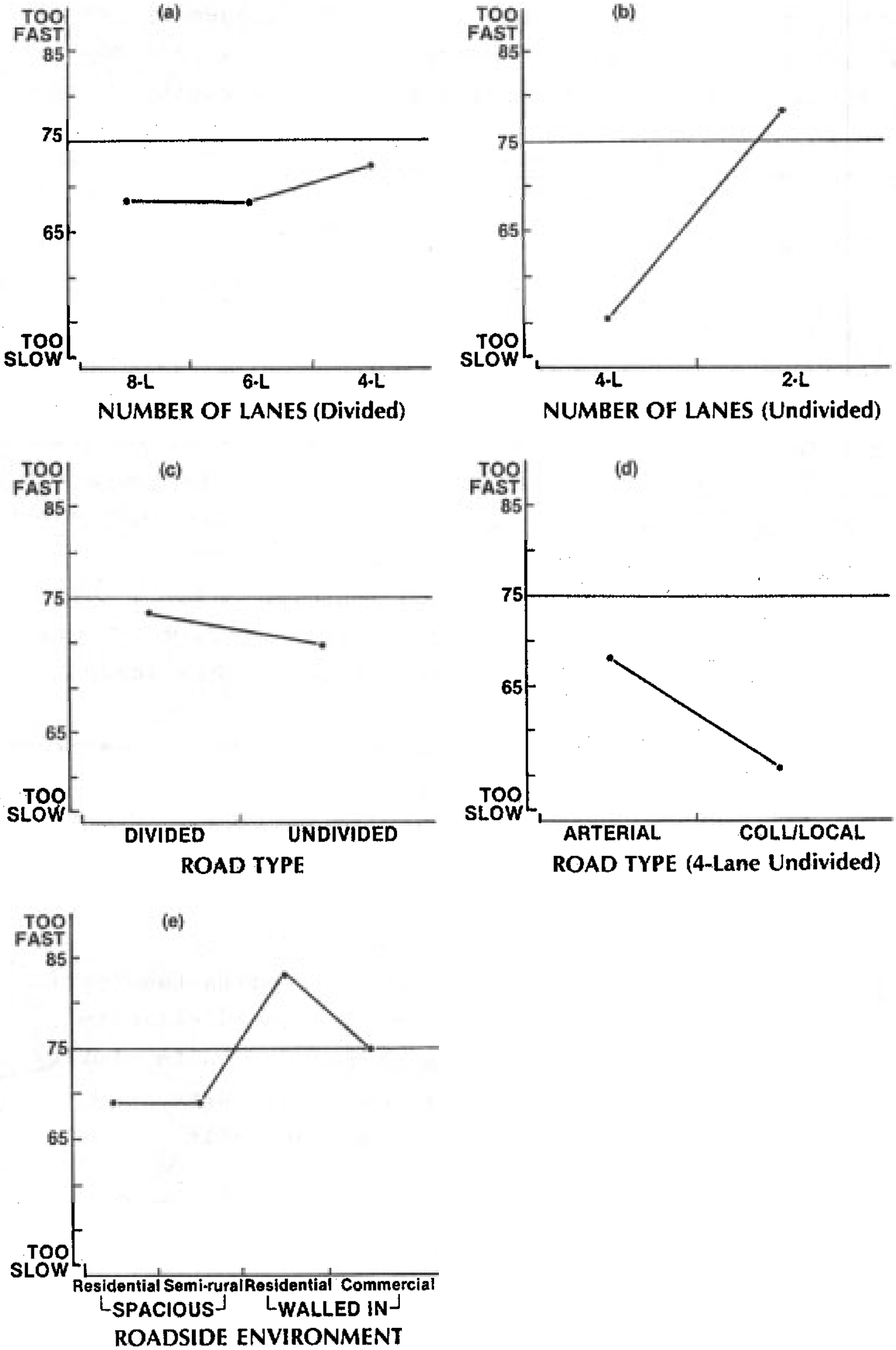


FIGURE 5.6 Safe operating speed judgements for a range of road factors studied in the laboratory validation study.

Walled roadside environments resulted in judgements at or above a safe operating speed, compared to spacious environments which were assessed generally as too slow. In particular, speed in walled residential environments appeared much too fast on average when viewed at the posted speed limit.

5.5 DISCUSSION

The results of the validation study confirm the appropriateness of using laboratory simulation for eliciting road speed perceptions. While the safe operating speed average was higher for laboratory presentations than road trials, the pattern of results obtained was similar at each test site for both safe operating speed judgements and speed estimates. In other words, the loss of reality from laboratory presentation has been generally consistent across trials and measures. The interaction observed between presentation method and test sites was minimal and resulted from only one of the sites used in this study.

While this result was achieved with only a small number of subjects in each condition (n=6 for both the road and the laboratory trials), the use of repeated measures and the highly significant results obtained confirm that the effects are robust and negate the need for additional testing.

There was not a lot of difference observed in the results between safe operating speed judgements and speed estimates. The pattern of results from both these measures was quite similar, although the safe operating speed estimates may have been slightly more sensitive to the independent variable manipulations.

It should be noted though that the experimental design was not orthogonal (each variable was not represented at each level of the other variables). Moreover, in some cases, there was only a single example of a particular variable combination. Thus, it is still necessary to collect both safe speed estimates and travel speed judgements in any future testing.

The free speed data showed that speed limits were generally not adhered to at the test sites, especially those with 60 km/h limits. The average speed for these lower limit sites was approximately 10 km/h above the posted limit and 85th percentile speeds were up to 22 km/h (37 per cent) faster than the legal level. This result needs further testing in both rural, semi-rural, and urban environments and has important ramifications for the role of perception in driving.

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 evaluation of these variables will uncover new and important reasons for understanding why drivers choose to travel at the speeds they do.

6.

The pilot study confirmed that the laboratory method elicited similar speed responses to those taken on the road. In addition, the preliminary site data from the pilot study showed substantial variations in the safe operating speed responses and speed estimates. Thus, the laboratory presentation method seemed to be a suitable means of evaluating the effects of perceptual changes on drivers' speed estimates.

A single experiment for rural, semi-rural and urban environments was not possible; the variables and their levels were not perfectly replicated in each of these environments and a single experiment would have been unmanageable in terms of the number of stimulus presentations needed. Hence, separate experiments were designed for the three different environments.

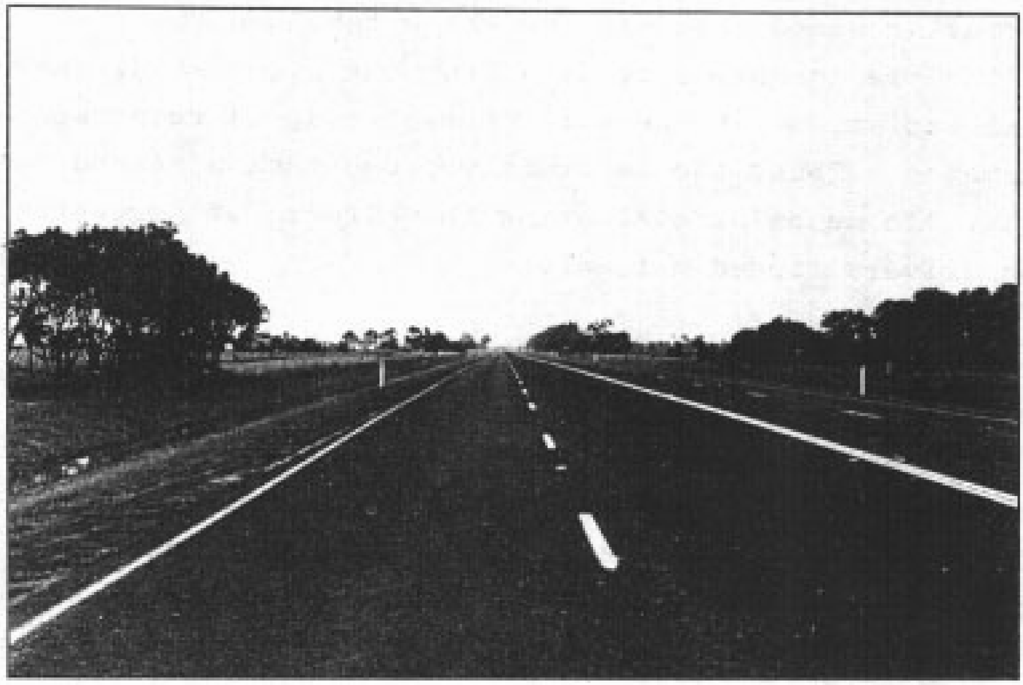
The experiments for each of these environments will be described separately. However, the final chapter will attempt to draw general conclusions that can be made for all environments.

6.1 STIMULUS MATERIALS

In line with the research strategy outlined in chapter 4, twenty-eight rural road sites were located within 2 hours of Melbourne which encompassed the range and levels of the particular road and environment factors of interest. Appendices A-2 to A-5 detail the 28 sites selected and Figure 6.0 shows typical sites used in the rural experiment.

The independent variables included seven road types, divided-wide (D/W), divided-narrow (D/N), 4-lane (4-L), 2-lane-wide (2L/W), 2-lane-narrow (2L/N), gravel-wide (G/W), gravel-narrow (G/N), two roadside environments (spacious, walled), two repetitions (different sites with the same characteristics) and two film speeds (15 per cent above and below the posted limit). This yielded 56 road scenes in a fully crossed factorial design experiment.

FIGURE 6.0
RURAL SITES



Site 9 - Undivided, 4-Lane, Spacious road

Site 24 - Undivided, 2-Lane, Gravel wide, Walled road.

A suitable road segment was identified at each site that ensured a minimum of 5 sec film time with specified sight distance requirements. Each site was then filmed from the research vehicle providing the two film segments, 15 per cent above and below the posted speed limit. Sites were filmed using a Bolex H16 reflex movie camera on 16mm Kodak colour negative daylight film (64 ASA), processed into work prints and subsequently edited into 5 sec sequences.

Four experimental films were then produced, each containing 14 randomly selected road scenes followed by 10 sec 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 reels or were spaced as far apart as possible. The order of presentation of the four reels was structured across subjects to ensure that each film was presented equally in every serial position.

6.2 EXPERIMENTAL PROCEDURE

Thirty-six licensed drivers were recruited as subjects for the experiment. Nine subjects were allocated to each of four groups (male-experienced, female-experienced, male-1st year, female-1st year) to test for experience or sex effects in speed perception. Subjects were tested individually in a session lasting approximately 40 min and were paid for their participation. The laboratory set up was identical with that used in the validation study (see Figure 5.3 in the previous Chapter).

Each subject was played a pre-recorded tape describing the experimental instructions at the start of the session (see appendix B-2 for details). The film used in the previous study was then presented for practice. Questions about task requirements were answered prior to commencing the main experiment.

The experimental procedure was similar to that used previously. For each experimental trial, subjects viewed the moving scene for 5 sec until the screen went blank. The subject then looked down at the response book and made his or her safety assessment, followed by an estimate of travel speed. This was repeated until the film ran out. Subjects were encouraged to rest while the film was changed and any questions relating to the purpose of the experiment were deferred until the experimental trials were completed. At the end of the session, the experimenter discussed the experiment with the subject to highlight strategies or difficulties associated with the task.

6.3 RESULTS

As before, the safe operating speed responses for each judgement were converted into millimetres between 0 = too slow and 150 = too fast. These responses, along with the speed error estimates, were computed, unscrambled and analysed using analysis of variance and omega-squared statistics. For ease of reporting, these two analyses will be described separately. The mean, standard deviation and 85th percentile of the free speed measurements were also computed and reported in a later section.

6.3.1 Safe Operating Speed Responses

Appendix C-2 lists the summary table of the analysis of variance of the safe operating speed data while Figure 6.1 shows the effects of interest. There were four main effects and one 2-way interaction that warrant close attention and these are described in order of their strength of effect (ranking).

Presentation speed shown in Figure 6.1b was a significant effect ($F(1,32)=118.3$, $p<.001$, $\omega^2=.0895$). **Subjects estimated** slow speeds to be too slow while fast travel speeds were judged too fast. **This variable was the strongest effect recorded (** ω^2 $=.0895$) and captured more than half the variance due to the independent variable manipulations.

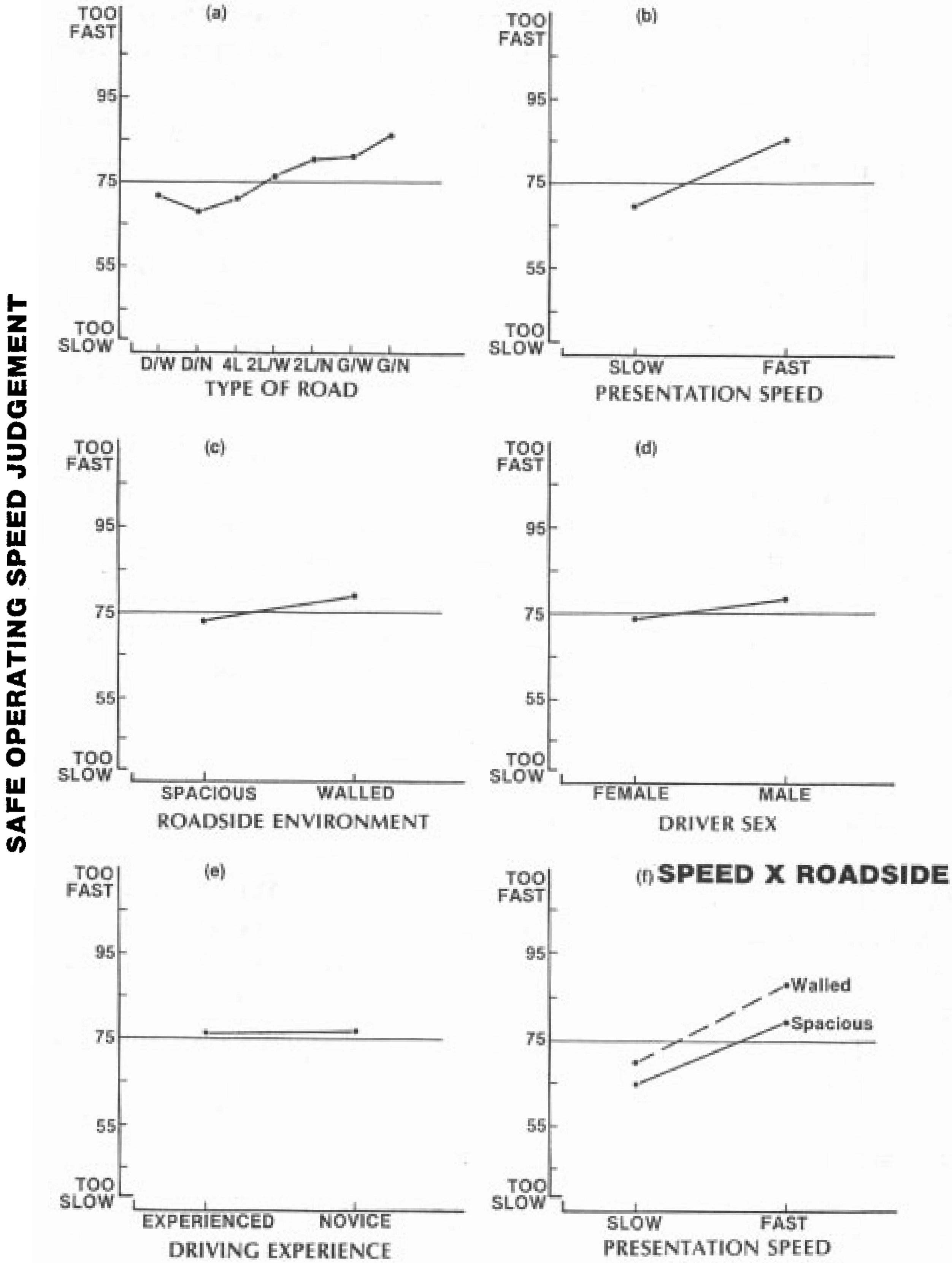


FIGURE 6.1 Safe operating speed results of interest for rural roads in experiment 1.

Type of road in Figure 6.1a was also significant ($F(6,192)= 18.7$, $p<.001$, $\omega^2=.0484$). Subjects estimates varied from too slow for major arterial roads through to too fast for minor and gravel roads. This variable was the second strongest effect ($\omega^2=.0484$) and accounted for almost 30 per cent of the treatment variance.

Roadside environment shown in Figure 6.1c was also significant ($F(1,32)=40.2$, $p<.001$, $\omega^2=.0165$). Subjects estimated the speeds of spacious environment film segments to be safe, whereas walled environments were assessed too fast. With $\omega^2=.0165$, this variable was ranked third, although only one-fifth as strong an effect as presentation speed.

The sex of the subject shown in Figure 6.1d almost reached significance at the 5 per cent level ($F(1,32)=3.9$, $p=.055$, $\omega^2=.007$). As this variable was a between-subject factor, additional data here could result in sex being a significant effect. This variable accounted for 5 per cent of the variance and was less than one-tenth the strength of effect as presentation speed.

The interaction between speed and roadside shown in Figure 6.1f was also significant ($F(1,32)=6.3$, $p<.05$, $\omega^2=.0014$). Simple effects analysis showed that for slow presentations, spacious sites were judged slower than walled sites ($F(1,32) = 38.7$, $p<.001$), while for fast presentations, walled sites were assessed much faster than spacious sites ($F(1,32) = 65.1$, $p<.001$). This interaction, however, was not a particularly strong effect, capturing only 1 per cent of the variance attributed to the treatment manipulations.

6.3.2 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-3 lists the analysis of variance summary table of these error scores while Figures 6.2 and 6.3 show the effects of

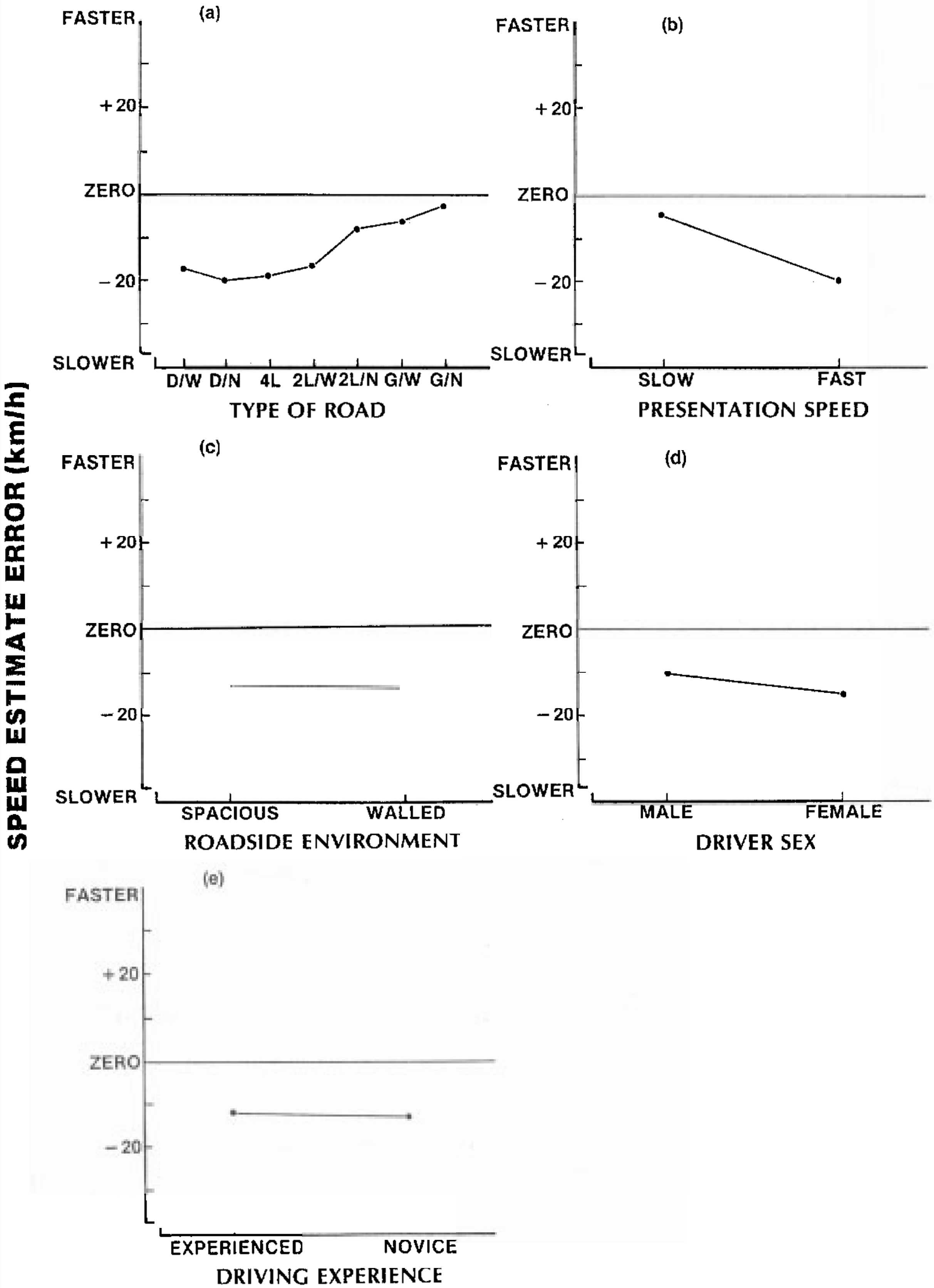


FIGURE 6.2 Travel speed errors for the main effects of interest for rural roads in experiment 1.

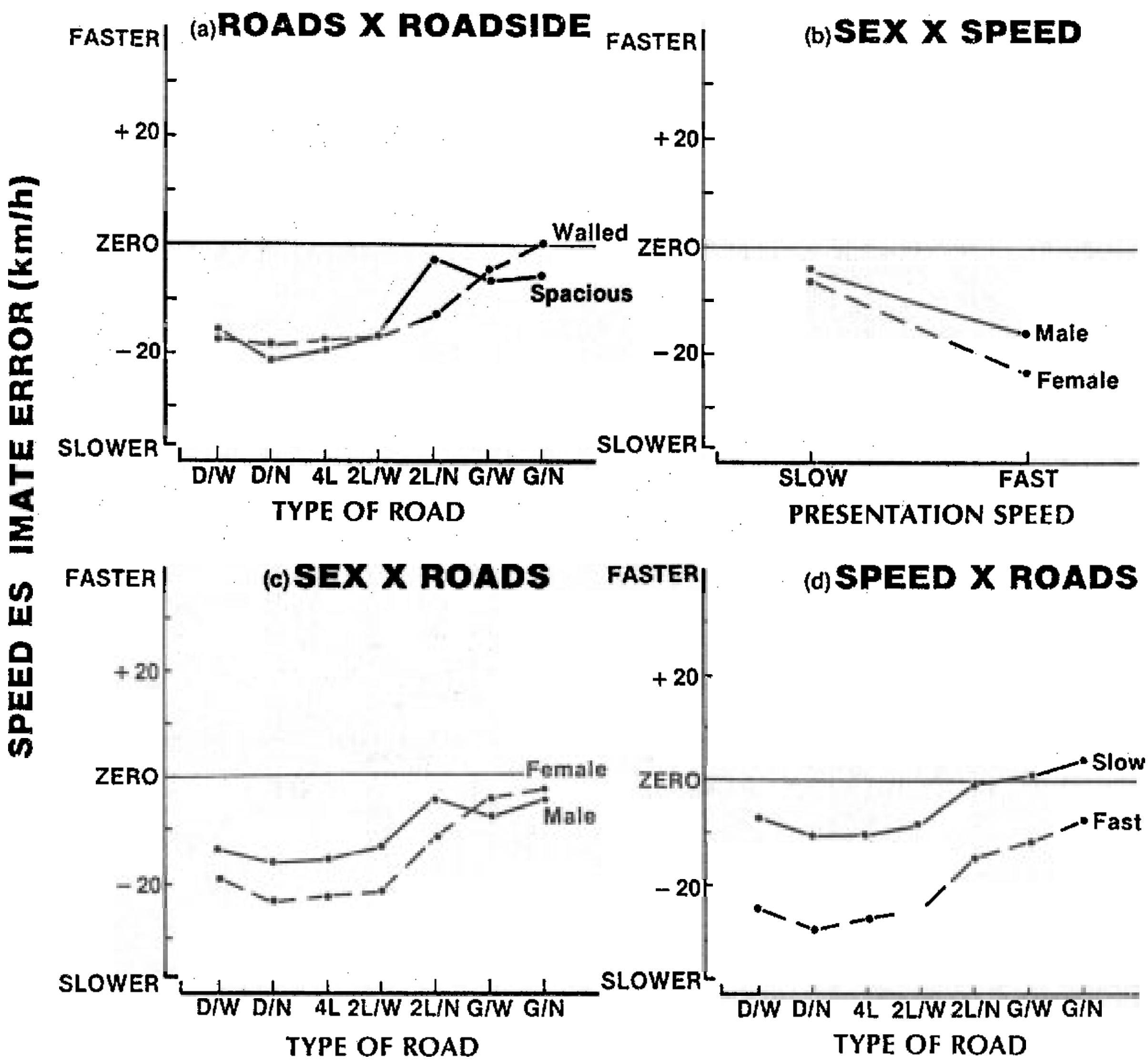


FIGURE 6.3 Travel speed errors for the significant interactions observed for rural roads in experiment 1.

prime interest here. Three main effects and four interactions are described in order of the strength of effect.

Presentation speed, shown in Figure 6.2b, was significant ($F(1,32)=285.4$, $p<.001$, $\omega^2=.1398$). The speed of slow presentations was judged accurately, while fast presentation speeds were under-estimated. Once again, this variable was the strongest effect observed, capturing 50 per cent of the variance attributed to the variable manipulations.

Type of road in Figure 6.3a was significant also ($F(16,192)=59.4$, $p<.001$, $\omega^2=.1041$). In general terms, subjects under-estimated the speed of major arterial roads while their estimates became more accurate as the road category reduced. This variable was the second strongest effect observed again, accounting for 37 per cent of the factor variance.

An interaction was observed between type of road and roadside environment, shown in Figure 6.3a ($F(6,192)=15.9$, $p<.001$, $\omega^2=.0146$). Simple main effects analysis confirms that the source of this interaction was for divided wide ($F(1,32)=9.05$, $p<.01$), divided narrow ($F(1,32=8.4$, $p<.01$), two-lane narrow ($F(1,32)=133.2$, $p<.001$) and gravel narow roads ($F(1,32)=35.0$, $p<.001$). None of the other road categories were significant at the 1 per cent level. With $\omega^2=.0146$, this interaction accounted for 5 per cent of the treatment variance.

There was also a significant interaction between the subject's sex and type of road, shown in Figure 6.3c ($F(6,192)= 7.0$, $p<.001$, $\omega^2= .0107$). Simple effects analyses showed a significant type of road main effect for male and female subjects ($F(6,192)=16.9$ and 22.7, $p<.001$ respectively) but no significant sex effect for any particular road type ($F(1,32)=2.0$, 2.6, 3.4, 3.8, 2.5, 0.6 and 0.4, $p<.05$ respectively). This interaction accounted for 4 per cent of the treatment variance in this analysis.

The interaction between sex of the subject and presentation speed, shown in Figure 6.3, was significant ($F(1,32)=8.7$, $p<.01$, $\omega^2=.0038$) . Simple effects analysis, however, did not reveal any further information; speed was significant for both male and female drivers ($F(1,32)=22.1$ and 44.3, $p<.001$ respectively), but sex was not significant for either slow or fast presentations ($F(1,32)=0.5$ and 2.7, $p>.05$ respectively). This interaction accounted for only 1 per cent of the treatment variance.

The interaction between presentation speed and type of road, shown in Figure 6.3d, was also significant ($F(6,192)=5.5$, $p<.001$, $\omega^2=.0025$). Simple effects analysis revealed a significant main effect for type of road at both slow and fast presentation speeds ($F(6,192)=36.6$ and 53.4, $p<.001$ respectively) as well as a significant speed effect for each road type ($F(1,32)=163.2$, 145.5, 118.8, 169.9, 86.7, 119.5 and 53.2, $p<.001$ respectively). This interaction captured less than 1 per cent of the total treatment variance in this experiment.

There was no main effect for sex of the subject ($F(1,32)=1.2$, $p>.05$, $\omega^2=.002$). However, sex was a between-subject factor again in this analysis and did have a noteworthy strength of effect (omega-squared values greater than .001 deserve detailed attention; Triggs, Harris and Fildes, 1979; Fildes, 1979, 1987; and need to be tested more stringently in any future experimentation, Keppel, 1982).

6.3.3 Free Speed Measurements

Free speed data were collected at 20 of the 28 selected road sites (at site number 10, the road was realigned and the site bypassed between filming and collection of speed measurements, while for the gravel sites, only site 22 had sufficient traffic to enable free speed measurement). The mean speed, 85th percentile and standard deviation of the free speed records taken at each site are listed in Appendices A-2 to A-5.

The grand mean free speed across all measured sites was less than the mean posted speed limit (96.7 km/h compared with 100 km/h). The mean standard deviation for these sites was 11.4 giving a mean 85th percentile value of 108.6 km/h or 8.6 km/h above the posted speed limit. It is unclear whether these values are statistically different from the posted speed, given the uneven nature of the sites measured and the relatively large standard deviations obtained.

Figure 6.4 shows the plots of the mean free speed deviations around the speed limit for the available roadside environment and type of road variables and their interaction. The main effects also include a plot of the 85th percentile values at each level. These figures show that walled environments appeared to result in slower free speeds than spacious environments (Figure 6.4a) while free speed seemed to reduce as the type of road and number of lanes reduced (Figure 6.4b).

Moreover, comparing the effects of type of road with roadside environment shown in Figure 6.4c suggests that 4-lane and divided roads had mean free speeds around the posted speed limit, while 2-lane (and especially narrow roads) appeared noticeably less than the speed limit (approximately 12.5 km/h below). The difference between spacious and walled results for 2-lane-wide roads suggests there may be some optimum value at which roadside environment influences free speeds on the road.

The 85th percentile plots show similar trends to the mean plots in terms of the influence of roadside environment and type of road. With the exception of 2-lane-narrow roads, however, these values were consistently above the posted speed limit (a maximum value of 113 km/h was recorded at the divided narrow sites).

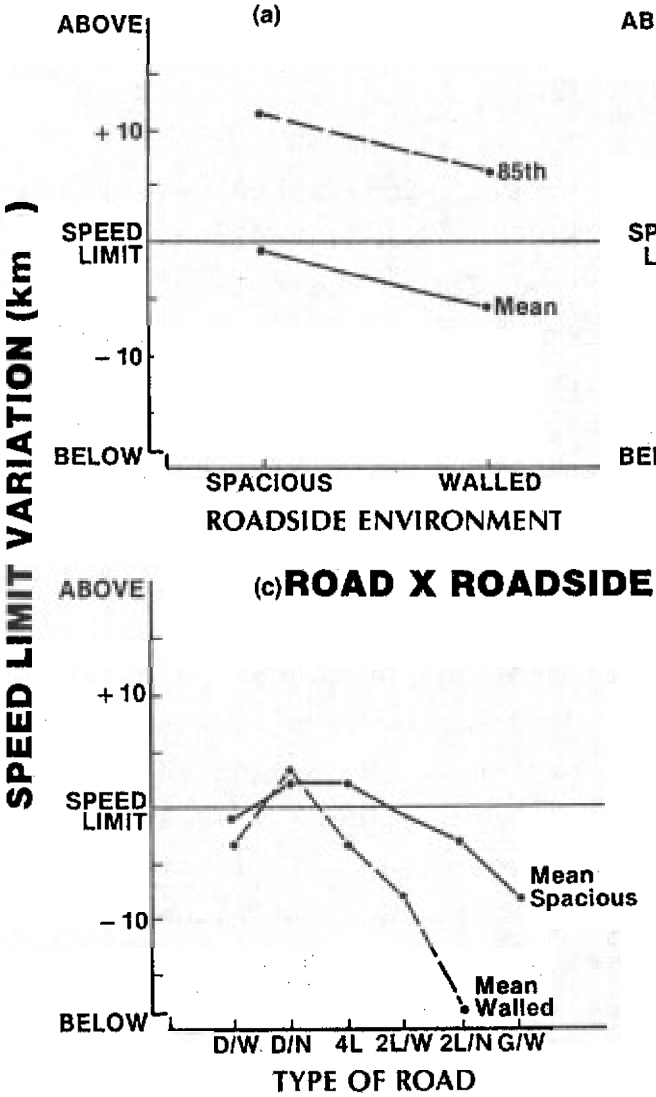


FIGURE 6.4 Free speed variations in km/h for type of road and roadside environment for rural roads in experiment 1.

6.4 DISCUSSION

The results from this experiment will be discussed in terms of the independent variables that were tested. The findings from the three sets of data can now be assimilated to provide a comprehensive account of the role of these factors in a driver's perception of speed.

6.4.1 Presentation Speed

The presentation speed of the stimulus materials had the strongest effect on both the subjects' safe operating speed judgements and speed estimates in the rural experiment. Slow presentation speeds (15 per cent below the posted speed limit) were generally judged to be too slow for safety in these environments and subjects' speed estimates were quite accurate Fast presentation speeds (up to 115 km/h), on the other hand, evoked a too fast response and subjects consistently under-estimated these travel speeds.

This result demonstrates the importance that subjects placed on the speed of presentation when making their estimates of safety and travel speed of these road scenes. While other variables such as type of road, roadside environment or the sex of the driver were significant main effects or interactions in this experiment, they accounted for considerably less of the treatment variance than did presentation speed. This confirms the need for moving stimulus materials when eliciting perceptual responses of safety and travel speed in the laboratory.

This result is not too surprising, given the relative lack of critical visual features in rural environments. It will be interesting to compare the trends reported above from the rural experiment with those for semi-rural and urban scenes. Conceivably, the slower posted speeds and the different roadside environments may have a marked effect on this result.

6.4.2 Type of Road

The overall finding was that road category (arterial, collector or gravel) and width of the road surface was critical for a driver's perception of speed. Type of road was the second strongest effect in both analyses, accounting for a sizeable proportion of the experimental variance.

The safe operating speed data showed that as the road category and number of lanes reduced, subjects' judgements tended towards the less safe end of the scale. For the error data, reducing road category and the number and width of the lanes resulted in less error when estimating travel speed. In short, the more major the road, the greater the feeling of safety and the greater the tendency to under-estimate travel speed.

The number of lanes on divided roads, however, was an exception to this finding. For this road category, wide roads (more than two standard width lanes in each direction) were judged less safe than the same type of road with only two lanes. Moreover, the speed estimates on these wide roads appeared slightly more accurate than those on 2-lane divided roads, and free speeds recorded at wide-divided sites were, on average, 3 km/h less than at narrow-divided rural sites.

This finding was not expected and, if robust, has important connotations for the perception of speed. However, it is necessary first to establish the full extent of this rural anomaly in other environments.

6.4.3 Roadside Environment

This variable had more effect on drivers' safety responses than on their ability to judge travel speed. Spacious sites were generally assessed much safer than walled sites , especially for fast presentation speeds. There was no sign of any interaction between roadside environment and type of road suggesting that the type of walling normally encountered in rural environments (roadside trees and forests) does not unduly influence a driver's feelings of safety on any one particular type of road.

Speed estimates, on the other hand were particularly accurate for spacious environments on 2-lane narrow rural roads. This was not influenced by presentation speed, but may have been a function of the sex of the driver. It is unclear, however, how this result would influence speed perception or behaviour on the road.

There was also a suggestion from the free speed data collected at these sites that a walled environment had some effect on travel speed for 2-lane highways. This result is interesting as it is not really reflected in the perceptual data (there was some sign of a difference in the safety estimate between walled and spacious 2-lane sites but this was not significant). Moreover, while there was a significant reduction in accuracy at estimating travel speed for these sites, it is not clear how this relates to performance on the road. This is another aspect of the rural results that needs further examination.

6.4.4 Driver Variables

The subject pool consisted of equal numbers of experienced (full driving license) and inexperienced (first year, provisional license) drivers as well as males and females. Hence, it was possible to evaluate the effects of these two driver variables in the perception of speed.

The amount of driving experience did not have any significant effect on the results of this experiment. Both experienced and inexperienced drivers responded in essentially the same way, and this variable has practically no influence on any other factor in the experiment in both analyses. The only sign of any experience effect was in the experience, sex, speed and roadside interaction in the speed estimate analysis, but then with very little power ($\omega^2 = 0$) and not worthy of serious consideration. While driver experience may be a significant performance variable on the road, it is clearly not so important for the perception of speed on rural roads.

The sex of the driver, however, showed signs of influence on these data. Sex was close to being a significant main effect in the safe responses as a between-subject manipulation. In addition, it did interact with roadside environment in these data as well as with type of road and presentation speed in the speed estimate error data.

In general terms, female responses tended towards the less safe end of the scale than male responses, and this subject group tended to under-estimate speed more than their male counterparts. Interestingly, the range of female responses tended to be larger than males for both the safe operating speed and travel speed estimates suggesting less certainty in these responses. This result was not expected from previous studies in road perception (Fildes, 1979; Triggs, Harris and Fildes, 1979).

It should be stressed that the driver variables in this experiment were between-subject manipulations with considerably fewer data points than the road and roadside within-subject manipulations. While Poulton and Freeman (1966) argued that under certain circumstances, 6 subjects would provide reliable effects in repeated measures designs, they nevertheless stated that more subjects are normally always desirable in these experiments.

As there were only 9 subjects in each driver variable condition in the rural experiment, these findings must be considered more tentative than the other results and further testing in any future experimentation would be desirable. Moreover, it would be interesting to compare the free speeds of male and female drivers on the road which, unfortunately, was not possible with the experimental design adopted here.

7. THE SEMI-RURAL EXPERIMENT

A semi-rural environment was defined as a rural setting in a built-up area. These environments can be found on the outskirts of towns and cities where urban design requirement, such as kerbing and overhead lighting, are included on otherwise rural roads. In addition, urban roads near some golf courses and those that travel through undeveloped areas, such as riverines, also constitute semi-rural environments. These environments are often subject to speed restrictions, although usually not less than 75 km/h. A divided semi-rural arterial can include urban freeways by this definition.

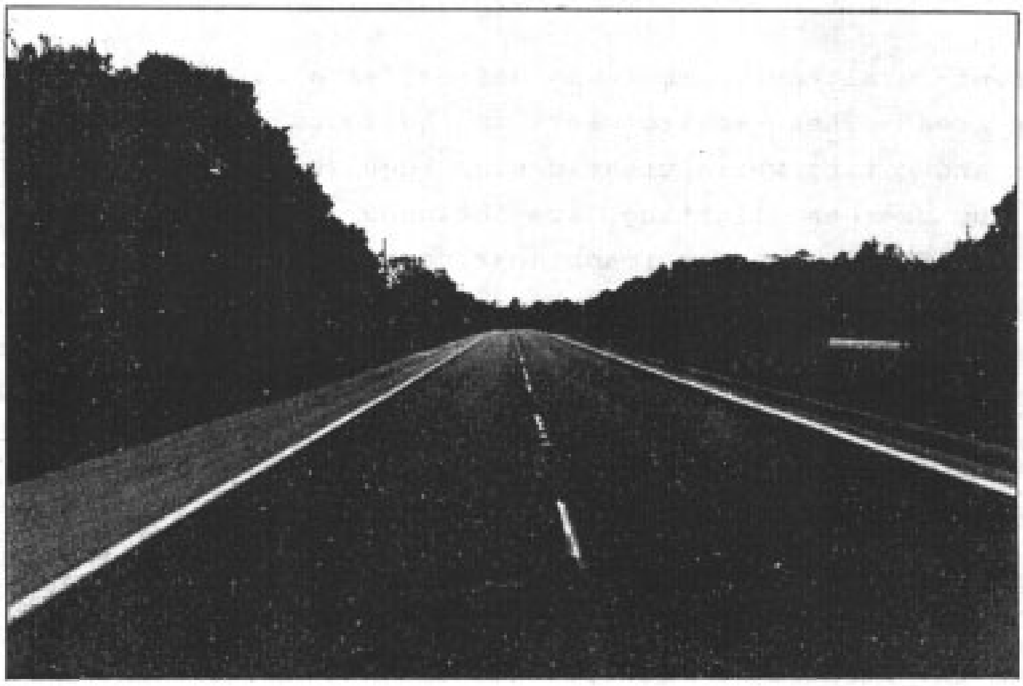
7.1 STIMULUS MATERIALS

From the research strategy outlined in Chapter 4, twenty semi-rural road sites were located within 2 hours of Melbourne that encompassed the range and levels of the independent variables of interest. Appendices A-6 to A-8 describe the 20 sites selected for the semi-rural experiment, and Figure 7.0 shows some typical examples of these sites.

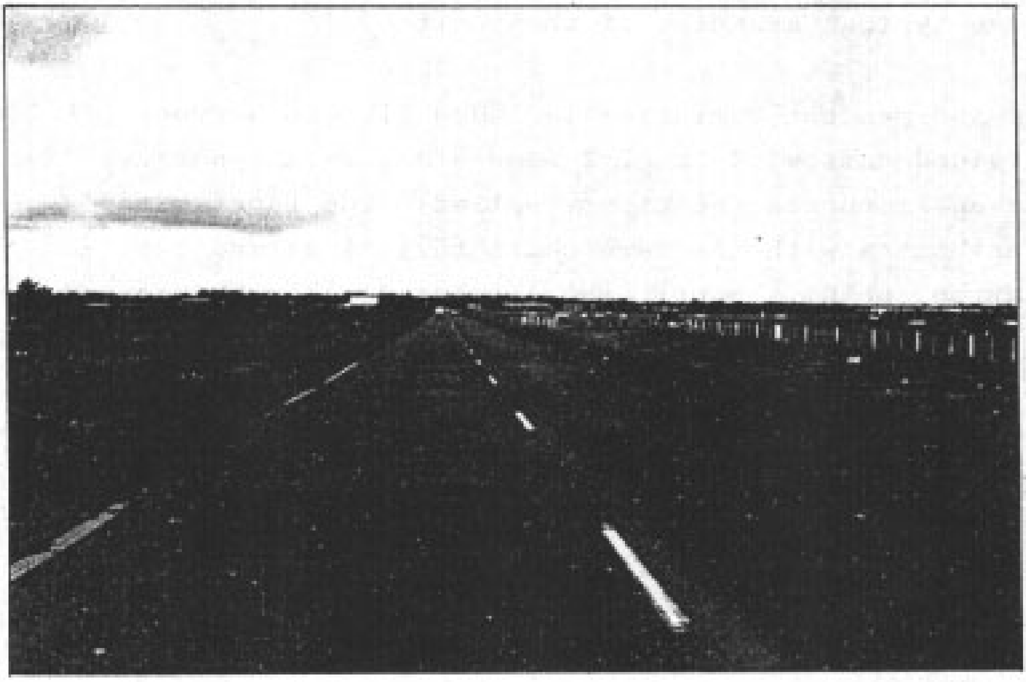
The independent variables included five road types (divided-wide, divided-narrow, 4-lane, 2-lane-wide, 2-lane-narrow), two roadside environments (spacious, walled), two repetitions (different sites with the same characteristics) and two presentation speeds (15 per cent above and below the posted limit). This yielded forty different road scenes in a fully crossed factorial design experiment.

Each site was filmed in a similar manner to that described in the previous experiment. Four experimental films were then constructed, each containing ten random, 5 sec road sequences followed by 10 sec of blank film. Presentation order was again structured to ensure that each film was presented equally in every serial position.

FIGURE 7.0
SEMI—RURAL SITES



Site 35 - Divided, Narrow, Walled road.



Site 45 - Undivided, 2-Lane, Narrow, Spacious road.

7.2 EXPERIMENTAL PROCEDURE

An additional thirty-six licensed drivers were recruited as subjects for the semi-rural experiment (nine subjects qualified in each of the four driver groups, male-experienced, female-experienced, male-1st year and female-1st year). Each subject was tested individually in the laboratory used previously.

7.3 RESULTS

Statistical analyses, involving analysis of variance and omega-squared, were performed on the safe operating speed responses and the travel speed estimate errors as before. Free speed data was once more confined to a descriptive analysis only. These analyses again will be discussed separately for uniformity.

7.3.1 Safe Operating Speed Responses

Appendix C-4 lists the statistical summary table of the analysis of variance performed on these data, while Figures 7.1 and 7.2 show the plots of the results of interest. There were two main effects and three interactions that warrant close inspection and these are described in order of their strength of effect (ω^2 ranking).

Presentation speed shown in Figure 7.1b was again significant for the semi-rural sites ($F(1,32)=82.8$, $p<.001$, $\omega^2 =.1678$). Subjects judged slow presentations as too slow, compared to what they considered to be a safe operating speed and fast presentations as either safe or slightly too fast. As in the rural experiment, this variable was the strongest effect in the analysis, accounting for 79 per cent of the variance due to the independent variable manipulations.

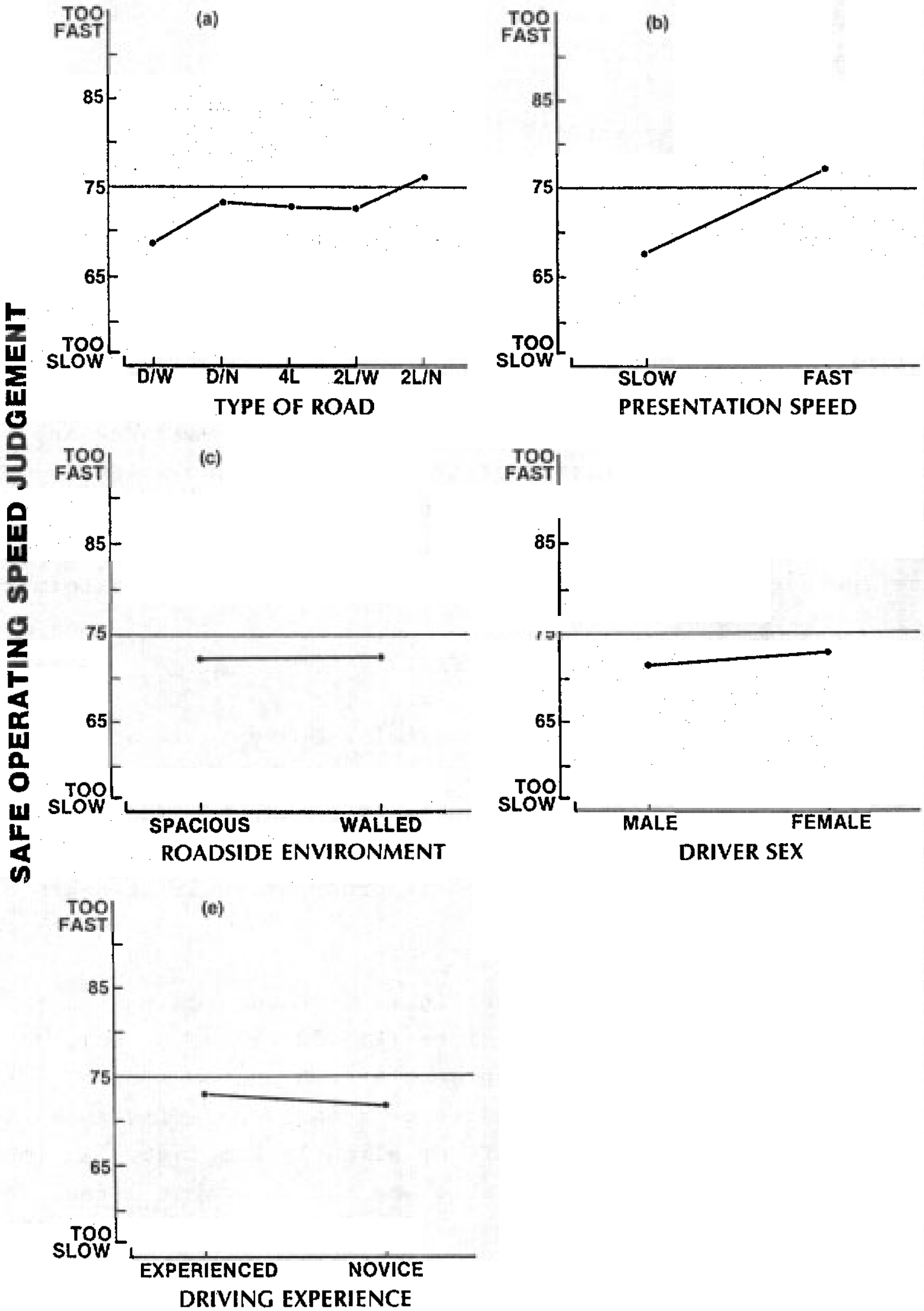


FIGURE 7.1 Safe operating speed main effects of interest for semi-rural roads in experiment 2.

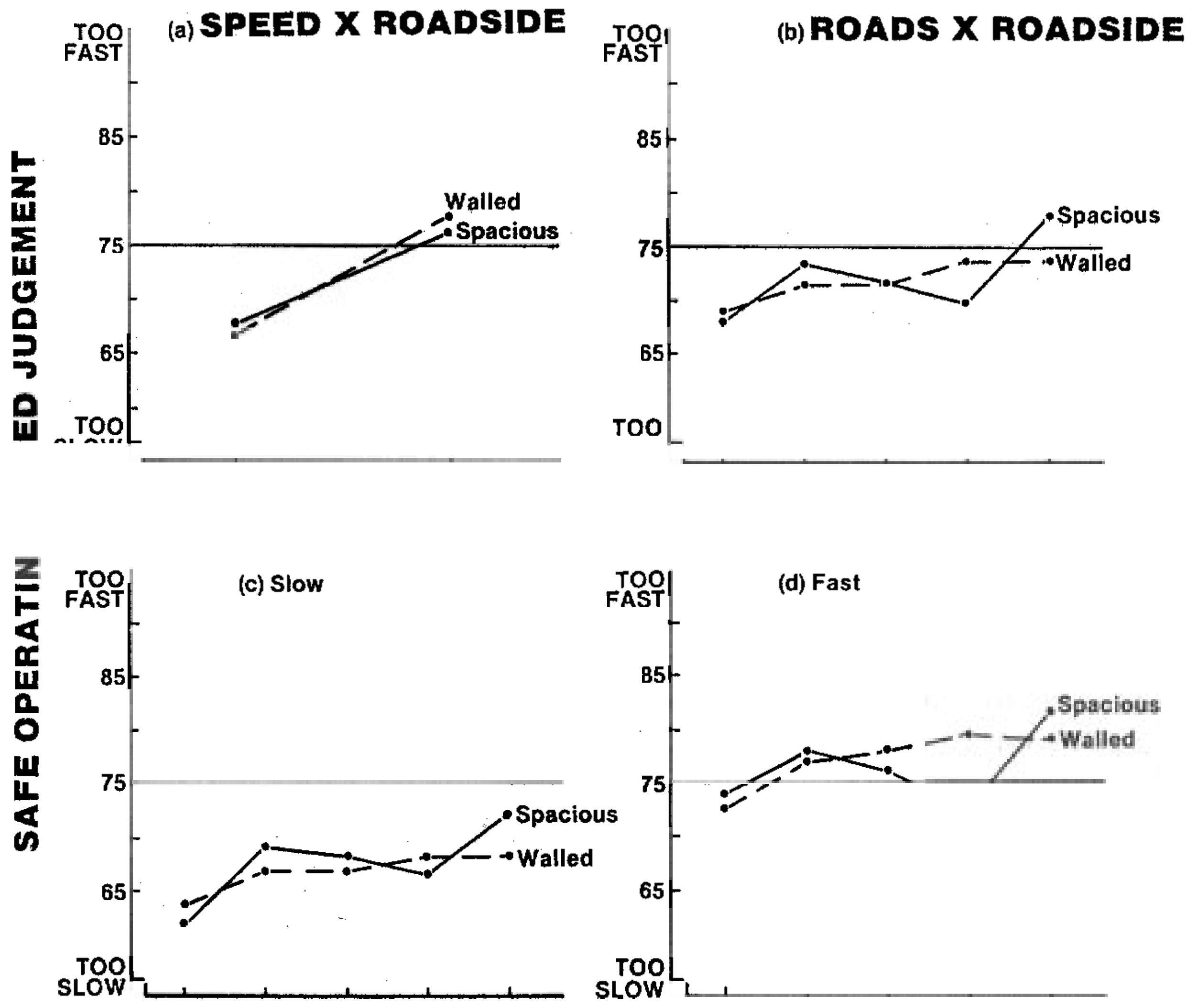


FIGURE 7.2 Safe operating speed interactions of interest for semi-rural roads in experiment 2.

The main effect for type of road shown in Figure 7.1a was also significant ($F(4,128)=24.0$, $p>.001$, $\omega^2=.034$). While no road type was assessed as unsafe in this experiment, subjects did judge the speeds on major roads to be more safe than on minor roads. This variable was the second strongest effect in the experiment and captured 16 per cent of the treatment variance.

There was a significant interaction between type of road and roadside environment, shown in Figure 7.2b ($F(1,32)=8.3$, $p<.01$, $\omega^2=.0076$). Simple effects analysis showed that the only significant roadside differences were for divided wide roads ($F(1,32)=4.5$, $p<.05$), two-lane wide roads ($F(1,32)=16.0$, $p<.001$), and two-lane narrow roads ($F(1,32)=7.7$, $p<.01$). This interaction attracted 4 per cent of the treatment variance.

The interaction between presentation speed and roadside environment, shown in Figure 7.2a was also significant ($F(1,32)=10.8$, $p<.01$ $\omega^2=.0015$). Simple effects analysis showed that the effect of roadside environment was significant for slow presentations ($F(1,32)=20.9$, $p<.001$), but not for fast presentations ($F(1,32)=0.2$, $p>.05$). This variable combination captured less than 1 per cent of the treatment variance.

The triple interaction between presentation speed, type of road and roadside environment, shown in Figures 7.2c and d, was also significant ($F(4,128)=2.9$, $p.<.05$, $\omega^2=.0014$). A simple interaction effects analysis showed a significant speed by roadside interaction for 4-lane, 2-lane wide and 2-lane narrow roads only ($F(1,32) = 13.3$, 12.6 and 103, $p<.001$ respectively). Further analyses for the significant interactions revealed that the effect of the roadside was significant for 2-lane roads for both presentation speeds ($F(1,32) = 4.3$, and 5.4, $p<.05$, 25.3, $p<.001$ and 9.0, $p<.01$ respectively). However, roadside was only significant for 4-lane roads at slow presentation speeds ($F(1,32) = 14.9$, $p<.001$). This interaction was not a particularly strong effect, accounting for only one-half a per cent of the treatment variance.

7.3.2 Speed Estimation Errors

Appendix C-5 lists the statistical summary table of the error score data while Figures 7.3 to 7.5 show the plots of the results of interest. Three main effects and three interactions are subsequently described in order of their strength of effect

The strongest effect in this analysis, once again, was the main effect of presentation speed shown in Figure 7.3b ($F(1,32)= 140.7$, $p<.001$, $\omega^2=.1293$). The travel speed of the slow presentation scenes was judged accurately, while faster speeds were under-estimated. This variable accounted for 61 per cent of the variance attributed to the independent variables.

Type of road shown in Figure 7.3a was the second strongest significant effect ($F(4,128)=25.4$, $p<.001$, $\omega^2=.0426$). Subjects' estimates of speed were under-estimated much more for divided and 2-lane-wide roads than they were for any other road category. This variable manipulation captured 20 per cent of the treatment variance in the analysis.

The third strongest effect was the significant interaction between type of road and roadside environment, shown in Figure 7.4c ($F(4,128)=8.7$, $p<.001$, $\omega^2=.0128$). Simple effects analysis revealed that there were significant roadside environment differences for both divided wide and divided narrow roads ($F(1,32) = 9.9$, $p<.01$ and 32.4, $p<.001$ respectively) but not for any other road type ($F(1,32) = 1.2$, 0.6 and 0.6, $p>.05$ respectively). This variable combination accounted for 6 per cent of the total treatment variance.

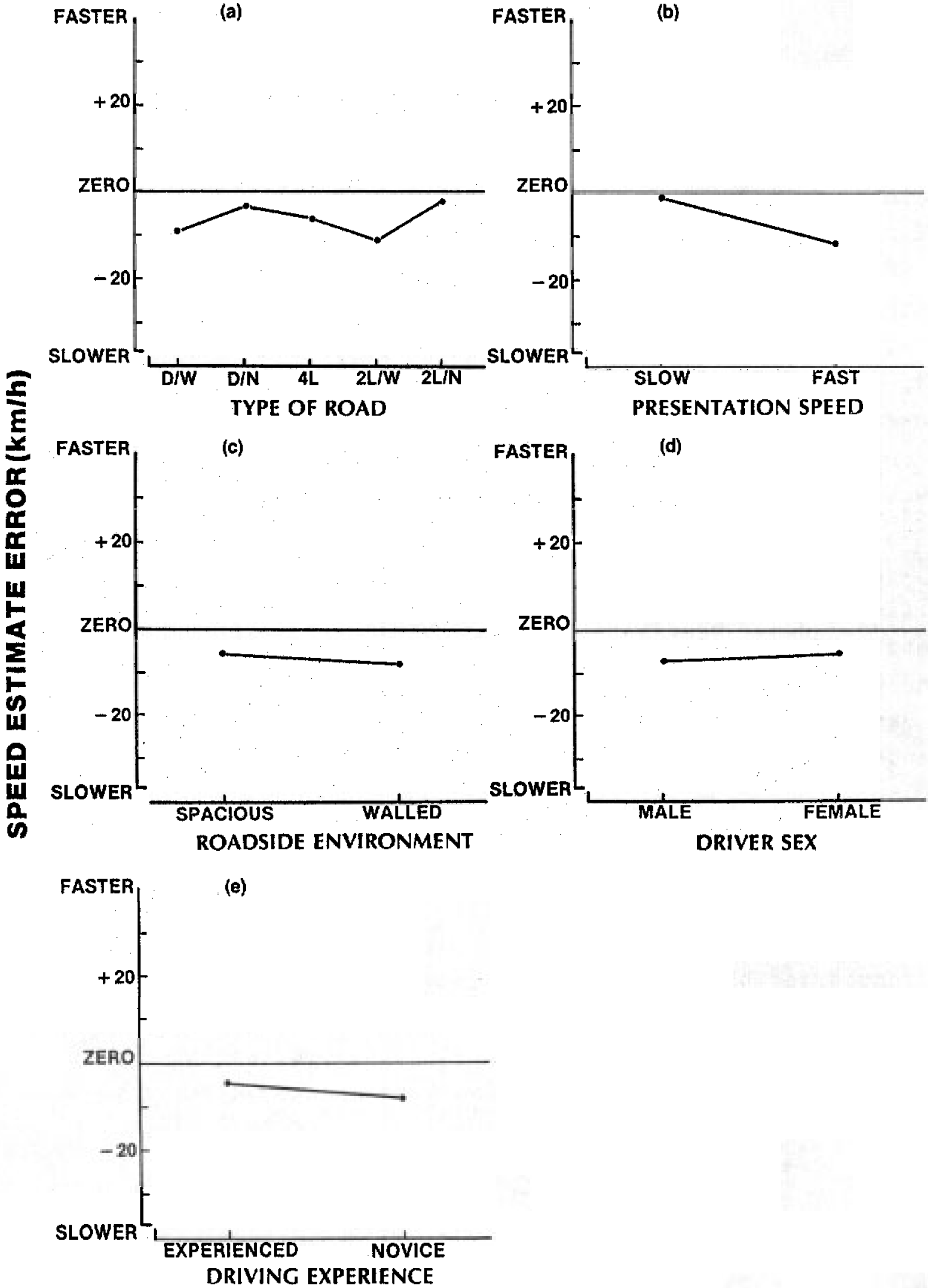


FIGURE 7.3 Travel speed errors of the main effects of interest for semi-rural roads in experiment 2.

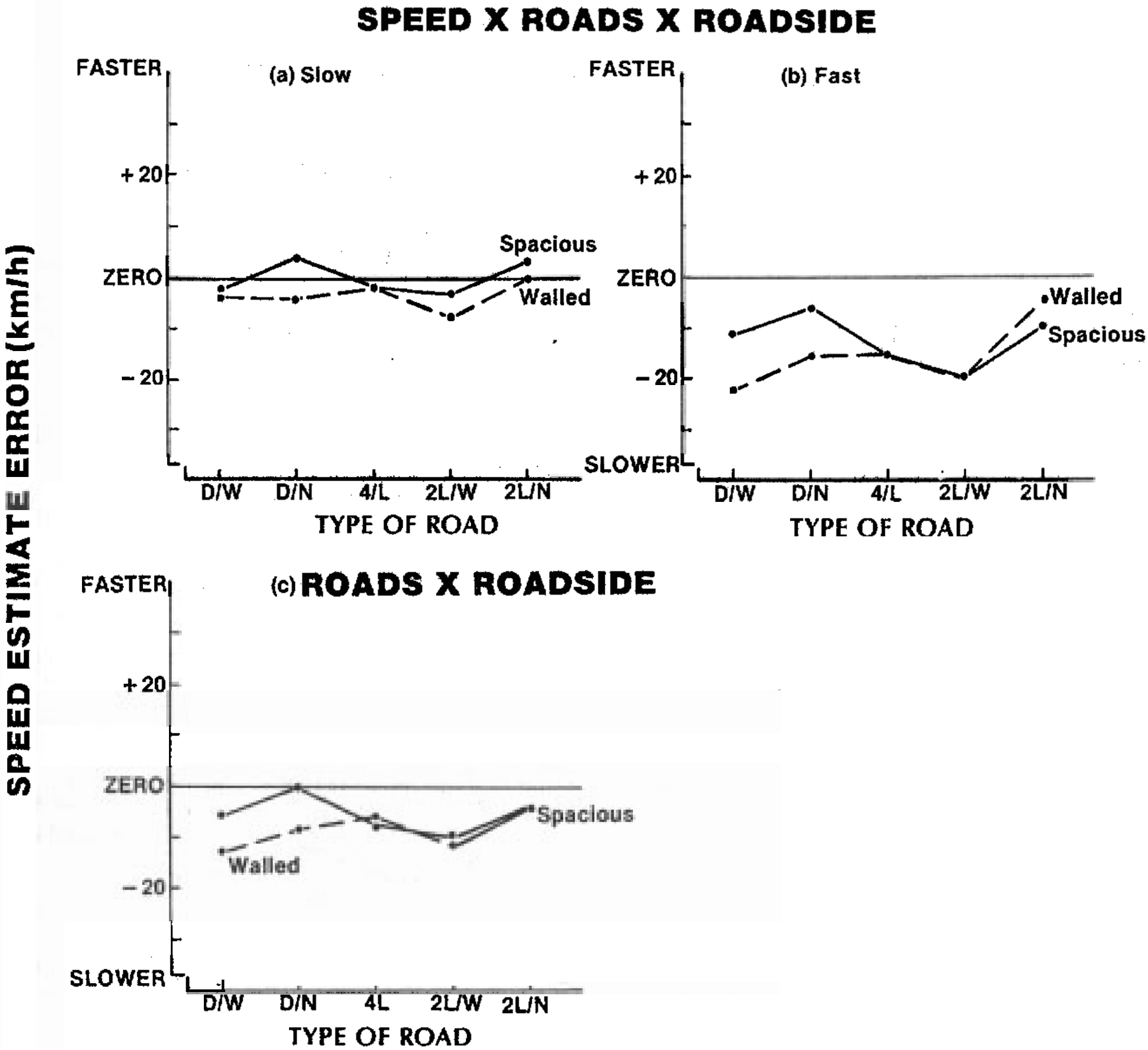


FIGURE 7.4 Travel speed errors for the significant 2- and 3- way interactions for semi-rural roads in experiments 2.

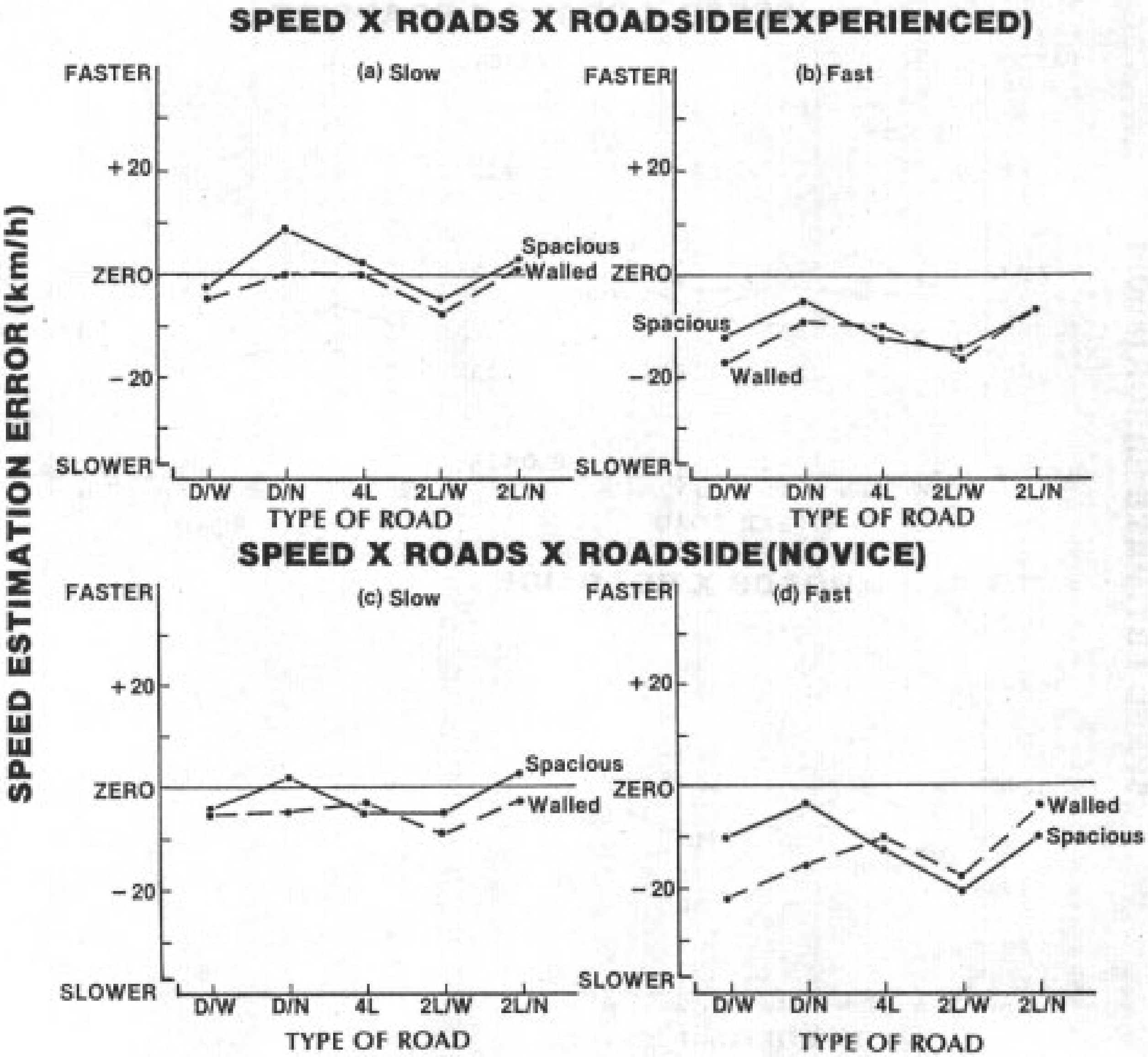


FIGURE 7.5 Travel speed errors for the significant 4- way interaction for semi-rural roads in experiment 2.

Roadside environment in Figure 7.3c was also a significant main effect ($F(1,32)=14.2$, $p<.001$, $\omega^2=.0064$). Spacious road speeds were slightly under-estimated while the speeds for walled scenes were substantially under-estimated. This effect was the fourth strongest effect, accounting for 3 per cent of the factor variance.

The interaction between presentation speed, type of road and roadside environment, shown in Figure 7.4a and b was also significant ($F(4,128)=7.0$, $p<.001$, $\omega^2= .0058$). Simple effects analysis revealed that the source of this effect was a significant roadside environment difference for divided narrow roads at slow presentation speeds ($F(1,32)=20.5$, $p<.001$) and for divided wide, divided narrow and two-lane narrow roads at fast presentation speeds ($F(1,32)=22.5$ and 15.4, $p<.001$, and 4.9, $p<.01$ respectively). With $\omega^2=.0058$, this interaction attracted 3 per cent of the treatment variance.

The four-way interaction between driver experience, presentation speed, type of road and roadside environment, shown in Figure 7.5 was significant too ($F(4,128)=4.9$, $p<.01$, $\omega^2=.0038$). Further analysis here revealed that the previous speed, road and roadside environment interaction was only significant for novice drivers ($F(4,64)=12.0$, $p<.001$). Additional simple effects analyses pin-pointed the source of this interaction to divided wide, divided narrow and two-lane narrow roads for fast presentation speeds ($F(1,16)=19.5$ and 37.6, $p<.001$ and 8.6, $p<.01$ respectively). By contrast here, however, there was no significant road and roadside interaction for slow presentation speeds ($F(4,46)=1.5$, $p<.05$). This variable interaction captured less than 2 per cent of the total treatment variance.

7.3.3 Free Speed Measurements

Free speed data were collected at all 20 selected road sites in the semi-rural experiment. The mean speed, 85th percentile, and standard deviation of the free speed records obtained at each site are listed in Appendices A-6 to A-8. In keeping with previous format, no statistical analysis was performed on these data. Figure 7.6 shows the plots of the mean and 85th percentile speed deviations around the posted speed limit for the roadside environment and type of road variables, as well as their apparent interaction.

The overall mean free speed for all sites was 79.1 km/h or 0.6 km/h lower than the average posted speed limit for these semi-rural roads. In other words, the average speed across the 20 sites used in this experiment was roughly equal to the posted speed. On average, the 85th percentile speed was roughly 9 km/h above the posted speed limit for the semi-rural road environments.

Walled sites, again, appear to have had slower free speeds overall than spacious environments, shown in Figure 7.6a (the mean free speed at spacious sites was roughly 3 km/h above the posted speed, compared to the -4 km/h differential for walled environments). This meant that the 85th percentile values for both environments varied from +13 km/h to +5 km/h above the posted limit.

Type of road shown in Figure 7.6b appears to have influenced mean free speed, where wide roads had average free speeds less than the speed limit and narrow road speeds slightly above the speed limit. In contrast with the rural findings, there does not appear to have been any systematic effect for road category in these semi-rural environments.

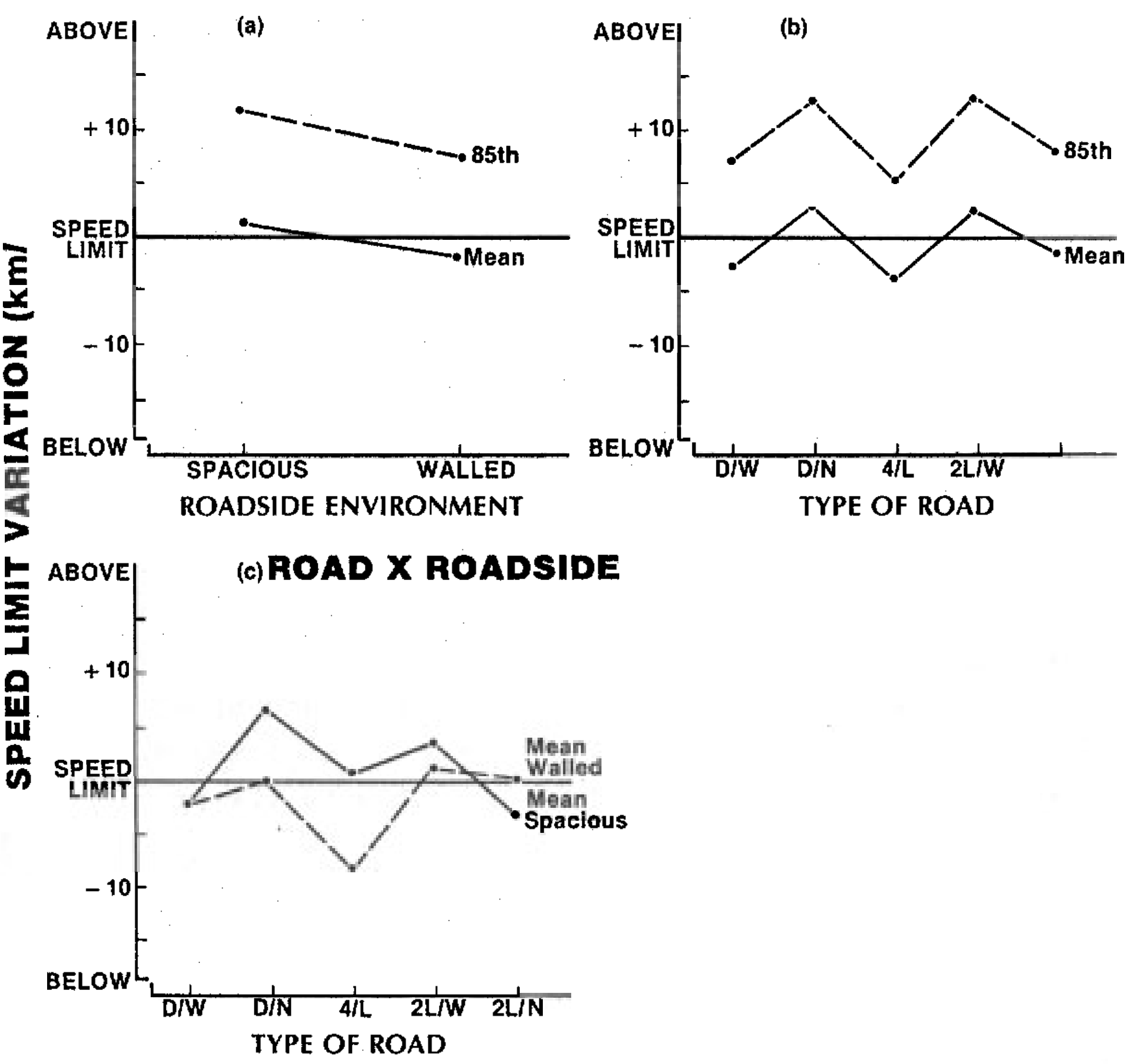


FIGURE 7.6 Free speed variations in km/h for type of road and roadside environment for semi-rural roads in experiment 2.

The apparent interaction between type of road and roadside environment, shown in Figure 7.6c, suggests that the effect for walled environments was more pronounced for divided-narrow, 4-lane, and 2-lane-wide sites. This result is consistent with the previous rural finding, except for the divided road result. Walling effects again were more obvious for 2-lane wide roads, adding further support to the notion of an optimum value between road (or walling) width and free speed.

7.4 DISCUSSION

These results will again be discussed in terms of the factors of interest in this experiment, drawing from the three sets of data.

7.4.1 Presentation Speed

The speed of presentation of the stimulus materials again exerted most influence on the subjects' judgements in the semi-rural experiment. This variable manipulation was the strongest significant effect observed in both the safety and speed estimates, capturing between 61 and 79 per cent of the treatment variance. This result was almost identical with the previous rural findings.

There was some suggestion of a general increase in safety for semi-rural sites, compared with rural sites. The plot in Figure 7.1b shifted further towards the too slow end of the scale over that observed in Figure 6.1b. This could reflect the fact that many of the semi-rural sites included in this experiment had posted speeds of 75 km/h (only sites 31, 35, 43 and 44 had unrestricted 100 km/h limits). For these restricted sites, the presentation speeds were 21 to 29 km/h slower overall than their unrestricted rural counterparts.

It was shown earlier that laboratory responses were slightly less sensitive measures of a driver's perception of safety on the road. The validation study in Chapter 5 showed that road responses were consistently judged much slower than were the laboratory responses. Nevertheless, a shift towards more safe in the laboratory is also likely on the road itself, albeit of a different (perhaps larger) magnitude.

This result, then, suggests that some of the speed limits currently applying in semi-rural zones may be too slow in terms of drivers' perceptions of what is an appropriate travel speed. Indeed, the number of instances where mean free speeds were above the posted speed limit in this experiment further demonstrate that drivers tend to travel in excess of the speed limit in these situations. An increased speed limit in some of these semi-rural zones (especially divided and spacious roads) would be justified to produce a uniform perception of safety across comparable rural environments. Naturally, this action should only be taken if it can be demonstrated that there are no potential road safety disbenefits.

7.4.2 Type of Road

Once again, this variable influenced the subjects' estimates of safe operating speed and travel speed. In general terms, the higher the road category and the greater the number of lanes, the higher the perception of safety shown by the subjects to these moving road scenes. Speed estimates were less systematic in that wide roads produced greater under-estimates of speed than narrow roads, but road category had little systematic effect on these responses. For both analyses, type of road was the second strongest effect observed behind presentation speeds, capturing a sizable proportion of the total treatment variance.

By contrast with the rural result for this variable, divided wide roads were judged more safe than divided narrow roads (c.f. Figure's 6.1a and 7.1a). In fact, the semi-rural result is much more in accordance with the hypothesis that road category and roadwidth are critical factors in a driver's perception of a safe operating speed. This result casts doubt on the previous finding that divided-narrow rural roads are somehow more safe than divided wide rural roads, suggesting that the anomaly reported for these rural roads may have been site specific. This warrants further investigation.

The finding that road category and width had a direct influence on driving performance was reported earlier by Oppenlander (1966), Leong (1966), Vey and Ferrari (1968), McLean and Hoffman (1972) and Smith and Appleyard (1981). The results reported here are in general agreement with the performance findings, and, in particular, support Smith and Appleyard's contention that "apparent width" encompassing the immediate surrounding environment has a special effect on driver's speed. However, road width, rather than roadside surrounds, seem to be most critical from the data collected here.

Moreover, the results from this study further suggest that the sensory perceptual system of drivers may be the mechanism behind the proposed relationship between apparent width and driver's speed. If this is so, then drivers are probably unaware of the effect that the road and surrounding environment have on their driving performance. This suggests there is considerable scope for unobtrusive manipulation of travel speed on the road using engineering and environmental countermeasures.

7.4.3 Roadside Environment

There was no main effect for roadside environment on the safe operating speed responses in semi-rural environments. However, walled sites did result in greater under-estimates of travel speed in the laboratory, as well as slower free speeds at most of these sites on the road. Roadside environment, however, was not a particularly strong effect in this experiment, capturing at best only 3 per cent of the experimental variance.

Of interest, though, was the effect that roadside environment had on the other variables in this experiment. The interactions between presentation speed, type of road and roadside environment, as well as the interaction between type of road and roadside environment in both data sets has interesting implications for speed perception.

Spacious environments had their greatest influence on safe operating speed judgements for 2-lane wide roads, especially at fast presentation speeds. For travel speed estimates, spaciousness was more influential on divided roads, again, at the faster presentation speeds. **A walled environment appeared to** influence the perception of speed by reducing the degree of safety on particular semi-rural roads at higher speeds. **This is** further evidence of the potential for a walled roadside environment, in conjunction with other road variables, to act as a countermeasure against excessive speeding on these roads.

7.4.4 Driver Variables

There was not very much evidence of any driving experience effect in speed perception. Experience was not significant as a main effect or interaction in the safe operating speed data, and had practically no strength of statistical association in these responses.

For the speed estimates, experience was not a significant main effect, although it did interact with presentation speed, type of road and roadside environment. For fast presentation speeds and on divided roads only, novice drivers under-estimated travel speed for walled roadside environments, contrary to the accurate judgements of experienced drivers.

While this was a robust effect, it should not be over emphasised. Keppel (1982) and others have argued that with multiple testing involving many variables, the chance of a significant effect increases substantially and one should be guarded against placing too much importance on these single occurrences. Moreover, the consequences of this finding in terms of the experimental hypotheses are difficult to determine because of the problem in interpreting the speed estimate data. Additional testing may show whether the amount of driver experience is important in the perception of speed.

Unlike the rural finding, the sex of the subject in the semi-rural experiment had no statistical effect on the subjects' responses. Female mean estimates of safe operating speed and travel speed were essentially the same as those of males, and the range of females responses was not noticeably different either. In short, the earlier sex differences observed in rural environments were not observed for semi-rural environments, suggesting either that females respond differently to males in rural environments only, or that the earlier findings are not particularly robust. Further testing is necessary to clarify this anomaly.

8. THE URBAN EXPERIMENT

The third and final experiment in this series involved urban settings. Urban environments consist of built-up areas containing residential, commercial or industrial establishments and, for this experiment, comprised suburbs of Melbourne.

Spacious and walled urban roadside environments were noticeably different to rural and semi-rural settings. Whereas a spacious rural setting consisted of areas lacking in trees or developments, urban spacious settings comprised residential areas with wide nature strips (a minimum of 3.5m was required from the edge of the road to the nearest building line) and low fences. Walled urban settings comprised commercial or industrial developments compared to the equivalent treed conditions in rural and semi-rural environments.

Urban areas, too, are subject to considerable speed restriction. While some sites are posted at 75 and 90 km/h, travel speeds in the vast majority of urban areas are limited to 60 km/h. Thus, there were substantial differences in the factors and levels between urban and rural or semi-rural environments.

8.1 STIMULUS MATERIALS

Using the research strategy outlined in Chapter 4, twenty urban road sites were located in the Melbourne Metropolitan area that encompassed the range and levels of the independent variables of interest. Appendices A-9 to A-11 detail the sites selected for the urban experiment, while Figure 8.0 shows some typical examples of the urban sites used.

The independent variables included five road types (divided wide D/W , divided narrow D/N, 4-lane 4-L, 2-lane wide 2-L/W, 2-lane narrow 2-L/N), roadside environments (spacious, walled), two repetitions (different sites with the same characteristics) and two speeds (15 per cent above and below the posted speed limit). This produced forty different road scene presentations in a fully crossed factorial design experiment.

FIGURE 8.0
URBAN SITES

Site 64 - Undivided, 2-Lane, Wide, Walled road.

Site 54 - Divided, Narrow, Spacious road.

Filming procedures and sequences in the urban experiment were similar to those described for the rural and semi-rural experiments. Four experimental films were again constructed, each containing ten random 5 sec road sequences, followed by 10 sec of blank film. Presentation order of the films again was structured to ensure that each roll of film was presented roughly equally in each serial position.

8.2 EXPERIMENTAL PROCEDURE

A further thirty-six licensed drivers were recruited as subjects for the urban experiment. As previously, there were 9 subjects allocated to each of the four driver groups, male-experienced, female-experienced, male-1st year, and female-1st year. Each subject was tested individually in the laboratory described earlier using the same procedure as before.

8.3 RESULTS

Statistical analysis, involving analysis of variance and omega-squared statistics, was performed on the safe operating speed responses and the travel speed estimate errors. Free speed data was again not analysed statistically and, therefore, only described in general terms. These three sets of results are described separately.

8.3.1 Safe Operating Speed Responses

The analysis of variance statistical summary table of these data is detailed in Appendix C-6, while Figure 8.1 shows the plots of interest here. There were three main effects and one interaction that will be described in order of their strength of statisical association (ω^2 ranking).

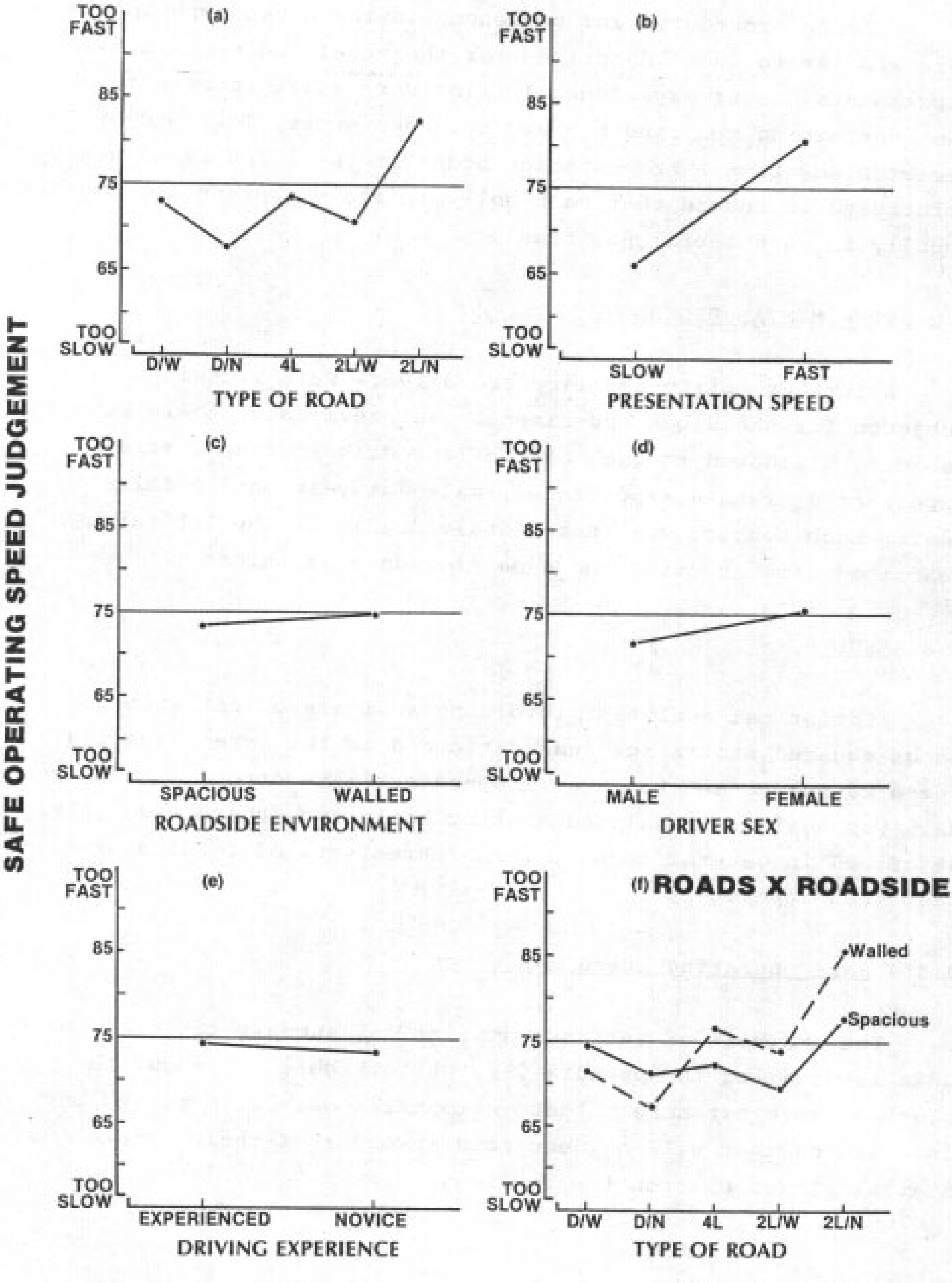


FIGURE 8.1 Safe operating speed results of interest for urban roads in experiment 3.

The main effect of presentation speed shown in Figure 8.1b was significant ($F(1,32=115.8$, $p<.001$, $\omega^2=.1014$). Slow presentations were judged to be too slow while fast presentations were assessed as being too fast. This variable, again, had the strongest effect in this experiment, capturing 56 per cent of all the treatment variance.

Type of road shown in Figure 8.1a was also a significant main effect ($F(4,128)=21.1$, $p<.001$, $\omega^2=.0448$). The safe operating speed for divided roads was assessed to be much faster than on 4-lane roads, while both were judged to be faster than on 2-lane roads. The results for the number and size of the travel lane were equivocal for 2-lane and divided roads. This variable had the second strongest effect, accounting for 25 per cent of the treatment variance.

A significant interaction was observed between type of road and roadside environment, shown in Figure 8.1f ($F(4,128=9.3$, $p<.001$, $\omega^2 = .0165$). A simple effects analysis showed that for divided roads, walled sites were assessed to be more safe than spacious sites ($F(1,32)=8.08$, $p<.01$ and 5.9, $p<.05$ respectively) while for 4-lane and 2-lane narrow roads, walled sites were judged to be less safe than spacious sites ($F(1,32)= 8.2$, $p<.01$ and 49.8, $p<.001$ respectively). There was no significant difference observed for roadside environment for 2-lane wide sites ($F(1,32)=2.0$, $p>.05$). This interaction accounted for 9 per cent of the treatment variance in the urban experiment.

There was a small but significant main effect for roadside environment, shown in Figure 8.1c ($F(1,32)=4.3$, $p<.05$, $\omega^2 =.0019$). Spacious environments were assessed to be safer than walled environments, although neither were judged to be unsafe. In terms of its strength of effect, this variable captured only 1 per cent of the treatment variance and was considerably smaller than either of the other two main effects in this experiment.

8.3.2 Speed Estimation Errors

Appendix C-7 details the analysis of variance statistical summary of the speed estimate error scores, while Figures 8.2 and 8.3 show the findings of interest. Three main effects and four two-way interactions require detailed attention and are described in order of their strength of effect (ω^2 ranking).

The main effect for presentation speed shown in Figure 8.2b was again significant and the strongest effect in this analysis ($F(1,32)=147.0$, $p<.001$, $\omega^2= .0191$). The speed of slow presentations was judged correctly or slightly over-estimated, while fast presentations tended to be under-estimated. This variable captured 36 per cent of the treatment variance in this analysis, although only 3 per cent stronger than the next strongest experimental manipulation. In short, the strength of this variable was reduced substantially, compared to that observed in the previous sets of results.

The type of road in Figure 8.2a was also a significant main effect in this analysis ($F(4,128)=66.3$, $p<.001$, $\omega^2 = .0988$). The travel speed for divided wide roads was under-estimated, while for 2-lane narrow roads, speeds were over-estimated. All other road speeds were estimated correctly. This variable captured 33 per cent of the factor variance and was also noticeably stronger than in previous experiments and analyses.

There was a significant interaction between type of road and roadside environment, shown in Figure 8.3c ($F(4,128)=80.5$, $p<.001$, $\omega^2=.0775$). Walled speed estimates were under-estimated more than spacious speed estimates for divided roads ($F(1,32)=$ 123.2 and 46.8, $p<.001$ respectively), but were relatively over-estimated for 4-lane and 2-lane roads ($F(1,32)=56.5$, $p<.001$; 58, $p<.05$ and 17.5, $p<.001$, respectively). This variable combination accounted for 26 per cent of the treatment variance and is also a much stronger effect in this analysis than that previously reported in the earlier experiments.

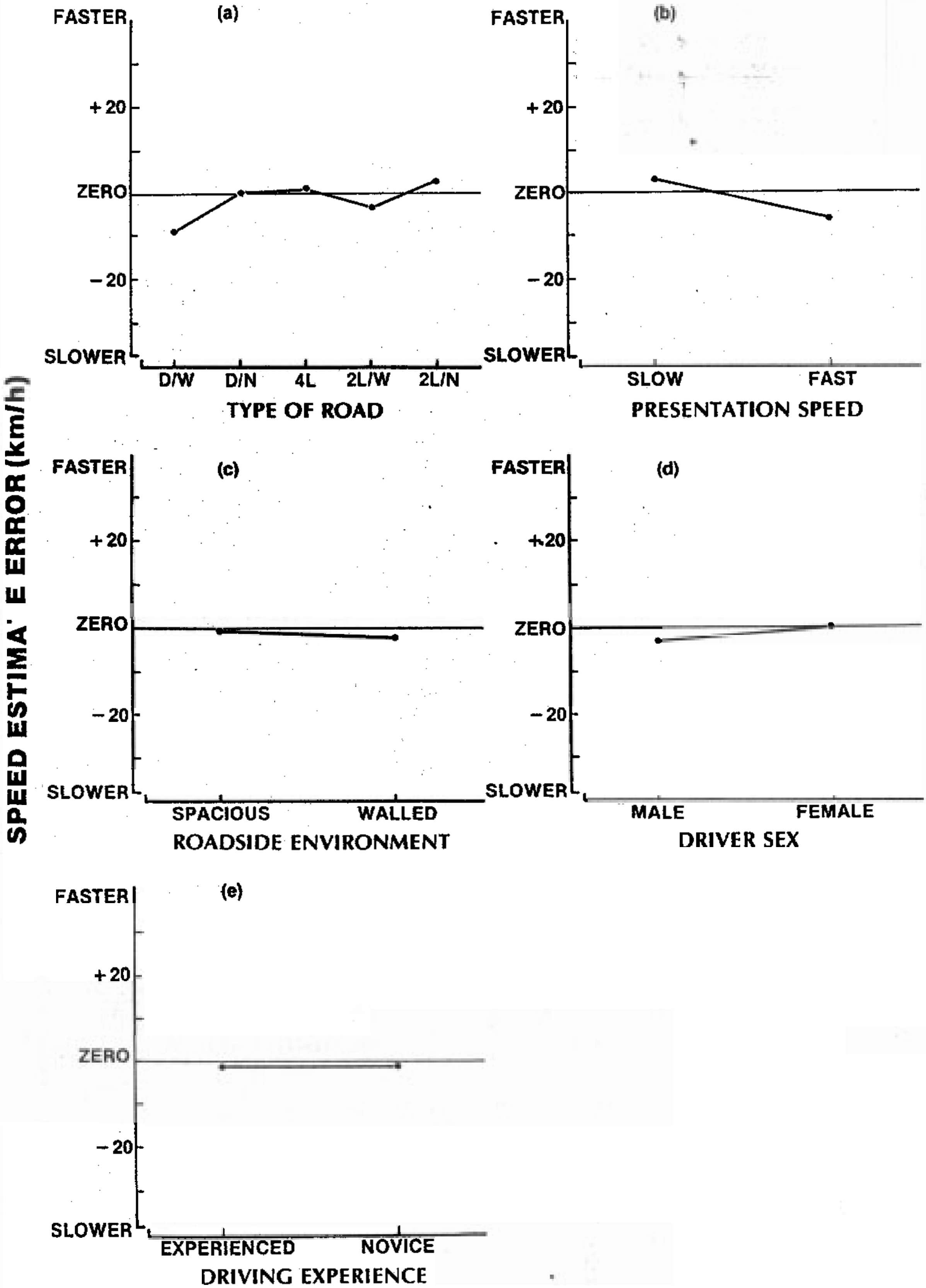


FIGURE 8.2 Travel speed errors for the main effects of interest for urban roads in experiment 3.

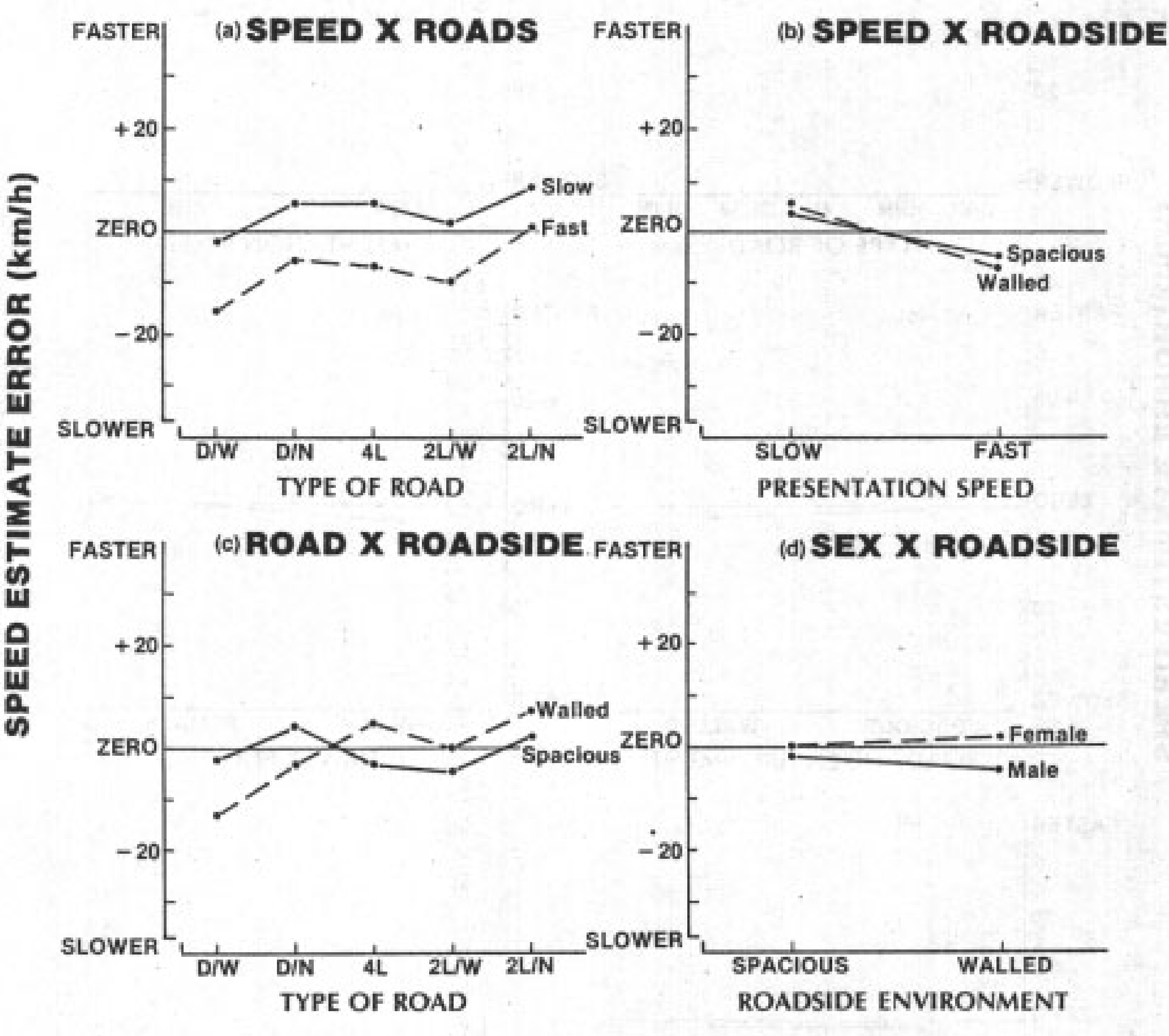


FIGURE 8.3 Travel speed errors for the significant interactions observed for urban roads in experiment 3.

The interaction between presentation speed and type of road shown in Figure 8.3a was the next strongest and significant effect observed in this analysis ($F(4,128)=5.2$, $p<.001$, $\omega^2=.004$). The speed for fast presentations roads were under-estimated more than the speeds of slow presentations ($F(1,32)=106.7$, 76.9, 82.5, 30.3 and 54.9, $p<.001$ respectively). With $\omega^2=.004$, this variable combination captured between 1 and 2 per cent of the total treatment variance.

The interaction between presentation speed and roadside environment, shown in Figure 8.3b was also significant ($F(1,32)=9.8$, $p<.01$, $\omega^2=.0016$). Simple effects analysis showed that travel speed estimates at spacious sites were more accurate for both slow and fast presentations than walled estimates ($F(4,128)=36.6$ and 60.3, $p<.001$ respectively). This variable attracted only 0.5 per cent of the treatment variance and was not an especially strong effect.

The interaction between sex of the subject and roadside environment in Figure 8.3d was significant too ($F(1,32)=4.5$, $p<.05$, $\omega^2=.0014$). Simple effects analysis revealed that walled sites were under-estimated more than spacious sites for the male responses ($F(1,32)=5.2$, $p<.05$), whereas female estimates were not significantly affected by roadside environment ($F(1,32)= 0.8$, $p<.05$). This result, too, was not a particularly strong effect in terms of its omega-squared value and ranking.

Sex of the subject shown in Figure 8.2d and the interaction between driver experience and sex were not significant effects ($F(1,32)= 1.5$ and 13, $p>.05$, $\omega^2 = .0041$ and .0026, respectively). However, they both attracted noteworthy amounts of the treatment variance (ie. ω^2 values greater than .001). As mentioned previously, these two variables were both between-subject factors with only 9 subjects in each condition. Thus, even with relatively less data points than the within-subject manipulations, they still attracted sizable proportions of the total treatment variance.

8.3.3 Free Speed Measurements

Free speed data were again collected at each of the 20 selected urban road sites. The mean speed, 85th percentile and standard deviation of the free speed records obtained at each site are listed in Appendices A-9 to A-11. No statistical analysis was again performed on these data and the results are described once more in terms of apparent trends. Figure 8.4 shows the plots of the mean and 85th percentile values and posted speed limits for the type of road and roadside environment variables, as well as the interaction between these two factors.

The overall mean free speed for the urban sites was 67.9 km/h. This was approximately 4 km/h above the average posted speed limit (the arithmetical average value of the posted speed limits for all sites). On average, the 85th percentile free speed were approximately 12 km/h (roughly 20 per cent) above the posted speed limit for the range of urban sites included in this study.

Walled urban road sites again appeared to yield slower mean free speeds than comparable spacious sites, as shown in Figure 8.4a. The mean free speed value for walled urban sites was close to the posted speed limit, compared to the +8 km/h mean speed for spacious sites. The 85th percentile values were +8 and +17 km/h respectively for these urban road sites.

The type of road, shown in Figure 8.4b, again appeared to have influenced free speeds in urban areas. Divided wide road speeds and 2-lane narrow speeds were slightly less than the posted speed limit, while divided narrow 4-lane and 2-lane wide roads were all faster than the posted speed limits. The 85th percentile speed was above the speed limit in all cases, varying from a minimum of +5 km/h to a maximum of +18 km/h. It should be noted that the speed limit on divided roads was between 33 and 67 per cent higher (i.e., 100 km/h compared to 75 or 60 km/h) than for other urban road sites.

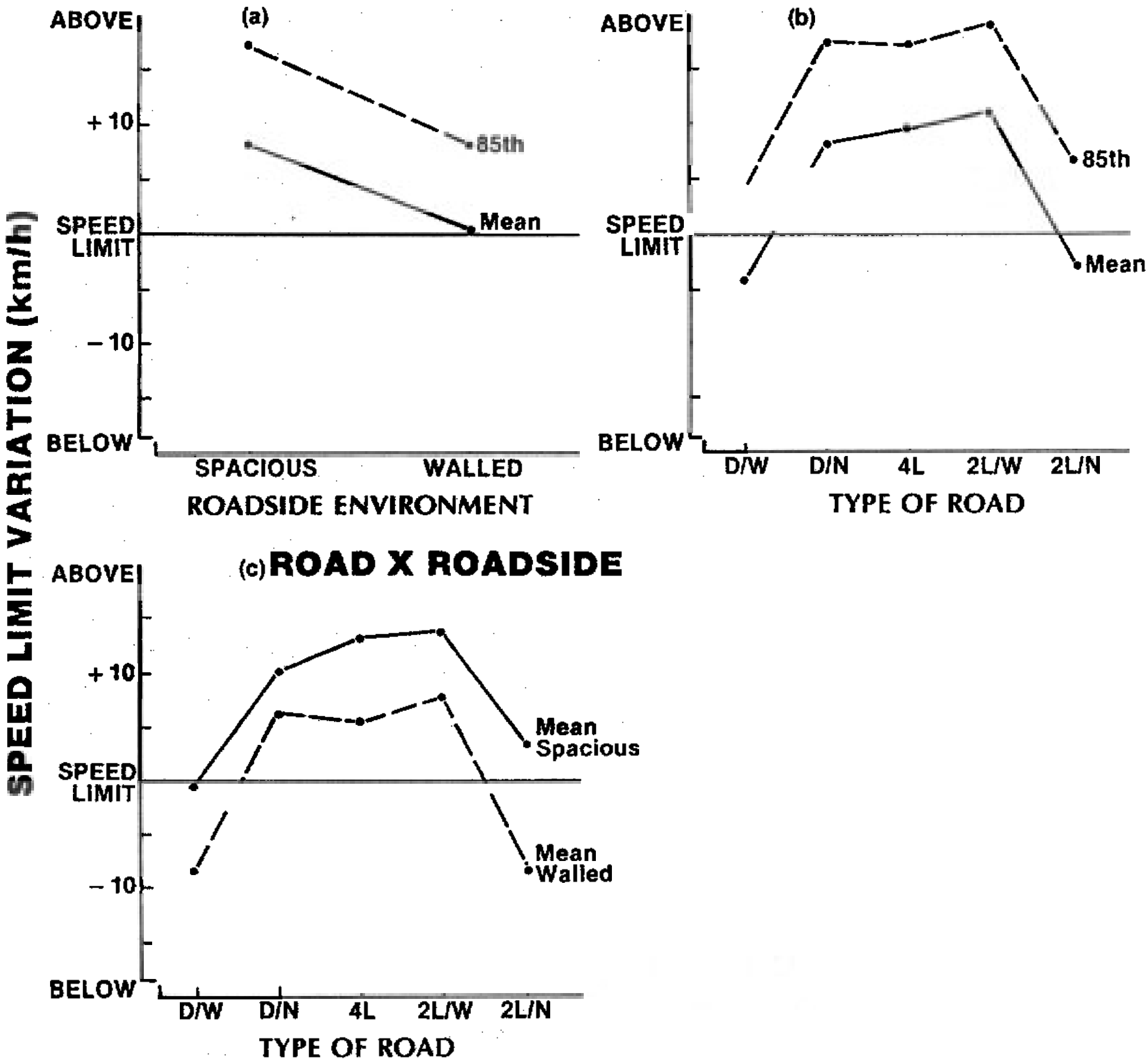


FIGURE 8.4 Free speed variations in km/h for type of road and roadside environment for urban roads in experiment 3.

There was some suggestion of an interaction between the type of road and roadside environment, shown in Figure 8.4c. The effect of a walled roadside environment appears to be more pronounced for 4-lane and 2-lane sites than for divided road sites. While this result was reported previously in the earlier rural and semi-rural experiments, it is likely to be influenced here to a large degree by the large differences in the posted speed limits within the urban areas tested.

8.4 DISCUSSION

For consistency, the discussion of these results will be structured once again around the independent variables, drawing from the three sets of urban data collected.

8.4.1 Presentation Speed

The presentation speed of the moving road scenes again exerted most influence on the subjects' safe operating speed judgements, and to a lesser degree, on their estimates of travel speed. As found in the previous two experiments, faster presentation speeds were judged too fast for safety and their speeds tended to be over-estimated. Slow presentation speeds, on the other hand, were perceived to be much slower that the ideal safe operating speed, and their speeds were under-estimated. This is further support of the importance of movement for the perception of speed on the road.

One aspect of these results, however, was a little puzzling. It was reported in the introduction that previous laboratory experiments found that slow travel speeds (around 60 km/h) were generally under-estimated, while fast travel speeds (100 km/h or more) were either judged correctly or slightly over-estimated (Hakkinen, 1963; Salvatore, 1968; 1969; Evans, 1970a; Reason, 1974). Indeed, this relationship was also found here between fast and slow presentations within each experiment. However, the mean posted speed in the rural experiment was roughly 65 per cent higher than in the urban experiment (100 km/h compared to only

63.8 km/h on average). One would have expected a difference, therefore, in the absolute level of each function because of the different range of travel speeds between experiments. As there were no apparent shifts between the functions reported for the safe operating speed and travel speed data in all 3 experiments, it seems likely that there may have been some task influence at work within each experiment. This is a further suggestion of some slight attenuation in absolute road safety terms as a result of the laboratory method.

8.4.2 Type of Road

The type of road, again, exerted a strong influence on the safe operating speed and travel speed estimates. Consistent with the earlier findings, increasing the road category in urban environments resulted in a systematic increase in the subject's perception of safety, and a tendency to under-estimate travel speed. In addition, free speeds measured at these sites showed substantial variations around the speed limit depending on the road type. Several aspects of this result, however, need to be discussed further.

First, the finding that wide divided roads were perceived less safe than narrow divided roads was reported earlier for rural, but not semi-rural, environments. It was argued that this may have been the result of subtle changes in the design specifications of these more recent major arterials. Alternatively, the particular stimulus materials could have induced this result for reasons not readily apparent. Confirmation of the discrepant trend for wide divided roads in urban environments supports the proposition that subtle changes in road geometry may be influencing drivers' perceptions of safe operating speeds on these roads.

It should also be noted that when filming these roads, the vehicle was positioned in the lane that provided roughly an equal view of the road, left and right of the camera, in the direction of travel. As the camera was aligned with the driver's view (the right-hand side of the vehicle), this meant the vehicle was in the inner lane of 2-lane roads, the middle lane of 3-lane roads and the equivalent lane (second from the left) on 4-lane divided roads. Thus, vehicle position may also have contributed to the unexpected finding for wide divided roads as there was more pavement, especially left of the camera, on these wide roads than on their narrow counterparts. Further experimentation is warranted here to test fully the effect of travel lane on a driver's speed perception.

The greater strength of statistical association, reported for type of road in the travel speed error analysis, highlighted the increased importance subjects placed on this variable in urban settings. The effect of road type was only one-third to two-thirds that of presentation speed in rural and semi-rural settings, whereas both factors attracted roughly the same amount of variance in urban environments. In addition, the interaction between type of road and roadside environment in the speed estimate data was noticeably stronger for urban than for rural or semi-rural scenes. This greater strength of effect, however, was not so apparent in the urban safe operating speed responses

This result was consistent with comments made by several of the subjects after completing the urban experiment. They remarked on a strong sensitivity towards the presence and number of intersections when making their judgements in the urban experiment. By contrast, very few similar comments were made by subjects in the rural and semi-rural experiments. It would appear, then, that road geometry in urban environments (including the number of major and minor intersections) is critical for estimating travel speed on urban roads. Naturally, the slower speeds normally encountered on these roads may also play some part in this finding.

8.4.3 Roadside Environment

As mentioned in the previous discussion, roadside environment seems to have played a more important role in urban environments than in rural settings. Walled sites were perceived to be less safe than spacious sites for 2-lane and 4-lane roads, although more safe on divided roads. In addition the speeds on divided roads were under-estimated more for walled sites than for spacious sites. Interestingly, the number of lanes or lane width did not appear to have interacted with roadside environment in this experiment.

This confirms the importance that the type of road plays in urban speed perception. While commercial and industrial environments can induce different perceptions of safety on these roads to residential settings, the road itself seems to have the greatest bearing on a driver's speed perceptions in these areas. Thus, any countermeasure aimed at reducing excessive speed in urban areas should concentrate primarily on road characteristics, such as narrow roads and lanes, rather than to emphasise roadside fittings and attachments. This approach is also consistent with the need to eliminate hazardous furniture from the sides of roads to minimise road crashes (Fox, Good and Joubert, 1979; McLean et al, 1979; Sanderson and Fildes, 1984).

8.4.4 Driver Variables

Once again, there was not much evidence of any strong driver effects in the perception of speed in urban areas. Driver experience or sex was not a main effect and did not interact on any other variable in the safe operating speed reponses. The sex of the driver did have some effect on roadside environment in the speed estimation results. Males tended to under-estimate walled environments, while females' estimates were not affected. As driver sex did not interact with type of roads here, it is unclear how this effect would be expressed on the road itself.

It should be noted that both driver variables did attract noteworthy amounts of the treatment variance (ω^2 >.001) separately and together. Keppel (1980) argued that any variable that attracted a sizeable omega-squared, irrespective of whether it was a significant effect or not, was worth following up in any new field of experimentation.

As there were only nine subjects in each driver condition (albeit using repeated measures), it would be worth testing these effects more stringently in any additional experiments in speed perception. **However, in terms of its relative importance, driver** effects would seem to have a much lower priority than other variables.