DRIVER BEHAVIOUR AT RURAL T-INTERSECTIONS

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EXECUTIVE SUMMARY

1. Introduction

Fatal accidents at rural T-intersections in the Waikato region, New Zealand, were observed to typically involve older male drivers, and occurred in daylight and in fine weather. The aim of the study, carried out in 1994, was to compare the performance of 80 licensed drivers, in four groups of 20 (10 males; 10 females), aged under 30 years, 40-59 years, 60-69 years, and 70 years and over (subsequently identified as 70+) respectively, in a series of laboratory and road-side tests covering relevant capacities and skills. The sample included a range of self-identified ethnic origins.

2. Laboratory-based Tests

These tests were conducted in a Pyschology Department research room at the University of Waikato, Hamilton.

2.1 Driver behaviour questionnaire

This questionnaire covered driving patterns and traffic accident and offence history. It revealed that reported corrected vision and hearing deficits were most common in those aged over 59 years. It also revealed that those under 60 years reported that they had covered the largest distances in a year, had more infringements and accidents in the past 5 years, and were more likely to drive with the radio on.

2.2 Tests of Vision

These included monocular and binocular visual acuity, stereovision, phoria and fusion, colour vision, and horizontal peripheral vision.

Tests of *monocular vision* (one eye) revealed that 12 persons had severe impairment in one eye, 11 of whom were aged 60 years or more. Five of the seven aged 70+ years who had unacceptable monocular acuity could be classified as functionally one-eyed drivers.

Tests of *stereovision* revealed that 15% of the 60 to 69 year-old, and 50% of the 70+ year-old, participants' scores fell below acceptable limits.

Tests of *peripheral vision* showed that those performing at unacceptable levels for the right visual field (N=8), necessary for seeing vehicles coming from the right, were aged 60 years or over.

2.3 Tests of Cognitive Performance

Multiple choice reaction time tests (i.e. responding correctly to different stimuli as quickly as possible after they are displayed) produced age-related differences with respect to speed (slower with increasing age) but not with respect to accuracy.

Decrements in *short-term memory performance* became more evident as age increased above 60 years, but there was no evidence of serious deterioration.

2.4 Test of Degree of Neck Articulation

Measurements of *neck articulation* (arc of head turning) showed that by age 70+ years the loss of about 1/3 of movement was typically more evident in males. Second attempts at the test almost always produced better results.

2.5 Summary

These age-related factors may contribute to older drivers' failures in effective judgement and decision-making at intersections. They include visual and physical defects (e.g. monocular vision, diminished peripheral vision, restricted neck articulation) that reduce older drivers' ability to detect and judge quickly the speed and distance (e.g. monocular vision, poor stereovision) of approaching vehicles, and to respond rapidly (e.g. reaction time) when vehicles are detected.

3. Road-side Tests

These included a driving test and tests conducted at a rural road-side site with the vehicle parked at a right-angle to a state highway, simulating a rural T-intersection. Participants sat in the driver's seat and were asked to imagine that they were at a T-intersection, intending to turn right onto the major road, while they made their judgements of speed and safe gaps relating to traffic approaching from their right.

3.1 Driving Test

Lane crossing times for making a right turn across lanes produced clear age and gender effects. Times became slower as participants' ages increased above 59 years, and males were always faster at crossing than females.

3.2 Gap Acceptance Testing

Gap acceptance data from the *threshold trials* (judgements of last possible moment) showed:

- drivers in all age groups allowed shorter time gaps for vehicles that were approaching at higher speeds;
- the under 30 year-olds consistently accepted the shortest time gaps over all approach speed categories;
- of this youngest group, males always accepted shorter gaps than their female counterparts.

Safe distance gap acceptance revealed that safe time gaps were evaluated on the basis of distance rather than speed, which may explain the under- and over-estimation of approach speeds evident in the time gap estimation data. These findings suggest that, because of under-estimation of faster approaching vehicles, all drivers face some risk at rural intersections. While younger drivers may appear to take more risks by accepting smaller gaps, the apparent caution of drivers over 59 years may be negated by restricted vision and neck articulation, both of which impair detection of, and delay response to, approaching vehicles, and slow lane clearance.

Signal detection trials produced results which generally corresponded to those from threshold judgements, although there were some differences in detail. Participants aged under 30 years were willing to accept the shortest time and distance gaps while older drivers tended to be more cautious in their judgements and somewhat more likely to decline a gap.

3.3 Speed Estimation Testing

The data revealed that the speed of vehicles travelling below 99 km/h was likely to be over-estimated, while that of vehicles exceeding 100 km/h was likely to be under-estimated. The extent of judgement error increased the more the approaching vehicle's speed deviated from 100 km/h. Such under-estimation poses considerable risk.

4. Conclusions

All drivers appear to be at some risk at T-intersections because of poor gap and speed estimation. However, older drivers' visual and physical deficits and slower reaction and acceleration times increase the magnitude of risk of an accident. The most evident problem for all drivers is estimating speeds of vehicles exceeding 100 km/h, while physical impairments of older drivers compound their difficulties in detection of, and response to, approaching vehicles.

5. Countermeasures

- More thorough screening of visual performance and neck articulation;
- Restricted licences;
- Changes to road signs;
- Use of "Stop" signs and roundabouts at "Black spots";
- Traffic speed enforcement with radar and speed cameras near dangerous intersections;
- Road engineering solutions to improve field of view at intersections.

ABSTRACT

Eighty drivers in four groups of 20 (10 males; 10 females), aged under 30 years, 40-59, 60-69, and 70 years and over respectively, participated in a study, carried out in 1994 in the Waikato region, New Zealand, to identify factors contributing to crashes at rural T-intersections involving older drivers.

Laboratory-based tests involved tests of vision, memory, reaction time, and neck articulation. Drivers aged over 59 years had most visual defects and the poorest neck articulation. Participants in road-side tests, using a test vehicle parked at a right-angle to the highway simulating a T-intersection, were then asked to estimate the safe gaps and speeds for traffic approaching from their right. Safe gaps for a right turn onto the highway were estimated using threshold (last possible moment) and signal detection procedures (go/not go). A laser device recorded actual traffic speed and distance. The time taken by each participant to turn right across the road was also tested in a driving test.

Participants in all age groups judged speed poorly, over-estimating slower traffic and under-estimating faster traffic. They used distance rather than speed in gap estimation. While those aged under 30 years allowed the smallest gaps, those over 59 years were the least consistent judges and were slower to clear the next lane when turning right. Older drivers may be at higher risk at intersections, especially when speed of approaching traffic exceeds 100 km/h, because of their failure to detect approaching vehicles, their poor estimation of speed and available gaps once vehicles are detected, and their slower lane clearance when turning. A range of countermeasures is suggested.

1. INTRODUCTION

1.1 Background

The New Zealand motor accident statistics for 1990 (New Zealand Ministry of Transport (MOT) 1991) indicate that, of the driver factors contributing to accidents, about 15% were caused by failure to give way at intersections. Of these 15%, failure to give way or stop was the primary factor accounting for 25% of injury accidents, and for 10% of fatal accidents. Data from Sweden (Brude 1990), Norway (Elvik 1990) and Britain (Hills 1980) support the view that intersections are high accident-rate sites. In Sweden one half of urban accidents and a quarter of rural accidents occur at road intersections. One third of the Norwegian road accidents are at intersections. Hills (1980) identified turning right as one of the most serious accident-producing events.

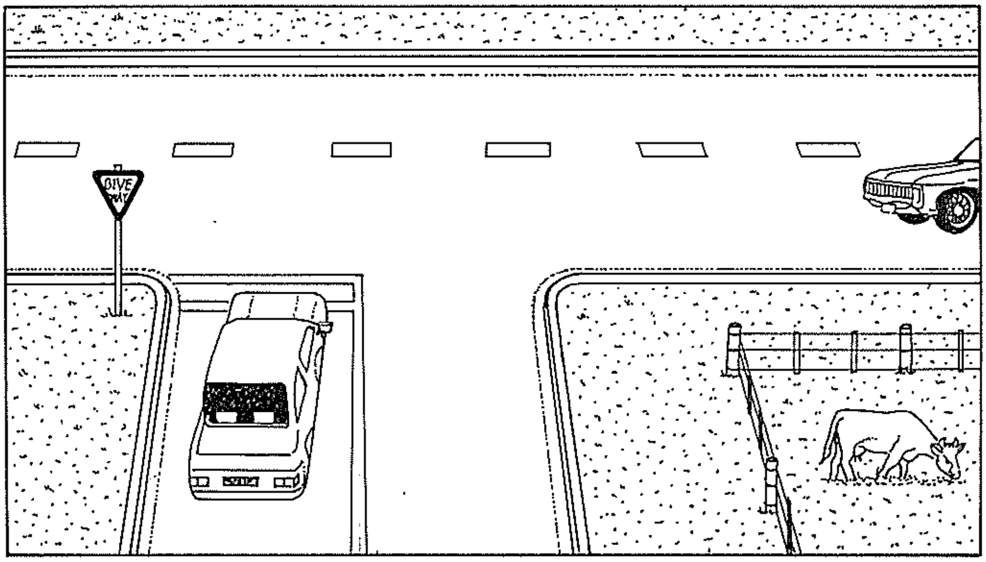


Figure 1.1 The rural T-intersection, as an accident black spot.

The present study, carried out in 1994, arose from a concern at the high rate of fatal rural T-intersection accidents (Figure 1.1) occurring at a number of intersections with major roads in the Waikato region, North Island, New Zealand. The majority of these accidents involved older male drivers, occurred in daylight, and in good weather and road conditions. All intersections involved were controlled by "Give Way" signs and most accident reports indicated that the older driver had failed to stop or give way, despite oncoming traffic. The characteristics of these accidents exactly match those described by Evans (1991b) and Frith (1991).

1.2 Accident Data Concerning Older Drivers

Previous research data obtained about older drivers involved in vehicle accidents show that they are more likely to be male, and the most common site is at an intersection (Bernhoft 1990; Evans 1988, 1991a,b, 1992; Frith 1991) or during a U-turn (Frith 1991), the accident most often is multiple vehicle, and involves side impact (Evans 1991b). Urban sites figure most highly in some studies (e.g. Frith 1991), probably because more older persons live in urban environments and because the density of intersections is higher in those settings. However, British data (Faulkner 1975, cited in Hills 1980) show that older drivers have a higher accident risk when crossing or joining major roads in rural settings. Similar, but less salient, findings were evident for urban intersections. Rural intersection accidents may have more serious consequences than similar accidents in urban areas because of the higher vehicle speeds involved. Daytime accidents predominate, primarily because the older drivers travel most often in daylight (Evans 1991b).

1.3 Causes of Accidents

Unlike other age-groups, the older driver accident data show alcohol not to be a significant factor. Rather, age-related deficits in visual functions (Klein 1991; Botwinick 1984), visual attention, search and information processing (Owsley et al. 1991; Shinar and Schieber 1991; Waller 1991) and associated cognitive functioning (Cerella 1985; Owsley et al. 1991) are considered salient factors. Owsley et al. (1991) studied a sample of 53 older male and female drivers and found that two thirds of their accidents were at intersections. Analysis of visual and cognitive functioning revealed that two factors, Useful Field of View (UFOV) and cognitive functioning as measured on a mental status test, were the best predictors of intersection accidents. Older drivers who are aware of deficits in their visual functioning may tend to drive with greater caution (Ball and Owsley 1991) or may decide to stop driving altogether (Kosnik et al. 1990).

1.4 Physical Impairments in Older Drivers

Limitation of central or peripheral vision in the older driver may be caused by age-related changes in the cornea, lens, intra-ocular fluid pressure, or retina (Owsley et al. 1991) and not be compensated adequately by use of corrective lenses. Also, in instances in which the eye is fully turned, the corrective lens may not be effective because of distortion at its periphery or because the pupil is turned for peripheral viewing beyond the outer edge of the lens. In some cases the spectacle frame itself may obstruct vision at the extreme periphery. In drivers with only one functional eye, the nose may restrict their field of view on the impaired side. Arthritic neck conditions which constrain head turning may compound any of the above peripheral vision deficits. The contribution of these latter factors to perceptual deficits in older drivers has not been examined in research to date.

These variables become particularly salient in the intersection environment, where sensing, perceiving, identifying and responding appropriately to the presence of approaching vehicles are important. Intersections are also decision points at which choices are made about direction of travel. They may present the driver with both relevant (e.g. lanes, road signs) and irrelevant (e.g. advertising) information that has to be processed as part of decision-making activity associated with safely negotiating the intersection.

Decision-making demands (Staplin and Fisk 1991) and processing of complex information that requires dividing attention, for example, between driving the vehicle and identifying and responding to environmental information (such as signs and lane lines), are less well managed with advancing age (Brouwer et al. 1991). If both vision and cognitive functioning are impaired the process of judgement must suffer significantly. Mackie (1972, cited in Hills 1980) studied 251 right-turning accidents and found that poor judgement or poor perception (looked but failed to see) by the driver of the turning vehicle accounted for the majority of accidents.

Right turns may be more complex than left turns because they can involve simultaneous judgements about traffic approaching from both the right and the left, as well as the need to clear closer lanes and merge with the traffic stream in the more distant lane. This may require different types of judgement concerning gaps and acceleration times.

1.5 Gap Acceptance Behaviour

Sound judgement and decision-making are essential at intersections. A critical behaviour in safely negotiating an intersection, especially if a change of direction is being made, is that of effectively judging the appropriate gap in the traffic stream for safe completion of the manoeuvre.

"Gap acceptance" is the term most commonly applied to the judgement of a space in the traffic stream that is sufficient to allow a driver safely to move through or merge with the stream at an intersection. Many gap acceptance studies generate mathematical formulae and models derived from observations of intersections (e.g. Cooper et al. 1976, 1977; Kimber 1989) which are then used to make statements about driver behaviour and/or decisions about intersection design. These models do not necessarily accurately reflect actual driver behaviour (Kimber 1989).

Gibbs (1968) identified seven hypotheses relating gap acceptance at intersections to aspects of the structure or the cognitive organisation of cues. He identified these as time (essentially time-to-impact), modified time (incorporating both time and distance), distance (distance regardless of speed), rate of change of angular position, rate of change of horizontal dimension related to apparent rotation, rate of change of dimension related to distance, and experience. From his research, Gibbs concluded that the time hypothesis was the most probable one used by drivers.

Conversely, Cooper et al. (1976, 1977) concluded from their road-side observational data that the modified time hypothesis may describe the behaviour of turning drivers crossing in front of oncoming traffic, but that it was not clear whether the drivers actually used this strategy. They were of the opinion that a part of the variation observed in gap acceptance could be explained by perceptual errors of judgement relating to vehicles whose speed was above or below average. They proposed that accident risk may increase as the range of main road speeds increases, with faster vehicles being more of a risk than slower ones.

This suggests that judgement of the speed of oncoming vehicles may not be easy for drivers, which is supported in findings reported by Hills (1980) in his review of the literature. In summarising a study by Hills and Johnson (1980, cited in Hills 1980), he reports that older drivers (61-70 years) waiting to cross a dual carriageway were more likely to under-estimate speed of approaching vehicles than their younger (21-40 years) counterparts. As vehicle approach speeds increased, the greater the under-estimation. Hills (1980) concluded that older drivers have poorer sensitivity to speed, which affects the quality of their gap judgements.

An in-depth study of intersection accidents involving older Norwegian drivers by Bernhoft (1990), found that two of the major contributory factors were under-estimation of the speed of approaching traffic and under-estimation of the time gap available for safe completion of their turn. Ebbesen et al. (1977) found that in the laboratory both time and speed figured in gap-acceptance decisions, while on the road the temporal gap available for crossing was the primary factor in the decision strategy. This difference in "risk taking" strategies and judgements may reflect the comparative magnitude of the consequences of a miscalculation in the laboratory versus that on the road. The use of a unidimensional factor in the real road setting may simplify the decision process in a complex judgement environment.

Unfortunately, Ebbesen et al. (1977) do not identify the cues their drivers used to estimate safe temporal gaps but, if judgement of speed is difficult, perhaps judgement of a safe distance is easier. Choosing a sufficient distance between the intersection and the oncoming vehicle may provide a safe temporal buffer as long as the driver is not caught out by a vehicle whose speed is significantly above the mean of the traffic flow. Cooper et al. (1977) identified this event as a danger. Hills (1980) cited the study by Hills and Johnson (1980) in which older males showed the most risky gap acceptance at an intersection, with the safety margins decreasing as vehicle approach speeds increased. This latter effect was common for all drivers sampled, regardless of age or gender, but older males accepted the smallest gaps. The older male drivers appeared to employ a distance criterion (150 m) for determining "last safe moment to cross" that was independent of the speed of approaching traffic.

Research on gap acceptance has considered the more simple of the decisions about crossing lanes or merging with traffic streams (e.g. a left turn at a T-intersection or a crossing at a two- or four-way controlled intersection). The right turn at a T-intersection can pose a more complex set of options, because the driver is faced with estimating safe gaps on both right and left, the former sufficient to clear the lane, the latter sufficient for safe merging. Given that T-intersections are common accident sites, research into the decision-making processes needs to examine these more challenging settings.

Decisions about when it is safe to cross or merge with traffic at an intersection may be made under pressure when the driver has been forced to wait for a break and/or when a queue is forming behind them. For example, Adebesi and Sama's (1989) findings suggest that, in the queuing situation, drivers turning across the traffic stream at a T-intersection who have waited for over 30 seconds are more likely to accept a shorter gap than drivers who have waited for less than 25 seconds. Ebbesen and Hanley (1973, cited in Hills 1980) attributed acceptance of smaller gaps by drivers forced to wait in a queue before being permitted to turn at intersections as indicative of frustration. Similar findings would be expected for drivers at the head of a queue at a junction, but the results are conflicting. Ebbesen and Hanley (in Hills 1980) reported no effect on risk taking in this situation, or in the situation where another car is alongside. However, smaller gaps were accepted by drivers at the head of the queue in studies by Ashworth and Bottom (1977), Bottom and Ashworth (1978), and Kittelson and Vandehey (1991).

Data from these studies can be interpreted to suggest that the margin of tolerance for delay is small, and that judgement suffers accordingly, with risky decisions being made to accept smaller gaps. Alternatively, as Hills (1980) suggests, the data may indicate that a delay at the intersection allows time for an evaluation of traffic behaviour, allowing better judgement of speed and gap acceptability, resulting in the ability to use smaller gaps effectively.

1.6 Judgement Processes

Research on judgement of time-to-arrival, time-to-collision, or time-to-impact (as it is variously termed in the literature) provides a further source of information on the decision-making process. A study by Cavallo and Laurent (1988), undertaken in a vehicle on a test track approaching a mock-up of the rear of a stationary vehicle, found that distance-change information was a primary factor in judgements by experienced drivers. Younger drivers tended to use a combination of speed and distance.

Cavallo and Laurent (1988) note that visually induced speed sensations decrease over time of travel (speed adaptation), suggesting that use of distance information by experienced drivers may be adaptive, since it is less sensitive to fatigue and thus more reliable. Their data from tests of monocular and binocular vision also suggest that distance information, based on retinal disparity, is used to estimate time-to-collision.

An important finding was that narrowing of the visual field to 10 degrees had a more detrimental effect on the judgements of inexperienced than experienced drivers. Cavallo and Laurent (1988) attribute this to the greater reliance on estimating speed in the judgements of the inexperienced drivers. These findings suggest that decrements in the accuracy of judgements of time-to-impact by elderly drivers, because of impaired peripheral vision, may be compensated to some extent by their greater reliance on distance when making judgements. Cavallo and Laurent (1988) only evaluated straight-ahead judgements, so it is impossible to ascertain from their data what happens when judging side-on (transverse) traffic, i.e. at intersections.

The results obtained by Schiff and Detwiler (1979) and Schiff and Oldak (1990) in the laboratory with model vehicles suggest that over-estimation of the time that an object will take to impact is more likely with objects approaching from the side (transverse approach). Under-estimation is more likely with radial and oblique approaches. Accuracy was greatest for transverse approach and least for radial and was affected by time-to-arrival to the extent that the longer the time, the less accurate the judgement. It also was found that females made more conservative judgements than males.

If these laboratory data have any applicability to the on-road setting, Schiff and Oldak's findings suggest that drivers may over-estimate the gap available when making judgements about vehicles approaching from the side at intersections, that male drivers may accept smaller gaps than females, and that judgement errors may be made more often with slower vehicles. With respect to the latter, over-estimation of slow speeds is probably less risky than under-estimation of high speeds. Hills and Johnson's (1980, cited in Hills 1980) study, using older drivers as participants, support the extrapolation of Schiff and Oldak 's laboratory findings to the road environment.

Given the acknowledged importance of visual information and perception in making judgements about safe gaps, it is notable that none of the studies of gap acceptance or time-to-impact reviewed above have included screening of the participants' visual functioning, even when evaluating the performance of older drivers. Accordingly, the contribution of visual deficits to any performance differences in comparisons of younger and older drivers cannot be assessed. In addition, the bulk of the studies have been undertaken in laboratory or controlled conditions which may not replicate on-road conditions.

Of the studies that have observed actual driving behaviour, most have done so using film records or observations of drivers' behaviour at intersections, typically without the drivers' knowledge and with no opportunity to assess their vision, judgement strategies, driving record, etc. As a result, understanding of driver behaviour at intersections is limited.

1.7 Lane Crossing

Once a decision has been made by a driver to accept a gap, her or his speed of acceleration to facilitate the vehicle's clearing of the lane(s) in which approaching traffic is travelling needs to be considered. Cooper et al. (1977) suggest that gap acceptance alone may not be a sufficient measure of risk and note that all simulation models assume constant acceleration properties for all vehicles, an assumption which is counter-intuitive. They cite an unpublished study by Bottom which revealed that drivers accepting short gaps accelerated faster than those accepting long gaps. Our experience as drivers suggests that there are differences in acceleration across all types of vehicles and ages of drivers, but this appears to be a little-studied phenomenon.

In the only reference to actual research (Hills 1980, citing Spicer 1972), the crossing times of older drivers were little, if at all, longer than those of younger drivers. No details of vehicle types or gender of drivers are given. Spicer's data do not match well with actual experience. For example, Bernhoft's (1990) in-depth analysis of intersection accidents involving older drivers indicated that one of the major factors was their impaired reaction capacity, leading to failure to clear the intersection in time, along with over-estimation of their ability to accelerate their car.

Clearly, more research is needed on this aspect of driver behaviour at intersections for a more complete understanding of accident causes. Such research should cover both crossing of lanes and merging with the traffic stream, since the requirements of each manoeuvre may be different. A right turn at a T-intersection may involve both lane crossing and merging, depending on the traffic flow, and may further be complicated by the need to simultaneously accelerate and turn the vehicle.

1.8 Research Procedures

1.8.1 Threshold Procedures

Threshold procedures used in on-road studies of judgement of safe gaps at intersections (Hills 1980) have to date tended to require from drivers an estimate of the speed of an approaching vehicle when it has reached a given point on the roadway, or an estimate of the "last safe moment to cross". This estimation enables the time gap allowed, less the time they required to free the lane occupied by the oncoming vehicle, to be evaluated. In this way an indication of a driver's safety threshold can be ascertained over a series of judgement trials. It is possible that bias and/or adaptation become factors in repeated judgements, especially if traffic volumes and/or speeds are relatively constant over any given set of trials.

Urban or motorway settings are more likely to provide smaller variations in speed and higher traffic densities than rural roads, so the latter represent good sites for assessment and offer more challenges to the driver. In the on-road environment, the usual psychophysical methods for establishing thresholds cannot readily be applied because, unlike in the laboratory, there is no control over the important aspect of presenting the stimuli in an orderly fashion. An alternative approach is to use signal detection procedures.

1.8.2 Signal Detection Procedures

Signal detection procedures have been used over the past 25 years in a wide range of domains requiring binary judgements, including psychophysics, memory performance, military target detection, industrial quality control, and high-stake diagnostics (e.g. Swets et al. 1961; Baron and Le Breck 1987; Banks 1990; McCarthy 1991; Swets

1992). They also have been applied to gap acceptance in judgements of vehicle width and a parallel parking task (Wolf et al. 1988) and to risk-taking behaviour in a computerised gap closure task (Calbourn 1978).

The signal detection procedure involves the choice between two clearly defined and mutually exclusive responses. Examples in a driving environment might be "Yes" or "No", "Safe" or "Unsafe", "Stop" or "Go", "Turn" or "Straight ahead", "Left" or "Right". Such responses depend not only on traffic situations, e.g. on whether certain gaps are safe or not safe, but also on the decision processes within the drivers. The quality of their sensory processes determines how able they are to discriminate between safe and unsafe situations. But their decisions depend also on their individual criteria (response bias), or willingness to engage in risky or less risky behaviour. In a T-intersection experiment, signal detection theory can be applied in an attempt to measure the driver's sensitivity (ability to discriminate between safe and unsafe gaps) independently of their response bias towards saying "Yes" (risky behaviour) and "No" (less risky behaviour).

1.9 Study Objective and Aims

The objective was to investigate gap acceptance behaviour by young, middle-aged and older male and female drivers under conditions that approximated a rural T-intersection entering a major road.

The primary aim was to identify which factors associated with the traffic approaching from the right were salient in judgements about when it was safe or unsafe to make a right turn onto the major road. The judgement process was designed to examine the differential efficacy of assessing gap acceptance using a threshold (last safe moment) procedure and that using a signal detection (go/ not go) procedure.

A second aim was to determine the extent to which driver characteristics and skills were factors in the judgement process. To fulfill this aim, all participants underwent prescreening on a range of laboratory tests covering vision, neck articulation, reaction time, memory and personal driving history, as well as road tests of their acceleration time through a right turn from a stopped position, as if at a T-intersection.

2. METHOD

2.1 Sample

The sample consisted of 80 drivers, comprising 10 male and 10 female participants in each of four age groups (under 30, 40 to 59, 60 to 69, and over 70 years) from Hamilton, a city of 105,000 located in the Waikato region, central North Island of New Zealand. Demographic details are shown in Table 2.1 (age and self-identified ethnicity of 68 European, 11 Maori, 1 Pacific Islander) and Table 2.2 (occupation).

2.2 Recruitment of Participants

As well as obtaining equal numbers of male and female participants, an effort was made to include participants from a range of ethnic backgrounds and occupations. Participants were recruited as volunteers (with travel costs reimbursed) from the following sources:

(a) **Age Concern.** This organisation aims at helping older people to overcome age-related problems. In a meeting for its members focusing on driving issues, the researchers set up a stall advertising the project and invited members to participate.

(b) **Articles and Advertisements.** An article in the Waikato University magazine ("On Campus") and in an official campus circular briefly described the study and invited readers and friends and families of readers to participate. An advertisement placed in the local Hamilton newspaper ("Waikato Times") invited participation from the broader community.

(c) **Word-of-mouth.** Participants already recruited were asked if they knew people (friends and family) who might be interested.

Table 2.1 Mean age and ethnicity of participants by age and gender.

AGE	**<30 Years**		**40-59 Years**		**60-69 Years**		**70+ Years**	
Gender (m=males;f=females)	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**
Mean Age:	24.0	22.9	48.5	51.4	64.5	66.2	76.8	75.5
Ethnicity:								
Maori	3	2		1	1	1	1	
Pacific Islander				1				
Maori/European		1					1	
European	7	7	10	8	9	9	8	10

Table 2.2 Occupation type of participants by age and gender.

AGE	**<30 Years**		**40-59 Years**		**60-69 Years**		**70+ Years**	
Gender (m=males; f=females)	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**
Occupation Type:								
Professional (manager, doctor, etc.)	1	1	3	1				
Technician (programmer, engineer, etc.)	2		2	2				
Service trade (salesperson, shop owner, etc.)		1	2	2		1		
Farming (forestry, agriculture, fisheries, etc.)							1	
Labourer (driver, machine operator, etc.)	1	1						
Homemaker		2		5		5		3
Retired			1		10	3	9	7
Unemployed	4							
Student	1	5	1			1		
Other	1		1					

2.3 Apparatus

2.3.1 Laboratory-based Tests

- A **driver behaviour questionnaire** comprising 28 items (Appendix 1) sought information about each participant's self-reported sensory impairments, driver's licence, driving behaviour, traffic infringements, and accidents. A consent form was used which outlined what was required of the participants, assured confidentiality and acknowledged other ethical obligations.

- **Vision testing** was conducted with the aid of a Vision Screener (Keystone VS-II, model 1135A; Appendix 2). Each vision test could be advanced by the experimenter with a control unit.

- **Cognitive performance** included two tests:
  (a) **Multiple choice reaction** time was determined with the aid of a MITAC-notebook 80386SX-20 computer and associated software developed in-house.

  (b) A measure of **short-term memory performance** was obtained using an array of 40 line drawings of common objects and animals displayed on a single A4 sheet of paper.

- **Neck articulation** was measured using a device (Figure 2.1) that was developed for the study. It consisted of a cycle helmet with a stylus pointer protruding from the centre front, parallel with the centre of the wearer's line of vision when the eyes were looking directly ahead. A plumb bob suspended on a cord from the stylus allowed a reading to be taken of the neck articulation (in degrees of arc). The 210 degree arc, marked in five-degree segments from zero at the front centre to 105 degrees on either side, was made of a transparent plastic and mounted on a shoulder harness. Once the participant had turned their head to the extreme of articulation on either side, a reading of the degree of turn was made.

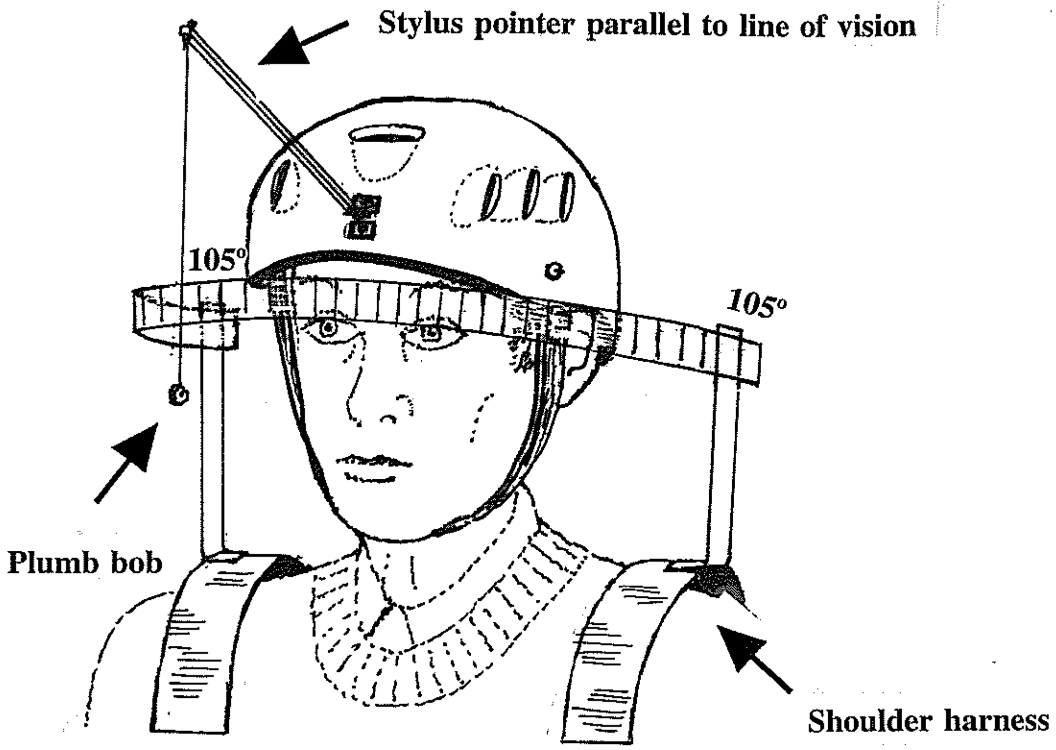


Figure 2.1 Device for measuring neck articulation.

2.3.2 Road-side Tests

Most of the **road-side tests** were conducted in a research vehicle (Mitsubishi Lancer station wagon) parked as if at a rural T-intersection (i.e. at a right angle to the major road). A Laser speed/distance device from Laser Technologies Inc. (LTI 20x20, Appendix 3) was used to measure the speed and distance of selected vehicles approaching the parked vehicle. The device plugged into the electrical system of the car (via the cigarette lighter port), and was compact and light enough to be operated at shoulder height from the front passenger seat of the car. Stop-watches were used to determine the length of time taken for participants to (a) make decisions, and (b) make right hand turns in their own vehicle.

2.4 Procedure

After approval for all experiments was received from the Ethics Committee of the Psychology Department, University of Waikato, Hamilton, participants were tested in two separate sessions for laboratory-based tests and for road-side tests. All laboratory-based tests were conducted in a Psychology Department research room at the University of Waikato.

2.4.1 Laboratory-based Tests

These tests took about one hour. After the participant had signed the consent form and completed the questionnaire on driver behaviour, **vision testing** was carried out. It included assessment of visual acuity (binocular and monocular), stereovision, phoria, fusion, colour vision and horizontal peripheral vision. Participants who required correcting lenses for driving wore them during vision testing. Tests of **cognitive performance** (multiple choice reaction time and short-term memory) and **neck articulation** followed.

2.4.1.1 Vision testing

- **Visual acuity** Far point (20 feet or 6 metres) monocular and binocular visual acuity testing was performed. Seven ratings (Snellen values from 20/20 to 20/200) were possible. Participants commenced reading the smallest numbers (for maximum acuity) from the top left box (i.e. values of 20/20) and were stopped when they could accurately read all numbers or made no more than one error. If they made several errors or were not able to read the letters, larger letters were presented (i.e. 20/25 up to 20/200) until they either read the presented set accurately or failed at 20/200. A Snellen value of 20/25 means that from a distance of 20 feet (6 m), the tested person can just distinguish an object that would subtend 1 minute of arc, while a normally sighted person could see the same object when 25 feet (7.62 m) away.

- **Stereovision** (depth perception) Stereovisual performance defines the extent to which objects may be discriminated in three dimensions. In this test, the participant identified which of five different symbols appeared to stand out from the others. Five levels of stereovision were tested, with the first being the easiest (10% stereovision), followed by three intermediary levels (30, 60 and 75%) and the final being the most difficult (85% stereovision). Stereovision of 75% (level 4) or greater was considered acceptable according to criteria set by the Keystone VS-II Vision Screener manual (Appendix 2).

- **Phoria** (eye co-ordination) This test identifies whether the two eyes are working in precise co-ordination or if there are discrepancies between them when they are turned inwards or outwards (lateral phoria), and up or down (vertical phoria). The possible range of scores is 0 to 9. Scores between 1.5 and 6.5 were considered to be within acceptable limits (according to criteria set by the Keystone VS-II Vision Screener manual) for lateral phoria, and those between 3.5 and 5.5 were acceptable for vertical phoria, with the ideal score being 4.5 for both.

- **Fusion** (integrated image) This tests whether different images presented to each eye merge (or "fuse") into one integrated image (three balls merging into a single column). Participants counting four balls fail the test, while those seeing three, or four then three, balls pass.

- **Colour vision** Failure to see specific Ishihara test numbers indicates either severe (red/green) or mild (blue/violet) colour blindness. Persons with normal colour vision would identify all four numbers on the chart.

- **Horizontal peripheral vision** Both eyes were tested together to check for "tunnel vision". Four angles were tested on each side: 45 degrees (nasal visual field), 55 degrees, 70 degrees, and 85 degrees (temporal visual field).

2.4.1.2 Cognitive performance

- **Multiple choice reaction time** This test measured both the reaction time and the accuracy of the response. The test comprised two elements. The first was 10 practice trials, in which participants were required to obtain 80% accuracy in order to proceed to the second element.

The second element comprised 30 trials. Within these the letter "G" appeared on ten randomly programmed occasions, as did the letter "H". Together they represented the 20 reaction time and accuracy test trials. Ten trials, using the letter "N" required no response. Participants were unaware that accuracy data were not recorded for the "N" trials.

Each presentation was as follows: when the letter "G" appeared directly above a fixation cross ("+") on a computer screen, participants were to press the "G" on the keyboard. Similarly, if an "H" appeared the corresponding key was to be pressed. However, if an "N" appeared, participants were to refrain from pressing any key. In order to proceed from one trial to the next, participants pressed the space bar.

- **Short-term memory performance** Participants were shown 40 line drawings (presented on one A4 sheet) for 30 seconds, after which the sheet was removed and they wrote down as many items as they could recall.

2.4.1.3 Neck articulation

A device (see Figure 2.1) was used to measure the range (in degrees) of neck articulation (extent of head turning separately to the left and the right side). Data were obtained from two trials for turning to each side.

2.4.2 Road-side Tests

Road-side tests were carried out at a site chosen to simulate a T-intersection and took approximately one hour to complete.

An appropriate site on the verge of a road, where a car could be parked at right angles to simulate a T-intersection, was located, as a real rural T-intersection could not be used with safety. A suitable traffic density, a clear field of view to the left and right of the site, and reasonable similarity to a rural T-intersection with a state highway were also required.

A site on State Highway 26, 5.8 km from the start of the open road speed limit (100 km/h) east of Hamilton city boundary, was selected. Traffic density was sufficient to complete trials in a reasonable time, but not so high that opportunities for entry (both real and simulated) into the traffic stream were few. All tests were performed in daylight under clear weather conditions.

The normal sequence of events was the **driving test for lane crossing times (Experiment 1)**, for 5 trials; the **gap acceptance testing (Experiment 2)** for 40 trials, which was conducted by alternating (after every five trials) between **threshold** and **signal detection** procedures, until 20 trials on each procedure had been performed; and then the **speed estimation testing (Experiment 3)** for 20 trials.

2.4.2.1 Experiment 1. Driving test

The participant first parked their own vehicle at a right angle to the major road, as if at a T-intersection. They were instructed as described in Appendix 4.

When the researcher judged it safe to drive across the road, participants were asked to make a right hand turn on to the road, and to start to do so in their own time. The researcher stood on the road side with a stop-watch. The stop-watch was started when the front bumper of the participant's car crossed the nearside kerb-line and was stopped when their car's back bumper had completely crossed the centre line of the major road. The participant continued along the road for approximately 100 m before returning to the original starting position. The process was repeated over five trials.

2.4.2.2 Experiment 2. Gap acceptance testing

- **Threshold trials** The object of the procedure was to identify the final point ("threshold") at which participants considered it safe to make a right hand turn in front of a vehicle approaching from the right. The sequence for 20 trials was as follows:

(a) The participant was seated in the driver's seat of the research vehicle, looking straight ahead, and instructed as in Appendix 4.

(b) Researcher 1 (seated behind the driver) identified an appropriately distant on-coming vehicle and instructed the participant to "Look now".

(c) The participant looked at the approaching vehicle on their right and responded with a "Yes" - indicating it was safe to turn.
If the participant's initial response was "No", the trial was discounted.

(d) Participants were requested to repeatedly say "Yes" for as long as they judged it safe to drive out from the intersection, and to say "No" the moment they judged it unsafe.

(e) Researcher 2 (seated beside the driver) activated the Laser speed/distance device for every "Yes" response, but only recorded the oncoming vehicle's speed and distance for the final "Yes".

(f) Researcher 1 recorded the type of vehicle (e.g. truck).

- **Signal detection trials** The procedure for this task (for 20 trials) was similar to that for the threshold procedure. The same initial instructions were given to the participant (Appendix 4). However, instead of the participant giving several responses, a single "Yes" or "No" only was required. An equal number of responses was sought from the two response alternatives. In addition to recording the type of vehicle, Researcher 1 used a stop-watch to measure the time taken to make the initial decision (i.e. the time from the "Look now" instruction to the participant's response). Researcher 2 recorded the approaching vehicle's speed and distance using the Laser speed/distance device for each response.

2.4.2.3 Experiment 3. Speed estimation testing

Participants were asked to estimate the speed of on-coming traffic. The procedure took the following sequence:

(a) When Researcher 1 identified an on-coming vehicle at a distance of 150 m, the participant was instructed to "Look now". The participant turned to the right, looked at the on-coming vehicle for 50 m of its travel and was asked for an estimate of its speed.

(b) At this moment the participant turned away from looking at the vehicle and estimated the speed, while Researcher 2 activated the Laser speed/distance device and recorded the actual speed of the target vehicle.

(c) Researcher 1 recorded the participant's response. Participants were not given any feedback concerning the accuracy of their estimations until all 20 trials were completed. Appendix 4 describes the instructions.

3. RESULTS AND DISCUSSION

The results of this study are reported in the order in which the data were recorded. A brief discussion follows each report.

A discussion of broader issues is provided in Section 4 (Countermeasures).

3.1 Laboratory-based Tests

3.1.1 Driver Behaviour Questionnaire

All participants completed a 28 item Driver Behaviour Questionnaire (Appendix 1). The rationale of the questionnaire was to identify differences between the self-reported driver behaviour of the four different age groups studied. The results are in Table 3.1.

3.1.1.1 Sensory impairments

The first part of the questionnaire included items concerning visual and auditory impairments which, if uncorrected, may affect a driver's performance. The results show that the number of drivers with corrective lenses (glasses) gradually increases as age of participants increases. In the young age group (<30 years) only 15% of the participants had corrected vision, but 75% of the older drivers (70+ years) were wearing glasses. Increasingly impaired vision is a well documented phenomenon of aging people (e.g. Munn 1966) and is certainly a risk factor for drivers if unsatisfactorily corrected. The aim of the laboratory-based vision tests (reported in Section 3.1.2) was to examine participants on a wide range of visual performances relevant for driving behaviour.

Auditory impairments were reported predominantly among the oldest group of participants (70+ years), 40% of whom were using hearing aids.

3.1.1.2 Driver's licence

- **Failed driver's licence test** Of all young participants (<30 years), 35% reported having failed at least one driver's licence test. The older drivers' data revealed a much smaller proportion (5%) of failed driver's tests. This does not necessarily imply that the older drivers are more competent than younger drivers.

First, no research appears to show that passing a driver's licence test can be used as valid predictor of future driving performance. Second, the driver's licence test might recently have become more difficult to pass. Third, it was not possible to verify how willing or able the older drivers were to report their failing a driver's test which occurred a long time ago.

Table 3.1 Data obtained from Driver Behaviour Questionnaire by age and gender.

AGE	**<30 Years**			**40-59 Years**			**60-69 Years**			**70+ Years**		
GENDER(Total)%	m	f	(Tot)**%**	m	f	(Tot)**%**	m	f	(Tot)**%**	m	f	(Tot)**%**
SENSORY IMPAIRMENTS **Corrected vision:**												
Yes	1	2	(3)**15**	3	4	(7)**35**	6	6	(12)**60**	8	7	(15)**75**
Hearing aid:												
Yes	0	0	(0)**0**	1	0	(1)**5**	2	0	(2)**10**	5	3	(8)**40**
DRIVER'S LICENCE **Failed Driver's Licence Test:**												
Yes	4	5	(7)**35**	2	1	(3)**15**	2	0	(2)**10**	1	0	(1)**5**
Learnt to drive:												
Driving School	6	5	(11)**55**	3	4	(7)**35**	3	5	(8)**40**	1	3	(4)**20**
Relatives	8	9	(17)**85**	7	4	(11)**55**	4	5	(9)**45**	6	5	(11)**55**
Friends	4	4	(8)**40**	2	2	(4)**20**	1	2	(3)**15**	2	2	(4)**20**
Self-taught	7	1	(8)**40**	2	1	(3)**15**	5	1	(6)**30**	1	1	(2)**10**
Defensive driving courses:												
Yes	4	0	(4)**20**	6	3	(9)**45**	4	0	(4)**20**	4	2	(6)**30**
DRIVING ROUTINES **Distance(km) travelled in last 12 months:**												
< 5,000	1	4	(5)**25**	1	2	(3)**15**	0	3	(3)**15**	2	3	(5)**25**
5,000-10,000	1	3	(4)**20**	1	3	(4)**20**	4	3	(7)**35**	6	4	(10)**50**
10,000-15,000	2	3	(5)**25**	7	3	(10)**50**	5	3	(8)**40**	0	3	(3)**15**
15,000-20,000	0	0	(0)**0**	1	1	(2)**10**	0	1	(1)**5**	1	0	(1)**5**
>20,000	6	0	(6)**30**	0	1	(1)**5**	1	0	(1)**5**	1	0	(1)**5**
Driving frequency:												
<1 day per week	0	2	(2)**10**	1	0	(1)**5**	0	0	(0)**0**	0	0	(0)**0**
1-2 days per week	1	2	(3)**15**	0	0	(0)**0**	0	1	(1)**5**	3	0	(3)**15**
3-4 days per week	1	2	(3)**15**	0	1	(1)**5**	2	4	(6)**30**	2	2	(4)**20**
>4 days per week	8	4	(12)**60**	9	9	(18)**90**	8	5	(13)**65**	5	8	(13)**65**
on week-days	0	0	(0)**0**	1	0	(1)**5**	0	2	(2)**10**	0	1	(1)**5**
on weekends	1	1	(2)**10**	1	0	(1)**5**	0	0	(0)**0**	0	0	(0)**0**
both	9	9	(18)**90**	1	10	(18)**90**	10	8	(18)**90**	10	9	(19)**95**

Table 3.1 (continued) Data obtained from Driver Behaviour Questionnaire by age and gender.

AGE	**<30 Years**			**40-59 Years**			**60-69 Years**			**70+ Years**		
GENDER (Total)%	m	f	(Tot)%	m	f	(Tot)%	m	f	(Tot)%	m	f	Tot(%)
DRIVING ROUTINES (continued) **Driving environment:**												
Country areas	0	0	(0)**0**	0	0	(0)**0**	1	1	(1)**5**	0	0	(0)**0**
City areas	2	2	(4)**20**	2	4	(6)**30**	0	2	(2)**10**	1	3	(4)**20**
Both	8	8	(16)**80**	8	6	(14)**70**	9	7	(16)**80**	9	7	(16)**80**
By self	2	1	(3)**15**	2	1	(3)**15**	2	3	(5)**25**	0	3	(3)**15**
With others	1	1	(2)**10**	0	0	(0)**0**	1	0	(1)**5**	0	0	(0)**0**
Both	7	8	(15)**75**	8	9	(17)**85**	7	7	(14)**70**	10	7	(17)**85**
With radio on	8	5	(13)**65**	5	6	(11)**55**	5	4	(9)**45**	2	3	(5)**25**
With radio off	2	5	(7)**35**	5	4	(9)**45**	5	6	(11)**55**	8	7	(15)**75**
Driving ability:												
Below average	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**
Average	2	9	(11)**55**	4	5	(9)**45**	4	6	(10)**50**	6	6	(12)**60**
Above average	8	1	(9)**45**	6	5	(11)**55**	6	4	(10)**50**	4	4	(8)**40**
Car mostly driven:												
Automatic	3	5	(8)**40**	4	3	(7)**35**	5	6	(11)**55**	4	7	(11)**55**
Manual	7	4	(11)**55**	6	7	(13)**65**	5	4	(9)**45**	6	3	(9)**45**
Car owned by:												
You only	9	5	(14)**70**	5	4	(9)**45**	5	7	(12)**60**	4	10	(14)**70**
Jointly owned	0	2	(2)**10**	4	6	(10)**50**	5	3	(8)**40**	6	0	(6)**30**
Borrowed	1	3	(4)**20**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**
Company owned	0	0	(0)**0**	1	0	(1)**5**	0	0	(0)**0**	0	0	(0)**0**
Driving diff. cars:												
Yes	8	3	(11)**55**	7	5	(12)**60**	2	1	(3)**15**	2	1	(3)**15**
TRAFFIC INFRINGEMENTS **Traffic tickets (last 5 years):**												
0	2	9	(11)**55**	7	9	(16)**80**	10	9	(19)**95**	10	9	(19)**95**
1	5	1	(6)**30**	2	1	(3)**15**	0	1	(1)**5**	0	1	(1)**5**
2	0	0	(0)**0**	1	0	(1)**5**	0	0	(0)**0**	0	0	(0)**0**
3	2	0	(2)**10**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**
>10	1	0	(1)**5**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**

Table 3.1 (continued) Data obtained from Driver Behaviour Questionnaire by age and gender.

AGE	**<30 Years**			**40-59 Years**			**60-69 Years**			**70+ Years**		
GENDER (Total)%	m	f	(Tot)%	m	f	(Tot)%	m	f	(Tot)%	m	f	(Tot)%
TRAFFIC ACCIDENTS **Traffic accidents (last 5 years):**												
Yes	5	3	(8)**40**	4	4	(8)**40**	2	1	(3)**15**	1	3	(4)**20**
Fault in most recent accident:												
No fault	0	0	(0)**0**	0	0	(0)**0**	0	1	(1)**5**	0	0	(0)**0**
Own fault	3	0	(3)**15**	0	0	(0)**0**	2	0	(2)**10**	0	1	(1)**5**
Another driver's	1	2	(3)**15**	2	1	(3)**15**	0	0	(0)**0**	0	2	(2)**10**
Shared fault	1	1	(2)**10**	2	3	(5)**25**	0	0	(0)**0**	1	0	(1)**5**
Intersection accidents (last 5 years):												
Yes	0	1	(1)**5**	1	2	(3)**15**	0	0	(0)**0**	0	0	(0)**0**
Type of intersection:												
City crossroad	0	0	(0)**0**	0	2	(2)**10**	0	0	(0)**0**	0	0	(0)**0**
Rural crossroad	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**
City T-intersection	0	1	(1)**5**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**
Rural T-intersection	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**
Roundabout	0	0	(0)**0**	1	0	(1)**5**	0	0	(0)**0**	0	0	(0)**0**
Intersection control:												
Stop sign	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**
Give Way	0	0	(0)**0**	1	0	(1)**5**	0	0	(0)**0**	0	0	(0)**0**
Traffic lights	0	1	(1)**5**	0	2	(2)**10**	0	0	(0)**0**	0	0	(0)**0**
Uncontrolled	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**	0	0	(0)**0**

- **Learnt to drive and defensive driving courses** More participants in all groups had been taught to drive by relatives than by a driving school. Comparing the four age groups, the highest percentage (45%) of participants who had attended a defensive driving course was in the 40-59 year-old range. Over all groups, more males had attended such a course than females. The reason for attendance at a defensive driving course, whether voluntary or required by the Court, was not determined.

3.1.1.3 Driving routines

- **Distance (km) travelled in last 12 months** Comparing the four test groups, the young male drivers (<30 years) reported having travelled the longest distances in the last 12 months (30% driving more than 20,000 km).

- **Driving frequency** Most participants in all age groups reported driving every day (90%), on both weekdays and weekends, in the country as well as in city areas, alone and with others. The group 40-59 years of age seems to contain the most frequent drivers (90% reported driving more than four days per week).

- **Driving environment** Of the participants in all age groups, 70 to 80% reported that most of their driving included both country and city areas. Only three of the participants reported that they mostly drove with others in the car. More younger (<30 years, 65%) and middle-aged (40-59 years, 55%) than older (25%) participants reported that they normally drive with their radio on.

- **Driving ability** The question regarding participant's self-judged driving ability revealed interesting results. Not one participant in the whole sample of 80 drivers considered him/herself as a below average driver. Eight of the ten young male drivers saw themselves as above average drivers, while nine of the ten female young drivers identified themselves as average drivers. About equal numbers in the remaining age groups rated themselves either as average or above average drivers. There was no clear gender effect on this variable in the older age groups.

These results match well with those of Guerin (1993). His results suggest that people generally think of themselves as better than average drivers. Older people rated themselves slightly better than a peer, while younger people rated their peers as the worst drivers, but themselves as better.

3.1.1.4 Traffic infringements and accidents

- **Traffic tickets (last 5 years)** The young male drivers (<30 years) reported by far the highest number of traffic tickets in the last five years with 80% of them being penalised for one or more driving infringements. One particular male driver (19 years) reported 18 tickets in the last five years. In contrast, only one (10%) of the female young drivers (<30 years) reported an infringement (one traffic ticket) in that period. A similarly low number (one) in the other groups had reported tickets.

- **Traffic accidents (last 5 years)** The 80 participants in the sample reported being involved in a total of 23 accidents in the last five years. Eight (40%) were caused by the youngest group (<30 years). Five young male drivers (or 50% of that sample) had at least one accident during this time period. The 19 year-old male participant who had had 18 traffic tickets during the last four years reported three accidents during the same time period, yet he considered his driving ability to be above average and drove mostly in borrowed cars. Eight drivers from the 40-59 year-old age group had had a single accident during the last five years. The two groups with older participants (60-69 years, and 70+ years of age) reported only a small number (seven in total) of accidents.

Locations of these accidents showed that four drivers (1 female <30 years, 2 females 40-49 years, 1 male 40-59 years) reported intersection accidents within the last five years. All these had occurred in a city environment, two at crossroads and one each at a T-intersection and a roundabout. Three of the accidents occurred at intersections controlled by traffic lights and one, presumably the roundabout, was controlled by a Give Way sign. It is notable that none of those reporting intersection accidents were older drivers.

3.1.1.5 Summary

The driving behaviour questionnaire revealed some important results. The largest difference in the response patterns was found between the young male drivers and all other groups. This particular group reported the highest number of accidents and received more traffic tickets in the last five years than the other groups. Further, more of these drivers than those in any of the other groups considered themselves to be above average drivers.

Such response patterns match well with earlier research findings and recent accident statistics. For example, Mason et al. (1992) found that young and inexperienced drivers consistently over-rate their own ability and under-rate the level of risk, and as well are relatively poor at identifying a variety of distant hazards (e.g. gravel roads, wet roads, etc.). Page et al. (1992) reported, in a recent review on road safety and young drivers, that New Zealand has a serious problem of high fatality and injury patterns from road crashes in the 15-24 year-old age group. They found that this trend follows a similar world-wide pattern for highly motorised countries (e.g. UK, Japan) but also indicates that in this particular age group New Zealand has one of the highest per capita injury and fatality rates in the world.

The response patterns of the oldest age group did not differ substantially from the two middle aged-groups (40-59 years and 60-69 years of age). Several research publications, however, call for caution when interpreting the self-reported data of older drivers. It seems that older drivers are more reluctant to reveal any information which could question their driving competence. For example, Sloane et al. (1990, cited in Owsley et al. 1991) found that most of the older drivers with the highest number of recorded accidents are men, who tend to under-report accident involvement in responses to questionnaires on driving history.

3.1.2 Vision Testing

3.1.2.1 Visual acuity (binocular)

The results for visual acuity of both eyes tested simultaneously (binocular) by age and gender are shown in Figure 3.1. All groups had mean visual acuities well within the critical value of 20/40, which in New Zealand is required as the minimal visual limit (with or without correcting lenses) for drivers requesting a driver's licence. The graph shows a slight deterioration in visual acuity for both males and females in the oldest age group (70+ years) and for the female participants in the age group 60-69 years. Nevertheless all participants in these two older groups fulfilled the minimal standards for binocular visual acuity required for driving in New Zealand.

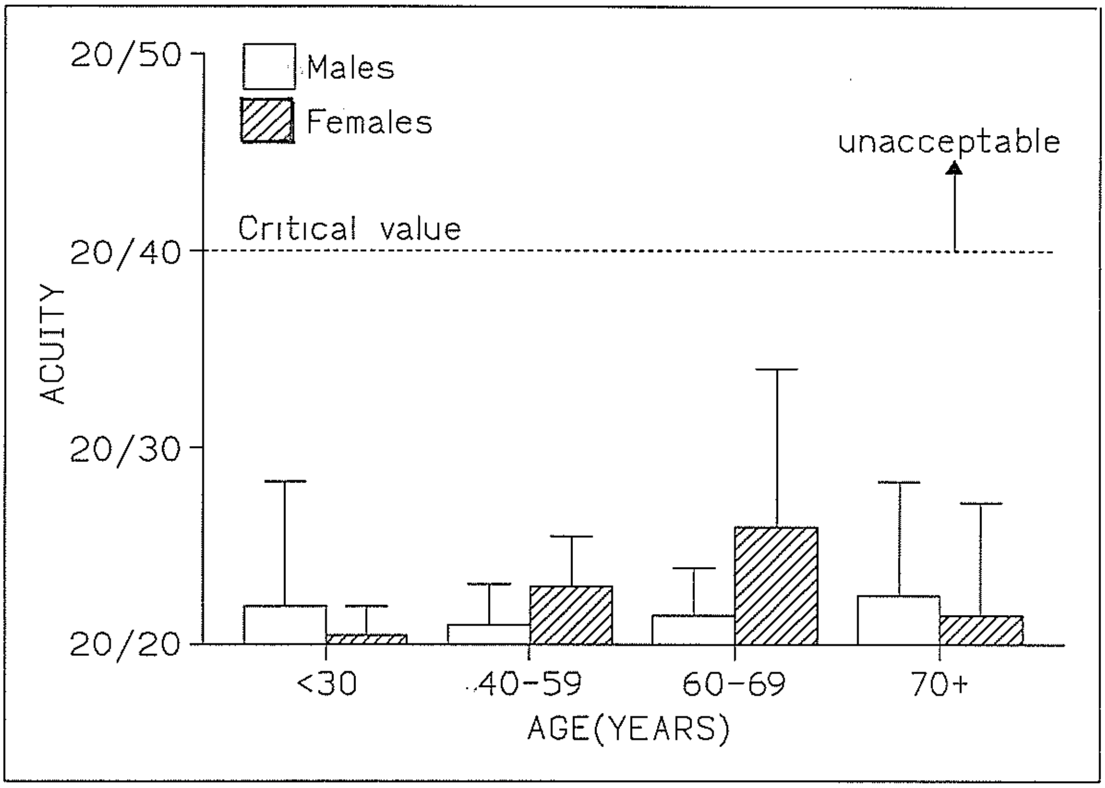


Figure 3.1 Mean and standard deviation (SD = ⊤) for binocular visual acuity by age and gender.

3.1.2.2 Visual acuity (monocular)

Table 3.2 shows the frequency distribution of visual acuities tested separately for the left and right eyes (monocular) by age and gender. Twelve drivers had severely impaired visual acuity in one of their eyes. Eleven were aged 60 years or more, and seven were in the oldest age group (70+ years). Of these, four had such a severe visual acuity impairment in one eye (20/200 or less) that they could be considered as monocular drivers.

Table 3.2 Frequency distribution for visual acuity (monocular) by age (and gender).

AGE	**<30 Years**		**40-59 Years**		**60-69 Years**		**70+ Years**	
LEFT/RIGHT EYE	l	r	l	r	l	r	l	r
Visual Acuity: Acceptable								
20/20	14	16	15	13	10	7	5	1
20/25	2	3	3	3	4	3	2	3
20/30	3	0	1	4	3	5	7	9
20/40	1	1	0	0	1	3	1	5
Unacceptable (m=males, f=females)								
20/50	0	0	0	0	**1f**	0	**2m**	**1f**
20/60	0	0	0	0	0	**1m**	**1f**	0
20/70	0	0	0	0	0	0	**1f**	0
20/200	0	0	**1f**	0	**1m**	**1f**	**1m**	**1m**

3.1.2.3 Stereovision (depth perception)

Proper functioning of both eyes is required for stereovision. Table 3.3 shows the frequency distribution for stereovision levels (expressed as % full stereovision) by age and gender.

Table 3.3 Frequency distribution for stereovision levels by age and gender (m=males; f=females).

AGE	**<30 Years**			**40-59 Years**			**60-69 Years**			**70+ Years**		
GENDER (Total)%	m	f	(Tot)%	m	f	(Tot)%	m	f	(Tot)%	m	f	(Tot)%
Stereovision:												
Good	7	6	(13)65	8	5	(13)65	5	5	(10)50	2	3	(5)25
Acceptable	1	1	(2)10	0	1	(1)5	1	0	(1)5	0	2	(2)10
Just Acceptable	1	2	(3)15	2	3	(5)25	3	3	(6)30	1	2	(3)15
Unacceptable	1	0	(1)5	0	0	(0)0	0	0	(0)0	3	1	(4)**20**
Most Unacceptable	0	1	(1)5	0	1	(1)5	1	2	(3)**15**	4	2	(6)**30**

Sixteen participants (20% of the sample) had unacceptable or most unacceptable stereovision as defined in the Keystone VS-II Vision Screener manual. Ten of these drivers were in the 70+ year-old group and had either unacceptable (20% of this sample) or most unacceptable (30%) levels of stereovision.

Lack of stereovision seems to be a predominant feature of many drivers over 70 years old, and loss of vision in one eye would be a primary factor. Judgement of depth, in the absence of stereovision, requires use of monocular depth cues, such as texture, gradient and relative movement. Gradual loss of vision in one eye may not be noticed, and the driver may fail to learn to use monocular cues to judge depth and distance as an adaptive response to the loss.

3.1.2.4 Phoria (eye co-ordination) and fusion

All participants had acceptable results (according to criteria for the Keystone VS-II Vision Screener) for both the phoria (eye co-ordination) and the fusion tests.

3.1.2.5 Colour vision

All participants were tested for severe (red/green) and mild (blue/violet) colour discrimination deficiency. No participant had a severe colour vision deficiency, although seven participants had a slight mild (blue/violet) colour discrimination problem.

3.1.2.6 Horizontal peripheral vision

Peripheral vision data (Table 3.4) for the right visual field (relevant to judgement of traffic approaching from the right, as in the present study) show that all participants with some restriction were aged 60 years or more. The four whose restriction was beyond the unacceptable range (>70 degrees), according to criteria for the Keystone VS-II Vision Screener, were aged 70 years or more.

Restriction of peripheral vision would affect detection and judgement of on-coming traffic at an intersection, and would be compounded by any impairment of neck articulation, which is common in older persons. In such cases, head and eye movements might not be sufficient to bring target vehicles into the central area of the visual field where visual acuity is highest.

Table 3.4 Frequency distribution for restricted peripheral vision (right visual field) by age and gender (m=males; f=females).

AGE	**<30 Years**			**40-59 Years**			**60-69 Years**			**70+ Years**		
GENDER (Total)%	m	f	(Tot)%	m	f	(Tot)%	m	f	(Tot)%	m	f	(Tot)%
Peripheral Vision: Restricted Field (Deg): **Acceptable**												
40 (nasal)	0	0	(0)0	0	0	(0)0	**2**	0	(2)**10**	**2**	0	(2)**10**
55 acceptable	0	0	(0)0	0	0	(0)0	0	0	(0)0	0	0	(0)0
Restricted Field (Deg): **Unacceptable**												
70 unacceptable	0	0	(0)0	0	0	(0)0	0	0	(0)0	**1**	1	(2)**10**
85 (temporal)	0	0	(0)0	0	0	(0)0	0	0	(0)0	**2**	0	(2)**10**

3.1.3 Cognitive Performance

3.1.3.1 Multiple choice reaction time and accuracy

Figure 3.2 shows mean response times from the 20 trials. The graph reveals a gradual increase in reaction times for participants as age increases. A 4(Age) x 2(Gender) factorial analysis of variance (ANOVA, Norusis 1988) on mean reaction times confirmed only a significant Age effect F(3,71)=130.8, $p<0.05$. Scheffe's post-hoc procedures (Norusis 1988) showed, at the 0.05 significance level, that participants in the oldest age group (70+ years old) had longer reaction times than any other group, while the 59-60 year-old participants had longer times than the youngest group (<30 years). However, no significant differences were found between the under 30 year-old and the 40-59 year-old participants. Figure 3.3 shows the mean values for accuracy by age and gender. Accuracy was calculated as the ratio of correct to incorrect responses. There were no meaningful differences.

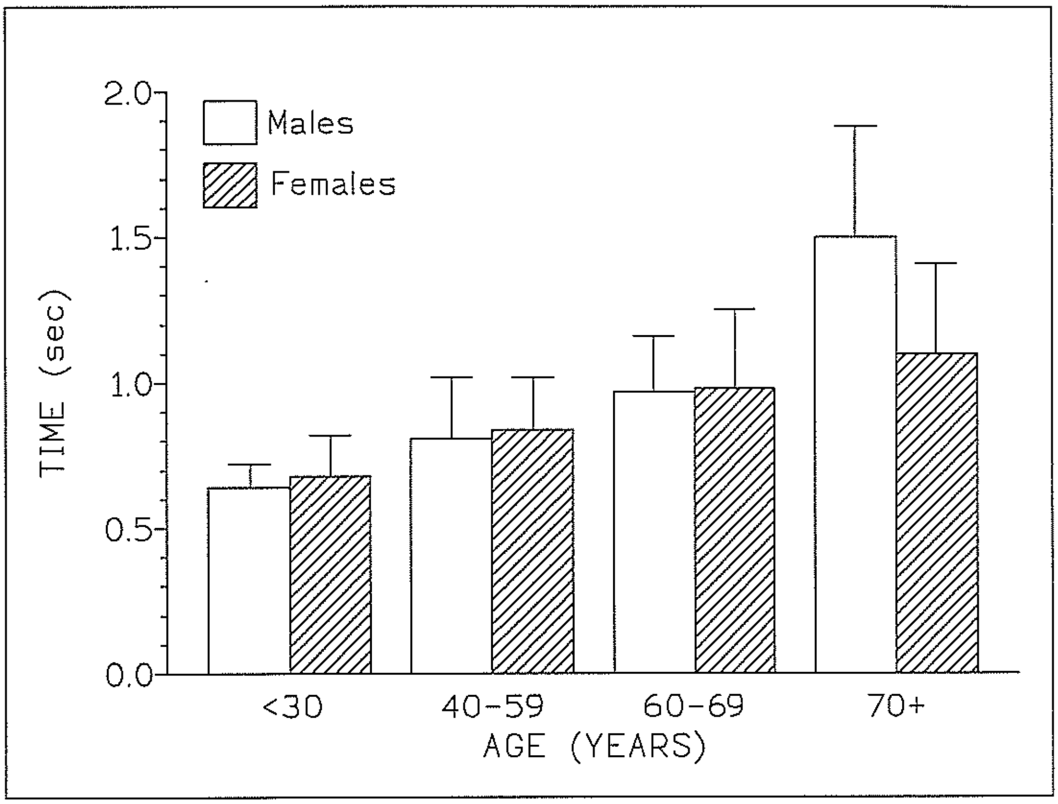


Figure 3.2 Mean reaction time (SD = ┬) by age and gender.

3.1.3.2 Short-term memory performance

Short-term memory performance by age and gender is shown in Figure 3.4. This graph shows a gradual performance deterioration across the two older groups (60-69 years and 70+ years). Interestingly, the 40-59 year-old participants performed better than the youngest group (<30 years).

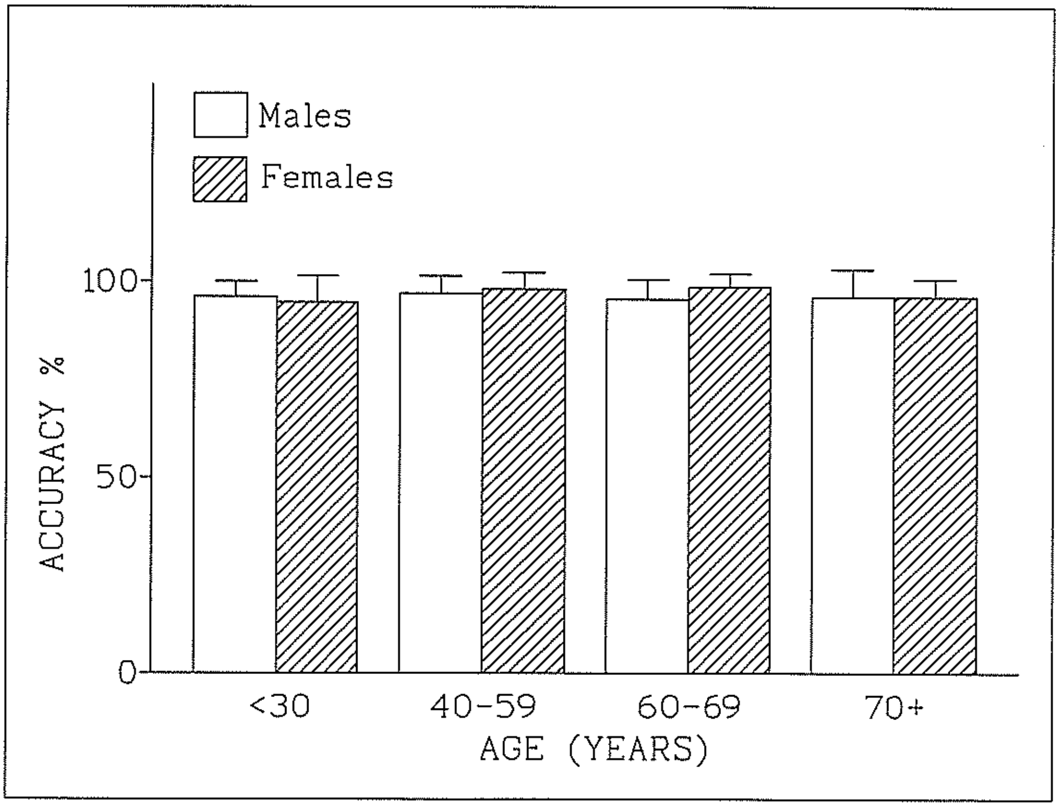


Figure 3.3 Mean accuracy (SD = ┬) for reaction time test by age and gender.

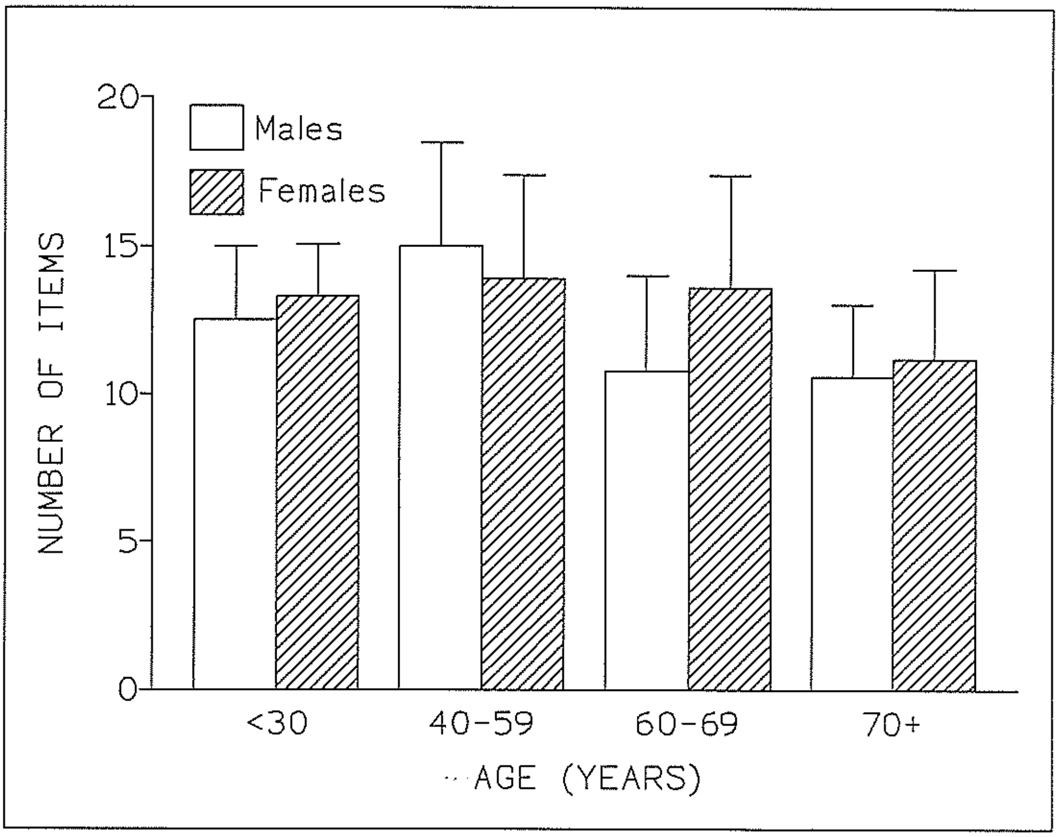


Figure 3.4 Short-term memory performance (mean number of recalled items (SD= ┬) of a total of 40) by age and gender.

An 4(Age) x 2(Gender) factorial ANOVA on the number of recalled items revealed only a significant Age effect F(3,72)=4.7, $p<0.05$. Scheffe's post-hoc procedures showed that the oldest group (70+ years) had a significantly lower memory performance than the 40-59 year-old group ($p<0.05$), but showed no significant difference between the oldest and the youngest (<30 years) groups.

Gradual decline of short-term memory performance across the life span is a well described phenomenon, but it is not clear how memory performance relates to driving performance. Short-term memory may be important in making judgements of speed of approaching vehicles especially if, at an intersection, the driver is checking traffic from both left and right. Judgement in this instance would require remembering where an approaching vehicle had been at a previous glance in order to assist estimation of approach speed.

3.1.3.3 Summary

Cognitive performance tests of multiple choice reaction time and short-term memory indicated age-related changes among the present driver sample. However, there was no evidence of serious deterioration in even the oldest participants, although the males in the 70+ years sample were markedly slower on the reaction time test. Alzheimer's Disease has been reported as affecting the older driver's performance (Cooper et al. 1993, Kaszniak 1991; Parasuraman and Nestor 1991). Testing for this disease will need to increase in the future as older drivers become a greater proportion of the driving population. The absence of severe disfunction in the present sample is not grounds for reassurance concerning the cognitive functioning of older drivers in New Zealand.

Two areas of further research are needed with respect to cognitive deficits in older drivers. First, the need is to develop effective screening instruments for detecting their presence. Second, there is a need for population data on their incidence.

3.1.4 Neck Articulation

Only the data for turning the head to the right side are presented here because these were relevant to judging traffic approaching from the right.

A 4(Age) x 2(Gender) x 2(Trial, first versus second attempt) factorial ANOVA on mean degrees of neck articulation with repeated measures on the factor trial revealed main effects for Age F(3,72)=21.8, $p<0.01$, Gender F(1,72)=7.5, $p<0.01$ and Trial F(1,72)=10.3, $p<0.01$.

Figure 3.5 shows mean degrees of neck articulation for the right side, for the first and second attempts, by age and gender. The graph shows a gradual decline in mean degrees of neck articulation with increasing age. The youngest participants achieved a mean neck articulation of 86 degrees, which is 14 degrees more than the 40-59 year-old participants, 19 degrees more than the 60-69 year-olds, and 27 degrees more than the 70+ year-old participants. Second attempts normally produced a slightly higher degree of neck articulation, with the middle-aged male group (40-59 years) as the exception. Except for the 60-69 year-old participants, the female participants in each group were able, on average, to turn their heads further than their male counterparts.

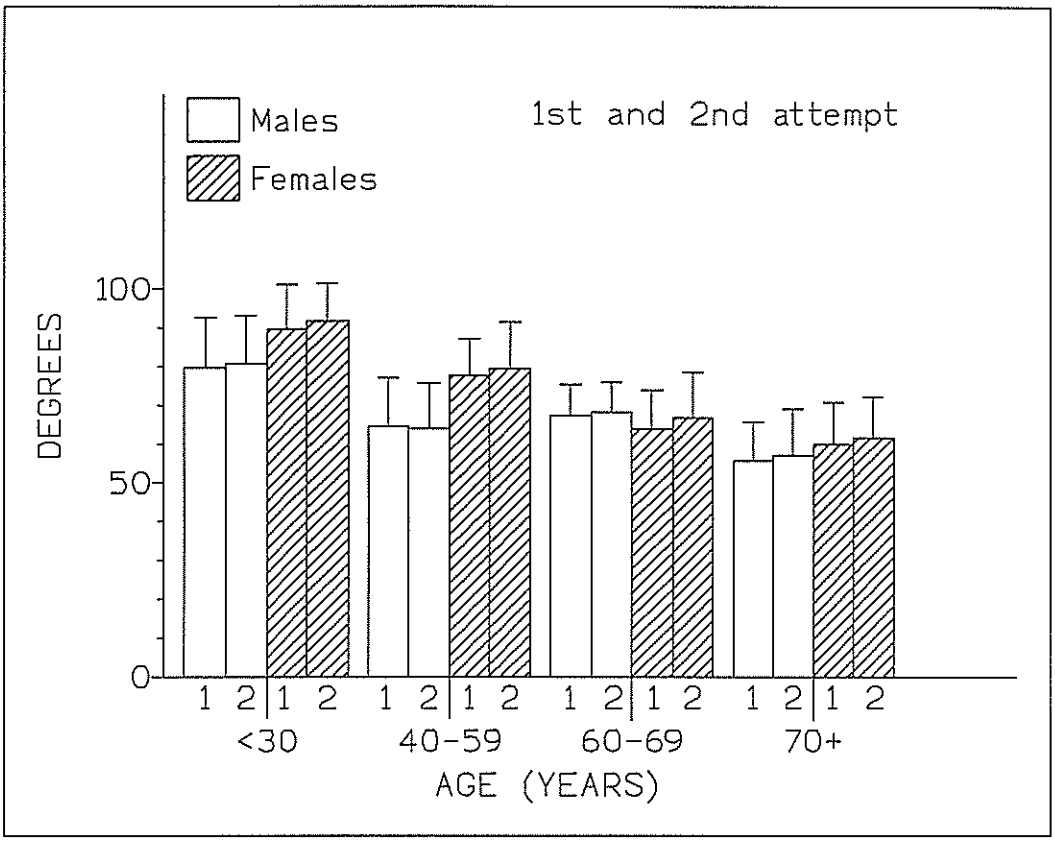


Figure 3.5 Mean degrees of neck articulation (SD= ⊤) to right side by age and gender.

The results show significant age- and gender-related differences, with the males usually performing less well than their female counterparts. The average decrement by the 70+ year-old participants was a loss of about one-third of movement in the right lateral plane when compared with the group aged <30 years. This loss of movement must compound visual deficits in stereovision and peripheral vision, increasing the difficulty of bringing the image of an approaching vehicle into central (foveal) vision, where visual acuity is highest. Also the nose may obstruct binocular vision and spectacle frames may obstruct peripheral vision. So when neck articulation is poor, detection of an oncoming vehicle may be delayed until it is too close for accurate assessment of its speed or of safe clearance of the intersection.

Mackie (1972, cited in Hills 1980) found that poor judgement and poor perception (failure to see) by the drivers of right-turning vehicles accounted for the majority of intersection accidents involving turning vehicles. Inability to accurately judge distance because of deficits in vision and neck articulation must seriously affect safe gap judgement by older drivers, and may be a major factor in the high rates of intersection and U-turn accidents (Frith 1991).

3.2 Road-side Tests

3.2.1 Experiment 1. Driving Test

The driving test involved recording the time the participants took to perform, from a stopped position, a right turn from the simulated T-intersection test-site and to clear the right (proximal) lane. The drivers were instructed (Appendix 4) to drive as they would normally at a T-intersection. Each participant completed five trials. The procedure and the testing site are described in detail in Section 2.4.2.1.

Figure 3.6 shows mean crossing times by age and gender. The graph shows a gradual increase in mean crossing times with increased age. The youngest participants (<30 years of age) cleared the lane on average 0.39 seconds faster than the oldest participants (70+ years), and 0.24 seconds faster than the 60-69 year-old participants. Male drivers of all ages consistently were quicker than similarly aged females, although gender difference reduces as age increases.

A 4(Age) x 2(Gender) factorial ANOVA on mean crossing times revealed a significant Age effect F(3,72)=3.4, $p<0.01$, but did not confirm a significant Gender effect F(1,72)=2.6, $p>0.05$, as visual inspection of Figure 3.6 has suggested.

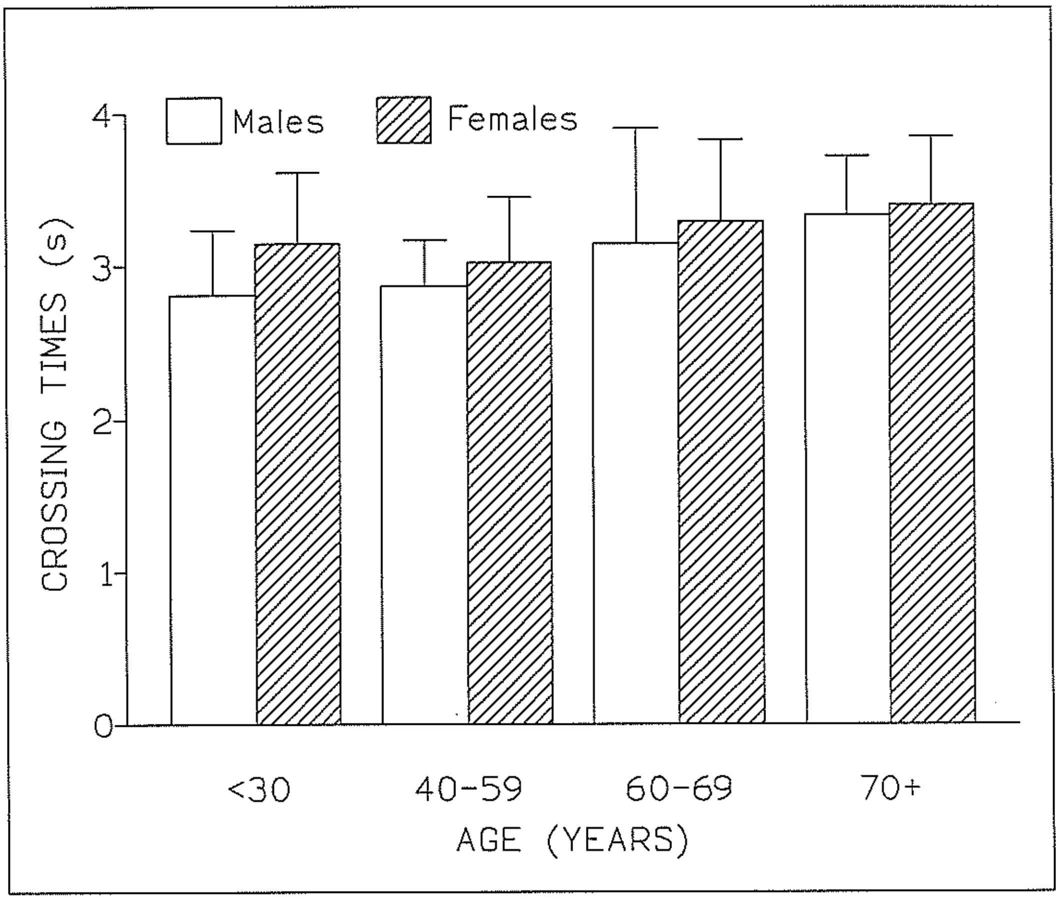


Figure 3.6 Mean crossing times (in seconds, SD = ┬) by age and gender.

Slower lane clearance times combined with the visual and physical (neck articulation) deficits, which most likely contribute to later detection and poorer judgement in the intersection environment, add up to high exposure to risk for the older drivers. These findings appear to support those of Bernhoft (1990), whose post-hoc study of intersection accidents involving older drivers suggested impaired reactions and over-estimation of their ability to accelerate their vehicle caused slow lane clearance. On the other hand they contradict Spicer's (1972, cited in Hills 1980) finding of little difference between younger and older drivers in an intersection crossing study.

3.2.2 Experiment 2. Gap Acceptance Testing

This experiment tested gap acceptance behaviour of the participants seated behind the steering wheel of a stationary research car on a simulated rural T-intersection site. Threshold and signal detection trials were alternated (after every five trials) until 20 trials on each procedure were performed. The procedures and the testing site are described in Section 2.4.2.2.

3.2.2.1 Threshold trials

In the threshold trials (see Section 2.4.2.2), Researcher 1 identified appropriate on-coming vehicles (target vehicles) from the right and the participants repeatedly said "Yes" for as long as they judged it safe to "drive out" from the intersection, and said "No" when they considered that it was unsafe. Distance and speed of the target vehicle for the last "Yes" were measured with a Laser speed/distance device. Mean accepted time and distance gaps were calculated for each participant, covering approaching vehicles in five different speed categories.

The mean speed at which the target vehicles were travelling did not differ substantially between the four tested age groups (<30 years of age: M(Mean)= 89.6 km/h, SD(Standard Deviation)=3.0; 40-59 years: M=90.6 km/h, SD=2.6; 60-69 years: M=90.2 km/h SD=2.6; 70+ years: M=90.2 km/h, SD=2.5).

- **Mean accepted time gap (last "Yes")** Figure 3.7 shows the mean accepted *time* gaps (for the last "Yes"), calculated separately for target vehicles in five different speed categories (60-79 km/h, 80-89 km/h, 90-99 km/h, 100-109 km/h, 110+ km/h), by age and gender.

The graph shows three important results. First, all groups allowed gradually shorter time gaps as target vehicle speed increased. Second, the youngest age group (<30 years), compared with the other age groups, accepted the shortest time gaps for all speed categories. Third, in the youngest age group, the male participants consistently accepted shorter time gaps (for all speed categories) than their female counterparts. Gender effect was not consistent for this variable in the three older age groups.

For the following statistical analysis, data from the two highest speed categories (100-109 km/h; 110+ km/h) were combined to ensure a complete set of data for each participant. A 4(Age) x 2(Gender) x 4(Speed, 4 speed categories for target vehicles) factorial ANOVA was calculated on the accepted time gaps ("method unique" was used for unbalanced designs, as described in Norusis 1988), with Speed as a within-subject factor. This analysis confirmed significant main effects for Age F(3,68)=4.0, $p<0.05$, and Speed F(3,204)=185.7, $p<0.01$, but not for Gender F(1,68)=0.2, $p>0.5$. There was a significant Age x Speed interaction F(9,204)=3.47, $p<0.01$.

Overall, the results of the statistical analysis are consistent with the findings of the visual inspection of Figure 3.7. All drivers, regardless of age, accepted smaller time gaps as speeds of approaching vehicles increased. While this finding is surprising, it conforms with a similar finding by Hills and Johnson (1980, cited in Hills 1980). This outcome suggests that drivers regularly over-estimate the speed of vehicles that are approaching slower than 90 km/h and that they tend to under-estimate when speeds exceed 100 km/h. Clearly, over-estimation of approach speed is more conservative, and thus less hazardous, than under-estimation.

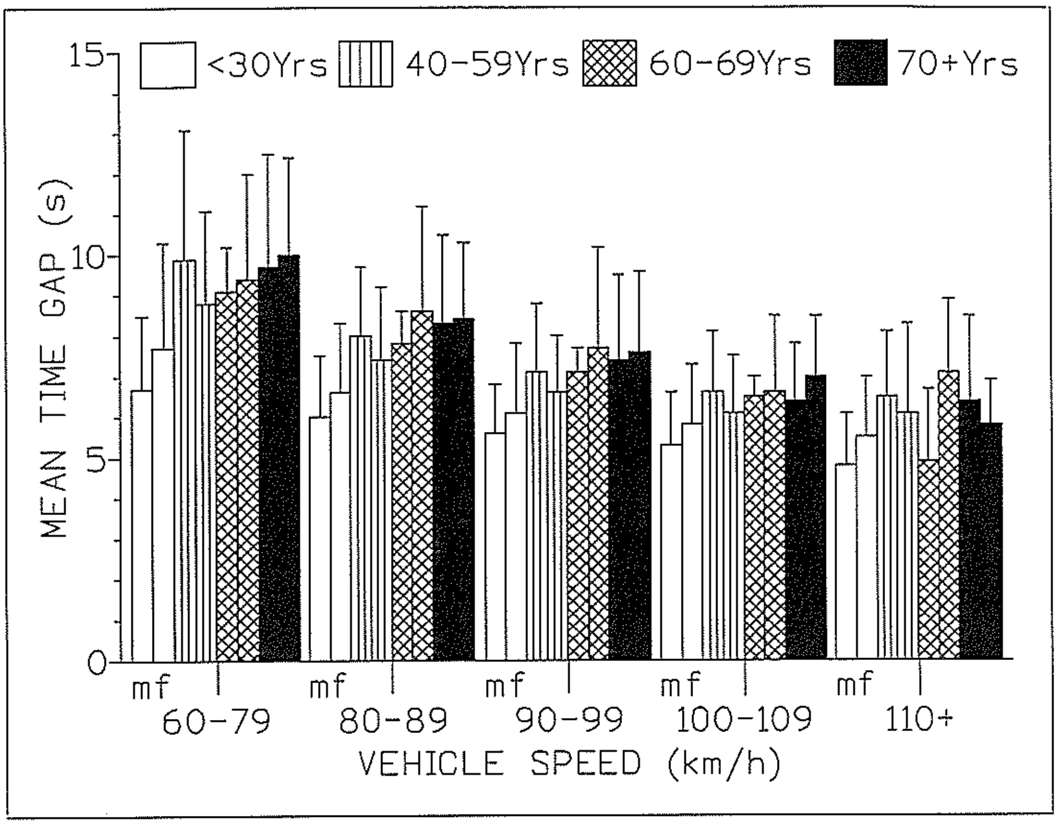
When male and female data are combined, the youngest (<30 year-old) drivers consistently accepted smaller gaps than those in other age groups. This finding conflicts with that of Hills and Johnson (cited in Hills 1980), for their data showed that older males accepted the smallest gaps. The difference in these findings may in part be explained by the use of different methodologies and also the use of participants of different ages. Hills and Johnson's youngest drivers were over 30 years, those in the present study were under 30 years and may have been more impulsive, prepared to take more risks, and less experienced. Their older drivers were aged between 61 and 70 years, and curiously the data from the present study show that males in the 60-69 year-age bracket accept as short a gap at 110+ km/h as the under 30 year-old males. The oldest sample of drivers in the present study was aged 70+ years and, while they accepted slightly shorter gaps on average than the "safest" group (40-59 years), they allowed themselves more time than the under 30 year-old participants.

- **Mean accepted distance gap (last "Yes")** Figure 3.8 shows the mean accepted *distance* gaps (for the last "Yes"), calculated separately for target vehicles in five different speed categories (60-79 km/h, 80-89 km/h, 90-99 km/h, 100-109 km/h, 110+ km/h), by age and gender.

The graph shows that for all speed categories of the target vehicles, the participants in each group accepted about equal distance gaps. The youngest group accepted consistently shorter gaps than any other group. The male participants in the youngest age group (<30 years) accepted shorter distance gaps than their female counterparts.

For the following statistical analysis, data for the two highest speed categories (100-109 km/h; 110+ km/h) were combined to ensure a complete set of data for each participant. A 4(Age) x 2(Gender) x 4(Speed, 4 speed categories for target vehicles) factorial ANOVA was calculated on the accepted distance gaps ("method unique" was used for unbalanced designs). This revealed a significant main effect for Age F(3,68)=3.7, $p<0.05$, but no significant effects for the factors Gender F(1,68)=0.1, $p>0.5$ or Speed F(3,204)=0.16,$p>0.05$. There was a significant Age x Speed interaction F(9,204)=2.1,$p<0.05$.

Figure 3.7 Mean accepted time gaps (in seconds, SD = ┬) by age and gender.



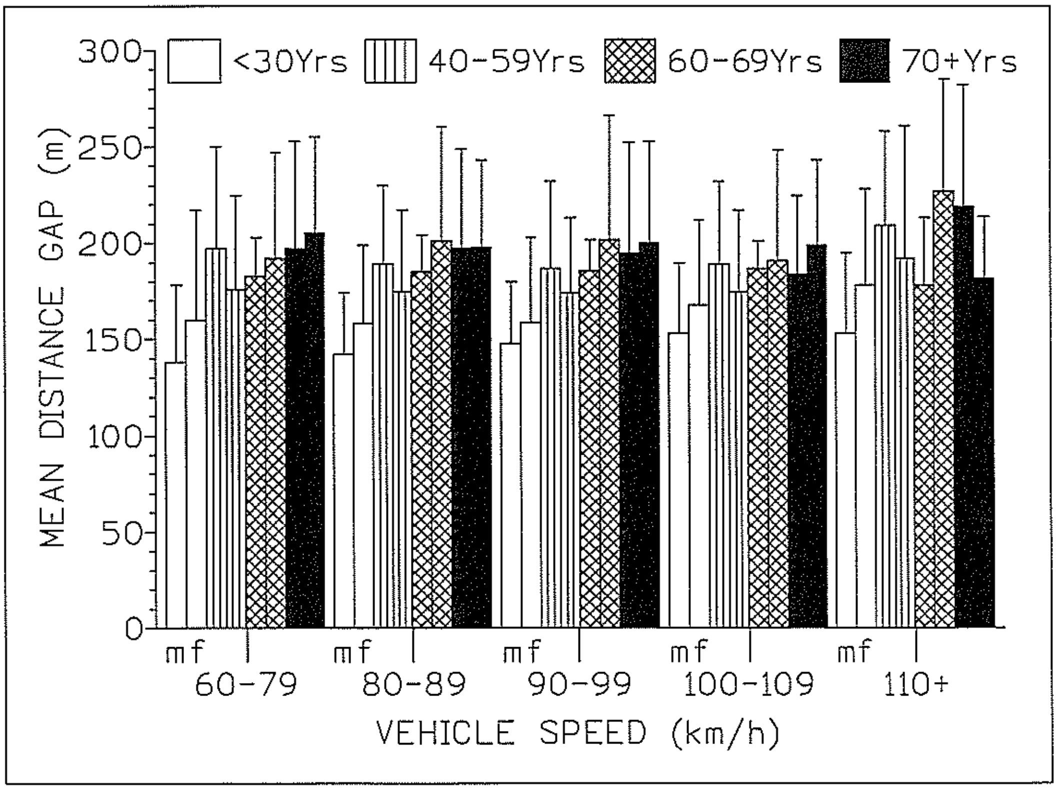


Figure 3.8 Mean accepted distance gaps (in metres, SD = ┬) by age and gender.

The data on the mean distance gaps show quite clearly that all drivers were judging safe time gaps on the basis of distance, rather than on vehicle speed, or some combination of speed and distance. This may partly explain the phenomenon of poor speed judgement (i.e. over-estimation of slow vehicles; under-estimation of faster vehicles) that is evident in the time gap data. When drivers use a distance-only criterion, having set a "safe" distance, they are likely to make gap judgement errors when vehicle speeds fall below or above the speed for which that distance is "safe". Errors are not problematic if they result in over-estimation, except when a driver subsequently detects the error and then makes a late decision to drive across the path of the approaching vehicle.

The data from the present study show that mean distances selected by drivers in given age groups were remarkably consistent across all vehicle speed bands. Drivers under 30 years of age show a clear tendency to choose a shorter distance "envelope" (males, 140 m; females, 160 m) than their older counterparts. The females tend to allow a slightly longer distance than their male counterparts, except in the 40-59 year-old group. These findings differ from those of Hills and Johnson (1980, cited in Hills 1980), who reported that only the older males in their sample appeared to use a constant distance (150 m).

3.2.2.2 Signal detection trials

The procedure for these trials was similar to that for the threshold trials (Section 3.2.2.1). The same initial instructions were given to the participants as for the threshold procedure except that, after Researcher 1 had instructed the participants to "Look now", they were required to look to the right and evaluate oncoming traffic, and to respond immediately with a single "Yes" (for judging it safe to drive out from the intersection) or "No" (for judging it unsafe). Researcher 2 activated the Laser speed/distance device for either response and noted the speed and distance of the on-coming vehicle.

- **Number of accepted/rejected gaps** Figure 3.9 shows eight scatterplots of all "Yes" (above horizontal axis) and "No" (below horizontal axis) decisions by the participants (identified by age and gender) against distance and time gaps of the on-coming traffic. An equal number of responses was sought from the two response alternatives. Additionally, an effort was made by Researcher 1 to give the instruction to look at the oncoming vehicle as close as possible to the critical gaps where decisions of "Yes" or "No" were not obvious. The graph shows a large variability between the participants regarding their gap-judging behaviour. This is shown by the quite symmetrical distribution of data points about the horizontal axis for the "Yes" and "No" decisions for all age groups. This distribution means that oncoming vehicles with equal distance or time gaps were sometimes accepted by some participants and on other occasions rejected by them.

Figure 3.9 Scatterplots for "Yes" and "No" decisions by age and gender for the groups: males <30 years; females <30 years; males 40-50 years; females 40-59 years.

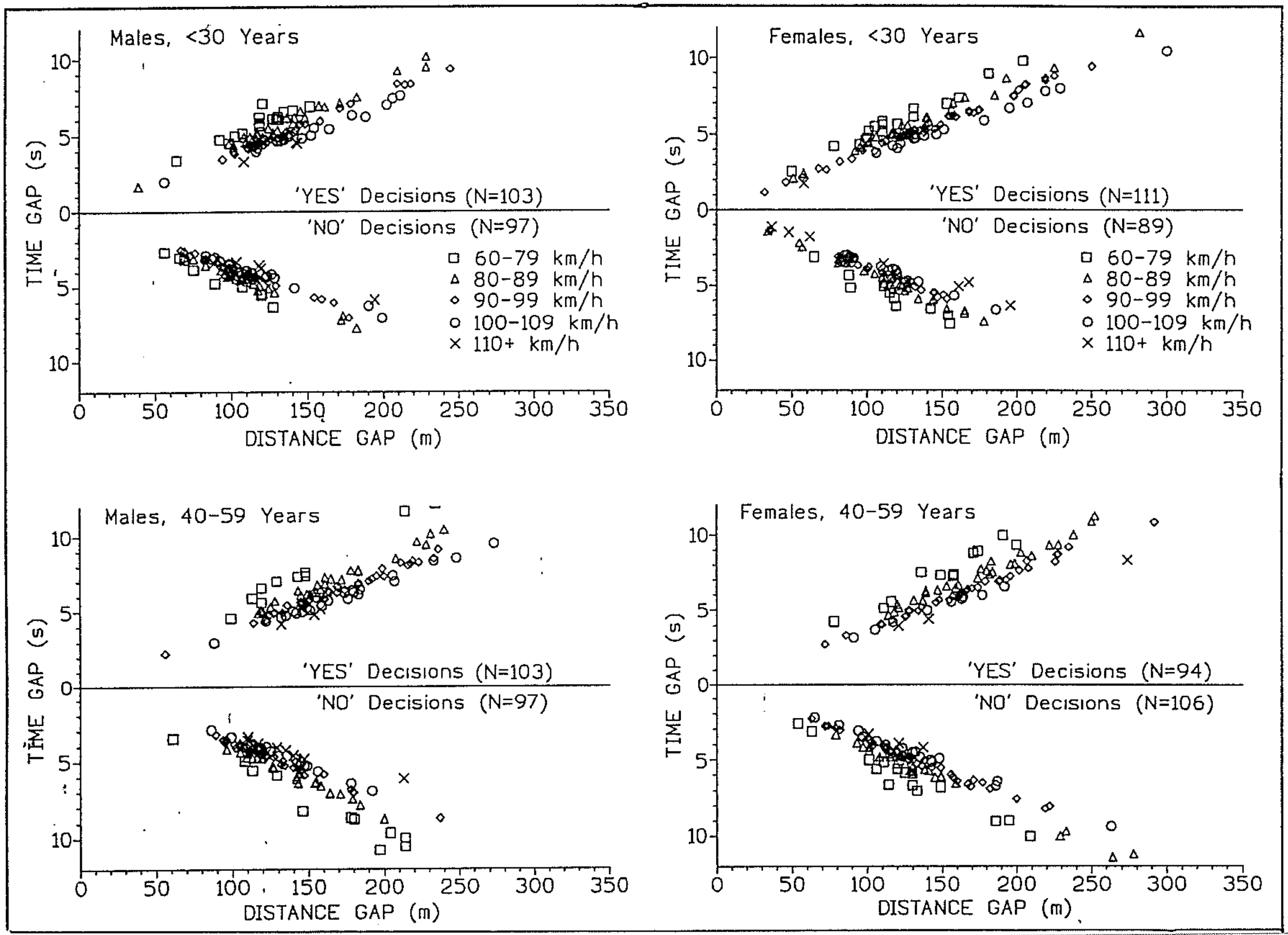
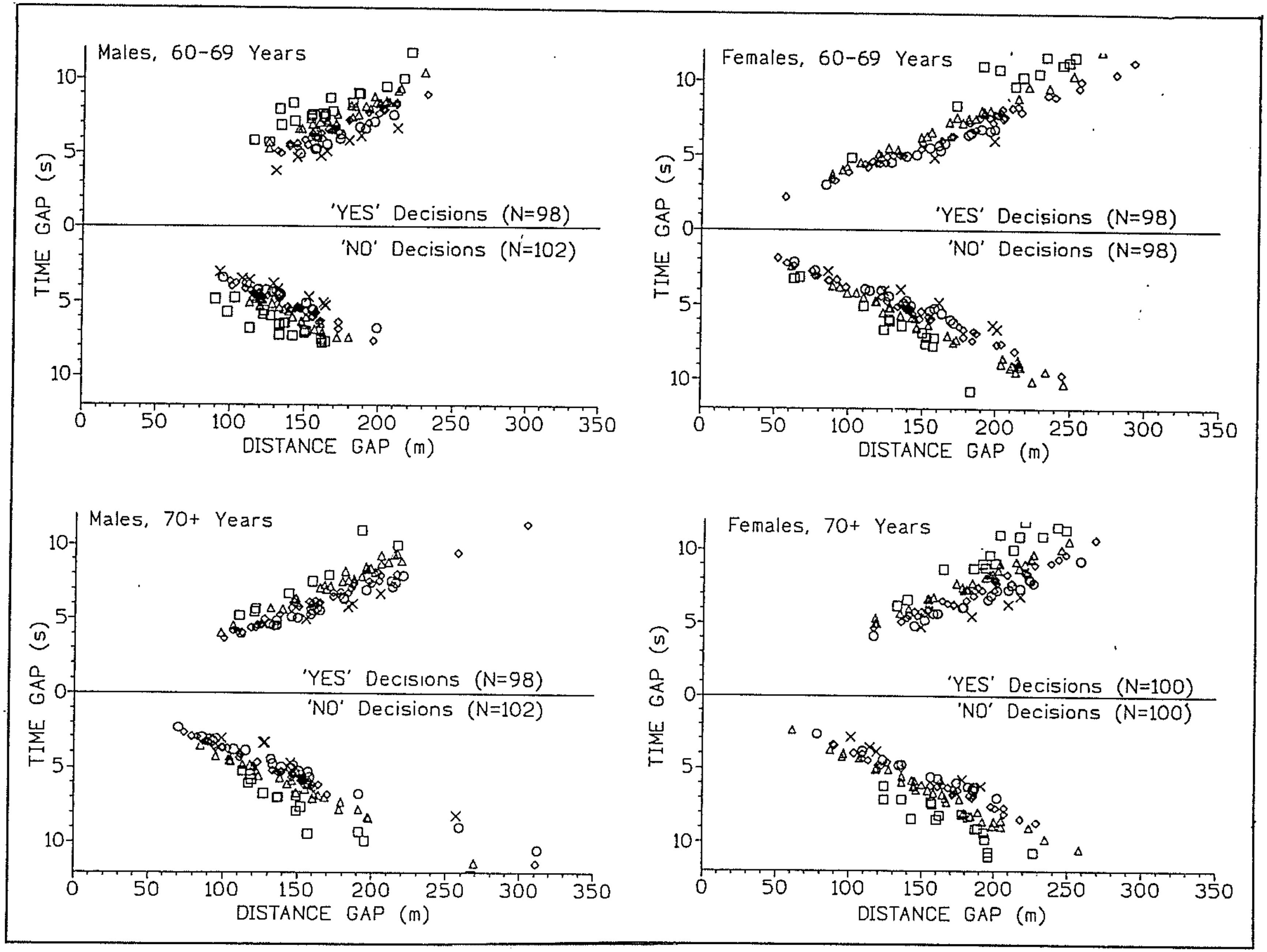


Figure 3.9 (continued).



The data show that the majority of approaching vehicles to which under 30-year-old male participants gave "Yes" judgements were within 4 to 7 seconds of impact (distance 90-160 m). These males also gave "No" judgements to many vehicles in the 2 to 6 second range (50-130 m). "Yes" judgements by females in this age group were more often risky, with many acceptances of time gaps under 5 seconds (distances of less than 100 m) and most acceptances falling between 1 and 7 seconds to impact (30-170 m). These very brief times in "Yes" judgements are unlikely to be significantly confounded by the recording process, given that the operator's reaction time is a factor common to all the data and that the laser equipment produced a record in 0.3 seconds.

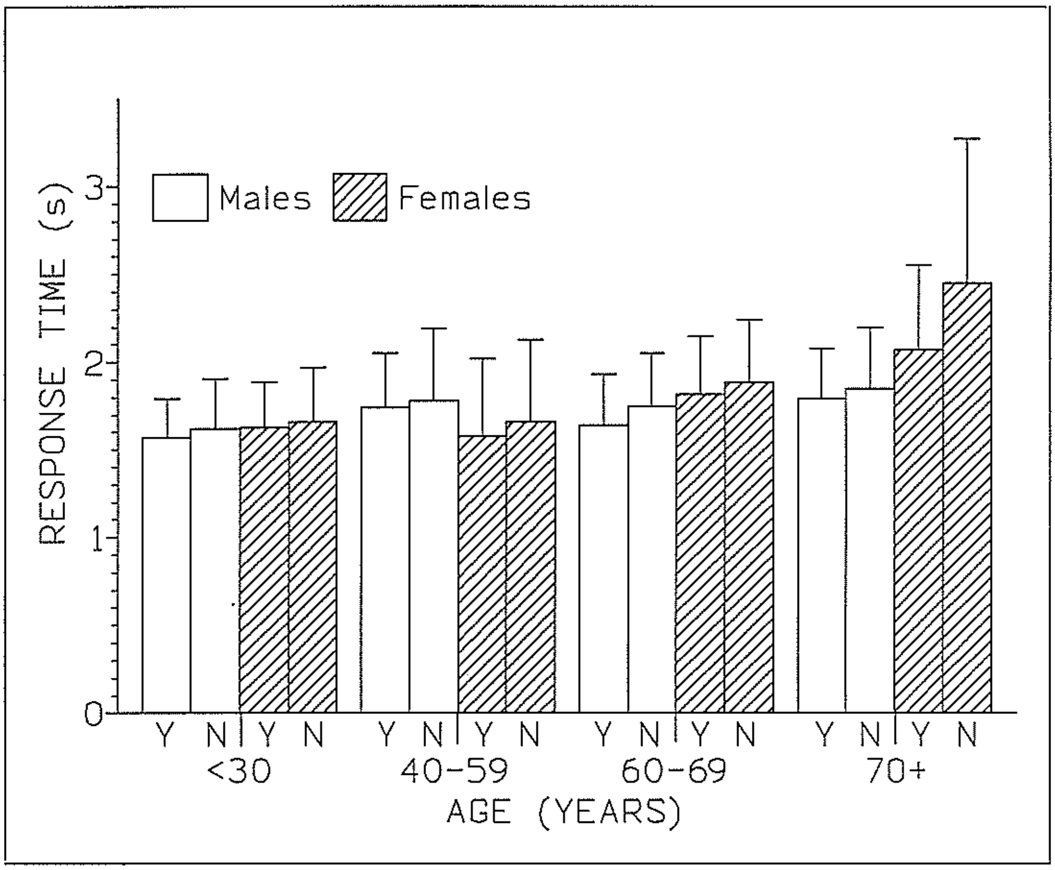
Conversely, the younger women showed greater caution than their male counterparts by more often accepting gaps when vehicles are at distances over 150 m. These data support the contention that younger drivers take more risks and they also suggest that gap acceptance judgements by younger women are less consistent than those of younger males. In fact, up to age 70 years, males made more consistent judgements and tended to more often accept gaps of over 7 seconds, when vehicles were at distances of over 180 m. Consistency may reflect greater practice, given that males reported driving greater distances in any given year.

- **Response times for "Yes" and "No" decisions** Figure 3.10 shows mean response times for "Yes" and "No" decisions by age and gender. The figure shows consistently longer response times for the "No" decisions compared with the "Yes" decisions for all groups. In the two oldest age groups (60-69 years and 70+ years), the female participants had consistently longer response times (for both "Yes" and "No") than their male counterparts. Gender difference was not evident in the response times of the youngest age group (<30 years), while the female participants in the "middle aged" group (40-59 years) responded faster than their male counterparts.

A 4(Age) x 2(Gender) x 2(Decision, "Yes" versus "No") factorial ANOVA was calculated on mean response times with Decision as a within-subject factor. This analysis confirmed main effects for Age $F(3,72)=12.0$, $p<0.05$ and Gender $F(2,72)=5.9$, $p<0.05$ and an interaction Age x Gender $F(3,72)=5.4$, $p<0.05$. There was no effect on Decision $F(1,72)= 1.83$, $p>0.5$, which was surprising as Figure 3.10 showed consistently longer response times for the "No" decisions compared with the "Yes" decisions for all age groups.

- **Signal detection analysis** The scatterplots in Figure 3.9 showed qualitatively that gap acceptance behaviour differs substantially between drivers within and between age and gender groups. However quantitative measures are needed to evaluate the participants' ability to
  - (a) discriminate safe from unsafe gaps and
  - (b) determine whether their judgments were possibly influenced by a response bias towards saying "Yes" (risky behaviour) or "No" (less risky behaviour).

Figure 3.10 Mean response times (in seconds, SD = ┬) for "Yes" (Y) and "No" (N) decisions by age and gender.



To comprehensively understand drivers' gap acceptance behaviour at T-intersections, their full decision matrix is considered (Table 3.5). This decision matrix has been adopted from the signal detection theory (e.g. Swets et al. 1961).

Table 3.5 Decision matrix of drivers at T-intersections (and of observers in a classical signal detection experiment).

Decision Matrix		Traffic situation (Signal presentation)	
		GAP SAFE (Signal present)	GAP UNSAFE (Signal absent)
Response	YES	**TRUE POSITIVE**	**FALSE POSITIVE**
	NO	**FALSE NEGATIVE**	**TRUE NEGATIVE**

In terms of classical signal detection theory, the two types of signal presentations are either the signal is present or it is absent. In the study T-intersection simulation (and in analogy to the signal detection theory), the gap between the driver and on-coming traffic is either large enough (signal present) to make a safe turn or it is too small (signal absent) and therefore unsafe to cross the road.

In a signal detection experiment as well as in the study T-intersection experiment, two possible responses can be made. "Yes" indicates that the driver (or observer) judges a gap as safe (or the signal as being present), and "No" indicates that the driver (observer) judges the gap as unsafe (or the signal as being absent).

The combination of two possible traffic situations (or signal presentations) and two possible responses leads to four possible outcomes on a given trial (the four cells in Table 3.5). When the gap is safe (or signal is present) and the response is "Yes" the observer makes a **True Positive** decision. But if the driver (observer) responds "Yes" when the gap is unsafe (signal is absent), than a **False Positive** decision is made. The other cells are called **False Negative**, referring to rejecting a safe gap ("No" when a signal is present), and **True Negative**, which is rejecting an unsafe gap ("No" when signal is absent). The proportions of the True Positive (PTP) and False Negative (PFN) decisions, as well the proportions of False Positives (PFP) and the True Negatives (PTN) are complementary and add up to 1. Therefore, in order to get the full decision matrix, only the proportions of the True Positives and False Positives need to be determined.

The relationship among these decision categories depends not only on the traffic situation (or nature of the signal), i.e. whether a gap is safe or unsafe (or whether a signal is strong or weak), but also on the decision processes within the driver (observer). The two responses ("Yes" or "No") depend in part on sensory processes (*sensitivity*) which enable the driver (observer) to discriminate between safe and unsafe gaps (or weak and strong signals). They also depend on the degree of the driver's (observer's) willingness or risk-taking behaviour (*response bias*) to accept critical gaps as safe (or weak stimuli as being present).

At T-intersections drivers might accept less safe gaps (bias towards saying "Yes") if for example:

(a) they are generally more willing to engage in risky behaviour;
(b) they feel confident in their ability to accelerate quickly so that the lane to be crossed can be cleared quickly;
(c) they are under time pressure, or the number of vehicles behind them is increasing;
(d) the number of safe gaps is low in dense traffic.

The design of the present experiment did not include provision for testing the situations outlined in (c) and (d) but included a sample of young drivers (<30 years) who are reputed to more frequently engage in risky driving behaviour than drivers in any other age groups (reason (a)). Additionally, the mean crossing time (reason (b)) for each participant (Experiment 1) was used in the following data analysis.

- **The minimum safety gap** At the study T-intersection simulation, Researcher 1 selected oncoming vehicles in such a way that an equal number of "Yes" and "No" decisions were obtained and also tried to get the vehicles as close as possible to the critical gaps where decisions were not obvious.

After data acquisition, a so-called **minimum safety gap** was determined for each participant. The minimum safety gap was calculated as the sum of a participant's individual mean crossing time (Experiment 1) and an arbitrary minimum additional safety margin of two seconds. (This was determined on the basis that, if traffic was spaced in accordance with the minima advised in the Road Code (NZ Ministry of Transport), a minimum of a 2-second gap would occur between approaching vehicles. This would effectively allow 50 m in which an oncoming driver travelling at 90 km/h could detect and respond to any attempt to cross the road by a driver of a vehicle that had been stopped at a T-intersection.) For example, a participant who had a mean crossing time of three seconds in Experiment 1 would have a minimum safety gap of five seconds (3 seconds crossing time + 2 seconds safety margin).

The minimum safety gaps were used to assign each of the participant's decisions to one of the four cells in the decision matrix in Table 3.5. For example, consider the participant who obtained a minimum safety gap of five seconds. All "Yes" decisions for on-coming traffic with a time gap of more than five seconds would be considered as True Positives (accepting safe gaps), while the "Yes" decisions for on-coming traffic with accepted time gaps of less than five seconds would be considered as False Positives (accepting unsafe gaps).

Figure 3.11 shows the proportions of the True Positive and False Positive decisions pooled for all participants in each age and gender group. The proportions of True or False Positives were calculated as a ratio of the number of True Positive or False Positive decisions to total number of safe gaps or unsafe gaps. The safest drivers are those who have a low proportion of False Positives by maintaining a reasonably high proportion of True Positives. Figure 3.11 shows the balance between the proportions of True and False Positives graphed as the difference (patterned) between these proportions.

Figure 3.11 shows that the youngest male group (<30 years) had the highest proportion of True Positives (accepting safe gaps), but they also had a high proportion of False Positives (accepting unsafe gaps). The graph also shows that the male participants in the 40-59 year-old age group and in the 60-69 year-old age group had the largest difference between the proportions of the True Positives and False Positives and were thus the safest judges. The oldest male drivers (70+ years) and the female drivers in the age groups <30 years and 60-69 years had relatively small differences between their proportions of True and False Positives, and thus were the least safe judges.

Signal detection theory attempts to measure the observer's sensitivity (ability to discriminate between safe and unsafe gaps) *independently* of their response bias towards saying "Yes" (risky behaviour) and "No" (less risky behaviour). Grier (1971) derived two (non-parametric) measures, A' (sensitivity) and B" (response bias), which are compatible with our experimental design.

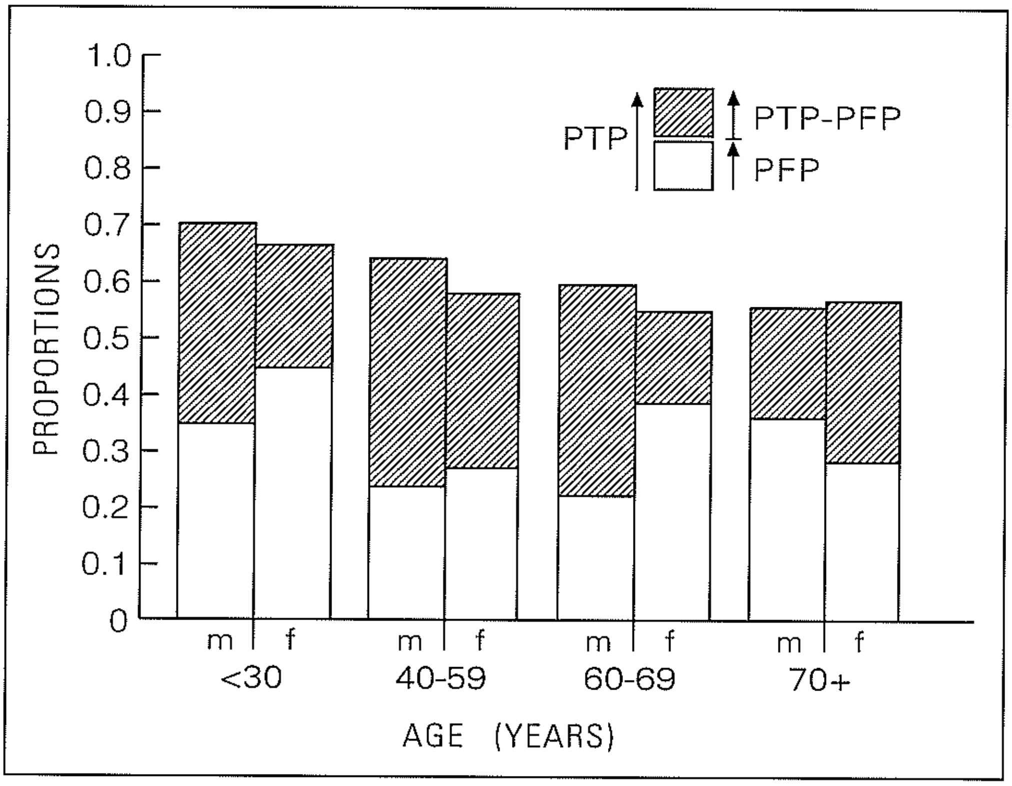


Figure 3.11 Proportions for True and False Positives by age and gender (f=females, m=males).

Balance between the proportions of True (PTP) and False Positives (PFP) graphed as the difference (patterned) between their proportions. The columns which show a higher ratio of patterned to white indicate safer judgements.

The computations of these two measures are:

$$A' \text{ (sensitivity)} = \frac{1}{2} + \frac{(PTP - PFP)\,(1 + PTP - PFP)}{4\,PTP\,(1 - PFP)}$$

$$B'' \text{ (response bias)} = \frac{PTP\,(1 - PFP) - PFP\,(1 - PFP)}{PTP\,(1 - PFP) + PFP\,(1 - PFP)}$$

Where: PTP= Proportion of True Positives;
PFP= Proportion of False Positives

Table 3.6 shows the computations of A' (sensitivity) and B" (response bias) for all "Yes" and "No" decisions pooled for different age and gender groups. For A', a completely insensitive participant would produce a value of 0.5 while perfect performance would produce an index of 1. B" can vary between –1 and 1, with negative scores indicating a response bias towards saying "Yes" and positive scores indicating a response bias towards saying "No."

Table 3.6 Computation of sensitivity (A') and response bias (B") by age and gender (m=males; f=females).

Response	PTP		PFP		A'		B"	
Gender	m	f	m	f	m	f	m	f
Age (Years)								
<30	0.700	0.663	0.364	0.457	0.752	0.672	–0.040	**–0.050**
40-59	0.644	0.577	0.246	0.271	**0.786**	**0.737**	**0.105**	**0.105**
60-69	0.594	0.537	0.228	0.391	**0.772**	**0.627**	**0.156**	**0.021**
70+	0.560	0.564	0.364	0.273	**0.664**	**0.729**	**0.031**	**0.106**

Table 3.6 shows that by comparing all age groups, the male drivers in the 40-59 year-old group had the highest score for sensitivity (A'=0.786), i.e. the highest ability to discriminate between safe gaps and unsafe gaps. The older male group (60-69 years) had a slightly lower score for sensitivity (A'=0.772) but had the strongest response bias towards saying "No" (B"=0.156). The youngest participants (<30 years) had a slight response bias towards saying "Yes" (B"(males)= –0.04, B"(females)= –0.05), but the male participants scored higher for the sensitivity measure (A'=0.752) than their female counterparts (A'=0.672). The oldest male participants (70+ years) scored second lowest for the sensitivity measure (A'=0.664), which was substantially lower than the corresponding measure for their female counterparts (A'=0.729). The lowest sensitivity measure was obtained by female participants in the 60-69 year-old group. In contrast with the youngest participants (<30 years), all older participants had a response bias towards saying "No".

- **Summary** The signal detection trials generally support the findings from the threshold judgement trials of the more risky gap acceptance made by younger drivers. Drivers aged under 30 years accepted (i.e. gave "Yes" responses) smaller distance and time gaps (i.e. made more risky decisions) than older drivers. Female drivers were generally less consistent judges than males, and males under 70 years (especially those aged 40-69 years) typically made safer judgements more often. Males over 70 years were poorer judges than females in that age range, and were less consistent at making judgements than any of the other male participants.

These findings about gap acceptance differ in some respects from the threshold data above and do not entirely support those of Hills and Johnson (1980, cited in Hills 1980). While the gender data of the threshold judgement experiment and of Hills and Johnson (1980) show males to consistently accept smaller time gaps than females, the present signal detection data show that females under 70 years occasionally will accept smaller gaps (<4.0 seconds) than their male counterparts, although they just as often reject small gaps.

The mean data, presented for the threshold trials and by Hills and Johnson, may have masked the variability evident in the scatterplots of the signal detection data, leading to these somewhat different conclusions.

A number of other factors, such as methodological and procedural variations or differential sensitivity of one procedure over another, may also contribute. Hills and Johnson (1980) found that older males (61-70 years) accepted smaller gaps (1-2 seconds) than males aged 31 to 40 years (2-2.5 seconds) at vehicle approach speeds of 100 km/h or over, while no male drivers in the present study (see Figure 3.9) accepted gaps of under 2.0 seconds for any vehicle and only male drivers aged under 60 years were more likely to accept a gap of less than 4.0 seconds.

3.2.3 Experiment 3. Speed Estimation Testing

In this experiment, participants were asked to estimate the speed of on-coming traffic when it was at a distance of about 150 m. Participants were not given any feedback concerning the accuracy of their estimations until 20 trials had been completed. (The full procedure for this experiment is described in Section 2.4.2.3, and instructions in Appendix 4.)

Figures 3.12 and 3.13 show mean estimation error as the difference between the estimated and the actual speed of the oncoming traffic, pooled across all trials by age (Figure 3.12) and age and gender (Figure 3.13). Figure 3.12 shows that the participants in all age groups over-estimated the speed of relatively slow vehicles (60-99 km/h) but under-estimated relatively fast vehicles (100-110+ km/h). For all groups, the degree of under-estimation was largest for the slowest vehicles (60-79 km/h) and gradually reduced for the speed categories 80-89 km/h and 90-99 km/h.

The degree of over-estimation was largest for the fastest vehicles (110+ km/h) and slightly less for the speed category 100-109 km/h. Only the youngest participants (<30 years) had a positive mean (over)estimation error for vehicles in the speed category of 100-109 km/h. Figure 3.13 shows that the male participants under-estimated slower vehicles (60-99 km/h) to a larger degree than their female counterparts. Such a gender effect is not visible for the estimation data for vehicles exceeding 100 km/h.

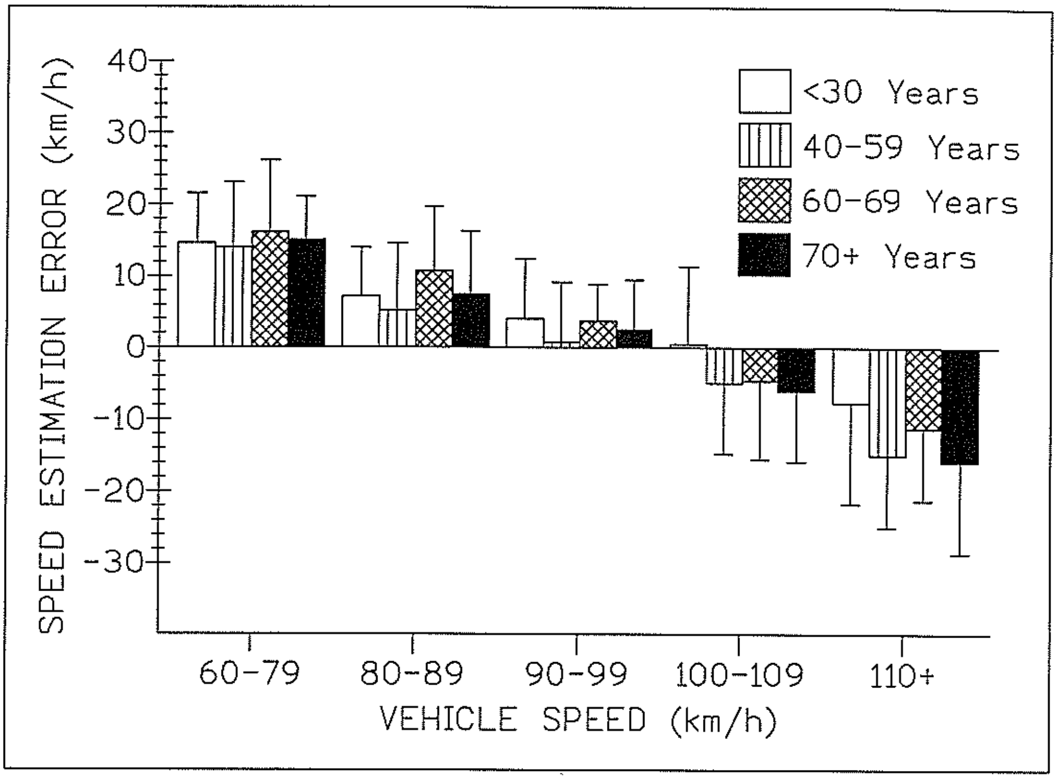


Figure 3.12 Mean speed estimation error (SD = ⊤) of participants by age.

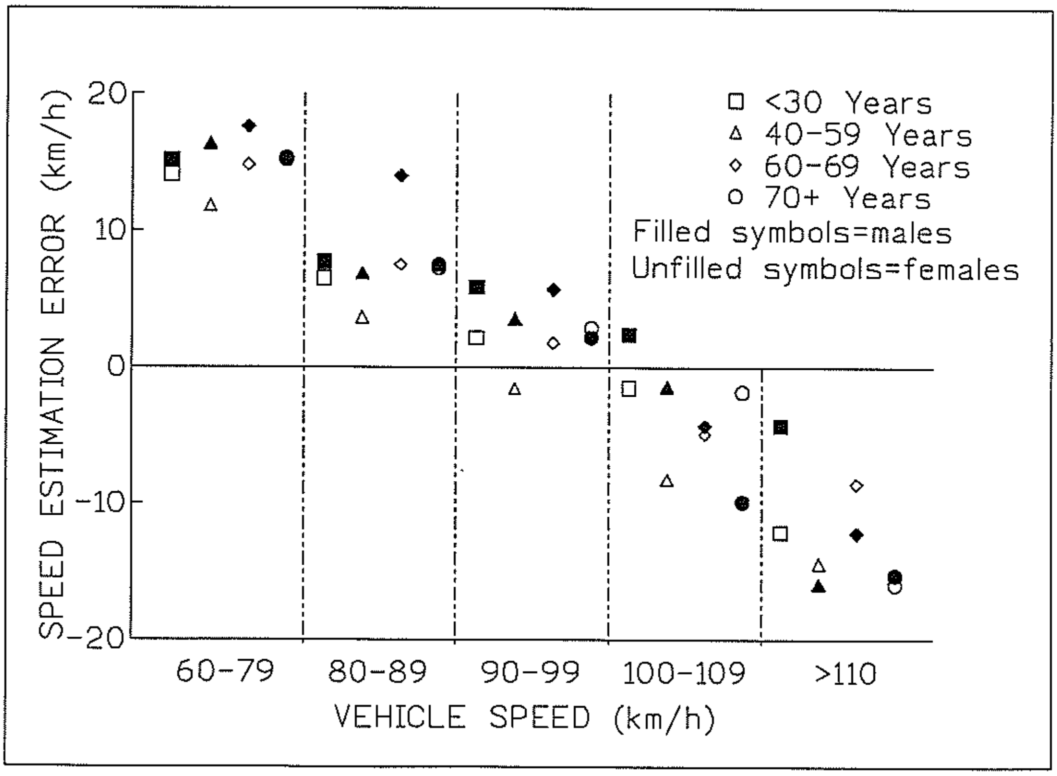


Figure 3.13 Mean speed estimation error of participants by age and gender.

For the following statistical analysis, data for the two highest speed categories (100-109 km/h and 110+ km/h) were combined to ensure a complete data set for each participant. A 2(Age) x 2(Gender) x 4(Speed, 4 speed categories) factorial ANOVA on mean speed estimation error, with Speed as a within-subject factor, revealed a main effect for Speed F(3,192)=186.2, $p<0.01$, and a significant interaction Age x Speed F(3,192)= 2.4, $p<0.05$.

These data suggest that most drivers expect that traffic approaching on the open road is travelling at about 100 km/h and tend to use that expectation as the basis for their judgements. If this is the case, it explains why participants of all ages over-estimated speeds of vehicles travelling slower than 100 km/h, with the error systematically reducing as actual vehicle speeds approached 100 km/h. As speeds exceeded 100 km/h, approach speeds became increasingly under-estimated. Males under 70 years always over-estimated sub-100 km/h speeds more than under 70-year old females, while males and females aged over 70 years made almost identical amounts of over-estimation (Figure 3.13). As vehicle speeds exceeded 100 km/h, the gender differences for under-estimation became less consistent, although males aged under 30 years were clearly the most accurate judges when speeds exceeded 110 km/h. Males aged over 70 years proved the worst judges at speeds between 100-109 km/h and also fared badly (along with their female counterparts) at speeds over 110 km/h.

Cooper et al. (1977) note that drivers waiting to enter a major road are likely to be caught out by traffic exceeding the mean traffic speed when attempting to judge appropriate gaps. Clearly, under-estimation of speed of vehicles travelling faster than expected is the problem. If drivers anticipate that on-coming traffic is travelling at or near the speed limit (e.g. 100 km/h), as the study participants appear to have done, and if they set a distance criterion, as also appears to have been the case, serious gap misjudgments will occur with high vehicle approach speeds. Accidents are likely to have more serious human consequences when the speed at crash impact is high.

Hills and Johnson (1980, cited in Hills 1980) also found that speeds of slower vehicles were over-estimated and those of faster vehicles were under-estimated. Inspection of their data suggests that the speed limit in effect at the test sites influenced the participants' expectations and, consequently, their judgements.

4. COUNTERMEASURES

4.1 Causes of Rural T-intersection Accidents

Overall, the results of this study show that drivers aged 60 years and over are at risk in T-intersection environments because of a combination of visual deficits, poor neck articulation and slower reaction time (causing slow clearance of the roadway) that affect detection, perception and avoidance of approaching vehicles. Furthermore, the risk is compounded by their poor estimation of the speed of approaching vehicles once they have detected their presence. The most dangerous errors are the increasing under-estimation of speeds of vehicles that are approaching at speeds over 100 km/h, and the associated willingness to accept smaller gaps as approach speeds increase.

The findings suggest that drivers under 30 years of age are at risk too, primarily because of their willingness to accept small gaps and their tendency to under-estimate high approach speeds. However, the risk may be less than that for older drivers because of their good vision, less under-estimation of extreme speeds, and faster reaction time to clear lanes. Nonetheless, drivers under 30 consistently are over-represented in the national road death and accident statistics. In the present sample the young males had the highest infringement and accident rates, so risk-taking is common and needs to be considered when identifying countermeasures.

The data from the present study clearly show that the major hazard in safe gap judgement for all drivers at T-intersections, but perhaps especially for those older drivers with visual and physical impairments that add to their problems of judgement, is the vehicle that approaches at speeds over 100 km/h. Further, since drivers tend to use distance as the criterion for determining safe gaps, visibility of approaching traffic also is important.

Consequently, countermeasures need to focus on
- keeping the speeds of vehicles approaching junctions at or below 100 km/h, and/or
- ensuring that drivers at the intersection, who intend to move onto the major road, take time to assess the approaching traffic and have a clear sight of approaching traffic for not less than 250 m. The data (cf. Figures 3.8 and 3.9) indicate that this is the distance at which most drivers, especially those over 40 years of age, start making decisions. The following suggestions for countermeasures take these two factors into account.

4.2 Countermeasures for Accident Prevention

4.2.1 Driver Competency

4.2.1.1 Vision testing

The findings from laboratory-based tests in the present study clearly show that a high proportion of the drivers aged 60 years and over had visual defects that are serious enough to impair the judgement necessary for safe driving. These defects need to be detected and, where possible, corrected or adapted (e.g. learning to use monocular depth cues).

More thorough vision testing, possibly using an instrument such as the Keystone VS-II Vision Screener used in this study, would be beneficial.

4.2.1.2 Neck articulation

This factor needs to be assessed, as it helps the driver to see clearly when checking the traffic environment. There is a need for research to establish appropriate standards of functional and restricted articulation because neck articulation, along with stereovision and peripheral vision, all contribute to an analysis of a driver's "Useful Field of View". Yet neck articulation has not been studied outside that of the present research.

Older drivers could improve their field of view by doing at least two head turns, moving through to the extreme of their articulation range, before driving off.

4.2.1.3 Restricted licences (Urban/off-peak/daylight)

Some older drivers may be able to continue to drive, despite sensory or physical deficits, as long as visual conditions and traffic speeds and densities are optimal for them. They may well be willing to trade some freedom of operation for the mobility a vehicle gives them.

Use of restricted licences that limit driving to given areas (e.g. urban) and/or times (e.g. off-peak or daylight hours) may well help to reduce accident probabilities yet allow some continuation of driving.

4.2.1.4 Training to use longer distance gaps

If drivers are using distance as a primary criterion in judging the speed and distance of approaching traffic, it may be useful to teach them to set longer distance gaps as the basis for their decision-making than the study (cf. Figures 3.8 and 3.9) showed them to be doing. This would reduce the risk from under-estimation of high vehicle approach speeds and allow more time to clear the proximal lane(s).

4.2.2 Traffic Speed Enforcement

4.2.2.1 Radar patrols and speed cameras

Use of radar patrols and speed cameras could be intensified on major roads at black spot intersections. Findings in the present study suggest that a driver judging speeds of approaching traffic tends to assume that the traffic is travelling at about 100 km/h, and tends to make distance gap judgements accordingly, regardless of the approaching vehicle's speed. The hazard at these black spots could be reduced by intensifying speed patrols at such points to increase the probability that major road traffic will travel close to the 100 km/h speed limit. Slower, more consistent traffic speed will enhance safe gap judgement.

4.2.2.2 Tamper-free auditory speed cue devices

All new cars sold in New Zealand could be required to have tamper-free auditory speed cue devices that start up when the car reaches a speed of 100 km/h. Some Japanese cars already have these devices. Fitting such devices could greatly increase the probability of drivers maintaining speeds closer to the legal open road limit, since the auditory cue is an aversive stimulus, especially if exposure to it is prolonged.

4.2.3 Road Signs

Give Way signs could be replaced with *Compulsory Stop* signs on T-intersections with moderate to high accident rates or those with restricted view of approaching traffic (i.e. less than the 300 m necessary for older drivers to detect approaching vehicles and to judge a safe gap), possibly in combination with:

- *Reduce Speed* and/or *80 km Speed Limit* signs on the major road;
- Large signs warning that a dangerous intersection is ahead, sited on both the major and minor roads;
- Appropriate prior warning signs of *Stop* or *Give Way* on the minor road before the intersection is reached, allowing the driver to prepare for appropriate action.

4.2.4 Road Engineering

4.2.4.1 Black spot T-intersections

Black spot T-intersections, especially those which are state highway junctions or have higher traffic densities, could be made safer by installation of roundabouts. These would reduce approach speeds of traffic and allow more time for judgement and for clearing the intersection.

4.2.4.2 Realignment

Realignment or re-siting of intersections with limited field of view of on-coming traffic. Such intersections allow little time for the driver to detect, judge and respond to approaching traffic. Creating an environment in which more time is available for such actions reduces the probability of accidents caused by these factors. It allows the driver, who is entering the major road, the time and distance to detect and assess oncoming vehicles. It also allows the drivers of approaching vehicles time to evaluate the situation and take any action necessary to avoid an accident.

4.2.4.3 Clearing vegetation

Roadside vegetation, hedges and trees can obscure vision at intersections. Attention to regular cutting back or clearing roadside vegetation that cause visual obstructions could increase the safety of the intersection.

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APPENDICES

APPENDIX 1 DRIVER BEHAVIOUR QUESTIONNAIRE

(Transit New Zealand Study)

Please be assured that all information provided by you will be kept confidential.

Participant Number:
Date of Birth:
Gender (Male/Female):

1. SENSORY IMPAIRMENTS

1.1 Are you required to use corrective lenses when driving? (Yes/No)

1.2 Do you use a hearing aid? (Yes/No)

1.3 Please list any other physical impairments that may affect your driving.

2. DRIVER'S LICENCE

2.1 Date when gained learner's licence (applicable to persons who have a licence for less than five years):

2.2 Date when gained full licence:

2.3 Have you ever failed a driver's licence test?

If yes, (a) when?
(b) please give reasons

2.4 How did you learn to drive? (tick one, or more)

driving school [ ]
parents/relations [ ]
friends [ ]
self-taught [ ]

2.5 If a driving school was involved, how many lessons did you have?

____

2.6 Have you attended a defensive driving course?
(Yes/No)

3. DRIVING BEHAVIOUR

3.1 How much driving did you do in the last 12 months?
less than 5,000 km ☐
5,000 - 10,000 km ☐
10,000 - 15,000 km ☐
15,000 - 20,000 km ☐
over 20,000 km ☐

3.2 On average do you drive mostly
(a) less than 1 day per week ☐
1 - 2 days per week ☐
3 - 4 days per week ☐
more than 4 days per week ☐

(b) on week-days ☐
on weekends ☐
both ☐

(c) country areas ☐
city areas ☐
both ☐

(d) by self ☐
with others ☐
both ☐

(e) with radio on ☐
with radio off ☐

3.3 Do you consider your driving ability to be
below average ☐
average ☐
above average ☐

3.4 Is the car you mostly drive
automatic ☐
manual ☐

3.5 Colour of the car you mostly drive

3.6 Year of manufacture ____________

3.7 Is the car you mostly drive
owned by you only ☐
jointly owned ☐
borrowed ☐
company owned ☐

3.8 Do you regularly drive different cars?
(Yes/No)

4. TRAFFIC INFRINGEMENTS (non-parking)

4.1 Have you had any traffic tickets (other than parking) in the past 5 years?
(a) If yes, how many?

(b) What were the offences? (please list)

____

____

____

____

5. TRAFFIC ACCIDENTS

5.1 In the last five years, have you been involved in any traffic accidents as a driver? (Yes/No)

If yes, how many? _____________

5.2 If you have been involved in a traffic accident in which you were the driver (in the last five years), who (if anyone) do you believe was at fault in the most recent incident?
no fault ☐
own fault ☐
another driver's fault ☐
partly own fault and partly other driver's fault ☐
other (please state) ☐

5.3 Please briefly describe the circumstances of the most recent accident (continue on back of page if necessary).

5.4 In the last five years, have you (as the driver) been involved in any traffic accidents at an intersection? (Yes/No)

If yes, (a) how many? (last five years only) [ ]

(b) what type of intersection?
crossroads in city [ ]
crossroads in country [ ]
T-junction in city [ ]
T-junction in country [ ]
roundabout [ ]

(c) how many of the intersections were controlled by:
stop sign [ ]
give way [ ]
traffic lights [ ]
uncontrolled [ ]

Please briefly describe the circumstances of the most recent intersection accident. If this is the same accident as described in question 5.3, please ignore this question.

APPENDIX 2 KEYSTONE VS-II VISION SCREENER

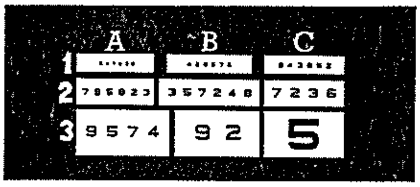
Eight stereoscopic test targets, eight miniature lamps and a supplemental lens system provide eighteen tests of ten visual functions. Most of the stereo tests are given at both far point (optically equivalent to 20 feet) and near point (equal to 16 inches). A supplemental lens system provides the optical equivalent of 26 inches.

Normally, all testing — monocular as well as binocular — is done with both eyes open and seeing. This insures the rapid detection of such problems as suppression (the mental blocking out of the image perceived by one of the eyes.) Problems of this type would escape conventional wall chart test techniques. (However, the VS-II does incorporate a means of occluding either eye, should this be desired.)

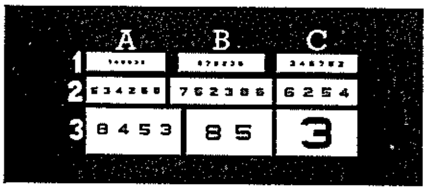
All tests are scientifically correct and psychologically sound. The complete series can be administered in only three to five minutes.

Stereoscopic Test Targets

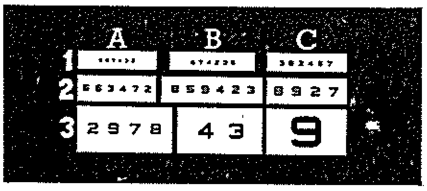
Each of these permanently-mounted test targets presents somewhat differing images to the two eyes: The eyes must work together to fuse — or merge — both images into a single image, as shown in the illustrations on this page.



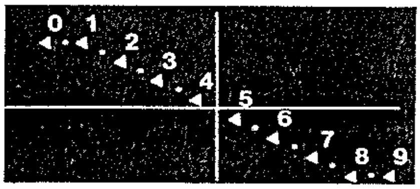
Acuity: Right Eye - *Tests at far and near points*
The acuity (fineness of visual discrimination) of the right eye is checked while the left eye is open and seeing. Results are calibrated at values from 20/200 to 20/20.



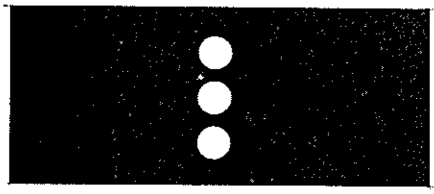
Acuity: Left Eye - *Tests at far and near points*
Similar to the preceding test, this target measures the visual acuity of the left eye while the right eye is open and seeing. Snellen values of from 20/200 to 20/20 are provided.



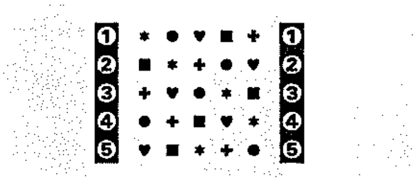
Acuity: Binocular - *At far, 26″ and near*
This acuity test presents the same number groups to *both* eyes simultaneously, provides seven ratings ranging from 20/200 to 20/20. All three acuity targets employ modern *Sloan-type* numerals without serifs (finishing strokes).



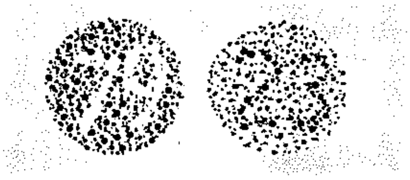
Phoria (eye coordination) - *Tests at far and near points*
Are the eyes balanced to work together with comfort and efficiency? This target measures vertical *and* lateral phorias (the tendency of an eye to turn in, out, up, or down) in prism diopters.



Fusion - *Tests at far and near points*
Here's a check of one of the basics of visual efficiency: Whether the images seen by the two eyes merge into a single, integrated image. Two balls are presented to each eye. They should fuse into a single column of three balls.



Stereopsis - *At far and near*
This 3-D target measures *stereopsis*, depth perception, due solely to the coordinated use of the eyes. The subject must name the symbol on each line that stands out from the others. A correct answer on row four shows 75% stereopsis.



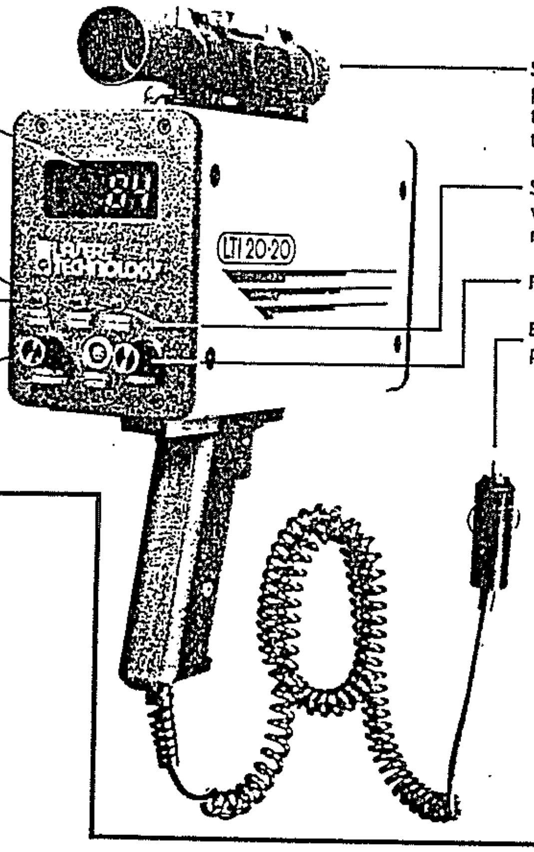
Color perception - *Two targets at far*
Each target presents numbers "hidden" in pseudo-isochromatic symbols. They indicate if a severe (red/green) or mild (blue/violet) discrimination deficiency exists, but do not further clarify the disorder.

Horizontal Peripheral Visual Fields Test

Miniature lamp (LED) targets between the lenses and recessed in the temple (side) areas of the viewing head show how far to the side a subject's visual field extends when (s)he looks straight ahead. Persons with "tunnel vision", a grossly-restricted peripheral field, are quickly identified. The targets are selectively lit by individual buttons on the control panel to show a 45° *nasal* field and to check *temporal* fields at angles of 85°, 70°, and 55°. (A total field of from 100° to 130° can be measured for each eye.) The eyes may be tested separately or together.

APPENDIX 3 LTI 20X20 LASER SPEED/DISTANCE DEVICE

LTI 20•20 LASER SPEED DETECTION SYSTEM FEATURES



LED Readout: Displays speed of vehicle coming to or going away from instrument. Also displays target range in feet utilizing speed/range function.

Test Mode: Verifies that all numeric segments of display are operable.

Test Mode: Allows user to check alignment of scope and laser beam providing absolute certainty that laser is on target.

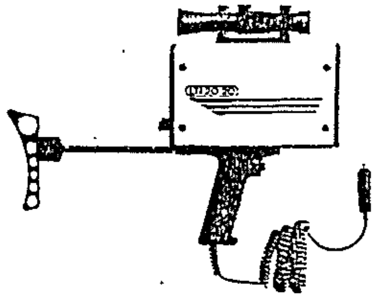
Display Intensity: Display is adjustable for maximum versatility in extreme light conditions.

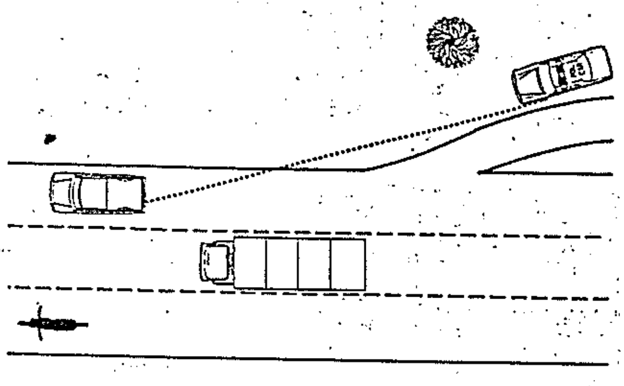
Sighting Scope: Scope incorporates a red dot to pinpoint the target vehicle while still providing the user plenty of field of view to visually identify the vehicle being monitored.

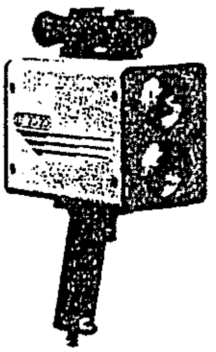
Speed Range: The LTI 20•20 measures target vehicle speed and also provides target range measurement capabilities.

Power On/Off

Easy Replacement Fuse: Located in plug, provides absolute surge protection.







APPENDIX 4 INSTRUCTIONS FOR EXPERIMENTS

Instructions for Experiment 1. Driving Test

Researcher gives the driver the following instructions.
"We want to measure the time it takes you to make a right hand turn, in your car. Wait until there is no traffic from either direction and make the turn in your own time just as you would when you were saying "Yes" or "No" earlier. We would like to do this five times. Any questions?"

Instructions for Experiment 2. Gap Acceptance Testing

Researcher gives the driver the following instructions.
"Shortly you will be asked to make a series of judgements about when you think it is safe to make a right turn. You are to imagine that you have stopped at a T-intersection, so at the start of each trial you will be asked to look straight ahead. After a period of time, I will say "Look now". You will then evaluate the traffic condition (ignoring the traffic from the left) and decide if it is safe to turn right onto the main road."

(a) Special instructions for the threshold trials (continuous evaluation until unsafe)
"For the first five trials, if it is safe, tell me by saying "Yes". If it is not safe, say "No". If you say "Yes", continue to say "Yes" until it becomes unsafe, then say "No". Please respond by giving a simple and distinct "Yes" or "No"." (Experimenter gives an example, followed by a practice trial.) "Are there any questions?"

(b) Special instructions for the signal detection trials (single evaluation)
"For the next five trials, all you have to do is say "Yes" if it is safe, and "No" if it is not safe." (Example and practice trial.) "Are there any questions?"

Instructions for Experiment 3. Speed Estimation Testing

Researcher gives the driver the following instructions.
"Next you will be asked to judge the speed of oncoming traffic. Please begin by looking directly across the road. When I say "Look now", look to your right and estimate the speed of the oncoming traffic. When I ask you for the speed, look straight ahead again and tell me the speed. Do you prefer to answer in km/h or miles/h?" (Example and practice trial.) "Any questions?"