

# HUMAN FACTORS & ROAD CRASHES - A REVIEW OF THEIR RELATIONSHIP

prepared by: WENDY A. MACDONALD Department of Mechanical Engineering, University of Melbourne

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Depar	tment of Mechani	cal Engineerin	9,		
Unive	rsity of Melbour	me,			
Gratt	an Street, Parkv	ville, Vic 305	2		
onsor (Name a	nd Address)				
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**stract :** Research findings within each of the major "human factor areas of road ifety research are reviewed. Attention is confined to research relevant to the revention of road crashes rather than to the amelioration of their effects. The main oncern is the road user: road and vehicle factors are considered only to the extent that hey interact with road user characteristics in relation to crash prevention or causation. He purpose of the review was to establish those areas in which there is the greatest need or further research; accordingly, the review concludes with a list of recommended esearch topics.

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Prepared by:

Wendy A. Macdonald

Department of Mechanical Engineering University of Melbourne

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# CONTENTS

INTRODUCTION	1
DRIVER BEHAVIOUR	3
INEXPERIENCED DRIVERS	14
DRIVER TRAINING	21
DRIVER LICENSING	29
ENFORCEMENT	39
MASS MEDIA PUBLICITY	44
VEHICLES	48
MOTORCYCLISTS	50
CYCLISTS	54
PEDESTRIANS	60
ROAD ENVIRONMENT	67
ALCOHOL AND OTHER DRUGS	76
FUTURE RESEARCH NEEDS	86
REFERENCES	91

# INTRODUCTION

The purpose of this report is to review the current state of knowledge within each of the major "human factor" aspects of research relevant to the prevention of road crashes, and to indicate those areas in which there is most scope for further, cost-effective research.

The research specification prepared by the Office of Road Safety (ORS) stated that:

"There is general recognition that road safety in Australia has now reached the stage where the easier gains have been achieved and that further spectacular improvements, particularly in the road and vehicle areas, are unlikely.

Increasing attention is therefore being directed at the road user, the so called "human factor" in road crashes. .. The ORS is concerned that outside the alcohol and drugs area, basic issues in human factors and road crashes remain unresolved. .. The ORS Research Program is placing increasing emphasis on human factors issues. At the moment this work is limited mainly to the alcohol and drugs area."

Thus, the primary concern of the present review is the road user, rather than vehicles or roads. However, road crashes occur within an interactive road/vehicle/human system, so road and vehicle factors are considered to the extent that they have been shown to interact with human factors in relation to crash occurrence. The role of alcohol and drugs, having been the

-1-

subject of recent ORS-funded work, is paid less attention than other major areas of road-user research. The review is concerned with factors related to crash causation or prevention, rather than with the prevention of injuries once a crash has occurred.

The literature reviewed was chosen mainly on the basis of a computer search of the following data bases: IRRD, NTIS, Social Scisearch, Psychinfo, Dissertation Abstracts, Sociological Abstracts, LASR, ARRD, and SDC(Orbit IV)Human Factors.

The research proposal submitted to the ORS specified that the main subject areas covered by the review would be Road-User Characteristics and Behaviour, Road-User Education and Training Programs, and Operation of Relevant Aspects of the Legal System; the computer search strategy adopted was chosen with these general topics in view. However, the content of individual research reports typically overlaps two or even all three of these topics, and the present report has been organised into sections to accommodate most conveniently the nature of the literature reviewed.

#### DRIVER BEHAVIOUR

Johnston and Perry (1980) began their discussion on needs and priorities in driver behaviour research as follows: "...both the quantity and quality of research on matters related to drivers and driving have increased exponentially in recent years. Unfortunately, the now vast literature is a morass of relatively disconnected elements, compounded by the fact that behavioural scientists of all persuasions continue to join the fray with piece-meal approaches." This statement remains true in 1985.

Two different approaches to the development of accident countermeasures were outlined by Johnston (1980). In the first case, accidents are viewed as being due to personal attributes of individual drivers, so countermeasures are aimed to improve individual driver performance by such means as licensing standards, education and training, and by legislation, enforcement and punishment.

In the second case, the driver is seen as an element in a wider, interacting system. Drivers perform their driving tasks according to the relationship between the demands imposed by road, traffic, vehicle and other environmental conditions and their own abilities and limitations. This approach has led to improvements in the vehicle and environment to facilitate better performance of the driving task.

-3-

Related to this dichotomy of approaches to the development of countermeasures is a division of theoretical models of driver behaviour into those emphasizing the importance of drivers' motives, needs and purposes, and those emphasizing the interaction between driving skill and external factors related to the immediate driving situation: models termed by Johnston and Perry (1980) as "motivational" and "task" conceptualisations of driving.

It is often stated that level of driving skill is relatively unimportant in determining a driver's risk of crashing. It is claimed that this conclusion is supported by evidence that racing car drivers, who presumably have a high degree of driving skill, have a higher on-road crash rate than the rest of the driving population (Williams and O'Neill, 1974). However, while their vehicle control skills are undoubtedly highly developed, there appears to be no basis for assuming that their perceptual and cognitive skills related to operating a vehicle in traffic are any better than normal.

It is undoubtedly true that some people drive in such a way as to create more opportunities for crashes than do others. However, there is currently insufficient evidence to determine the relative importance of driving skill (especially its perceptual/cognitive elements) and deliberate risk-taking propensity in explaining this situation. Undoubtedly, both skill and motivational factors are important.

Under most driving conditions driving is a largely self-paced task, in that drivers control their own speed and to

-4-

some extent their degree of interaction with other vehicles. By its nature, driving in traffic at normal speeds can never be completely free of risk, but to the extent that it is self-paced, drivers can increase or decrease their level of risk. The ability of drivers to estimate their own level of risk, and the possible effects of perceived risk on driving behaviour and hence on objective risk, are highly contentious issues.

Wasielewski (1982) reported an observational study to determine relationships between driver and vehicle characteristics, and unrestricted vehicle speeds, the latter being interpreted as reflecting drivers' willingness to expose themselves to risk of an accident. Higher speeds were observed for younger drivers, drivers with prior accidents and convictions, newer cars, heavier cars, and cars with no passengers.

It has been hypothesized that drivers attempt to maintain a constant level of perceived risk (Taylor, 1964, 1976; O'Neill, 1977; Brown, 1979), effort expenditure (Michon, 1973) or task load (Curry et al, 1975). In each case, this would be expected to be associated with a fairly constant level of physiological arousal; indeed, Taylor (1976) wrote that "If there are no other particular purposes, the driver will presumably choose a pace according to the level of arousal he finds most pleasant".

Wilde and Murdoch (1982) went so far as to claim that "there are good reasons for believing that all variables, other than motivational ones, only have a marginal influence upon the causation of accidents. Modifying these other variables can at

-5-

best have short-term effects upon the accident frequency-severity compound". They base this claim on the theory of "risk homeostasis", as propounded by Wilde (1982).

According to this theory, the target level of risk of individual drivers is the major determinant of accident rate. Wilde and Murdoch identified four groups of factors determining the target level, and associated with these four groups are four different tactics to decrease accident rate: (a) decrease the perceived benefits of risky behaviour, (b) decrease the perceived costs of cautious behaviour, (c) increase the perceived benefits of cautious behaviour, and (d) increase the perceived costs of risky behaviour.

They suggested that countermeasures which are designed to affect a specific aspect of behaviour, such as speeding or wearing a seat belt, will be followed by, at best, a short-term reduction in accident rate, and that it is better to direct countermeasures towards accidents themselves, such as administrative incentives for accident-free driving.

The risk homeostasis theory and its less extreme variants have recently received a great deal of attention, with critics disputing their validity on both empirical and theoretical grounds.

Wilson and Anderson (1980) pointed out that it is important for such hypotheses to be thoroughly evaluated "because of the potential political significance of the constant risk hypothesis for the opposing factions who would block or encourage the

-6-

development of safety measures in vehicles and roads".

Michon (1973) criticised the theory on theoretical grounds. He argued that absolute levels of objective risk encountered by drivers are so low as to be scarcely perceptible, and suggested that it is not perceived risk but expenditure of mental effort which drivers attempt to maintain constant at some optimal level.

The concepts of perceived risk, task demand and mental effort are not independent. Macdonald (1979) defined task demand as that aspect of total workload which determines effort expenditure. Individual motives, and the driver's perception of task difficulty, were viewed as factors additional to the objective difficulty of the task which affect effort expenditure. Perceived risk is conceptually independent but empirically has been shown to be a component of perceived task difficulty and hence a determinant of effort expenditure (Herbert, 1974).

Macdonald (1979) pointed out that "In considering the determinants of effort expenditure, and hence of task demand, a major question which emerges is the relative importance of task and operator characteristics". Parallel to this, Johnston and Perry (1980) wrote that a major unresolved issue in this area is "the extent to which perceived risk is a task-related judgement and the extent to which it depends on personal factors."

Naatanen and Summala (1976) considered the effects of personal factors on driving behaviour in terms of various motives affecting perceived gains and losses experienced by drivers.

-7-

These include a need to conform with peer group social norms (which in young males might be expected to encourage high speed), exhibitionism (e.g. of driving skill, which would be expected to be at its maximum in young males), hedonism (e.g. the sensual pleasures of competing in traffic), emotions associated with various task and non-task events, and goals such as those relating to trip time. In the context of the risk-compensation hypothesis, such personal factors might be seen as possible determinants of the individually preferred level of perceived risk (or effort expenditure).

There is some evidence that driver risk-taking is related to age, sex, driving experience (Colbourn, 1978; Wilson and Anderson, 1980) and general propensity for risk-taking as measured by a questionnaire (Robinson, 1975). However, most previous experiments used laboratory tasks of very dubious validity in relation to the driving task, even when they were designed to simulate driving or aspects of it.

Results bearing on the risk-compensation hypothesis are generally equivocal. Watts and Quimby (1980) recently reported an experiment in which ratings of perceived risk were made by drivers under normal traffic conditions. There was a significant relationship between perceived risk and estimated objective risk. For locations where drivers were free to set their own speed, there was a high correlation between calculated safety margin (based on speed and sight distance) and perceived risk, which appears inconsistent with the risk-compensation hypothesis.

Wilson and Anderson (1980) conducted two experiments, one on

-8-

a test track and one on rural roads in normal traffic, to investigate the effects of varying task difficulty (tyre type) on driving speed and associated levels of perceived risk and risk-taking. In the test track experiment they found that a group of older, more experienced drivers perceived the change in tyre type and varied their speed in accordance with what the authors referred to as the risk-compensation hypothesis, although in view of the nature of their independent variable (tyre type) it might more appropriately have been termed the effort-compensation hypothesis, since tyre type was known to affect task demand but no evidence was available concerning the effects of tyre type on accident risk.

A group of young drivers in the test track experiment did not perceive the changed difficulty of their driving task associated with different tyres and did not vary their speed; their over-all level of perceived risk was higher than that of the older drivers, even although they (the young drivers) had a lower mean speed. In the on-road experiment neither group of drivers varied their speed according to tyre type. Wilson and Anderson concluded that it is essential that age and skill variables should be included in any model of driver risk-taking behaviour.

There are several alternative or complementary reasons why the behaviour of young, inexperienced drivers might be expected to be less affected by level of objective risk than behaviour of older, more experienced drivers. Most obviously, it is likely that young drivers' perceptual and decision-making skills are less developed, resulting in greater insensitivity to some task

-9-

input stimuli (as found by Wilson and Anderson, 1980) and in more misperceptions of objective hazard. Evidence consistent with this proposition was reported by Clayton (1972), Russam and Sabey (1972) and Konecni, Ebbesen and Konecni (1976).

Another consequence of extreme inexperience is likely to be a generally higher level of perceived risk, associated with a higher level of task demand due to a lower level of driving skill. It is arguable that inexperienced drivers are frequently unable to reduce task demands and/or perceived risk to a comfortable level because of the constraints of other traffic and of social norms.

Thus, during the process of learning to drive (not confined to the pre-licence-test period) drivers may be virtually forced to tolerate high levels of perceived risk in spite of which, they gradually learn, accidents are rare. In this way, they might become de-sensitized to high perceived risk so that after perhaps two or three years of driving experience they may be relatively insensitive to changes in objective risk.

This hypothesis is consistent with results of a laboratory simulation experiment reported by Colbourn (1978), who found that young drivers with less than one year of driving experience had high levels of perceived risk and were sensitive to changes in objective risk. A slightly older group having four to five years of driving experience showed no sensitivity to changes in objective risk, and rated it as uniformly very low.

These results are of dubious validity because of the

-10-

inadequacies of the task, as recognized by Colbourn. However, he commented that "These results do perhaps suggest that the initial nervousness of the novice driver gives way to overconfidence after a couple of years, which is in accord with the accident statistics." It must be further postulated that as level of skill increases further, occasions of very high task demand, or relatively high objective risk, become rarer and drivers regain their sensitivity to such occurrences.

In addition to the possible effects of low levels of driving skill, it may be hypothesized that young people, independent of their skill, tend to operate at higher levels of perceived risk due to characteristically different personal motives associated with driving, of the type discussed by Naatanen and Summala (1976).

For example, it is a common belief that young males tend to derive more pleasure and less discomfort from perceived high levels of hazard than do older drivers - that young males deliberately take high risks "for kicks". This belief might be experimentally tested by obtaining ratings from drivers of different ages of driving situations, varying in perceived risk, on a scale ranging from boring through relaxing and stimulating to stressful.

One of the most carefully conducted and ambitious experiments in this field of recent years is that of Quimby and Watts (1981), which investigated the relative importance of a variety of human factor variables to driving performance, using a representative sample of 60 drivers, both on the road and in a

-11-

simulator. Special attention was given to identifying any factors that vary with age that might help explain the known relationship between age and accident rate. Factors considered included: visual and perceptual abilities, risk taking, reaction time measures, biographical, attitudinal and personality variables and physiological measures of stress. Driving performance was assessed by obtaining accident and exposure histories for the previous three years and also by considering the number of driving errors committed on a test drive.

Results indicated that the variable measuring risk taking (derived from the drivers' speeds at potentially hazardous locations on a test route) was most highly correlated with driving performance. It was not clear whether drivers set inappropriate speeds because they failed to recognise the potential danger or because they were prepared to take "calculated" risks while driving, or a combination of these factors. However, it was suggested that those drivers whose speeds resulted in the greatest risk taking tended to consider the danger or risk to be low.

Also, there were significant inverse correlations between number of hazards reported by drivers on the test drive and both observed driving errors and previous accidents. A variety of factors changed significantly with age. For example, the youngest and oldest age groups were on average slower to respond to potential hazards in the simulator and also adopted a lower safety index while driving on the road. The latter result was attributed mainly to the larger average response time to hazards of the older drivers and the faster speeds selected by the

-12-

younger drivers. In the simulator, the younger drivers appeared to be least sensitive to changes in risk.

Evans (1984, 1985) has argued convincingly that the risk homeostasis theory should be rejected "because there is: no convincing evidence supporting it (and) much evidence refuting it"! He conceded that "Although we show here that the theory is false and should be discarded, it has nonetheless contributed to our understanding of safety phenomena".

Evans (1984) presented instead a "human behavior feedback" theory, which includes the risk homeostasis theory as a special case. It is based on the concept that when a system is changed, users normally do not ignore the change but adapt their behaviour to it in some way. According to the risk homeostasis theory, this adaptation is always directed to maintain a desired level of risk; according to Evans' theory, the adaptive behaviour is highly variable and often unpredictable, particularly in the case of car driving because it is largely self-paced.

In a 1985 paper, Evans analysed a wide variety of traffic accident data and concluded that "almost whatever accident data one looks at, one finds evidence refuting the (risk homeostasis) theory." He admitted that his own theory has the major disadvantage of not making predictions as to the outcome of traffic system changes for which there is no prior experience, but in his own defence, pointed to the inaccuracy of predictions based on the risk homeostasis theory, and concluded with an apt quotation from Albert Einstein: "Everything should be made as simple as possible, but not simpler."

-13-

# INEXPERIENCED DRIVERS

There is considerable evidence that an individual's personal characteristics are significantly related to probability of accident involvement. The most comprehensive, recent investigation of the role of such factors was reported by Treat (1977).

He wrote that "Those driver attributes found to be best substantiated by the literature as predictive of poor driving were found to include age (under 25 or over 60); sex (male); marital status (unmarried or separated/divorced, unless under 25 years); occupation, education and income (lower); prior accident/violation history; heavy alcohol/drug use; records of conflict with social institution; current life changes and personal problems; depression; anti-social feelings, and, poor impulse control."

However, Johnston (1980), in a discussion of research on individual driver characteristics, concluded that "research into the relationship between individual differences among drivers and accident occurrence has produced few conclusive results and almost nothing of direct benefit to the formulation of road safety measures." It has become clear that what is missing from such research is attention to the mechanisms (in terms of driving behaviour) by which personal characteristics affect accident involvement.

Age and experience are highly correlated, and their

influence on accident rate, particularly in the case of males, is probably greater than that of any other personal driver characteristics; thus, it appears worthwhile to consider the evidence concerning the variety of ways in which young and inexperienced drivers have been found to differ significantly from the rest of the driver population.

Clayton (1972) obtained data from on-site investigations of crashes and from follow-up interviews, on the basis of which he developed a classification of road-user errors associated with the accidents. He found that young, inexperienced drivers were significantly more likely to have committed "excessive speed" and "panic reaction" errors than older, more experienced drivers. The former type of error tended to be related to restriction of sight distance, usually by a bend or crest, and to vehicle defects such as inadequate brakes or steering. The latter type of error was primarily caused by unexpected movements of other vehicles.

Clayton suggested that "A possible explanation of this phenomenon is that the reacting road users, because of their lack of driving experience, may have found it impossible to process all the available perceptual information accurately and guickly. Thus, instead of responding rationally to the situation, they merely tried to stop as quickly as possible. In doing so, they tended to lose control of their vehicles."

Treat (1977) found, in a detailed investigation and analysis of accident causation, that the driving error category termed "excessive speed" was particularly characteristic of drivers under 20 years of age. Such accidents typically occurred on

-15-

curves. Also, it was found that young drivers were significantly more likely to be driving vehicles in poor mechanical condition.

Jenkins (1979) carried out a two-part postal survey of a national (U.K.) sample of drivers taking their licence test. In the first part of the survey, all drivers, regardless of test outcome, were questioned. In the second part, conducted one year later, only those who had passed were included. It was found that young drivers and those with past driving or riding experience had higher pass rates than the others. In the second part it was found that young drivers, including those with previous motorcycling experience, had higher accident rates than other new drivers. All new drivers were more prone to accidents at night (and possibly in bad weather conditions) than more experienced drivers.

Generally more informative than accident data are the results of studies of driving performance, independent of accident occurrence. The main focus of such studies has been on drivers' ability to perceive hazards of various sorts, to judge "risk", and what has been termed their cognitive ability.

Benda and Hoyos (1983) noted that studies of "hazard perception" or "hazard cognition" may be divided into two groups: those in which drivers, confronted by either filmed or real traffic situations, are required to identify hazardous objects and events, and those in which drivers confronted by the same sort of stimulus material are required to rate the total hazardousness of the situation. They pointed out that the second type of task is more difficult, since it demands the integration

-16-

of different aspects of the situation to produce a single rating. A common source of difficulty is confusion of estimates of personal risk of an accident, which is influenced by personal risk-taking propensity and level of driving skill, with estimates of the objective hazard inherent in the traffic situation.

Benda and Hoyos conducted a study to determine the major variables influencing drivers' estimates of hazard. They found that the most important single variable was information load; situations in which information input is fairly low and unchanging, and in which relatively little control action was required, were regarded by all drivers as low in hazard. However, the effects of driving experience were significant. The more experienced drivers were much more likely to be able to integrate various aspects of situations into a single "hazard" attribute, regardless of whether the hazard arose from fixed environmental features such as intersections or from other moving vehicles.

Less experienced drivers were more likely to base their estimates on specific aspects, particularly poor environmental conditions such as bad weather and unfavorable road conditions including intersections, narrowing roads, etc. The latter result is consistent with the conclusion of Soliday and Allen (1972) that the failure of less experienced drivers to recognise hazards often results from their excessive concentration on non-moving objects.

Bragg and Finn (1982) compared young, inexperienced males with older, experienced males in terms of their rating of the riskiness of a variety of driving situations. Ratings were made

-17-

as a driver, as a passenger, and from photographs and videotape. They found that the inexperienced drivers considered speeding to be less risky, but driving on snow-covered roads to be more risky, than did the experienced drivers. As the young drivers became more familiar with a particular location such as an intersection, they reduced their rating of the risk associated with negotiating it, whereas experienced drivers did not.

Also, the inexperienced drivers saw themselves as significantly less likely to be involved in an accident than their peers, while experienced drivers saw their own chance of accident involvement as comparable to that of their peers. The authors suggested, in view of these results, that increasing inexperienced drivers' level of perceived risk would be helpful in reducing their level of objective risk taking, and hence should decrease their rate of accident involvement.

Bristow, Kirwan and Taylor (1982) reanalysed data from some of the well-known observational studies of Quenault in terms of two categories: affect (representing Quenault's active/passive dimension) and cognition (representing Quenault's dissociative dimension). Quenault categorised dissociated drivers as either active or passive on the basis of a measure which is highly correlated with drivers' speed relative to that of other traffic; Bristow et al. suggested that, since speed is presumably selected on the basis of some desired level of risk-taking, the active/passive dimension may be thought of as one of "affect", in contrast to the dissociative dimension which is one of

-18-

Quenault et al. (1968) found that a group of very young drivers drove faster than an older group, and noted that, of the dissociated drivers, all of the young ones were "active" while all the older ones were "passive". There were no differences in the speeds of the "safe" drivers in either group. This led Bristow et al. (1982) to suggest that "the change in speed (perhaps in level of affect) with age may only apply to drivers whose cognitive skills are poor; young drivers with good cognitive skills are not the ones who drive faster".

The finding of Bragg and Finn (1982), reported above, that inexperienced drivers rated speeding as less risky than did older drivers, seems to suggest a cognitive rather than an affective explanation for the difference in actual driving speed. This interpretation is consistent with the finding of Kirwan, reported in Bristow et al. (1982), concerning comments by male drivers on the hazards perceived in a film taken from a "driver's eye" viewpoint of some city driving. Number of comments categorised as cognitive in nature increased with the driving experience of the subjects.

Also consistent with these findings are the results of Brown (1982), who reported that less experienced drivers were relatively poor at identifying a variety of distant hazards, although they did not differ from experienced police drivers in the detection of near hazards, which is not surprising in view of evidence that experienced drivers' visual fixations and scanning patterns are generally located further ahead of the vehicle than those of inexperienced drivers. In addition, Brown concluded that inexperienced drivers, especially males, appeared to be

-19-

overconfident of their vehicle control skills, particularly in terms of their ability to recover from error.

On the basis of such results, Brown (1982) proposed a model describing the effects of age and experience on accident probability in terms of the differential rates of acquisition of vehicle control and cognitive aspects of driving skill. Inexperienced drivers, particularly young males, apparently fail to understand the nature and importance of cognitive skills, do not appreciate their own lack of them, and consequently are overconfident and drive at inappropriately high speeds.

In this context, it is pertinent to note that two of the very few reported instances of pre-licence driver training programs which resulted in significant reductions in subsequent accident rates were described by Veling (1980) as "cognitive" in nature. They are described in the section on driver training.

Thus, inexperienced drivers appear to be relatively poor in perceptual and cognitive aspects of driving skill and over-confident of their ability to avoid crashes. Since driving is to some extent self-paced, their actual risk of accident is likely to be higher than their perceived risk, although personal characteristics such as sex and personality would contribute to large individual differences in the relationship between perceived and actual risk.

-20-

# DRIVER TRAINING

Attempts to evaluate and improve the effectiveness of driver training programs are made extremely difficult by the lack of agreement as to what constitutes safe and proficient driving performance. This demands information on the nature of "normal" driving behaviour in a variety of situations, for comparison with accident-related behaviour in such situations.

Evidence on the sort of driver behaviour which may lead to accidents is available from several accident investigations. For example, Clayton (1972) defined errors in terms of criteria laid down by the U.K. Ministry of Transport Highway Code, any contravention of the Code being termed an error. Errors were then classified on the basis of the human decision-making model of Welford (1960) into six categories: failure to look, misperception, excessive speed, panic reaction, other types of decision error, and error of implementation.

Accident data from on-site investigations and follow-up interviews were then analysed in terms of this classification. Failure to look (28.5%) and excessive speed (25.3%) together accounted for over half the errors.

Treat (1977), reporting a large scale and very comprehensive analysis of data from on-site investigations and follow-up interviews, stated that human factors were found to be probable causes in 93% of accidents, compared to 34% for environmental factors and 13% for vehicular factors. Major general categories

-21-

of human errors were: recognition errors (56%), decision errors (52%), performance errors (11%) and critical non-performances (2%). More specifically, most common causal factors were: improper lookout (23%), excessive speed (17%), inattention (15%) and improper evasive action (13%).

Shaoul (1976) discussed the relationship between driving errors, defined in terms of compliance with U.K. Highway Code procedures, and accident occurrence. While recognising that a direct relationship between correct performance of procedures and the absence of accidents could not be substantiated, she pointed out that the relationship between error rate and driving experience had been found to be the same as that between accidents and experience.

As part of an investigation into the relationship between driver training and subsequent accident rates, in-vehicle observations were made of driving behaviour when encountering a variety of hazards along a route. Behaviour was assessed in terms of its degree of compliance with the relevant Highway Code procedure. For example, the Code specifies that, when driving through green traffic lights, drivers should look right/left/right: it was found that at most traffic lights fewer than a third of drivers followed this procedure, but that at a few, geometrically complex intersections, the proportion was much higher.

The major determinants of behaviour were driving experience and the road configuration; these outweighed any effects of training. In particular, the specific activities performed during

-22-

a manoeuvre such as turning right at a signalised intersection were found to vary significantly according to the particular intersection characteristics.

Shaoul suggested that "Individual failures to carry out a particular sequence which is carried out by the overwhelming majority of drivers would yield useful information about individual drivers. On the other hand, if certain types of road configurations regularly produce activities on the part of the road user over and above those required by the advised procedures, this would go some way towards indicating where and in what circumstances the procedures are deficient."

Shaoul (1976) argued that effective driver training demands the establishment of a taxonomy of the various hazardous situations and manoeuvres arising from different road and traffic configurations, and a comprehensive list of the characteristics of invariably negotiating such hazards safely.

In view of the current lack of such knowledge, it is not surprising that formal pre-licence driver training programs are generally found to be ineffective.

For example, a comparison of range, non-range and informal driver training methods was reported by Strang, Deutsch, James and Manders (1982). Four groups of young males were randomly assigned to one of four experimental groups. Students in two of the groups undertook a four-day course, receiving five hours of behind-the-wheel training, six hours as an observer of either an instructor or another student driving, and 11 hours of classroom

-23-

instruction. The difference between the two groups was that in one, all driving was done on a range, while students in the other group had two hours training on public roads. A third group received the same amount of behind-the-wheel training, all on public roads from a commercial driving school, and a two hour lecture. The fourth group received no formal training.

At the completion of training there were no significant differences in driving skill, as scored by observers, but all three trained groups were superior in knowledge to the control group, and the two range groups were also superior in attitude test scores. However, analysis of accident and violation data for the following two years showed no significant differences between any of the groups.

Dreyer and Janke (1979) reported a very well-controlled study in which the effects of "range" and "non-range" driver training courses were compared for two groups of approximately 2000 high school students, randomly assigned. The driving range accommodated 16 vehicles at a time, and was designed to simulate traffic conditions found in city driving, except that speeds were restricted to 24 kilometers per hour (40 kph on the simulated freeway merging ramp). Students received instruction and feedback via radio from an instructor in a control tower.

Range students had 8 hours of range training, while non-range students had none. Both range and non-range groups received driving simulator training (10 hours and 12 hours, respectively) and on-road training (2 hours as driver and 4 hours as an observer for range students, and 3 hours as driver plus 9

-24-

hours observing for non-range students).

The main finding was that range students had significantly fewer accidents during the subsequent year. In contrast, the performance of range students on tests of driving skill during training and at licensing was essentially equivalent to that of the non-range students, as was the amount of time they spent in acquiring their licences. Unfortunately, data on distance driven by the two groups after licensing was not reported, so it is not known whether the smaller number of accidents experienced by range students was due to their lesser exposure or to greater skill in avoiding accidents.

Simonnet, Delaunay and Forestier (1982) compared results of the traditional method of driving instruction with those from a new, more intensive system which was introduced in France in 1976. Unfortunately, the authors give little detail of the content of the intensive course.

"With the intensive method, a simulator is sometimes used for part of the practical instruction and some driving may be undertaken on a test track as well as in traffic. Under these circumstances learners spend time in the driver's seat; and they also spend time in the passenger seat "looking and learning", while another learner drives the car. ... Although the intensive method includes much more practical instruction than the traditional method, the numbers of hours spent actually at the wheel are much the same in both cases. ... Candidates taught by the intensive method take the full examination as a rule on the last day of the course. Thus the time taken is identical to the

-25-

length of the course; that is, 5-11 days for those successful at the first attempt and a few days more for the remainder."

They concluded that "There are no substantial differences ... between the two methods of driving instruction. ... Most of the problems encountered by drivers, once they have passed the test, are the same, whichever method of instruction they received: after 4 months, manoeuvres that still cause concern are overtaking, parking and joining main roads. The exception is the ability to steer a straight line and take corners, in which learners who have had the intensive course experience less difficulty than those who learned by traditional methods.

It appears that the intensive method, at least in the form applied in France, does not bring any important change in the behaviour of recently qualified drivers, and probably has no perceptible effect on the level of road safety." Unfortunately, the two groups of drivers in this study were not randomly assigned, and no information on their accident records was reported.

In a comparison of U.K. drivers who were taught to drive by professional driving instructors with those who were taught by family members or friends (Raymond, Jolly, Risk and Shaoul, 1973) it was found that the formally trained group had fewer subsequent crashes, but this was explicable entirely in terms of their lower distance driven. There was no evidence that the training course had reduced accident rate per unit distance.

Shaoul (1976) commented that "The chief outcome of driver

-26-

education was not behavioural, but social." The main results of the training course were that students subsequently drove less, particularly at night, than those in a control group. Evidently the information provided by the course was used by the students at a conscious decision-making level. This implies that driver training courses might usefully spend more time on the way drivers might use their cars, particularly considering occasions on which the decision might be made not to use the car at all.

A related suggestion was made by Hampson (1984). He pointed out that drivers who habitually adopt large safety margins, or who have a low target level of risk, are able to commit many more errors without being involved in an accident than those who adopt low safety margins. He then suggested that, "Drivers might be better informed of the errors they are prone to commit and be taught to adjust their safety margins accordingly." Such an approach would, for example, encourage fewer overtaking manoeuvres rather than concentrate on perfecting overtaking techniques.

Cameron and Davidson (1983) wrote that "The novice, who has no spare capacity and lacks knowledge, is under constant pressure to develop skill quickly. An attitude of caution must be overcome in order to reach an acceptable level of practical ability. The critical factor is the inability of the novice to recognise the onset of conditions that exceed his capacity. Rather than attempt to modify attitude, driver training should perhaps concern itself with providing knowledge and experience that will allow the novice to expand the inherent limitations of his ability in safety."

-27-

Cameron and Davidson (1983) quote Harrison (1968) as follows. "Until a driver knows what to look for and how to read the road and traffic pattern he can't know when to make his moves. One of the chief causes of accidents is failure of drivers to recognise hazards while they still have time to take defensive action to avoid them." In this context it should be noted again that pre-licence training programs which are "cognitive" in nature have been shown to reduce subsequent accident rate (Veling, 1980).

For example, in a study by Schuster (1978) an experimental and a control group of just over 50 new drivers each (randomly assigned) were compared in terms of accident record for each of the three years following completion of a "cognitive accident-avoidance training program". The experimental group received training with immediate item feedback and testing twice, with item feedback; the control group received no training feedback and no testing. In the first year of driving, the controls were involved in four times as many accidents; in the subsequent two years there was no significant difference between the two groups.

It seems, then, that the driver training programs most likely to be effective are those which emphasise the perceptual and cognitive aspects of driving skill. However, much more work is required to determine the precise nature of such skills.

-28-

# DRIVER LICENSING

Budd, Boughton and Quayle (1982) pointed out that there is no strong evidence that the existence of a licence testing procedure has any beneficial effect on road safety. In other words, the licence test does not appear to "screen out" drivers who are most likely to be involved in crashes. In any case, it is unlikely that a licensing program which prevented a significant proportion of people from driving would be politically acceptable.

The licensing system is intended to exclude people whose physical disabilities render them unsafe. It is sometimes suggested that extremely agressive or socially maladjusted people should also be prevented from holding a driving licence. However, the sensitivity and predictive power (in terms of subsequent accident rate) of tests to diagnose such individuals are quite inadequate for general licensing use.

For example, Treat (1977) devised a questionnaire on the basis of a literature review of the relationship between personal and social attributes of drivers and their accident involvement. The questionnaire was administered to accident-free and accident-repeater groups of drivers. From their responses a discriminant function was calculated and then validated with two new groups of high and non-accident young drivers; the function correctly assigned 12 of 14 (85%) of matched subjects. However, this unusually high success rate was achieved with small groups of carefully matched individuals; its predictive power would not

-29-

be sufficient to justify its use in license testing.

Miller and Schuster (1983) investigated the long-term predictive power of a personality test by using multiple regression to predict current accidents and violations for a large sample of drivers who 10-18 years previously had completed a driver attitude survey. It was found that current violations were predictable on the basis of these data, while current accidents were not.

Current licence tests attempt to screen out people with dangerously defective vision. However, the validity of this procedure is debatable.

In a driver vision testing study reported by Treat (1977), a battery of 12 tests, covering such visual skills as acuity for static and dynamic targets, visual field and dynamic movement detection thresholds, was administered to various groups of accident-involved and accident-free drivers. Of the more reliable measures, dynamic visual acuity was found to be the only one to be significantly and consistently related to accident involvement. Static acuity under normal illumination - at present the only visual check to be included in most licensing tests was not related to accidents.

Cole (1979) concluded from a long-term investigation of the need for a peripheral vision standard as a licensing requirement that there was no significant evidence of the need for such a standard. While there was evidence of higher crash rates per mile for drivers with limited visual fields, they had lower total

-30-

mileages, so that their risk in terms of absolute numbers of accidents was no higher than normal.

Burg (1974) found that "Of all the vision variables, dynamic visual acuity is the most consistent predictor of accidents. It significantly predicts daytime, left or left front and right or right front accidents".

However, Hills and Burg (1978), in a follow-up to this work, failed to find direct relationships between poor visual performance and high accident rate for either young or middle-aged drivers, and for old drivers, where there was a significant but weak relationship, the authors stressed that the relationship was not necessarily causal. They wrote that "These findings lend support to current attempts to find perceptual tests of visual performance that are much better accident predictors than the largely classical sensory tests of vision studied here".

Janke and Kazarian (1983) investigated the accident record of drivers with bioptic telescopic lenses and found that they had a significantly higher rate than the populaion average. However, it was pointed out that their accident risk was no greater than that of many other sub-groups, and recommended that they should not be prevented from holding licences. Instead, consideration should be given to the imposition of licence restrictions.

Thus, although there is evidence of associations between some types of defective vision and crash involvement, these relationships are so weak that, in view of the expensive nature of proper vision-testing procedures, the introduction of more thorough vision testing as a pre-requisite for licensing is probably not justified.

Similarly, drivers with other forms of physical disability do not constitute a particularly high-accident group. There is some evidence that drivers in all such categories modify their driving practices to compensate for any reduction in ability.

Drummond, Torpey and Wood (1983) summarized and reviewed all evidence concerning the role which known medical conditions should play in relation to driver licensing. They concluded that "The onset of some medical conditions would appear to increase the risk associated with the driving task. Physical handicaps are the exception to this rule. Indications are, however, that this increase in risk is generally more than offset by changes in the type and amount of driving." Furthermore, "older drivers are generally aware of their limitations and modify their driving patterns accordingly. A comparison of the costs of implementing a retesting program (for older drivers) and the expected cost reduction achieved by a lower accident rate indicates that retesting is unlikely to be cost effective."

The latter recommendation, that retesting of older drivers with each licence renewal would not be cost-effective, is at odds with the recommendation of the Australian House of Representatives Standing Committee on Road Safety (1982) that drivers aged 55 years and over should undergo visual re-testing every 5 years. There appears to be inadequate evidence to justify such a procedure for all drivers over 55; retesting should be

-32-
confined to those older drivers who come to notice.

In relation to medical conditions, the recommendations of Drummond et al. (1983) appear to be soundly based. They concluded that compulsory periodic medical testing would not be cost-effective, but that the feasibility of introducing a system of compulsory reporting by medical practitioners of medical defects likely to affect safe driving should be investigated.

Probably the most unfortunate feature of the present licensing system is that, in the absence of an established method of driver training, the content of the licence test tends to determine the content of driver training procedures. This situation can only be remedied by the establishment of proper standards of safe and proficient driving performance, as discussed in the section on driver training. The licence test should then be modified to increase its validity.

Research on the perceptual and cognitive abilities of drivers of varying levels of experience, particularly in relation to hazard perception, was discussed in the section on Inexperienced Drivers. This research area appears to be one of the most promising for the future development of more valid licence test procedures as well as for the improvement of driver training programs.

The educational value of licence testing would also be improved by testing knowledge of safety-related information with obvious specific application to individual drivers, such as that concerning the relationship between blood alcohol content and

-33-

alcohol consumption patterns, the effects of tyre inflation and tread depth on vehicle handling and crash involvement, etc. This would be consistent with the earlier conclusion that driver training should place more emphasis on information relevant to the conditions under which cars should be used.

Research to define the most appropriate content of the knowledge-testing component of present licence tests is warranted. The content should be periodically revised.

Apart from the potential educational value of the licence test, the licensing system itself might serve to facilitate a safer learning process by imposing more controls and restrictions on the conditions under which novice drivers operate.

This is the rationale for a graduated licensing system, in which restrictions are imposed on blood alcohol level, times at which driving is permitted, other passengers, vehicle engine capacity, maximum permitted speed, etc. Such a system is intended to decrease task demands so that novice drivers are less likely to experience dangerous overload. The system might also serve to increase pre-licence driving experience, particularly if the minimum age for a learner permit is reduced, so that the official learning period is extended. In view of the reported tendency for young, inexperienced males to be over-confident of their driving ability, such an extension may well be beneficial.

Discussing minimum desirable licensing age, Budd et al. (1982) noted that major U.S.A reviews recommended 16 years as an appropriate minimum licensing age, and New Zealand authorities

-34-

have recently concluded that their present age of 15 years should be retained (White,1982). Budd et al. pointed out that an Australian decision would have to take into account "the degree of mobility the community is prepared to grant young people relative to their higher accident rates".

Budd et al.(1982) proposed that, in view of the lack of evidence that the present probationary licence system is effective in reducing accidents, the Victorian licensing system should be modified so that driver training could commence at 16 years, unsupervised daytime driving be permitted at 17 years, subject to having passed an appropriate test, and full licensure be granted at 18 years, subject to the requirement that no driver under 19 years of age have a measurable level of blood alcohol.

There is general agreement that some such graduated licensing system is desirable, but its implementation is hindered by lack of agreement on the appropriate nature of its associated controls and restrictions. Research to resolve this issue should be carried out to enable the system to be implemented. Its effects on the subsequent driving exposure and experience of participant drivers should be carefully monitored and evaluated.

Another question related to licensing concerns the conditions under which licences should be suspended or revoked, and the associated measures which might be taken to improve the performance of people with an unsatisfactory driving record as indicated by the accumulation of violations and associated de-merit points, and/or accidents. Tannahill and Tarrants (1982) reviewed evidence for the effectiveness of a wide variety of driver licensing and improvement procedures. Of the 33 measures considered, the following nine were specified as being potentially cost-effective: motorcycle testing, motorcycle testing and training, provisional licensing, knowledge testing (passenger car), warning letters, instruction programs, individual counselling, probation restriction, suspension/revocation.

Budd et al. (1982) noted that compulsory driver improvement programs, aimed at improving the performance of drivers coming under adverse notice, have been shown to be effective (Peck and Harano, 1975). Such programs may include individual counselling, group educational meetings, rehabilitative programs for drink/driving offenders and referral to instructional programs. Their successful implementation is, however, dependent on the existence of a detailed, accurate and up-to-date data base.

There is evidence for the effectiveness, in some programs, of both negative and positive sanctions. For example, it has been found that drivers who were under threat of licence suspension because they had accumulated a large number of demerit points had a lower crash rate per kilometer than drivers who had accumulated fewer points and were therefore not in any immediate danger of losing their licence (Chipman, 1982).

It has also been found that when drivers were promised a one-year free extension of their driver's licence if they could remain accident and conviction free during the following year, there was a significant reduction in their accident and

~36-

conviction rates (Harano and Hubert, 1974). Incentives are generally more likely to be effective than rewards (Wilde and Murdoch, 1982).

A more expensive but for some drivers probably a more effective approach is compulsory completion of a safe driving course. For example, in one program, accumulation of six demerit points results in a warning letter; accumulation of a further two points brings a summons to attend a driver improvement clinic. Following a knowledge test, training in safe driving practice is given, at the completion of which drivers are under threat of licence suspension if more points are accumulated during the subsequent period. By comparison with a similar group of drivers who were dealt with by penalties or threat of licence suspension only, attendance at the clinic was claimed to result in a 30% greater improvement in driving record (Hult, 1964).

Other approaches include individual interviews and group educational meetings, informal judicial hearings and probation violator hearings. All have been found to be effective to varying degrees at some time. However, there appears to be no countermeasure which invariably or even usually can be assumed to be effective.

In view of the conflicting evidence, and the multiplicity of countermeasures which have been employed, research is required to determine which aspects of the programs are the most cost-effective. Cameron and Macdonald (1973), in a detailed literature review and discussion of driver improvement programs, reached a similar conclusion. It is probable that some types of program will be more suitable for inexperienced drivers, and others for older recidivists whose problems are associated with their social and personal characteristics.

# ENFORCEMENT

Evidence concerning the effectiveness of different types of enforcement operations in terms of their contribution to road safety was comprehensively reviewed by Cameron and Sanderson (1982). They concluded that greater emphasis should be given to general deterrence rather than detection/apprehension, and in view of this it was recommended that the following priorities should be given to police operations:

\*(1) General deterrence operations aimed at fixed offences. This could take the form of highly visible random check stops, or publicised and visible police patrols. The target offences should include drink-driving and failing to use an available seat belt.
(2) General deterrence operations aimed at transient offences at signalised intersections. This could take the form of sporadic but frequent visible patrols or, perhaps with higher cost-effectiveness, visible mechanical surveillance devices accompanied by advanced warning signs. The target offences should be disobeying any traffic control signal.

(3) General deterrence operations aimed at transient offences at non-intersection locations. This should take the form of a mixture of visible and non-visible operations (marked and unmarked patrol cars, or visible and hidden speed detectors) and this form of operations should be publicised. The target offences should include crossing double centre-line and exceeding rural speed limits by more than 25 km/h.

(4) Selective detection/apprehension operations. This should take the form of traditional detection/apprehension methods focussed on the times and locations where substantial numbers of accidents

-39-

have occurred, and on illegal road user behaviours for which there is well-based evidence of a relationship with increased accident risk or increased injury severity. On present evidence the target offences should be: (a) drink-driving (b) failing to use available seat belts (c) disobeying traffic control signal (d) crossing double centre-line (e) exceeding rural speed limits by more than 25 km/h.

The consequences of some apprehensions should be publicised to support the effects of general deterrence operations."

They noted that, while mass media publicity appears to increase the effectiveness of all kinds of general deterrence operations, it is not essential in the cases of highly visible random check stops or highly visible intersection operations.

Sanderson et al. (1983) critically reviewed the methodology of the major studies on which the above conclusions were based, and pointed out that there are relatively few studies of the effects of police enforcement which supply adequate information concerning the exact quantity and nature of the enforcement procedures. Other common weaknesses are a lack of recognition of the stochastic variation in road accidents and of the "regression to the mean" phenomenon, and the absence of adequate control data.

Nevertheless, the general findings appear to be sufficiently reliable to warrant their application as recommended. The optimum mixture of different types and durations of enforcement operations requires further research.

-40-

A recent study of the effects of speed limit enforcement on vehicle speeds by Hauer et al. (1982) appears to have avoided most methodological pitfalls. The form of enforcement was clearly specified, and speeds were measured before, during and after it occurred, at the enforcement site, at sites various distances upstream and downstream from it, and on a control section of road with no enforcement occurring. The effects of varying time and distance separations from the point of enforcement were determined (i.e. time and distance "halo" effects), and the effects on habitually fast and habitually slow drivers, as well as on the overall speed distribution patterns, were determined by means of identifying individual licence plates.

Their conclusions included the following. Average vehicle speed at the enforcement site was reduced to close to the posted speed limit, but the change in standard deviation of the speed distribution varied between experiments, being sometimes reduced and sometimes not. Both the habitually slow and habitually fast drivers tended to reduce their speed more than median speed drivers; this tendency of fast drivers tended to reduce the variance of speed distribution, but the reduction was counteracted by the behaviour of slow drivers.

The "downstream distance halo" decayed exponentially, as found in earlier studies; the effect of enforcement was reduced by half for every 900m downstream from enforcement. There was also an "upstream distance halo", which the authors assumed to be due to the use of CB radios, light flashing, and in one experiment to prior experience of the enforcement.

-41-

The "time halo" appeared to be the only phenomenon affected by the quantity of enforcement. It appeared that the effects of one day of enforcement had disappeared within 3 days, but several days of exposure resulted in a much longer term effect. The authors stated that "A full week after the last day on enforcement, the residual speed reduction shows no sign of abating". However, increasing the number of days of enforcement had no effect on the size of the reduction in speed. Such research has obvious implications concerning the most effective patterns of speed limit enforcement.

Hashimoto (1979) measured the effects of enforcement on "vulnerable" behaviour at an intersection. Vulnerable behaviours were selected on the basis of the possibility that they could result in a collision and the examination of police accident records to determine the major categories of such actions associated with collisions. Enforcement did not entail apprehension and followed three different patterns, varying according to whether there were one or two police officers and to where they were located at the intersection.

All enforcement patterns significantly decreased the occurrence of vulnerable behaviour, but there were significant differences between the forms and significant interactions between form of enforcement and type of vulnerable behaviour.

The advantages of using the occurrence of vulnerable behaviour rather than accidents as a measure of enforcement effectiveness are obvious, but, as the author acknowledged, the most convincing evidence of its validity would be the

-42-

establishment of an empirical relationship between changes in accident rates and vulnerable behaviour.

Lyneham (1983) reported results of a literature review and questionnaire survey to investigate motivational, attitudinal and psychological factors influencing road user behaviour, as a basis for "the introduction of enforcement procedures that would increase an individual's sensitivity and subjective risk of being detected, prosecuted and penalised".

It was recommended that attempts should be directed to: "increase the perceived level of enforcement; increase the perceived risk and actual rate of detection; increase the perceived risk of prosecution/penalisation; increase penalties, particularly fines." The point was made that such measures should be introduced together so that, for example, the deterrent value of fines would be maximised by concurrent increases in their size and in detection rate, accompanied by appropriate publicity.

### MASS MEDIA PUBLICITY

In the area of drinking and driving, mass media advertising is of considerable value in communicating specific information. However, it appears to be of limited value in changing attitudes.

These conclusions were drawn from the "Slob" publicity campaign, conducted via television, radio and press on behalf of the N.S.W. Traffic Accident Research Unit (Freedman and Rothman, 1979). The campaign was designed to increase knowledge about alcohol and traffic crashes and to change attitudes towards drinking and driving among young people aged between 17 and 30 years. It was part of a research program to define the educational potential and limitations of mass media campaigns related to drink-driving, and constitutes one of the most thorough evaluations of the potential value of this approach to decreasing crash rate.

The campaign resulted in significant improvements in both knowledge and attitudes, but the changes in attitude were small. In view of the latter result, and of the fact that existing attitudes to alcohol use are continually reinforced by advertising, the authors commented that "When a relatively small change in attitude occurs at high cost and when a continuing educational effort is required to build on this change, it becomes important to look to alternatives to the mass media campaign". They went on to suggest that an education program aimed at secondary school children might be a more cost-effective way of changing attitudes in the long term, with mass media advertising perhaps serving to reinforce the desirable attitudes existing in the community as a result of the school-based program.

According to Wood (1980), attempts to change behaviour by use of mass-media campaigns may operate by promising some gain to individuals who behave in the desired way, by threatening some loss as a consequence of failure to behave in the desired way, or, more traditionally, by attempting to change people's attitudes, on the assumption that this will lead to changes in behaviour.

While there is evidence that modifying behaviour results in modification to related attitudes, there is no convincing evidence that the reverse is true. Cameron and Macdonald (1973), in a review of driver training research, concluded that "Attempts to modify driver attitudes appear to have little effect; it appears to be better, in the case of a problem driver, to attempt to identify his specific difficulties and to help him to overcome them."

It appears, then, that attempts should be directed to changing behaviour rather than attitudes, and there is evidence that, when the target behaviour is clearly specified, a television campaign can be a very effective means of modifying it. Thus. Johnston and Cameron (1979) reported an exceptionally well-controlled field study of the effects of television publicity on the correct wearing of seat belts. Improvements in behaviour were both statistically significant and substantial in

-45-

absolute terms. The authors considered that the elements of the program contributing to its success were as follows. -Target behaviours were: directly related to injury causation; specific and capable of unambiguous demonstration; aspects of a widespread parent behaviour (seat belt wearing) towards which the target group had favourable attitudes.

-The form of publicity: used a message source of high credibility and high status; used a mild fear setting as a motivating factor; comprised a specific, concrete demonstration of the target behaviours.

The success which may be achieved by clearly specifying and demonstrating target behaviours is well illustrated in work reported by Hutchinson, Cox and Maffet (1969). Using a "candid camera" technique, driver errors were recorded at several intersections in a particular county of Kentucky, U.S.A. The recorded segments were presented in a series of two to three minute films on the local television channel over a period of eighteen months. Each type of error was analysed and the correct driving procedure was demonstrated. Analysis of 48 intersections in the county indicated a reduction in the type of errors illustrated of 17.4% and an accident reduction of 12.5%.

Cameron and Macdonald (1973) considered that the most noteworthy feature of this result, apart from the magnitude of the improvement, was the spread of the effect to intersections not specifically illustrated. In other words, specification of the target behaviour at a particular location did not limit the application of the target behaviour to that location. In view of these successful uses of publicity campaigns, in communicating specific pieces of information and in modifying specific aspects of behaviour, a greater research effort should be made to identify those elements of driving behaviour which it would be most beneficial, in terms of crash and/or injury reduction, to modify. This might be achieved by a detailed study of the normal behaviour of high-risk and low-risk drivers in high-risk and low-risk situations. The major obstacle to such work at present is the absence of an established methodology.

### VEHICLES

It is generally accepted that vehicle defects play a very minor role in accident causation.

McLean et al.(1979) found from on-site investigation of accidents in Adelaide that passenger car defects definitely contributed to the causation of 0.8% of accidents and probably contributed to a further 2.8%. Tyre characteristics, both lack of tread depth and mismatch of radial and cross-ply tyres, were the most important single class of defect despite the fact that very few of the accidents occurred on wet roads.

In the same study it was found that motorcycle brakes were not used efficiently by almost half the riders involved in crashes, and redesign of the braking system of motorcycles to eliminate the need for separate control of front and rear brakes was suggested as a potentially effective countermeasure.

From an American on-site accident investigation, Treat (1977) reported that the main vehicular problems involved brakes (5%) and tyres/wheels (4%), with the leading specific problems being gross brake failure (3% of accidents), inadequate tyre tread depth (3%) and side-to-side brake imbalance (2%).

A Melbourne study of accidents involving collisions

with roadside utility poles (Fox, Good and Joubert, 1979) found that "A substantial proportion of accident-involved yehicles have handling characteristics that have been dangerously degraded through use of improper inflation pressures. Efforts should be made to educate drivers and garage attendants on the importance of maintaining tyre pressures at the levels recommended by the vehicle manufacturer."

Since tyre characteristics (inadequate tread depth, incorrect inflation, mismatch of radial and cross-ply) appear from Australian studies to be the most significant vehicle factor, research should be conducted to establish the feasibility and likely cost-effectiveness of improving tyre inflation and replacement practices of drivers and service station staff.

# MOTORCYCLISTS

The effects of inexperience are relatively greater for motorcyclists, in terms of differential crash rates, than for car drivers. Moreover, the very significant decrease in accident rate among novice riders associated with the introduction of a law restricting them to bikes of less than 260cc capacity suggests that at least part of the explanation for the high accident rate is inadequate control skill.

King, Torpey and Wood (1982) documented the effects of the 1979 amendment to Victorian law to restrict learner and first year probationary motorcyclists to motorcycles with engine capacities of less than 260cc. After the introduction of the restriction, learner and first year probationary motorcyclists accounted for a significantly smaller percentage of all motorcycle casualties than previously. Compared to full licence holder casualties, learner permit casualties were 40% lower than expected, and first year probationary casualties were 39% down.

Hurt (1979, 1981) reported findings of a large, on-site investigation of motorcycle accidents in the U.S.A. In 41% of accidents a significant cause was motorcyclist error, typically running wide on a turn due to excess speed or undercornering. Motorcyclists showed significant collision avoidance problems. Most riders would overbrake and skid the rear wheel, and underbrake the front wheel, greatly reducing collision avoidance deceleration.

-50-

McLean et al.(1979) reported similar findings to the above, particularly concerning inadequate use of the front brake. They wrote that "The failure to use the front brake was not confined to inexperienced riders, many of whom did not normally use it. Some experienced riders, who used both brakes regularly, used only the back brake in the emergency situation immediately before the crash."

Jonah and Dawson (1979) investigated the relationship of factors such as age, sex, training and experience to performance on the Motorcycle Operator Skill Test (McPherson and McKnight, 1976). Subjects were administered the Skill Test prior to the normal licensing test. Only data from people passing the licence test were analysed.

Only 30% of these successful licence test applicants passed the Skill Test. Males and younger people were more likely to pass, as were those with the greatest previous experience. Surprisingly, those who had undergone a formal training course were significantly less likely to pass than those who had not. It appeared that those with the least riding experience were the most likely to have taken a training course, and that training had not compensated for their lack of experience.

It has been suggested that motorcyclists should have to undergo an off-road training course to acquire basic control skills before being granted a learner permit to ride on roads. However, research would be required to evaluate possible courses and if necessary to develop an effective one.

-51-

Jonah and Dawson (1979) pointed out that lack of control skill may be a less important cause of accidents than, for example, lack of skill in hazard perception, or risk-taking propensity, and concluded that "more research is urgently required into the importance of poor hazard perception and risk-taking as causes of accidents, not only among motorcyclists but among all vehicle operators".

A major factor in accidents involving motorcycles is the failure of car drivers to notice the presence of the bike. Hurt (1979, 1981) found that the major cause of accidents (64.5%) was failure of car drivers to see and/or give way to the motorcyclist; the most common type of accident occurred when the driver turned in front of the oncoming motorcycle.

It appears that crash rate would be reduced if the motorcycle/rider were more conspicuous, particularly from the front. Thomson (1980) reported a literature review evaluating the role of frontal motorcycle conspicuity in accident occurrence, and concluded that compulsory use of motorcycle headlights would be a cost-effective measure for New Zealand.

Williams and Hoffmann (1979) reported an analysis of Victorian police accident data, in which they found that inadequate motorcycle visibility was a factor in 64.5% of motorcycle/automobile collisions. It was judged to be the sole identifiable cause of 21% of collisions. Once again, inadequate motorcycle conspicuity was a major factor.

Facts concerning the effects of inadequate conspicuity on

-52-

crash rate, together with recommended simple countermeasures such as daytime use of headlights and use of fluorescent colours on clothing, appear to be suitable for inclusion as required knowledge for a learner permit test.

### CYCLISTS

From several recent analyses of accidents involving cyclists (McLean, Brewer and Sandow, 1979; Triggs, Meehan and Harris, 1981; Atkinson and Hurst, 1982) it is clear that, as with motorcyclists, a major problem for cyclists is their lack of conspicuity relative to the larger vehicles which constitute the majority of road traffic.

Thus, Triggs et al. (1981) wrote "The data from this study support previous emphasis on the fact that many bicycles are struck because the motorist fails to see the bicycle in time to avoid a collision. ..

"The problem at night is largely the detection of a bicycle. The use of corner cube reflectors to Australian Standards Association specification on bicycles would be an effective method for providing night time visibility of cyclists. ..Pedal reflectors, while providing a distinctive display, will tend to be less iess important if the recommendations of the "Cyclist Visibility" study by J.F.M.Bryant for the Victorian State Bicycle Committee (1981) are adopted."

Atkinson and Hurst (1982) concluded that the provision of adequate tail lights and/or reflectors constitutes "the most obviously cost-effective means of reducing serious and fatal collisions. ..This measure has perhaps the greatest potential for fatality reduction of anything that can be readily implemented."

Regarding daytime conspicuity, Triggs et al. (1981) pointed

-54-

out that this is mainly a contrast problem, and as such it demands somewhat different countermeasures. "The problem is to modify the small low-contrast target a bicycle represents into a large solid area which will contrast with a great range of conditions in the visual environment. This is where light-coloured or fluorescent clothing, helmets and pannier bags would be effective. The visual target size of a bicycle can be increased by fitting devices of large surface area such as flags or flexible arm-like panels extending from the bicycle frame on the traffic side, providing a broader profile of the bicycle when viewed from the rear. All these aspects of conspicuity lend themselves well to investigation and evaluation in experiments."

Watts (1980) conducted daylight tests, using a peripheral detection task, on a number of clothing items and vehicle attachments intended to increase cycle conspicuity. Jackets were found to be preferable to waistcoats, and the best colour was a fluorescent yellow.

Watts (1983) investigated the use of bicycle spacers designed both to increase conspicuity and to discourage overtaking drivers from passing dangerously close to cyclists Data were gathered by questionnaire and from observers who recorded riding and driving errors. Evidence was generally in favour of their use.

Apart from their lack of conspicuity, another inherent problem with cyclists is that their speed is generally much lower than prevailing traffic speeds. McLean et al.(1979) pointed out that many accidents are to some degree a consequence of this

-55-

large speed differential, and suggested that consideration should therefore be given to reducing the urban speed limit from 60 to 50 km/h. Triggs et al.(1981) also suggested such a measure, at least for residential streets.

The speed differential between cyclists and other road users would also be reduced if cyclists shared the footpath with pedestrians rather than the road with motorised vehicles. McLean et al. (1979) recommended that it should be made legal for a cyclist to ride on the footpath. The standard argument against such a proposal is that pedestrians would be endangered, but the potential consequences of a collision between a pedestrian and a cyclist, particularly a child cyclist, are much less severe than those of a collision between a cyclist and a motor vehicle.

Other suggested legal countermeasures arise from the common observation that "most fatalities are the result of cyclist errors .. Sudden swerves are the biggest single cause of daytime fatalities" (Atkinson and Hurst, 1982). McLean et al.(1979) proposed that consideration be given to allowing cyclists to ride on the right hand side of the road so that, like pedestrians in the absence of a footpath, they would be facing oncoming traffic. They suggested that such a measure would reduce the occurrence of accidents due to child cyclists turning, without looking, into the path of an overtaking car.

Also, Triggs et al.(1981) suggested that "A requirement for box turns, which many cyclists can be seen to execute instead of a centre turn would move the bicyclist from the centre of the intersection to the less exposed side of the carriageway. This

-56-

suggestion although not implemented to date still merits consideration."

There also appears to be a need for greater enforcement of existing laws applying to cyclists. In their investigations of accidents involving cyclists, McLean et al.(1979) observed that there were extremely few cases in which accident-involved cyclists who had committed an offence were prosecuted. They considered that such a situation can only encourage a continuing disregard for road traffic laws. Triggs et al.(1981) suggested that laws regarding bicycle lamps should be more widely enforced.

To date the most widely supported accident countermeasure, at least in relation to child cyclists, is education and/or training. However, as in the case of driver and motorcyclist training, evidence of its effectiveness is largely remarkable by its absence.

Various "bike-ed" programs are now operative in Australian schools. There is evidence of their effectiveness in improving children's test performance (Trotter and Kearns, 1983), but there does not appear to have been any thorough evaluation of their effectiveness in terms of changes in participants' behaviour in traffic under normal conditions, in their exposure, or in accident rate. Such research should compare before and after the training program not just for participant children but also for a matched control group of children in a socio-economically and environmentally similar area.

-57-

Preston (1980a) investigated the effects of a children's cycling proficiency training course in which, unfortunately, participants were self-selected. However, it was found that children who failed the proficiency test, having completed the course, had much higher subsequent accident rates than all other children. Thus, while there was little evidence for the effectiveness of the training course, the test itself was evidently a valid measure of skills relevant to safe cycling.

Triggs et al.(1981) provided a good summary of what is required of a satisfactory training program.

"There are five aspects of bicycle education which should be considered. The first is a knowledge of road law and traffic movement. Children in particular need to be taught the rules which mediate traffic behaviour.

The second concerns bicycle operation skills. These are perceptual-motor and control skills that need to be acquired. Thirdly, both these aspects need to be integrated with practical supervised experience on actual roadway...

Fourthly, the rules and behaviour learned should be enforced. This would require co-operation between education and enforcement authorities and some considerable change in community attitudes. The last aspect of bicycle education concerns its very nature. ..children do not have the capacity to make sound judgements in traffic upon which correct decisions about appropriate behaviour can be made. Therefore, the aim of any bicycle education programme possible should be the modification of children's behaviour in traffic, rather than an attempt to impart wisdom."

MAtkinson and Hurst (1982) stressed the need for the teaching

of basic skills such as maintaining a steady course while looking behind and/or signalling, the proper choice of lanes and position within lanes.

Development of accident countermeasures and the evaluation of existing ones requires basic data on numbers of different categories of cyclists in a representative sample of situations. As in the case of both drivers and pedestrians, there is also a need to study the normal behaviour of cyclists, particularly in high-risk locations and in the performance of high-risk manoeuvre

### PEDESTRIANS

Pedestrians are the most uncontrollable category of road system users. They are not subject to any licensing procedure, so cannot be excluded from use of the road system. They are under few legal constraints, and their behaviour is more unpredictable than that of any other category of road user.

The three categories of pedestrian who are most commonly involved in accidents are children, old people and those with high blood alcohol level.

The behaviour of child pedestrians has been found to differ from that of adults in a variety of ways. Observations of behaviour in non-accident situations has shown that, according to normal road safety rules, children generally display safer road crossing behaviour than adults; they are more likely to stop at the kerb before crossing, and less likely to cross diagonally (see Firth, 1982). In view of this, and their known physical and psychological deficiencies relative to adults, it appears that children tend normally to compensate for their lesser abilities by being more careful. In fact there may be little relationship between "normal" behaviour and that preceding an accident.

The situation is a complex one in which the major difficulty lies not so much in identifying risky behaviour (in that it frequently occurs prior to an accident) as in determining how, if at all, such behaviour might be reduced below its present level of occurrence. To this end, there is a need for research to determine why it is that child pedestrian behaviour differs from that of adults. For example, is it primarily because of their lesser information-processing ability, or because of an inadequate awareness of the potential danger of roads and traffic, or simply because children are more likely than adults to act impulsively?

Therefore, research is needed to study in detail some of the psychological characteristics of children in relation to potential "target behaviours", to determine whether the behaviour can feasibly be modified to decrease accident risk, and if so, how?

Based on accident statistics, studies of children's abilities and of their behaviour in traffic it is generally agreed that children under the age of about six years old should not be allowed to cross roads alone or to play in or near traffic. There is also evidence that parents, on the whole, do not realise this (see Singh, 1982). Research should therefore be carried out on the best way to communicate such information to parents of young children - a process which should be an on-going one as the parent population changes.

If any Australian versions of European-style "traffic clubs" for pre-school children and their parents are established (see Christie et al, 1983), research should be carried out to compare the behaviour of club children with that of a properly selected control group.

Evaluations of the effectiveness of European clubs generally

-61-

suffer from the absence of a proper control group (since club members and control group members are not randomly assigned). Apart from the problem of club participants being self-selected, it is not clear whether improvements in accident rate following club membership are due to decreased exposure to accident risk, perhaps associated with better adult protection, or to improved child behaviour. It is known that the behaviour of quite young children can be improved under test conditions, but whether this improvement is maintained under normal conditions is unclear.

Did people are also over-represented in pedestrian accident statistics, having an accident rate more than twice that of adults under sixty years old. This fact has been variously attributed to sensory deficiencies, slower reaction times, inability to adapt to modern traffic conditions and poor motor skills. However, there is little evidence to support the importance of such factors, in spite of their inherent plausibility (Grayson, 1980).

There is evidence that elderly pedestrians tend to behave more carefully than younger adults when crossing roads (as do children, who also have a high accident rate), and they are more likely to look before crossing a road but less likely to report having seen the striking vehicle (see Firth, 1982). However, the differences are small and appear inadequate to explain the large discrepancy in accident rates. Apart from this, they exhibit few differences from younger people.

The potential benefits of pedestrian education programs are necessarily limited. The fact that careless behaviour on the part

-62-

of pedestrians is a major contributor to accidents does not necessarily imply that the most effective countermeasures lie in the area of modifying pedestrian behaviour. Modification of the environment may well prove more feasible and cost-effective.

Pedestrian-actuated signals obviously make it easier and safer for a pedestrian to cross a busy road, but installation is limited by application of traffic engineering warrants which require fairly high minimum flows for both pedestrian and vehicular traffic. It has been found that both children and the elderly normally take more care when crossing roads than do others, so it may be presumed that these two high-risk groups would be the most likely to make use of a signalized crossing. (In fact, there is evidence (Firth, 1982) that such is the case with children.) In view of their safety benefits it is suggested that consideration should be given to liberalizing the warrants.

Other environmental countermeasures which should be evaluated are the provision of median strips in undivided, urban arterial roads, where practicable; the use of barrier fences to channel pedestrians to safe crossing places; amd improved lighting at night in high risk locations (McLean, Brewer and Sandow, 1979; Jordan and Young, 1982). Such countermeasures are likely to be particularly effective in the case of drunk pedestrians.

Wade, Foot and Chapman (1982) pointed out that the layout of residential streets is a major factor influencing child pedestrian accidents. Measures to restrict vehicle access, speed and traffic flow through residential areas have been shown to

~63-

reduce accident rates. It seems that the environmental measures most likely to affect child pedestrian accidents are those measures which force drivers to reduce their speed and acknowledge the presence of children in the child's own and neighbouring streets.

Howarth and Gunn (1982) proposed that "Since most child pedestrian accidents occur in residential areas near to the child's home, ..in such areas children should be given similar rights, and similar protection, to that which all pedetrians now receive on pedestrian crossings. ..There are some other minor engineering measures which would help. ..Roads should be made narrower rather than wider, junctions should be made sharper rather than smoother, while corners and bends in the road should be accentuated rather than straightened."

Wade et al.(1982) noted that environmental measures which might radically affect adult pedestrian accident rates are less easily discerned. Adult accidents tend to occur on major roads; the effects of alcohol, rain and darkness have been isolated as important variables.

McLean and Woodward (1983), discussing changes in the pattern of pedestrian accidents in Adelaide over the previous two decades, noted that "The marked changes that have occurred in the road and traffic environment in metropolitan Adelaide over the past two decades have reduced the relative frequency, and possibly the severity, of pedestrian accidents.

 $_{\odot}$  For example, "In the mid-1960s it was estimated that about

-64-

one-quarter of the pedestrian accidents in the first Adelaide in-depth study (Robertson, McLean and Ryan, 1966) might have been prevented had a pedestrian crossing been available. ..By the late-1970s the number of pedestrian crossing had been increased tenfold and yet there was still considerable potential for prevention by installing even more crossings. Based on the cases covered by the second in-depth study, one-eighth of the pedestrian accidents might have been prevented in this way."

However, "The pedestrian who takes undue risks, whether it be through immaturity, as with children, intoxication or infirmity, is unlikely to benefit greatly from these changes to the road system. It therefore comes as no surprise that the percentage of careless pedestrians was considerably higher in the second in-depth study than in the first."

It is clear, then, that both educational and environmental measures are necessary. Preston (1980b) emphasized that the potential benefits of safety education of children are necessarily limited, and that "The provision of safe play areas, reduced speeds in residential areas, and the provision of safer crossing facilities on main roads could be much more effective." On the other hand, a recent study by Fortenberry and Brown (1982) demonstrated a significant reduction in pedestrian accidents for 6-7 year olds in four cities in Alabama, following implementation of a safety education and training program directed at this age group and conducted through schools.

One major approach to decreasing pedestrian accidents is to investigate these accidents to provide information on the

-65-

specific actions of pedestrians and drivers immediately preceding the accident, on road and traffic characteristics of the accident site, and on personal characteristics of the pedestrian and driver. In this way, information is obtained on areas and locations with large numbers of accidents, and on those categories of pedestrian who are most often involved in accidents.

However, in interpreting this information it is essential to be able to calculate accident risk in terms of the total numbers of different categories of pedestrians at a particular site, and the normal rate of occurrence of those actions of pedestrians and drivers which have been found to occur quite often immediately prior to accidents. Such information on normal behaviour is currently lacking. It is needed not only for a better understanding of pedestrian accident causes, but to permit the proper evaluation of the effectiveness of education programs.

-66-

# ROAD ENVIRONMENT

The role of environmental factors in crash causation, as revealed by accident investigations, is not large. For example, Treat (1977) reported that the main environmental factors were view obstructions (12%) and slippery roads (10%). Most obstructions were those limiting sight distance at urban intersections, and more than half consisted of trees and bushes. Another large category was parked vehicles, many being parked illegally.

Treat pointed out that, in interpreting such data, it should be noted that "only certain types of objectively-defined deficiencies or problems were able to be assessed. Thus, the absence of a divided highway would not be considered an accident cause, even though in fact an installation of such a highway might have served to prevent an accident." Once again, the point is made that the identified accident causes do not necessarily indicate the most effective countermeasures.

The value of a great many engineering accident countermeasures is well established. Delaney (1972) listed a wide variety of measures which have been shown, in specific studies, to be highly effective. For example, McLean, Offler and Sandow (1979), reported that roadside objects played a role in determining the consequences of about one-third of accidents which they investigated in Adelaide, and it has been shown that the elimination of hazardous roadside objects is clearly beneficial in safety terms, although not always cost-effective.

-67-

Fox et al. (1979) concluded from a study of collisions with roadside utility poles that "urban roadsides in Australia are made unnecessarily hazardous by the presence of badly located, unyielding utility poles. About one in ten urban road fatalities results from a collision with a pole. .. A program of loss-reduction is made feasible by the fact that .. the small proportion of poles involved in the majority of accidents can be identified from simple site measurements."

Symons and Cleal (1982) tested and evaluated the predictive techniques developed by Fox et al.(1979). The techniques were found to be effective for roadside objects at mid-block locations on major roads, but ineffective for other locations. Pak-Poy and Kneebone (1982), also applying the technique developed by Fox et al. (1979) found that "Where theoretical risk levels are high .. there is good aggregate agreement between predicted and reported accident rates. Where theoretical risk levels are medium to low .. there is little aggregate agreement".

If engineering improvements to the road environment are to be other than ad hoc in nature, they must be based on hypotheses concerning interactions between the environment and road users. The environment is a major source of information on which drivers make decisions. Thus, modifications might be directed to enhance perception, improve attentional sampling or align expectancies with reality. It has been suggested that a significant proportion of "looked but failed to see" accidents result from perceptual failures because the object collided with was not expected in that context.

-68-
For example, in road-rail crossing accidents it has been found that most drivers were familiar with the accident site, and that a major contributing factor was low driver expectancy of encountering a train. One of the recommended countermeasures is to greatly increase the conspicuity of the train engine, since warning signs associated with the site, rather than with the hazard itself (the train) suffer from low credibility (Wigglesworth, 1979). There is evidence that many other warning signs suffer a lack of credibility for the same sort of reason (see Macdonald and Hoffmann, 1984).

Another example of the importance of expectancy is the observation that drivers generally perceive the overall standard of a road and adjust their behaviour accordingly. Therefore, consistent alignment standard is as significant, in terms of safety, as the specification of a particular minimum standard (McLean, 1980).

Related to the above is the principle that road users should be able to estimate accurately and quickly the real level of task difficulty. In many cases it is probably more cost-effective to make hazards perceptible than to eliminate them completely, because the presence of known and readily identifiable hazards at least sustains alertness.

Boone and Idaho (1979) found that more experienced drivers were better able to distinguish between geometrically similar high-accident and low-accident curves on rural roads. They concluded that "The superior ability of some subjects to

-69-

discriminate accurately between high- and low-accident sections suggests that a panel of experts may be able to evaluate roadway sections using accident potential as the criterion. Modifications could then be made to the roads prior to the occurrence of accidents".

It was suggested that a curve may have a high accident rate either because of the presence of irrelevant information, making it difficult for drivers to extract relevant information, or because drivers are overloaded with information and cannot respond quickly enough because of their high speed and/or the large amount of information present.

Hungerford and Rockwell (1980) compared the effectiveness of various novel forms of roadway delineation for use on rural curves. It was concluded that "delineation systems can positively modify driver behavior on high-accident rural curves (i.e. reducing speed and correcting lateral placement). Long-term impact was much less than the "night after effect", suggesting adaptation by local drivers. Novel delineation systems are justified on two-lane rural curves with high night-time accident rates where most victims are not local drivers."

Just as crashes on curves in rural roads are often due to inadequate or inappropriate visual information delineating the nature of the curve, so the danger of an "easy" situation, such as an open intersection, is increased if it appears to be even easier than it is. In such cases a possible countermeasure is artificially to increase task demands by the use of road humps,

-70-

deceleration cues.

Rumar (1982) wrote that "Maybe the purpose of the human factor efforts should not be to make the task as simple as possible but to improve road user possibilities to estimate accurately and quickly the real level of difficulty. A difficult situation (e.g. a curvy road) is probably not dangerous if the real difficulty is recognised. On the other hand, an easy situation (e.g. an open intersection) is probably dangerous if the road user thinks it is even easier than it is."

Alcohol-affected drivers, or those affected by fatigue, are particularly prone to becoming sleepy or actually falling asleep at the wheel. Suggested countermeasures are the use of rumble strips in locations such as prior to curves on long, straight stretches of rural road, and the provision of road shoulders of very different texture from the road surface. The conspicuous delineation of rural curves, as discussed above, is also effective in such cases (Johnston, 1983).

If vehicles do leave the highway, due to the effects of alcohol, fatigue, inexperience or whatever, a crash is less likely if the shoulders are clear of objects such as posts and trees. Graham and Hardwood (1982) studied the safety effectiveness of clear recovery zones on two-lane highways, four-lane freeways and four-lane divided nonfreeways and found that the cost-effectiveness of roadside design improvements varies widely between highway sections due to differences in accident rates, traffic volumes, terrain, required construction quantities, unit construction costs, and right-of-way

-71-

requirements.

Prevailing road, traffic and environmental conditions are the prime determinants of speeds selected by drivers, even where absolute speed limits apply. If such limits are set unreasonably low then it is not surprising that drivers largely will be disobedient, given the practical constraints on enforcement of legal limits.

Ruschmann, Joscelyn and Treat (1981) stated that "For traditional enforcement procedures to effectively deter speeding, large increases in funds and personnel would be required. Therefore, strategies other than the legal approach for managing the speed crash risk should be considered." Arman (1982) also emphasised the importance of "self-imposed driver compliance" rather than police enforcement if speed limits are to be a satisfactory road safety measure. He argued that the relationship between speed limits and current vehicle speeds is an important factor in evaluating the appropriateness of an existing limit.

Sanderson and Cameron (1982) reported the results of an extensive literature review to evaluate the relationship between speed, speed control measures and accident rate. Some of their conclusions concerning rural highways were the following. -Accident rate is generally higher for very low and very high speed drivers, with the minimum rate being for drivers slightly above average speed.

-Modification of the speed distribution to minimise variation from the mean should generally result in a decreased accident rate.

-72-

-A reduction in mean speed brought about by a speed limit generally results in fewer total accidents, particularly injury accidents.

There has been very little work to determine relationships between speed and accidents on urban arterial roads, where there is the largest discrepancy between speed limits and vehicle speeds. Urban areas cover a great variety of roadway conditions, and yet traditionally they have been subjected to a general absolute speed limit. The diversity of road conditions suggests that a more appropriate approach would be a complete hierarchy of speed zones according to roadway classification, rather than a general standard from which some departures might be made.

On urban arterials and residential roads little work has been performed on the relationship between speed and accidents. Such work should be carried out as part of the basis for the establishment of a hierarchy of speed zones. The introduction of such a system could well be instrumental in the introduction of lower limits in zones residential areas, which would be expected to reduce pedestrian and child cyclist accidents.

Brindle (1983) pointed out that "overseas and local data suggests that up to 33 per cent of urban casualties typically occur on streets which are "local" in function and character, and which are not part of the arterial or cross-suburban network." Furthermore, "the accident rates on local streets (as a function of units of vehicle travel) are higher than those on arterials", and "The accident rate .. seems to peak at the local distributor class. These local street accidents tend not to be concentrated

-73-

at black spots but are typically a system-wide problem requiring area-wide solutions."

He concluded that "There is a critical need for research and observation in residential areas", to investigate, for example, traffic accidents in residential areas, and their relationship to road type, sight distances, etc.; patterns of pedestrian and cycle activity.

Poor visibility at night is generally assumed to be responsible for many night-time accidents, and there is evidence that the installation of road lighting can reduce such accidents. However, the level and quality of road lighting has been found to be only weakly correlated to the degree of accident reduction, and it has been suggested that accident reduction is too insensitive a measure to be used to specify the optimal quality of lighting (Armour and Jenkins, 1982).

Vincent (1981) took a more extreme position, concluding from a literature review that "However widespread and deeply held is the belief that road lighting reduces accidents, or that there is an optimal lighting level in cost terms, it is not supported by the scant amount of original investigation on the subject, particularly when that evidence is scrutinized closely. ..it is unlikely that an arguable case for justification of lighting expenditure on the basis of cost savings in accidents will ever be made. The justification instead will have to be on the basis of better driver reaction to hazards under lit conditions (if that can be proved)".

-74-

Given that the driving task is significantly different on a residential street from on an urban arterial or on a freeway, it follows that appropriate levels and quality of lighting for such different classes of road may differ. Their specification requires knowledge of the relationship between various aspects of driving performance and the visual environment. For example, driver detection of and reaction to some sorts of hazard are no doubt better with lighting than without it.

In view of the complex and weak relationship between lighting levels and accidents, the effects of lighting on relevant aspects of driving performance may provide a more appropriate measure of lighting effectiveness. Research is needed to determine, on the basis of night-time accident data, the aspects of driver behaviour which should most validly be investigated in terms of their relationship to lighting level.

## ALCOHOL AND OTHER DRUGS

Shinar et al (1978) found in an accident investigation that the most common causes of alcohol-related accidents were (1) falling asleep, and (2) speeding, overcompensation, internal distraction. An analysis of Australian data (Johnston, 1982) showed that single vehicle "ran off road" and "struck parked car" accidents together accounted for 2/3 of all alcohol-related accidents. Most of the former category occurred on curves; it was suggested, therefore, that one appropriate countermeasure is an improvement of visual information at curves, such as by better delineation (Johnston, 1982).

Corben and Young (1983) found that at signalized intersections, alcohol was over-represented in rear-end and single vehicle out-of-control accidents. Therefore, it was recommended that signal conspicuity and lane delineation should be improved.

It appears from such data that alcohol affects information acquisition and processing, especially with time-sharing between tasks, more than sensory responsiveness or motor ability. Its effects on risk-taking and risk-assessment are unknown (Johnston, 1982).

Johnston (1983) identified four major categories of countermeasure:

(1) raise level of arousal (raised pavement markers, etc);(2) indirectly raise arousal and improve hazard perception

-76-

(better hazard markers, warnings);

(3) ameliorate time-sharing problem by enhancing information(larger, brighter signs, markings);

(4) remove some hazards (e.g. roadside objects).

Nedas et al.(1982) evaluated extra-wide edgelines as an alcohol countermeasure. Test subjects showed improved driving performance when edgelines were present and reduced performance when they were alcohol-impaired. The wide edgelines significantly improved driving performance (in terms of lane position) for both normal and alcohol-impaired drivers. Thus, results indicated that "strengthening the visual signal at the road edge may compensate to some degree for alcohol impairment and hence reduce the risk of accidents. Since the effects of alcohol on driver vision are similar to the effects of fatigue, drugs, and reduced visual ability due to old age, wide edgelines are likely to also benefit those with these other types of impairment."

However, Johnston (1983) pointed out that comparisons between treatments were between separate, unmatched curves and the results were consistent with those that might have been expected on the basis of the varying curve geometry, which casts doubt on their conclusions as to the effects of the different edge treatments.

Johnston (1983) investigated the effects of roadway delineation on curve negotiation by drivers with BACs of zero and 0.05%. Alcohol had a negligible effect on mean speed but increased the incidence of extreme lane positioning at the curve mid-point and led to more frequent departures from the lane. The

-77-

optimum delineation treatment appeared to be one combining chevron alignment signs with a wide edgeline.

The great bulk of research in the area of alcohol and driving is concerned with various means of deterring drivers from driving with excessive blood alcohol levels. Homel (1980) and Ross (1982) have written very comprehensive reviews.

Homel (1980) investigated the impact of various judicial penalties on the likelihood that drink/drivers will re-offend. Based on his findings he made a number of recommendations, which included the following.

-Periods of licence disqualification should be of the order of 12-18 months.

-Good behaviour bonds, in addition to fines and disqualification, should be used more widely.

-Imprisonment should be used only when all else has failed. -Young men should not receive heavier penalties than older men for offences of similar seriousness. (There is evidence that at present they do.)

-Alternatives to traditional penalties should be pursued, in particular, specialized rehabilitation schemes and physical devices on cars.

-Ignition interlock devices or their equivalent should be developed and evaluated as a matter of urgency. Priority should be given to fitting these devices in cars of high risk offenders.

Homel particularly emphasized the importance of developing different rehabilitation schemes to suit the needs of different types of offenders. He emphasised the importance of regularly monitoring the impact of rehabilitation schemes on different groups of offenders, using attitudinal and life-style measures as well as reconviction data and accident records. Attention should be paid to the effects of penalties (especially licence suspension, which appears to be the most effective; Hagen, Williams and McConnell, 1982; Votey and Shapiro, 1983) in combination with rehabilitation schemes.

Ross (1982) discussed a number of important topics, sections of which are presented below.

-Changes in the law promising increased certainty or combined certainty and severity of punishment reduce the amount of drinking and driving.

-Changes in behaviour resulting from changes in the certainty of threat, of the order of those achieved by policy innovations to date, are evanescent.

-Innovations confined to manipulation of the severity of the legal punishment, without a concomitant change in its certainty, produce no effect on the apparent incidence of drinking and driving or its aftermath in crashes.

-Considerable evidence shows the positive effect of increments in perceived certainty of punishment due to the introduction of Scandinavian-type laws and as a consequence of enforcement campaigns. However, in the long run the declines are countered by tendencies to return to the status quo ante, whether or not the increased actual probabilities of detection, conviction, and

-79-

punishment are maintained.

-More needs to be known about the function of the components of legal threat in affecting the behaviour of drinking and driving. A major question ... concerns the relationship between actual and perceived certainty, severity, and celerity of punishment.

-Deterrence-based programs are far likelier to succeed than programs based on rehabilitation and treatment of offenders, partly because the latter are likely to be ineffective and partly because even if effective they could be applied only to that small fraction of potential participants in crashes who become known to authorities. Deterrence, if effective, acts on the entire population of potential drinking drivers, whether or not their prior record has marked them as likely to become involved in crashes.

-The possibilities for ameliorating the problem of drinking and driving become clearer if the nature of the problem to be addressed is redefined. Two definitions are proposed. One sees the drinking-and-driving problem as part of the general problem of controlling alcohol use, and the other sees the problem as part of the general problem of controlling the consequences of traffic crashes.

-We could raise the price of alcoholic beverages in order to reduce consumption, a measure that very likely would have road-safety benefits among others. More specific measures stress the desirability of reducing the dispensation of alcoholic beverages to people especially prone to drink and drive and in

-80-

situations where driving is a likely consequence. For instance, very young drivers are disproportionately likely to become involved in alcohol-related crashes. Studies of recent state laws that have raised or lowered drinking ages show important safety benefits to be achieved by making the legal drinking age as high as politically feasible.

-If the problem of drinking and driving is viewed as an aspect of the larger problem of controlling the consequences of motor-vehicle crashes, a whole host of alternative policies promises to be effective. A vehicle and highway that are safe for an alcohol-influenced driver are also safe for a driver who has a heart attack, who dozes off, who drops his lighted cigarette on his lap, who fails to see a stop sign or a vehicle approaching from an unexpected angle, and so forth.

-However ... the possibilities inherent in the deterrence of drinking and driving should not be discarded. The accumulated research reviewed here testifies to the achievability of loss reduction in the short run through vigorous enforcement of laws following the Scandinavian model, although no evidence currently is available concerning the potential for achievement in the long run. There are some promising modifications of existing deterrence-based law. These modifications should be adopted and evaluated.

Mann et al.(1983) concluded from a review of the effectiveness of drinking-driving rehabilitation programs that "certain of these programmes may reduce recidivism in DWI offenders. These results need to be replicated in future

-81-

well-controlled studies. Methods for assessing which individuals would benefit most from specific programmes are also required." This conclusion supports those presented above.

Cameron and Strang (1982) concluded that the effect of intensified random breath testing (RBT) in Melbourne during 1978 and 1979 was to reduce the risk of alcohol-related accidents (as measured by changes in the risk of nighttime serious casualty accidents) in the areas and weeks of operation and in the same areas for at least two weeks but less than four weeks after operations ceased. "Contamination" effects in nearby areas were also observed.

Woods and Calderwood (1982) evaluated the effects of mobile breath-testing units ("BAT mobiles") in New Mexico. Analyses of alcohol-related accidents for a ten year period using interrupted time-series analysis showed a decline in accident rates subsequent to the implemetation of the testing program.

Thomson (1983) investigated the effectiveness of breath testing program in N.S.W. during the 1970s by relating number of screening tests conducted by the police to number of fatalities by means of an econometric model (to control for the effects on fatalities of other influential variables). It was estimated that the program had been responsible for a reduction in fatalities of about 6.6%.

Thus, there is now substantial evidence that random breath testing is an effective deterrent to drink driving. Random breath testing works most effectively when accompanied by sustained

-82-

publicity and visibly high levels of enforcement.

McLean et al.(1980) recommended that "The information needed to enable a driver to estimate his BAC on the basis of his rate of drinking should be disseminated widely, together with information showing that for all drivers the risk of accident-involvement increases with increasing BAC." Such information could very appropriately be included in licence test material.

Jordan (1982) found from a literature review of the incidence of alcohol amongst injured pedestrians that a greater percentage of accident-involved pedestrians had BAC's above 0.15% than do accident-involved drivers or motorcyclists. As expected, alcohol involvement was greatest for male pedestrians at night.

Jordan and Young (1982) supported the view that, on the assumption that accident severity will be reduced if the impact speed is reduced, improved street lighting to make pedestrians more visible to oncoming motorists is desirable. In areas which can be identified as "high alcohol" locations floodlighting may even be justified. It may be necessary to direct the drunk pedestrian to locations with improved lighting, perhaps by the use of barrier fences.

Also, it has been found that farside accidents were a particular problem with high BAC pedestrians, and it was suggested that pedestrian refuges may therefore be useful in reducing the complexity of the decision when crossing two opposing streams of traffic.

-83-

Jacobson et al.(1983) reported a study in which questionnaire and blood analysis data from Swedish road traffic accident victims were analysed. Only 4% had measurable concentrations of drugs usually regarded as hazardous to traffic safety, and none exceeded the therapeutic range for these drugs. It was concluded that drugs other than alcohol are a very small risk factor.

Stein et al.(1983) conducted a simulator study of the combined effects of alcohol and marijuana on driving behaviour. "Alcohol was found to have a pervasive and significant impairing effect. Simulator accidents increased reliably under alcohol, which was accounted for by increased steering and speed control variability. Marijuana effects were minimal, the primary one being speed reduction. A significant drug interaction effect was observed in simulator accidents. However, the data do not allow us to identify the impairment mechanism."

In a summary of a report to the American Congress by the National Highway Traffic Safety Administration (1980) drugs of relevance to highway safety research were listed as follows: analgesics and antipyretics, anesthetics, antianxiety agents, antidepressants, antihistamines, antinauseants, antipsychotic agents, antivertigo agents, appetite suppressants, cardiovascular drugs, hallucinogens, marijuana and other illicit substances, psychostimulants, sedative-hypnotics.

The report stated that "Research to define the nature and magnitude of the drug and driving problem has produced some

-84-

information on the frequency of drug use among drivers and its possible consequences for highway safety. The present state of knowledge, however, is limited. Experimental studies have shown that marijuana, other controlled substances, and other therapeutic drugs at certain dose levels have adverse effects on skills and other measures associated with driving performance. Epidemiologic research has demonstrated that some drivers involved in fatal crashes or arrested for impaired driving have taken psychoactive drugs. The use of more than one drug, in addition to alcohol, is often found in these driving populations.

".. the absence of surveys that compare the frequency of drug incidence in accident and nonaccident drivers prevents the meaningful interpretation of studies that only report drug use by drivers involved in crashes or arrested for impaired driving.

"The evidence .. indicates that some drugs can impair human behaviour and skills related to driving .. Such information suggests that driving under the influence of some drugs increases the likelihood of traffic crashes. Nevertheless, given present information, the influence of drugs on crash risk can not be specified. However, the involvement of drugs in traffic crashes resulting in death, injury, and property damage appears to be considerably less than that of alcohol. Based on available data, the percentage of drug-involved crashes is in the range of 1% to 15%, including cases of combined alcohol and drug use."

-85-

## FUTURE RESEARCH NEEDS

A topic of the highest priority is the nature of "normal" driving behaviour for drivers in various age/sex categories and in a variety of types of road/traffic situations and driving manoeuvres. Driving behaviour should be categorised in such a way as to permit investigation of the patterns of occurrence of the sorts of driver "errors" which have been shown by accident investigations to be commonly associated with some types of accidents. This would increase our knowledge of the sorts of driving behaviour which characterize drivers of differing levels of driving experience, which is essential information for many purposes, particularly the improvement of driver training and driver licensing procedures. The usefulness of this information would be greatly enhanced by including in the investigation particular sites which are known to have high accident rates.

Equally high in priority should be a series of investigations to determine the nature of relationships between driving experience, age, perceptual/cognitive components of driving skill (such as hazard perception) and deliberate risk-taking propensity. Within this area, particular questions to be investigated would include the determinants of perceived level of hazard, particularly the relative contributions of task-related and personal factors, and the relationships between age, driving experience, level of perceived hazard and associated affective response. Such research is vital in that it would "answer questions such as "To what extent do young drivers have a higher accident rate because of their lack of driving skill and

-86-

to what extent because of a propensity for higher risk-taking associated with their youth rather than lack of driving experience?" The work would have major implications for road safety education and driver training programs, with some implications for traffic engineering also.

The following topics have also been identified as requiring research.

The feasibility of introducing a system of compulsory reporting by medical practitioners of medical defects likely to affect safe driving.

The most appropriate content of the knowledge-testing components of licence tests.

The optimum form of restrictions associated with a graduated licensing system.

The most cost-effective form of driver improvement program (given that a suitable data base was available for its implementation).

The optimum mixture of different types and durations of enforcement operations.

The feasibility and likely cost-effectiveness of improving tyre inflation and replacement practices of drivers and service station staff. The most appropriate means of implementing various measures to improve bicycle conspicuity.

The feasibility and cost-effectiveness of legalising the use of footpaths by child cyclists.

The evaluation of child cyclist training programs such as "Bike Ed" in terms of its effect on participants behaviour in traffic under normal conditions, on their exposure to traffic, and on their accident **involvement**.

The detailed nature of normal cycling behaviour for cyclists of different ages in situations varying in terms of type of manoeuvre and location.

The detailed nature of normal motorcycling behaviour in a variety of types of location, performing various manoeuvres, for riders of different amounts of experience.

The relationships between motorcycling experience, vehicle control skills and perceptual/cognitive skills.

The detailed nature of normal pedestrian behaviour in a variety of types of location, for pedestrians of different ages.

The feasibility of modifying high-risk aspects of child pedestrian behaviour, defined as such by having compared normal and accident-related behaviour.

The most effective means of educating parents on the need

for young children to be protected from road traffic.

The evaluation of pre-school children's "traffic clubs" in terms of participant children's exposure to and behaviour in road traffic environments and their accident involvement, by comparison with a control group.

The cost-effectiveness of liberalising warrants for pedestrian-actuated signalised crossings.

The relationships between speed and accidents on urban arterial roads, as a pre-requisite for the establishment of an urban hierarchy of speed zones.

Relationships between residential road characteristics, patterns of use by cars, cyclists and pedestrians, and accidents.

The aspects of driver behaviour, determined from an analysis of night-time accident data, which should most validly be investigated in terms of their relationship to level of road lighting.

The development and evaluation of ignition interlock devices or their equivalent, for use in vehicles of high-risk alcohol offenders.

The development and evaluation of different alcohol rehabilitation schemes, designed to suit the needs of diferent types of offenders.

The relationship between actual and perceived certainty, severity, and celerity of legal punishments of alcohol-related offences.

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