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HAZARD PERCEPTION AND RESPONDING BY MOTORCYCLISTS – BACKGROUND AND LITERATURE REVIEW

by

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Hazard perception and responding by motorcyclists – Background and literature review

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Abstract:
This project is the first stage of a larger program of research into hazard perception training for motorcyclists. Future stages of the project will investigate what type of environment can be used to teach hazard perception and responding, for example a simulator environment or combination of off-road and simulator training. This report summarises the research that has been conducted into hazard perception and responding, assesses what can be learnt from motorcycle crash data and describes current motorcycle simulators. The second stage 1 report (Wallace, Haworth & Regan, 2005) examines the best training methods for teaching hazard perception and responding skills to motorcycle riders.

The report identified that motorcycle riders must deal with the same hazards as car drivers, as well as the additional hazard of failure by car drivers to give way. The vehicle control skills involved in riding a motorcycle are more complex than driving a car and failure to correctly implement a response to a hazard may in itself be dangerous.

There has been a lot of research into hazard perception by car drivers but few studies have addressed hazard perception and responding by motorcycle riders. The research has shown that novice car drivers are slower or less likely to detect and respond to hazards and that car drivers who are slower at detecting hazards in a driving simulator report having more accidents.

No motorcyclist specific hazard perception test has been developed or introduced anywhere in the world. The tests developed for car drivers may not give sufficient emphasis to hazards specific to motorcyclists, particularly road surface hazards, and do not adequately measure responding. It is likely that these tests will underestimate any differences between novice and experienced riders.

Motorcycle simulators have been developed and are a mandatory part of training in Japan. Simulators are best used as part of a comprehensive rider education system that includes classroom training, skills practice using real vehicles, with simulation used to present situations that are too dangerous to practice using a real vehicle.

Key Words:
Motorcycle, motorcyclist training, hazard perception, simulation, rider testing

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Preface

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Contents

Figures

Tables

EXECUTIVE SUMMARY

This project is the first stage of a program of research into hazard perception training for motorcycle riders. Future stages of the program will investigate what type of environment can be used to teach hazard perception and responding, for example a motorcycle simulator or a combination of off-road and simulator training.

This report summarises the research that has been conducted into hazard perception and responding, assesses what can be learnt from motorcycle crash data and describes current motorcycle simulators. The second Stage 1 report (Wallace, Haworth and Regan, 2005) examines the best methods for training riders in hazard perception and responding skills.

DEFINITIONS AND THEORETICAL APPROACHES

In this report, a *hazard* is defined as “any permanent or transitory, stationary or moving object in the road environment that has the potential to increase the risk of a crash. Hazards exclude characteristics of the rider or the vehicle, which are classed as modifying factors." *Hazard perception* is defined as “the process whereby a road user notices the presence of a hazard”. Hazard perception is one of the stages in a chain of processes linking hazards to outcomes. The concept of *defensive riding*, as described by riders, appears to place more emphasis on the modifying factors and less on the perception of hazards.

A number of models of hazard perception have been developed for car driving. Probably the most useful model for motorcycling is the four-component model of responding to risk (Grayson, Maycock, Groeger, Hammond and Field, 2003) because it deals with both perceiving and responding to hazards.

HAZARDS AND MOTORCYCLING

Hazards can be classified into those that are road based and those that arise from the behaviour of other road users. Motorcyclists are subject to the hazards faced by car drivers but are also at risk from situations not hazardous for car drivers, such as gaps in bridge decking wide enough to catch a motorcycle wheel but too narrow to affect a car tyre. The reactions required from riders also need to be different, as motorcycles handle differently to cars. The extent of potential harm associated with any given hazard is commonly greater for motorcyclists, given their comparative lack of protection.

The hazards associated with the behaviour of other road users can be thought of as arising from failures of hazard perception by other road users. The extent to which this can and should be addressed by improving the hazard perception and responding skills of motorcycle riders, compared with the corresponding skills of car drivers is a matter for debate.

The following key issues relating to hazards and motorcycle riding were identified:

- Motorcycle riders must deal with the same hazards as car drivers, as well as the additional hazards of failure by car drivers to give way and road surface hazards.

- Hazard perception and responding is more crucial for riders than car drivers, because riders cannot rely on the other road user seeing them and avoiding them.

- The potential severity of crashes, regardless of the type of hazard, is greater for motorcyclists.

- The vehicle control skills involved in riding a motorcycle are more complex than driving a car and failure to correctly carry out the response to a hazard may in itself be dangerous.

- Novice riders may have problems sharing attention between controlling their bike and perceiving and responding to hazards.

HAZARDS AND HAZARDOUS SITUATIONS INDICATED BY THE CRASH DATA

Crashes reported to the Police provide little information about the role of hazards and hazard perception and responding. Many crashes involving only the rider, in which road-based hazards may have played a role, are not reported to Police. For those motorcycle crashes that are reported to Police, there is little mention of hazards related to the road surface and hazards related to the behaviour of other road users are not always easy to identify. Despite these difficulties, the crash data provides some useful information about the riding environments (e.g. intersections, speed zones, weather conditions) in which (at least reported) crashes occurred. Knowing these riding environments and situations helps to identify what should be included in training in hazard perception and responding.

Overall, about half of the riders involved in reported casualty crashes in Victoria in 1997-2001 were involved in collisions with vehicles. In the majority of these crashes, it is likely that the other road user failed to give right of way to the rider.

The crash patterns differ according to the age and licence status of riders. Older fully-licensed riders had more crashes in higher speed zones outside of the metropolitan area (and perhaps in higher speed zones inside the metropolitan area), which may reflect their patterns of riding. Even within a given riding environment, age and licence status appear to affect the crash pattern. Older new riders (learner and probationary riders) were less likely to have collisions with vehicles and were more likely to have single vehicle crashes than other riders in low speed riding environments and in higher speed areas outside of the metropolitan area. This needs further investigation. It may be that older new riders are relatively better at perceiving and responding to hazards arising from the behaviour of other road users or relatively poorer at dealing with road-based hazards than other riders.

HAZARD PERCEPTION RESEARCH

There has been very little research into investigated hazard perception and responding by motorcycle riders. For car drivers, research has shown that experienced drivers are quicker to detect hazards and that slower responses to hazards are associated with higher self-reported crash involvement – but this has not been tested for motorcycle riders.

The small number of studies of hazard perception and responding by motorcycle riders has found that:

- Riders are more likely to nominate road-based hazards than car drivers

- In a simulator, experienced riders react faster to hazards when acting as car drivers than when acting as riders

- Responding is a relatively more crucial part of the process for riders than for drivers

- Most novice riders are experienced car drivers and are older than novice car drivers

- Riders and car drivers differ in where they look. One study found that riders spend more time looking at the road and less time looking further away but another study disagrees.

HAZARD PERCEPTION TRAINING AND TESTING

Improving hazard perception skills can potentially lower the crash risk for all road users. However, teaching how to respond appropriately may be more critical for riders than for drivers because failures in responding may result in a failure to avoid the initial hazard or a different type of crash. If hazard perception and appropriate responding skills are necessary for safe riding, then an important question is whether their development can be accelerated by training. While research has shown that hazard perception training in novice drivers leads to improved performance on hazard perception tests, it is not yet known whether these drivers go on to be safer drivers and have fewer accidents.

Most approaches to hazard perception training for car drivers require only detection of the hazard and responding by pressing a button. They do not train improved responding to hazards, which is of greater importance to riders than drivers.

Given the reported links between crash involvement and poor hazard perception ability, some jurisdictions have developed tests to measure hazard perception skills among novice drivers at the probationary stage of licensing. Having to pass a test of hazard perception in order to obtain a licence helps to ensure that training in hazard perception occurs on a voluntary basis. However, most of the available tests do not measure whether the correct response is chosen or implemented – the focus is on the detection of the hazard only. In addition, the hazard perception tests may not give sufficient emphasis to hazards specific to riding, particularly road surface hazards. This may limit the extent to which such tests are able to predict the crash risk for riders.

No rider-specific hazard perception test has been developed or introduced anywhere in the world. At present, it appears that there are no plans to introduce a separate version of the test designed specifically for riders in any jurisdiction.

In the United Kingdom, candidates for a motorcycle licence are required to pass the car Hazard Perception Test (HPT), but this is not the case in Victoria, Western Australia and New South Wales. Most of the Victorian applicants for a motorcycle licence are not required to sit the car Hazard Perception Test because they already hold a car licence and it is assumed that they would have passed the Test (those who obtained their car licence after 1996) or would have developed hazard perception skills from years of driving cars. One study suggests riders are disadvantaged by the current UK licensing system that requires learners applying for their motorcycle licence to pass the HPT designed for car drivers. The study's authors recommend that a separate HPT for riders with associated training should be developed and introduced into licensing systems.

MOTORCYCLE SIMULATORS

Only in Japan have simulators been used widely in motorcycle rider training. In the Japanese licensing system, learning to drive or learning to ride must occur off-road and training sessions with simulators are a compulsory part of training for a motorcycle licence. Very little description of these programs and evaluations is available in English.

Riding simulators have been developed by the Honda Motor Company, by Kawasaki (a head mounted display unit) and some European companies. In Britain, TRL Limited may possibly develop a motorcycle simulator in the future. The Honda simulator appears to be the most relevant to hazard perception and responding. Little information was available regarding the Kawasaki simulator. A description and assessment of the first generation Honda driving simulator currently situated in Melbourne is provided as an appendix to the second report.

The two articles that addressed the best role for simulators in motorcycle training agreed that simulators should be used as part of a comprehensive rider education system that includes classroom training, skills practice using real vehicles and simulation training to learn to handle situations that are too dangerous to practice using a real vehicle.

RECOMMENDATIONS

The following recommendations are made:

1. Research should be undertaken to investigate whether experienced riders are faster at perceiving hazards than novice riders and whether this depends on the type of hazard (vehicle-based or road-based) and the level of car driving experience of the rider.

2. The results of the research outlined in 1. should be used to determine the relative emphasis given in training to the two types of hazards and who the training should target (novice car and motorcycle operators, novice motorcycle riders who are experienced car drivers etc.).

3. Hazard perception training products (or a hazard perception test) for motorcycle riders cannot be developed until more is known about what affects hazard perception, how this varies among the different classes of hazards, and the extent to which hazard perception can be trained.

4. Research should be undertaken to resolve whether training should focus on addressing hazard perception or responding or the modifying factors. It may be that addressing the modifying factors could be more useful than improving hazard perception or responding.

5. Any hazard perception training that is developed should fit the needs of the Victorian riders. Different approaches may be needed for younger and older novices. There is a need to assess for which categories of motorcycle riders – younger, older, novice, experienced, returning – hazard perception and responding needs to be improved and how this could be done.

GLOSSARY

Terms in *italics* are explained elsewhere in the glossary.

Automaticity	the state of being able to respond without allocation of conscious attention
Cognitive	relating to higher-order information processing, such as thinking and decision making
Commentary driving	a training method used during actual driving to help teach hazard perception skills to drivers whereby the driver continuously verbalizes his/her hazard perception and responding abilities to the instructor who offers feedback about his/her performance both during and after the drive
Defensive riding (or driving)	a concept that combines components of the *modifying factors* (e.g. choosing optimum position or speed) and *hazard perception*, with a large emphasis on *modifying factors*
Definition for Classifying Accidents (DCA) codes	a classification system used in Victoria to report and describe crashes based on their configurations. Similar systems are used in other Australian jurisdictions.
Driving behaviour/style	how someone chooses to drive
Driving performance/skill	how well someone can drive. *Hazard perception* is regarded as a component of driving skill.
Experienced rider	someone who has ridden regularly for many years and continues to do so. Not all people who have held motorcycle licences for a long time are experienced.
Fidelity	The extent to which a simulation has the same properties as the real-world situation it is simulating.
Hazard	any permanent or transitory, stationary or moving object in the road environment that has the potential to increase the risk of a crash. Hazards exclude characteristics of the rider or the vehicle, which are classed as *modifying factors*.
Hazard perception	the process whereby a road user notices the presence of a *hazard*. Other steps between the existence of a hazard and the outcome include *modifying factors* (which modify the risk associated with the hazard), decision making and responding.

Instructional design	design of learning systems. Approaches to instructional design may be viewed as being 'conservative' or 'liberal' (Bowen & Hobson, 1974). Instructional design typically makes extensive use of digitised video and high quality graphics to convey the intended message, and may extend to some level of simulation.
Learner	a person who is acquiring a knowledge or skill. The person does not have to be the holder of a Learner Permit, and may have a full licence.
LEARNER	a person who holds a Learner Permit
Modifying factors	characteristics of the rider or the motorcycle that modify the level of risk of a *hazard*. They can be long-term characteristics of the individual such as rider experience and rider skill in executing responses (real or perceived) or more transitory characteristics such as travel speed, type of protective clothing worn and mechanical condition of the motorcycle.
Novice rider	a rider who either holds a learner permit or has recently graduated to a probationary/provisional licence. Not all novice riders are young.
On-road licence testing	assessing the skills and knowledge of licence applicants while driving or riding on public roads
On-road rider training	teaching skills and knowledge to riders on public roads
Risk	chance or possibility of danger, loss, injury or other adverse consequences. The true risk in a situation is often termed the “objective risk”. The individual’s assessment of the probability of danger or harm is the “subjective risk” or “perceived risk”.
Risk perception	the process of developing an overall assessment of the level of *risk* in a situation. It is a component of driving skill. It differs from *hazard perception*, which is more focused on identifying *hazards* in the situation in order to respond to them in a way that reduces the perceived risk of the situation. Risk perception is considered to be inaccurate when the level of “subjective risk” in a situation differs considerably from the level of “objective risk”.
Risk taking	a component of *driving style* that is associated with increased crash involvement. Risk taking relates to attitudinal and motivational factors, rather than *skill*. Certain risk taking behaviours may contribute to failures of *hazard perception* (e.g. speeding may reduce the likelihood that the driver notices a hazard) or to failures to

	avoid a crash (e.g. speeding resulting in an inability to stop in time, given that the hazard has been detected). Risk-taking may also result in an increased exposure to *hazards* (e.g. the choice of more "hazardous" scenarios) or to the failure of other road users to be able to respond to actions of the risk taker.
Road hazards	permanent characteristics of the road surface (roughness, being an unsealed or gravel road, low skid resistance, tramlines, railway lines, painted lines on roads) or temporary characteristics of the road surface (potholes, surface irregularities, pit lid covers, oil or gravel on road, debris) or visual obstructions or characteristics of the road alignment (horizontal and vertical curves) that increase the risk of a crash.
Simulation	simulation is a process of using an artificial situation that has some characteristics in common with the real situation, rather than the real situation itself. Simulation is an instructional process that may be employed in a broad range of learning environments. For example riding a motorcycle on the open road while performing tasks set by an instructor and under instructional supervision is a way of gaining experience for real-world task performance; it is a simulation of eventual real-world performance. Specific simulation training methods may be defined by combining the process of instructional simulation with a specific environment.
Simulator	a mechanical and electronic device that attempts to simulate a vehicle. Simulators can range from low-end simulators which have little functional and physical *fidelity* to high-end simulators which have high functional and physical *fidelity*, including sophisticated motion feedback.
Situational awareness	an individual's understanding of a dynamic environment, perceiving events, developing a holistic understanding of the situation and predicting future actions of the various elements within the situation.
Skill	proficiency, facility, or dexterity that is acquired or developed through training or experience.
Vehicle control skills	the physical skills required for driving including steering, braking, using the pedals, buttons and other controls. These skills are generally learned quickly in learner drivers.

HAZARD PERCEPTION AND RESPONDING BY MOTORCYCLISTS – BACKGROUND AND LITERATURE REVIEW

1. INTRODUCTION

1.1 BACKGROUND TO THE ISSUE

The two general approaches to improving the safety of road users are to prevent crashes and to reduce the severity of injury in the event of a crash. Crash prevention is relatively more important for vulnerable road users such as pedestrians, bicyclists and motorcyclists who are not encased in metal structures. For bicyclists and motorcyclists in particular, the ability to perceive and respond to hazards posed by other vehicles and by the road surface forms is crucially important in crash prevention and avoidance.

The other vehicle is commonly judged to be at fault in multi-vehicle crashes involving motorcycles. In an analysis of 900 motorcycle accidents in Los Angeles, Hurt, Ouellet and Thom (1981) found that the most common motorcycle accident involved another vehicle (75%) violating the right-of-way of the motorcycle at an intersection, usually by turning left in front of the oncoming motorcycle. In Victoria, motorcyclists are commonly the vehicle going straight ahead in right-turn crashes, and in the ongoing lane in sideswipes.

The Case-Control Study of Motorcycle Crashes (Haworth, Smith, Brumen and Pronk, 1997) identified a substantial number of crashes in which the rider either failed to perceive a hazard or made an incorrect or poorly timed response to the hazard. The hazards were often other vehicles but sometimes included motorcyclist-specific hazards such as aspects of the road surface. Many of the riders who had crashes involving deficiencies in hazard perception or responding were inexperienced. Inexperienced motorcyclists include those riders who have little total riding experience, those who ride infrequently and those who have not ridden frequently for a number of years.

Motorcycle riders are subject to specific hazards in addition to those that they have in common with car drivers. The rider's evaluation of level of risk also needs to take account of the different performance characteristics of a motorcycle compared with a car and the lower levels of injury protection afforded by the motorcycle. Thus, the findings regarding hazard perception in car drivers and the content and delivery of training that has been developed for car drivers may not necessarily be appropriate for motorcycle riders.

The research examining the effectiveness of rider training programs has generally produced disappointing results, suggesting that training may not lead to a decrease in crash incidence (summarised in Haworth, Smith and Kowadlo, 1999). This may be because the rider training programs currently in use focus mainly on the development of vehicle control skills, rather than hazard perception.

This project is the first stage of a larger project to investigate hazard perception training for motorcyclists. Future stages of the project will investigate what type of environment can be used to teach hazard perception and responding, for example a simulator environment or combination of off-road and simulator training.

1.2 AIM OF THE PROJECT

The aim of the project is to determine what hazard-related skills are required by motorcyclists for safe riding. These skills include hazard perception, deciding on the correct response and successful execution of the response in order to avoid a crash or decrease the severity of a crash. These behaviours also relate to avoiding situations that may lead to crashes. The term ‘hazard perception and responding’ is used in this report and relates to the above description.

Stage 1 of the project aims to:

1. Determine hazard perception and responding skills required for safe motorcycling

2. Determine situations and conditions relevant to perceiving and responding to each type of hazard

3. Determine best training method(s) for teaching safe motorcycling hazard perception and responding

1.3 STRUCTURE OF THE REPORT

This report is the first report of Stage 1 of the project. It includes a description of the characteristics of motorcycling in Victoria, a discussion of relevant definitions and concepts and a summary of what is known about hazards for motorcyclists. A summary of analyses of Victorian crash data is then presented. The chapters that follow summarise the research that has been conducted into hazard perception and training and testing of hazard perception.

A number of methods were used to gather information for this project:

- Search of the published literature
- Search of electronic databases
- Contacts with individuals who have undertaken previous work in the area
- Examination of currently available simulators
- Analysis of most recent crash data
- Analysis of training methods by instructional design expert

The second Stage 1 report concentrates on identifying the best training methods for teaching hazard perception and responding skills to motorcycle riders. It provides an analysis of training methods and examines the potential usefulness of simulation and other training methods in motorcycle rider training.

1.4 MOTORCYCLING IN VICTORIA

It is important to consider the extent to which the findings of research into hazard perception and responding (mostly conducted with car drivers) are relevant to motorcyclists, given the different vehicle control skills required for safe riding and given the additional or different hazards relevant to motorcycling (see Haworth et al., 2000).

Another important issue is the extent to which the findings of research conducted elsewhere are relevant to Victorian motorcyclists, given their age and experience profiles (both in car driving and motorcycle riding). Much of the research in hazard perception and hazard perception training has focussed on young novice car drivers. This group is both young and inexperienced. The research has demonstrated that their hazard perception skills are poorer than older, more experienced drivers. It has also shown that hazard perception training can improve their performance on hazard perception tests to a level similar to older, more experienced drivers. As the sections below show, many Victorian motorcyclists are not young and many have more car driving experience than motorcycling experience. Little is known about the relationship between age and experience and ability in hazard perception and responding for such a group of motorcyclists.

1.4.1 The age profile of Victorian riders

Applicants for a motorcycle learner permit in Victoria must be a minimum of 18 years of age. Yet licensing data suggest that many riders do not obtain a motorcycle licence at this age. In June 2001, there were 1,096 18-year olds who held a motorcycle permit or licence, compared to 1,670 20-year olds, 2,649 22-year olds and 4,012 25-year olds. In contrast, 52,987 18-year olds held a car permit or licence and this increased only to 60,652 25-year olds (these figures do not include those who held a licence or permit for a car and a motorcycle). Thus, relatively more motorcyclists than car drivers obtain a licence considerably after the minimum age and so novice motorcycle riders are not always young.

The licensing data show that only 4% of motorcyclists aged over 30 hold a learner permit or restricted licence. However, these novices probably constitute a much larger proportion of riding since they are more likely to be active motorcyclists (to have ridden in the last year) and they ride more often and further than fully-licensed active motorcyclists (Haworth et al., 2002).

1.4.2 The car-driving experience of Victorian riders

In terms of car driving experience, the main groups of applicants for a motorcycle permit or licence are

- Young non-drivers
- Young novice drivers
- Older, fully-licensed drivers

The data suggest that young non-drivers are a very small proportion of permit or licence applicants. In 1995/96 to 1998/99, less than 3% of applicants for a motorcycle learner permit did not have a car driver learner permit (as indicated by being required to sit the KT2, a road law knowledge test based on Part A of “The road to solo driving”). Only 3% of applicants for a motorcycle licence did not have a car driver licence (L or P, i.e. were required to sit the KT3, a road law knowledge test based on Parts A and B of “The road to solo driving”). These data come from before the minimum age for obtaining a motorcycle learner permit was raised from 17 years 9 months to 18 years. Since that change, it is expected that even fewer applicants for a motorcycle learner permit would not hold a car learner permit. In June 2001, the number of riders aged 18-25 who held a motorcycle licence or permit only was about 3% of the number who held both a motorcycle licence or permit and a car licence or permit.

Most newly licensed motorcyclists have car licences. In 1998, 84% of riders obtaining a motorcycle licence in Victoria had a full car licence. This means that they had at least three years solo driving experience in addition to up to two years driving with a supervisor.

There is little in the hazard perception literature that addresses the issue of the extent to which experience as a car driver is expected to improve hazard perception and responding skills as a motorcycle rider. This is important, given that very few motorcyclists in Victoria do not have experience as a car driver.

Later in this report, the types of crashes in which young and older novices (defined as holders of learner, restricted or probationary licences) and fully licensed riders are involved are compared. It is assumed that the older (over 25) novices also hold full car licences. This provides an indication of the hazards and situations that they encounter. It also provides a general indication of the extent to which their abilities in hazard perception and responding differ.

1.4.3 The motorcycle riding experience of Victorian riders

For car drivers, there is a reasonably reliable relationship between how long a licence has been held and the level of experience gained (in terms of distance driven). The relationship is not as clear for motorcyclists. Many riders have held a licence for an extended period but have little riding experience. For many who currently hold a licence, their riding experience occurred many years ago. It is possible that the need for improved hazard perception and responding skills is not limited to riders entering the licence process but may apply to many fully licensed riders. Other groups of riders who may need improvement in their hazard perception and responding skills include

- Older, fully-licensed drivers who hold motorcycle licences but are returning to motorcycling after a long break (most of whom gained their licence before the Victorian Hazard Perception Test or DriveSmart – a PC-based hazard perception training product for young drivers - were introduced)

- Older, fully-licensed drivers who hold motorcycle licences and have not ridden enough to gain sufficient experience and thus hazard perception and responding skills (most of whom gained their licence before the Hazard Perception Test or DriveSmart were introduced)

In many countries, the involvement of “older” motorcyclists (variously defined) has increased in the last decade. The number and percentage of riders in casualty crashes in Victoria aged 30 and over doubled from 1991-2000 (Haworth et al., 2002). In NSW, the number of motorcycles registered to people aged 40 and over increased by 57% between 1995 and 2000, while the number of motorcycles registered to people under 25 years decreased by 33% (de Rome, Stanford and Wood, 2002). The number of motorcyclists involved in crashes in NSW aged under 25 has decreased since 1991 while the number aged 25 and over has increased (RTA data cited in Christie and Harrison, 2001, Figure 12). The Australia-wide motorcyclist fatality data since 1989 has shown a decrease in the number of riders aged under 25 and an increase in the number of riders aged over 25 (ATSB, 2002).

The median age of owners of registered motorcycles in the USA increased from 24 years in 1980 to 38 years in 1998 (Shankar, 2001, cited in Christie and Harrison, 2001). The number of motorcyclist fatalities in the US fell from 3,244 in 1990 to 2,116 in 1997 but increased to 2,483 in 1999 (National Center for Statistics and Analysis Research and Development, 2001). The increase in motorcyclists killed was only observed in the 40 years old and over age group. The number of motorcyclists killed aged under 30 declined considerably from 1990 to 1999. However, there are still proportionally more riders killed in the under 30 age group.

UK data show substantial reductions in the number of motorcyclist casualties for those aged under 20 and the number of casualties involving small motorcycles (less than 125cc) since the late 1980s/early 1990s (Lynam et al., 2001). In contrast, the number of casualties aged 30-39 has been growing since 1993. The riders of motorcycles with an engine capacity greater than 500cc (which require a full licence) dominate the casualty statistics with high proportions of fatalities occurring on non-built-up roads during the summer months (indicating recreational riding).

Thus, there is a need to assess for which categories of motorcycle riders – younger, older, novice, experienced, returning – hazard perception and responding needs to be improved and how this could be done.

2. DEFINITIONS, CONCEPTS AND PROCESSES

The term "hazard perception" is widely used, both in the scientific literature and by those interested in improving driver and rider safety. However, while it is widely used, different people use the term to refer to different concepts and this can lead to misunderstanding and confusion (as noted by Evans and Macdonald, 2002). In addition, terms such as hazard and risk are often used interchangeably and definitions of hazards vary. This section discusses these terms and the definitions that occur in the literature, followed by the definitions that will be used for the current project. The scope of hazard perception is then discussed, followed by an examination of potential theoretical frameworks.

2.1 THE RELATIONSHIP OF HAZARD PERCEPTION AND RESPONDING TO SAFE DRIVING OR RIDING

Before developing definitions of terms, it is useful to discuss what role hazard perception and responding play in safe driving or riding.

Much of the early work in hazard perception took place within a framework of trying to understand why some drivers are involved in more crashes than others. This was termed "differential accident involvement" (McKenna, 1983, cited in Elander, West and French, 1993; Quimby et al., 1986) or "individual differences in road-traffic crash risk" (Elander, West and French, 1993). A number of authors have proposed that two factors contribute to differential crash involvement: one related to the skills that a driver possesses and the other to the way in which he/she chooses to drive. Evans (1991b, cited in Elander et al., 1993) distinguished between driving performance (how well someone can drive) and driving behaviour (how someone chooses to drive). Similarly, Elander et al. (1993) distinguished measures of driving skill and measures of driving style. Hazard perception is regarded as a component of driving skill. Evans and Macdonald (2002) present a framework for driver competencies in which aspects of hazard perception comprise much of the perceptual/cognitive performance competencies.

While hazard perception is an important aspect of safe driving behaviour, on its own it does not make a driver safer. After a hazard has been perceived, the driver must choose and implement an appropriate response in order to avoid a crash, which involves decision making (Fitzgerald & Harrison, 1999). The complexities of decision making for a particular situation are the subject of several theoretical frameworks involving sensation, perception, allocation of resources (possibly at the expense of other situations), cognitive processing of incoming information with memories and motivations, and selection and implementation of an appropriate response.

Another important issue to consider is that responding to a hazard may actually create a more serious situation. For example, steering to avoid a nail on the road may place the driver in the path of oncoming traffic and a more severe crash might occur. Likewise, a driver may falsely perceive a situation to be hazardous and take unnecessary actions to avoid it, potentially posing hazards to others. Clearly then, perception of a hazard is not enough – the driver must have sufficient training to successfully avoid a hazard without *creating* hazards for other road users. It is therefore important to examine the factors that contribute to a driver noticing some unusual element to the situation, perceiving it as a hazard and therefore potentially dangerous, and then deciding on and taking appropriate action to avoid a crash.

2.2 DEFINITIONS

2.2.1 Risk

The Concise Oxford Dictionary (Hughes, Michell & Ramson, 1997) defines a risk as "a chance or possibility of danger, loss, injury or other adverse consequences" (p. 988), and danger as "…exposure to harm…a thing that causes or is likely to cause harm" (p. 280). Harm may include damage to one's vehicle, injury to oneself, damage to another's property, or injury to another person.

The true risk in a situation is often termed the "objective risk". The individual's assessment of the probability of danger or harm is the "subjective risk" or "perceived risk". "Risk perception" is considered to be poor when the level of "subjective risk" in a situation differs considerably from the level of "objective risk".

2.2.2 Risk perception

The term "risk perception" is used here for the process of developing an overall assessment of the level of risk in a situation. It is a component of driving skill. It differs from hazard perception, which is more focused on identifying hazards in the situation in order to respond to them in a way that reduces the perceived risk of the situation.

2.2.3 Risk taking

Risk taking is a component of driving style (or driving behaviour, as Evans uses the term) that is associated with increased crash involvement. Risk taking relates to attitudinal and motivational factors, rather than skill. Certain risk taking behaviours may contribute to failures of hazard perception (e.g. speeding may reduce the likelihood that the driver notices a hazard) or to failures to avoid a crash (e.g. speeding resulting in an inability to stop in time, given that the hazard has been detected). Risk-taking may also result in an increased exposure to hazards (e.g. the choice of more "hazardous" scenarios) or to the failure of other road users to be able to respond to actions of the risk taker.

2.2.4 Hazard

The Concise Oxford Dictionary (Hughes, Michell & Ramson, 1997) defines a hazard as "a danger or risk" (p. 517). In terms of hazards to road users, any object, situation, occurrence or combination of these that introduces the possibility of the individual road user experiencing harm should be included. Hazards may be obstructions in the roadway, a slippery road surface, merging traffic, weather conditions, distractions, a defective vehicle, or any number of other circumstances.

For the purposes of this report, the following definition has been developed by the authors:

> *"A hazard is any permanent or transitory, stationary or moving object in the road environment that has the potential to increase the risk of a crash. Hazards exclude characteristics of the rider or the vehicle, which are classed as modifying factors."*

This definition focuses on the hazard as an object, rather than as a probability of an outcome (as in Benda and Hoyos, 1983). This makes it possible to separate the concept of a hazard and the concept of the risk that is associated with the hazard.

2.2.5 Modifying factor

Modifying factors are defined as characteristics of the rider or the motorcycle that modify the level of risk of a hazard. They can be long-term characteristics of the individual such as rider experience and rider skill in executing responses (real or perceived) or more transitory characteristics such as travel speed, type of protective clothing worn and mechanical condition of the motorcycle. It is likely that many of the transitory modifying factors are affected by the longer-term modifying factors (e.g. travel speed may be higher in riders who perceive themselves as more skilled).

The same object could be considered as a hazard in some situations but as a modifying factor in other situations. For example, a wet road could be a hazard because it leads to reduced traction but it could be considered a modifying factor if it is present at the same time as the hazard of a car failing to give way (because the wet road increases braking distance and therefore the level of risk of the hazard).

2.2.6 Hazard perception

Hazard perception has been defined by Crick and McKenna (1992) as the ability to identify potentially dangerous traffic situations. Evans and Macdonald (2002) define hazard perception as "the process whereby a road user notices the presence of a hazard" (p.93). This definition fits well with the definition of a hazard that the authors have developed for this report (see above).

Figure 1.1 shows that hazard perception can be considered as one of the stages in responding to the presence of actual or potential hazards.

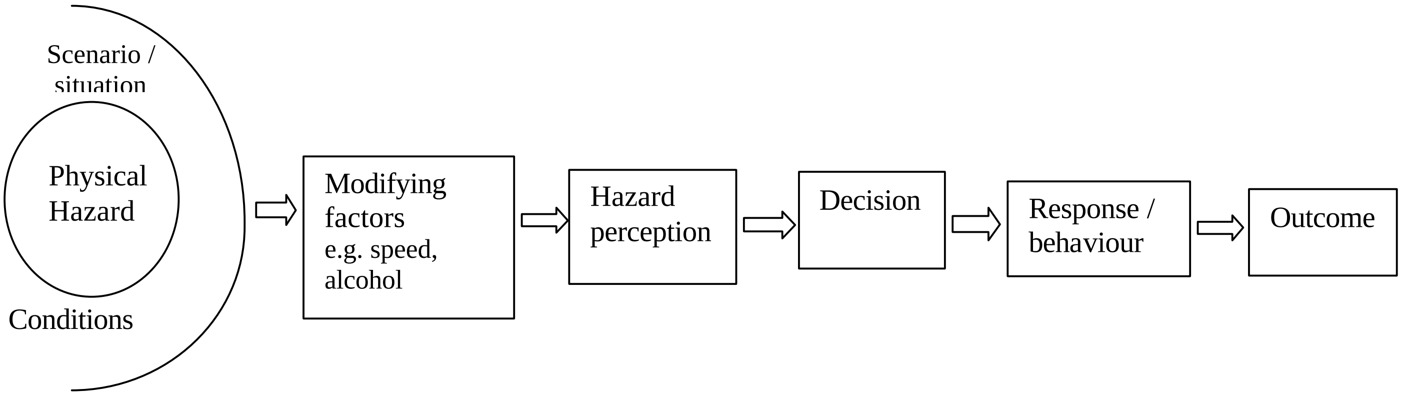

Figure 1.1 A possible model of the role of hazard perception in the chain of processes linking the existence of physical hazards and outcomes.

An outcome of the hazard perception and responding process might be to change the levels of the modifying variables – the response might be to slow down, which then changes the modifying variable of speed. Changes to the modifying variables might occur over a longer timeframe, and this may be what happens in gaining experience and learning to ride more safely.

2.2.7 Defensive driving or riding

In the course of the consultation conducted for this project, some riders queried whether defensive riding was a more useful concept than hazard perception and responding. This section seeks to address what is known about defensive riding (or driving) and how it relates to hazard perception and responding.

Defensive driving is mentioned rarely in the literature and defensive riding even more rarely. However, mentions of defensive driving training (or defensive riding training) are much more common.

Carstensen (2002) refers to defensive driving and hazard perception as being similar concepts. She describes defensive driving skills as including 'to drive carefully', 'keep track of traffic around me', or 'anticipate what is going to happen in traffic'. Some of the riders consulted for this project provided definitions such as: "Defensive riding is the ability to prevent accidents. This is done by anticipating dangerous situations and changing speed, direction, position or whatever else is required to minimise potential hazards. It can also be described as risk minimisation or being proactive in safety."

Defensive driving training and advanced driving training are often used interchangeably in the literature and in promotional material for courses. Christie (2001) describes defensive driving training as a basic type of driver training 'offered at a post-licence level with the aim of helping drivers avoid getting into critical situations.' It contrasts with advanced driving training which he defines as training 'offered at a post-licence level with the aim of helping drivers cope with critical situations that may arise.'

The distinction is less clear in Goldenbeld and Hatakka (1999), who refer to defensive driver training as a type of advanced driver training that involves theoretical training. According to Hatakka, Keskinen, Gregersen, Glad and Hernetkoski (2002), 'defensive driving courses may emphasise mainly skills based on vehicle manoeuvering when involved in a risky situation, and avoidance of risks and risky situations is secondary.' (Note this definition would seem to conflict with those described above).

It is not clear whether "defensive driving training" or "defensive riding training" provide much insight into the meaning of defensive driving or defensive riding.

In terms of the model of the hazard perception and responding process shown in Figure 1.1, defensive riding (or driving) appears to combine components of the modifying factors (e.g. choosing optimum position or speed) and hazard perception, with a large emphasis on modifying factors.

2.3 HAZARD PERCEPTION AND EXPERIENCE

According to Fitzgerald and Harrison (1999), hazard perception is a skill with cognitive and behavioural aspects that include cognitive workload, automation, and attention. Humans possess finite cognitive resources, and anything that requires attention taxes these resources. While driving, there are many situations both within and external to the vehicle that require the attention of the driver, such as reading dash instrumentation to maintain a legal speed and analysing the movements of the traffic around the vehicle.

A safe driver must concentrate on all of the space around the vehicle, not just in the direction of travel. In order to 'read the scene' for potential hazards the driver needs to continuously redirect his/her attention all around the vehicle in an ever-changing environment. Visually scanning the scene, recognising potential hazards and devoting extra attention to them without ignoring the rest of the scene is a skill that requires practice.

In order to attend to and assess all of these variables on a continuous basis, a finite amount of cognitive resources must be devoted to each one. Under such circumstances cognitive overload can easily occur, possibly leading to the ignorance of potential hazards.

With sufficient practice, the skills involved in driving a car become automatic, requiring little cognitive attention for each of the component skills. However, by their nature, hazards that require some change in behaviour of the driver may not occur often enough for their processing to become automated. For example, relative to the amount of time spent driving, the number of times a driver would need to swerve to avoid an obstacle is minimal. While the swerve itself may be reflex-like, the skills involved in emergency braking, keeping control of a possibly skidding vehicle, analysing the scene for new obstacles as the vehicle moves into another stream of traffic, and then regaining the original direction of travel – all while under a heightened level of arousal – are unlikely to be automatic behaviours for most drivers. As such, each action would have a high cognitive demand, quickly over-taxing the system and increasing the likelihood of error in any of these elements, possibly leading to a crash.

Harrison (2002) states that

> *Responding to hazards in an efficient, effective manner relies on fast decision making. Fast decision making is a consequence of these information processing mechanisms and experience of the cues, their consequences, and behavioural responses and their consequences accrued over time. Effective, fast responses to hazards are almost certainly a consequence of a broad range of driving experiences and the action of these cognitive mechanisms.*

2.4 THEORETICAL FRAMEWORKS FOR HAZARD PERCEPTION AND RESPONDING

A number of different theoretical frameworks have been used to explain hazard perception by car drivers. Recognition-primed decision making (Klein 1989, 1993) and situational awareness theory (Endsley, 1995) are described briefly below. Harrison’s (2002) consideration of the development of hazard-related skills in an evolutionary framework is then outlined. A recent four component model of responding to risk (Grayson, Maycock, Groeger, Hammond and Field, 2003) is described in more detail because of its inclusion of a response implementation phase, which may be more important in motorcycling than in car driving (for which the model was developed).

2.4.1 Recognition primed decision making

Fitzgerald and Harrison (1999) invoke Klein’s (1989, 1993, cited in Fitzgerald & Harrison, 1999) recognition-primed decision making model (RPD) to explain hazard perception by drivers of vehicles in dynamic, sensation-rich environments. RPD involves a number of steps between devoting attention to a situation and producing an appropriate behaviour in response.

‘Situation recognition’ is the first stage of the process, where the situation or context is classified as either novel or familiar, based on comparisons of the current events and stimuli with memories of situations encountered previously. If a match is found and the new event classified as familiar, previous responses and their outcomes can be evaluated for their potential effectiveness in the new situation.

Once a list of potential behaviours or responses is generated, the individual progresses to the second stage of RPD. ‘Serial option evaluation’ involves testing each possibility in the list of potential responses generated in Stage 1 in a mental simulation of its consequences to determine the most appropriate response. The optimality of this response will depend on the prior experience of the individual. For example, the most technically appropriate response may not be considered as a viable option because the driver has not used it previously, or the response may not have been successful for the driver in a previous situation. Furthermore, the driver may not have been in such a situation at all before.

If the driver has encountered a similar situation previously, the degree of similarity of the prior and current situations is important. For example, the particular actions in emergency braking and swerving to avoid an obstacle will be different depending on weather conditions, type of road surface, and whether the obstacle is dynamic or static (such as an animal versus a lump of wood). If several similar rather than one identical option is available, then time must be devoted to the mental testing of each one and a choice made, theoretically lengthening the response time.

Fitzgerald and Harrison (1999) point out that ‘hazard perception’, as it is generally viewed, only involves the situation recognition phase of RPD – deciding whether the situation is novel or familiar. They suggest that the focus should be on ‘hazard behaviour’. As indicated earlier, perceiving a hazard in itself does not allow a driver to avoid an accident, there must be an appropriate behaviour as well. Viewing the process in terms of a complete action (i.e. hazard behaviour rather than just the perception of a hazard) allows for the isolation of factors that can affect the likelihood of avoiding an accident. For example, hazard perception would depend on visual scanning effectiveness but not the effectiveness of the cognitive process of testing and evaluating potential responses. Clearly, an inefficient handling of the ‘option testing’ due to increased cognitive workload may make an accident more likely, and so Fitzgerald and Harrison suggest that this aspect may require particular attention when determining methods of training for novice drivers.

2.4.2 Situational awareness theory

Situational awareness refers to an individual’s understanding of a dynamic environment. This includes the perception and interpretation of both environmental and personal stimuli, and making predictions of the status of various elements of the situation in the near future. For example, the situational awareness (SA) of a motorcycle rider in a typical traffic situation may be an awareness of where other vehicles are around him, maintaining a suitable speed for the weather and road conditions, being vigilant for obstacles, and making predictions based on that information. An example of the latter might be expecting a particular car to change lanes due to a slow-moving truck in front of it – this judgement is made from observation and prior experience of similar situations.

According to Endsley (1995) there are three steps to SA in a hierarchical structure. Level 1 involves the perception of environmental elements, including sounds, sights, and textures. In Level 2, these stimuli are drawn together in a holistic understanding of the situation. This understanding will be very individualistic as interpretations will depend on the person's goals, motivations and prior knowledge. For example, an aggressive, time-pressured driver will concentrate on different stimuli and make different interpretations while looking for openings in the traffic, whereas a "Sunday driver" will have a different set of motivations and so will analyse the information differently.

From comprehension and understanding, the third level of SA should arise. Level 3 is the prediction of future actions of the various elements within the situation – essentially predicting how things will change. From these predictions decision making can occur, and Endsley (1995) stresses that this is separate from, but dependent upon, SA. As such, good decisions will be contingent upon making quick and valid predictions. Endsley also suggests that this process is similar to any skill, in that with practice comes automaticity.

When a skill is mastered it is said to become automatic and require little conscious effort. For example, learning to ride a bike initially requires training and practice, where the beginner must concentrate on each component skill. Once these skills have been mastered one can ride without devoting any attention to the individual skills involved, and indeed may find it difficult to explain the process to a novice.

According to Endsley (1995), the transfer from concentrating on each component skill to automaticity can occur for any skill or action that is practised often enough to form mental schemas (i.e. frameworks built up of past experiences and knowledge and schema scripts (essentially an accompanying "running sheet" of actions to be performed) in long term memory. Once automatic, it becomes a process of unconscious pattern matching. The elements of a particular stimulus or situation are compared to those in memory, and a relevant schema and its accompanying actions are triggered almost instantly, removing the time required to weigh up the options and make a considered decision.

Clearly the speed and ease of making SA predictions and then decisions depends very much on experience. Unless an individual has had practice in vehicle handling skills so that he/she can swerve to avoid an obstacle on the road, maintain control while emergency braking and avoid colliding with other traffic (which were not obstacles previously), he/she will not have an automatic response ready for when a child runs onto the road in front of the vehicle. Without an automatic response, there is unlikely to be time for the driver to absorb sufficient information, make considered judgements and take action to safely and successfully avoid the child. Due to the relatively rare occurrence of hazards to road users, without regular practice it is likely that few drivers are properly prepared to quickly deal with them.

Endsley (1995) outlines other factors and processes that are important considerations in SA. While scanning the environment a road user will be exposed to a lot of sensory information. The saliency of this information to the individual will determine what aspects receive extra attention. For example, the colours of the vehicles are not as important as their relative speeds in "fitting in" with the surrounding traffic. Those aspects that receive directed attention are processed in working memory in terms of the individual's goals. For example, hearing an odd noise may indicate a potential problem for a motorcyclist and so receive a lot of attention as the rider checks his/her motorcycle (such as the instrument panel and other immediately visible parts) and looks around for the source of the noise. Thus, people are actively involved in the process of information perception and attention.

Directing attention is also a skill that can be practised and improved, and individuals can be taught to divide their attention between multiple stimuli (Damos & Wickens, 1980, cited in Endsley, 1995). Being able to quickly direct attention to and divide attention between stimuli is particularly important for drivers due to the complex and dynamic nature of the information that must be processed in a short time. Regan, Triggs and Deery (1998) have demonstrated that risk perception by novice drivers can be indirectly enhanced through training in attentional control. So rather than only training novices in the hazards to look out for, drivers should be given training in how best to devote attention to these hazard stimuli while still paying attention to the driving process to ensure that all pertinent information will be sufficiently processed.

As real-time mental processing occurs in working memory, there is the potential to quickly reach a situation of overload, especially if attention is being divided between many stimuli. However, when cues trigger automatic responses from long term memory, working memory can be kept free of processing load, shortening the reaction time (Endsley, 1995).

It is also possible that a cue will trigger a response that was not specifically learnt for that situation. For example, a rider may develop motorcycle handling skills at a training track. It is unlikely that an orange cone will "jump out" at a motorcycle in a real situation, but the skills should be sufficiently generalisable that a dog running onto the road will trigger the same emergency response. A further advantage to automaticity is that a cue can trigger a response without waiting for all of the information to be perceived or processed. Noticing a dog on the side of the road looking at a child on the other side may be enough of a cue to heighten the driver's attention and trigger an initial response of slowing down and checking the traffic situation – preparing to take evasive action should the dog attempt to cross in front of the vehicle.

With increased experience and a history of successful hazard avoidance, a driver's confidence level will increase, further improving his/her performance (Endsley, 1995). Conversely, a lack of experience and skill will place stress on the novice driver. While some stress can produce an improvement in performance (Kahneman, 1973; cited in Endsley, 1995), too much stress tends to cause the driver to narrow his/her focus to a limited number of cues, increasing the likelihood that the driver will miss important hazard information. In addition, it is suggested that stress may also decrease working memory capacity and retrieval (Endsley, 1995).

Endsley (1995) describes four SA scenarios that vary depending on the situational awareness of the individual and the workload (i.e. complexity) of the situation.

- Low SA and low workload – inattentiveness and little vigilance produces an apathetic operator;
- Low SA and high workload – too much information for the operator to cope with;
- High SA and low workload – an ideal situation where information is easily processed;
- High SA and high workload – the operator is working hard but managing to process all of the necessary information.

A low level of SA or too high a workload can cause errors to be made due to incomplete information or inaccuracies in processing the information, respectively. Such errors can occur at any of the three levels of SA – perception of the environment, comprehension of the situation, or projection of future status.

Errors in performance can also occur when the correct response is not known or an incorrect one is enacted, or if the individual is limited in some way (e.g. time) from carrying out an appropriate response. An awareness of the error can enable the individual to ‘update’ the system to improve performance for the next time the situation occurs. However, in terms of hazards, an individual may be unaware that he/she has made an error because not all hazards will result in a crash (for example, a driver may not notice a nail on the road but miss it anyway, or cut off a motorcyclist and not realise that he/she has done so).

2.4.3 An evolutionary framework

Harrison (2002) discusses the development of hazard-related skills in terms of evolutionary psychology. This approach suggests that “the perceptual, cognitive, and behavioural processes that are the basis for safe driving behaviours evolved originally to provide the organism with the ability to make behavioural decisions under conditions of high workload and urgency” (p.3). He states that the higher-order skills thought to be important in driving, such as attentional control and hazard detection skills, are built on a foundation of perceptual and cognitive processes that are part of the information-processing system. Harrison claims that “while considerable effort is invested in the development, assessment, and potential training of higher order skills, little effort is put into understanding the consequences for these skills of the limitations and advantages of the underlying, evolved, perceptual and cognitive processes” (p.4).

In this framework, behavioural responses to hazards are viewed as the outcome of a number of processes that occur together: sensory processes, perceptual, memorial and associative processes, expectancies and scanning and conscious processes.

Sensory processes

Detection of a hazard depends on the sensory (commonly visual) systems detecting it. This depends on the salience of the stimuli and a number of other stimulus and contextual characteristics that are not under the control of the driver, and a number of factors that can be influenced by the driver. These factors that can be influenced by the driver include appropriate use of lights and could be considered as “modifying factors” in terms of the discussion in Section 2.2.5. There is also an attentional component that can assist or hinder the detection of hazards. Harrison (2002) cites research that shows that overt visual attention may be more controlled by stimulus characteristics rather than top-down attentional processes. Thus, the benefits of training in visual scanning may be limited.

Perceptual, memorial and associative processes

Information processing systems provide the linkage between sensory detection of a hazard and behavioural responses to minimise the risk of negative outcomes. These include “cognitive mechanisms that allow the storage of experiences in a way that ensures prior experience can influence behavioural decisions in future, mechanisms that map current experiences and demands onto stored information to ensure that behavioural decisions can be made efficiently in a way that maximises the possibility of positive outcomes, and mechanisms that update stored information about causal links between events in the environment so that new information becomes the basis for future behaviours” (p.6).

Harrison (2002) claims that these systems have two key consequences for behaviour in high-workload, dynamic situations. Firstly, behaviour tends to be habitual – organisms behave in ways that have been successful in a particular situation in the past. Secondly, human behaviour is strongly influenced by processes that are not under conscious control.

He concludes that the implication of this view is that teaching specific responses to specific hazards is only likely to be successful if combined with extensive and ongoing practice.

Harrison (2002) claims that behaviours to avoid hazards are significantly more important than behaviours that cope with a hazard once it is a problem. He cites as examples of behaviours to avoid hazards: early braking, driving more slowly, leaving appropriate gaps, and reducing distractions. He maintains that these behaviours are likely to occur only if practised to the point that they become automatic responses to hazard-related cues.

Expectancies and scanning

The pattern of scanning is most likely the consequence of a number of mechanisms, some of which would be influenced by expectations about the driving environment built up, primarily, by experience. Harrison (2002) cautions that attempting to change expectations and scanning behaviour using an educational approach may contradict the experience of the driver. If the scanning system evolved based on where hazards are most likely to occur, then it may be difficult to direct scanning towards low-risk or low-frequency hazards, and this could potentially result in missing more common hazards.

Conscious processes

Harrison (2002) expresses the view that education is a conscious, knowledge-related input that is unlikely to change hazard-related behaviours that are "almost certainly" built on information processing and behavioural mechanisms that evolved to handle high workload decision making without recourse to conscious processes or knowledge. He claims that there is potential for the knowledge to be translated into behavioural change as a result of extensive practice of the behaviour encouraged by the knowledge. "The issue for the training of hazard-related skills, therefore, may be how to best use an educational approach to encourage intense practice of safety-oriented behaviours until they become automated, when the driver's experience on its own may not encourage the desired behaviour" (pp.7-8).

2.4.4 Four component model of responding to risk

Grayson, Maycock, Groeger, Hammond and Field (2003) developed a model of the process of responding to risk. Their underlying principle was that "drivers differ in accident liability [similar to crash risk] because they differ at an individual level; that is, they differ in their abilities to detect and recognise potential hazards, and in their abilities to respond appropriately to those hazards" (p.38). The model has four components:

- Hazard Detection – being aware that a hazard may be present
- Threat Appraisal – evaluating whether the hazard is sufficiently important to merit a response
- Action Selection – having to select a response from one's repertoire of skills
- Implementation – performing the necessary actions involved in the response that has been selected

The model is represented in Figure 1.2.

Hazard detection

Grayson et al (2003) describe the process of hazard detection as follows.

> *For the process of response to risk to start some sort of discrepancy must be detected between the environment as it is and how it might normally be expected to be. This process may not be a conscious one and the individual concerned may not subsequently report the event. The relevant kind of discrepancy is one which is predictive of being endangered. Many of these predictive relationships, such as anticipating the presence of children near parked cars, need to be learned either through experience of driving or instruction. Some of the less subtle predictive relationships based on looming objects require little or no learning during the period of learning to drive as they may be generalised from the experience of learning in other circumstances. Where a number of different cues are required to discriminate a hazardous situation from a non-hazardous, then instruction or experience is required.*
>
> *Individuals will differ in their Hazard Detection due to experience, propensity to evaluate situations in general as threatening, and perceptual ability. (pp.4-5)*

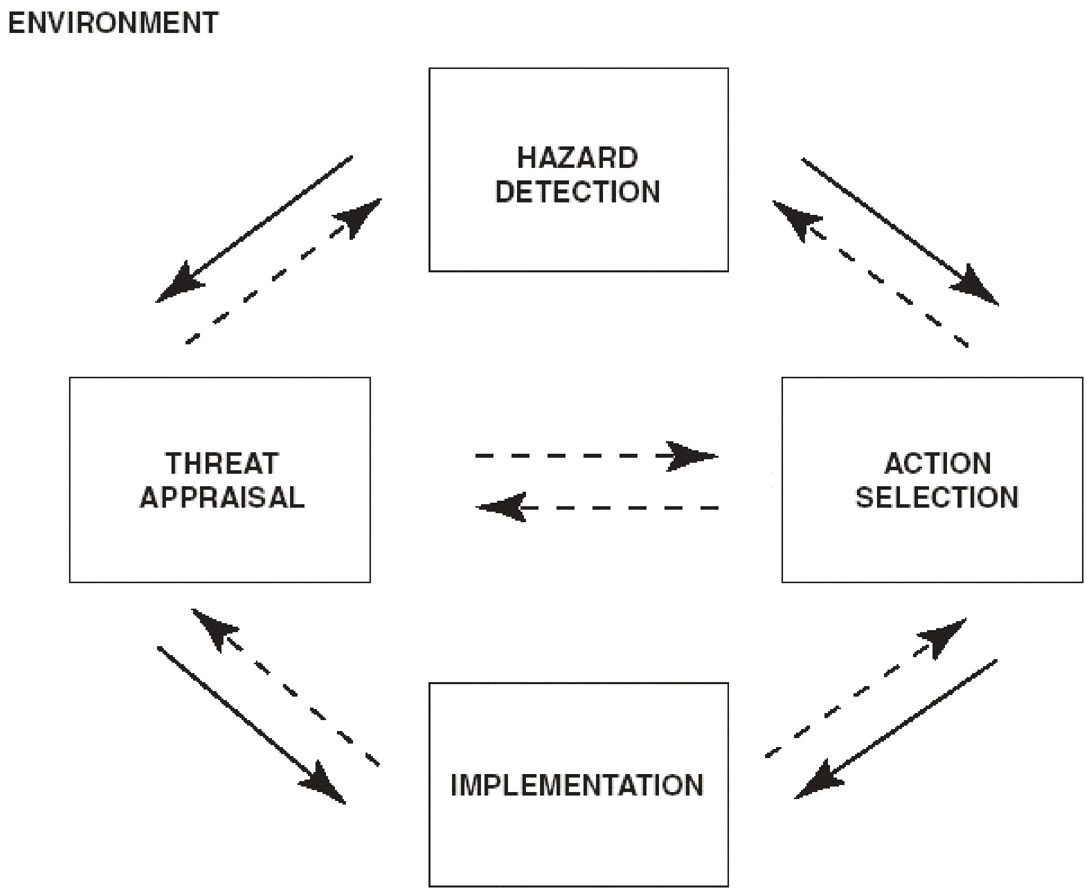

Figure 1.2 Processes involved in responding to risk (from Grayson et al., 2003). The bold arrows represent hypothetical forward links. The dashed arrows represent hypothetical feedback links.

In support of Grayson et al.'s claim that perception of looming objects requires little or no learning, Harrison (2002) cites evidence of neurons sensitive to looming that may underlie fast responses to looming objects.

Threat appraisal

Grayson et al describe the Threat Appraisal process in the following way:

> *the evaluation of a hazard must produce one of two basic outcomes, to act or not to act. Which choice is made will depend upon an assessment of the seriousness of the threat present in the situation, and an assessment of the likelihood of the negative outcome if no action is taken. …. Simple, well-learned risks may not require any significant Threat Appraisal process. We therefore speculate that the contribution that Threat Appraisal makes to drivers' capacities to detect and respond effectively to hazards will decline at the higher end of the experience distribution. (p.5)*

In addition to the cumulative effects of experience, they state that long-term personality traits and mood states are involved in the Threat Appraisal process. The trait of confidence may affect the extent to which individuals believe that negative outcomes of situations are likely. Individuals differ in the extent to which they perceive events as being controlled largely by themselves or by outside forces (internal versus external locus of control) and this will affect the assessment of whether action should be taken.

Action selection

The process of Action Selection is described as follows

> *During the course of driving a whole range of actions are routinely performed under the control of a hierarchy of goals. … The normal hierarchy of control is interrupted by the detection of a hazard which is appraised as being sufficiently serious to require a response. A serious threat will cause a reallocation of attention from all of the levels of the normal control structure. … In some cases the allocation of attention is so great that it actually prevents the selection of any course of action at all. The requirement to attend to a highly salient stimulus and still have attentional capacity left over to perform an action leads to the prediction that attentional capacity will be one of the individual differences contributing to this aspect of response to risk. As well as the absolute size of the attentional resource available to an individual, the way it is deployed is expected to influence Action Selection, this being largely determined by personality factors. The decision will necessarily be a probabilistic one because knowledge of the outcomes of the different possible actions will be incomplete to differing extents for each option. Knowledge of many equally practised courses of action may be counterproductive since decision time tends to increase as the number of alternative actions goes up, especially if those courses of action are thought to have similar chances of success. (p.5)*

Implementation

The process of Implementation is described as follows:

Individual differences in motor performance and reaction times are expected to influence the successful Implementation of a course of action. … For inexperienced drivers feedback from Implementation to Action Selection about outcomes is invaluable in improving Action Selection. Successful and unsuccessful Implementation also feed back into Threat Appraisal by increasing or decreasing the drivers' self-assessment of their skill. If drivers were given the opportunity to practise the Implementation of the kinds of action available to Action Selection under supervision then this might be valuable for decision making in Action Selection as well as increasing the chances of successful Implementations in the future. (Grayson et al., 2003, p.5)

Structure of the model

Grayson et al (2003) note that the most obvious sequence of processes would be the detection of a hazard which is appraised as sufficiently dangerous to require a response, followed by the selection of a defensive measure and then its implementation. However, they note that there may be no significant Threat Appraisal process where the threat is very clear and detectable by basic perceptual processes (such as a rapidly looming object). In this situation, Hazard Detection may be followed directly by Action Selection. The arrows in the model have been positioned to indicate that it is possible that the components operate in parallel once the initial Hazard Detection has occurred. As an example, they cite scenarios in which during or after the Implementation of an action the Threat Appraisal process continues to indicate that there is a danger, possibly caused by the first action. This would then lead to the modification of the first course of action or a further action being selected.

The dotted feedback lines indicate possible routes for learning which they describe as occurring in the following ways:

For inexperienced drivers every response to risk alters the state of the system as it will be when it encounters its next hazard. In particular both successful and unsuccessful Threat Appraisals provide information which can improve the efficiency of the Hazard Detection process. Experience of successful and unsuccessful Implementations shapes the developing Action Selection process. (pp.5-6)

Applying the four component model to motorcycling

Grayson et al. (2003) do not directly mention motorcycling, but the emphasis in their model on the response execution phase (Implementation) means that it is potentially useful for understanding motorcyclists' responses to hazards. Analyses of motorcycle crashes have demonstrated that response implementation may be where the process of hazard perception and responding fails in some crashes (e.g. Haworth et al., 2000).

The four component model focuses on the effects of stable personality traits, rather than states of the individual (e.g. sobriety). It is likely that modifying factors such as alcohol would affect several components of the model, including threat appraisal and implementation (e.g. by lengthening reaction time).

The model does not specifically deal with transient modifying factors that influence the potential severity of the outcome such as speed. It is unclear how the model accounts for improvement with experience.

2.5 SUMMARY OF DEFINITIONS, CONCEPTS AND PROCESSES

For the purposes of this report, a *hazard* was defined as "any permanent or transitory, stationary or moving object in the road environment that has the potential to increase the risk of a crash. Hazards exclude characteristics of the rider or the vehicle, which are classed as modifying factors."

Modifying factors are defined as characteristics of the rider or the motorcycle that modify the level of risk of a hazard. They can be long-term characteristics of the individual such as rider experience and rider skill in executing responses (real or perceived) or more transitory characteristics such as travel speed, type of protective clothing worn and mechanical condition of the motorcycle. The concept of *defensive riding*, as described by riders, appears to place more emphasis on the modifying factors and less on the perception of hazards.

Hazard perception is defined here as "the process whereby a road user notices the presence of a hazard" (from Evans and Macdonald, 2002, p.93). Hazard perception is the first stage in a chain of processes linking the existence of physical hazards to outcomes.

A number of different theoretical frameworks have been used to explain hazard perception by car drivers including recognition-primed decision making (Klein, 1989, 1993), situational awareness theory (Endsley, 1995) and the recent four-component model of responding to risk (Grayson et al., 2003). Grayson et al. (2003) do not directly mention motorcycling, but the emphasis in their model on the response execution phase (Implementation) means that it is potentially the most useful for understanding motorcyclists' responses to hazards. Analyses of motorcycle crashes have demonstrated that response implementation may be where the process of hazard perception and responding fails in some crashes (e.g. Haworth et al., 2000). It is likely that modifying factors such as alcohol would affect several components of the model, including threat appraisal and implementation (e.g. by lengthening reaction time). However, the model does not specifically deal with transient modifying factors that influence the potential severity of the outcome such as speed, and it is unclear how the model accounts for improvement with experience.

3. HAZARDS FOR MOTORCYCLISTS

This section presents the evidence that hazards to motorcyclists can be grouped into vehicle-based and road-based hazards and describes the research into these two classes of hazards.

3.1 CATEGORIES OF HAZARDS

Mills et al. (1998) classified hazardous situations into those where the driver could be a threat to others and hazards that could be a threat to the driver. They provided a rather extensive but not exhaustive list of hazards. Some of the hazards where the driver could be a threat to others included scenarios such as a stray dog by the kerb, a pedestrian trying to cross the street, and a cyclist on a country road. The hazards where there was a threat to the driver included scenarios of another vehicle doing a U-turn on the brow of a hill, parked vehicles, roadworks, and a bus pulling out into traffic. The scenarios were further classified into events occurring in front of the car, something joining the car's path, and events occurring in opposing traffic.

It is likely that motorcyclists would consider many of the "threat to other" hazards to be also a threat to the rider, given the potential dangers of taking evasive action (or of a collision). Therefore, the distinction between hazards where the rider could be a threat to others and those that are threats to the rider may not be useful for motorcyclists.

Motorcyclists are subject to the hazards faced by car drivers but are also at risk from situations not hazardous for car drivers, such as gaps in bridge decking wide enough to catch a motorcycle wheel but too narrow to effect a car tyre. The reactions required from riders also need to be different, as motorcycles handle differently to cars. The extent of potential harm associated with any given hazard is commonly greater for motorcyclists, given their comparative lack of protection.

Most of the hazards described by Mills et al. (1998) relate to the behaviour of other road users. Using a repertory grid technique, Armsby et al. (1989) found that the hazards identified by their participants formed two main construct clusters relating to "vehicles" and static features of the road environment. They noted that car drivers who also rode (or had ridden) motorcycles, were able to identify specific features of the road, and specific actions of other road users, as hazards to motorcyclists, while car drivers focused on hazards arising from the behaviour of other road users.

Grayson et al. (2003) note that, at the individual driver level, there is also a subjective component to hazards. A hazard for one driver may be a thrill for another.

In the sections that follow, hazards are divided into road based hazards and hazards that arise from the behaviour of other road users.

3.2 ROAD BASED HAZARDS

Road based hazards can be categorised as:

- Permanent characteristics of the road surface – roughness, being an unsealed or gravel road, low skid resistance, tramlines, railway lines, painted lines on roads

- Temporary characteristics of the road surface – potholes, surface irregularities, pit lid covers, oil or gravel on road, debris, gravel, melted tar in hot weather, roads that become greasy and slippery in summer during rainstorms (Allardice, 2002)

- Visual obstructions – stationary vehicles, vegetation, fog and heavy rain

- Characteristics of the road alignment – horizontal curves, vertical curves.

Royal Society for the Prevention of Accidents (ROSPA, 2001) states that, being two wheelers, motorcyclists are more susceptible to difficulties and hazards created by the design, construction, maintenance and surface condition of roads. Allardice (2002) notes that wooden bridges can be uneven and extremely slippery when wet. While traffic calming measures can reduce speed-related crashes, they can sometimes inadvertently provide hazards to motorcyclists.

3.2.1 Wet roads

It is unclear whether wet roads should be considered as a hazard in themselves, or as a factor that exacerbates the threat posed by other road surface hazards. Surface items such as painted markings and metal service-covers become extremely slippery when wet. After a prolonged dry spell, the road surface becomes contaminated with dust, oil droppings and tyre rubber particles. This becomes very slippery when mixed with the first of the rain, so there is a need to be especially cautious and conservative (Allardice, 2002).

In addition to the increased slipperiness of hazards, wet roads also reduce the efficiency of braking and so impair the implementation phase of hazard perception and responding. ROSPA (2001) cites TRL data showing that skidding occurs in about 30% of the motorcycle personal injury accidents in the wet.

3.2.2 Gravel roads

Motorcycle tyres have less grip on gravel roads, even if dual purpose tyres are used. In addition, flying stones, dust and mud can be thrown up by vehicles in front and oncoming vehicles. Allardice (2002) notes that gravel roads through farmland are “often plagued with wandering stock and used by locals who know the road and tend to use all of it” (p.59).

3.2.3 Road alignment

Road alignment has two types of hazardous effects: the extent to which it obscures the presence of the motorcyclists and other road users and the extent to which it affects the dynamics of the motorcycle and hence its travel path.

3.2.4 Roadside hazards

Street furniture that is located too close to the road can hinder visibility and potentially cause serious injury to motorcyclists (ROSPA, 2001 and VicRoads, 2001).

Some “roadside” hazards may be on-road hazards (i.e. hazards without the motorcycle leaving the road) because of the angle of the rider when cornering (see Allardice, 2002 and VicRoads, 2001).

3.2.5 Studies of the extent of involvement of road based hazards in crashes

The Hurt study of motorcycle crashes in the Los Angeles area (Hurt, Ouellet and Thom, 1981) concluded that only 2% of crashes were caused primarily by roadway defects (pavement ridges, potholes etc.). Only a very small proportion of the 2.2% of crashes that occurred during adverse weather conditions were the *result* of those conditions. Ouellet (1982) suggests that the figure might be higher in areas with harsher winters than Los Angeles. Animals accounted for only 1% of the 900 motorcycle crashes.

Ouellet (1982) concluded that obstruction of the pre-crash line of sight between the motorcycle and the vehicles with which it collides is perhaps the most substantial environmental contribution to crash causation. It was found that one third of motorcycle crashes involve obstruction of the motorcyclist's and/or car driver's view of each other in the moments just prior to the collision. Other vehicles in traffic and parked vehicles were the main cause of view obstruction (Hurt et al., 1981). As Ouellet (1982) points out, high conspicuity treatments of the motorcycle and rider are of no use if the view of and from the motorcycle is blocked.

While road based hazards can, in some cases, cause loss of control of the motorcycle, their role is more often contributory when the motorcycle is performing a complex manoeuvre such as turning or braking. For example, in one case a motorcycle was braking heavily to avoid colliding with a car turning left across its path. The action would have been successful if the motorcycle had not crossed a manhole cover with an inch high asphalt beam around it which caused the front wheel to lock up and slide out, throwing the rider and passenger to the ground.

Haworth (1999) reported the results of the site inspections and ride-throughs conducted for the *Case-Control Study of Motorcycle Crashes* (Haworth, Smith, Brumen and Pronk, 1997). An experienced rider rode a motorcycle through the location of 206 crashes at the same time of day and week and in as similar conditions as possible to when the crash occurred. This provided an opportunity to assess whether the road conditions or the surrounding environment contributed to the occurrence or severity of the crash.

In 31 cases (15% of inspected sites) it was found that the road surface actively contributed to the occurrence of the crash. In many other cases the variables were present at the crash site but did not actively contribute to the occurrence of the crash. The site factors were coded according to the scheme in Table 3.1. In 47% of cases, no site factors were judged to have contributed to the occurrence or severity of the crash. The most common site factors were: lack of visibility or obstructions (20%), unclean road or loose material (14%), poor road condition or road markings (12%), and horizontal curvature (12%).

Table 3.1 Number and percentage of crashes in which particular site factors played a role. More than one factor could be coded at one site so percentages do not sum to 100%.

Site factors	Number of cases	Percent of cases
Unclean road / loose material	29	14
Road condition, surface grip, patch repairs, degradation, road markings	25	12
Reduced effectiveness of emergency braking	11	5
Horizontal curvature	24	12
Vertical curvature	16	8
Gravel shoulder or soft shoulder	6	3
Lack of visibility, obstructions	41	20
Inadequate lighting	8	4
Timing of traffic signals	2	1
Inadequate road delineation	5	2
Lane reduction, merging	2	1
Speed humps and local area traffic management	4	2
Barriers	6	3
Trees and poles	10	5
Drains and culverts	2	1
Roundabouts	9	4
Inappropriate speed zoning	5	2
Gratings, grids and tram lines	6	3
None	97	47

Rider responses to a recent survey by the NSW Motorcycle Council showed that 67% of the single vehicle crashes were considered to be associated with loss of traction due to road surface conditions. Overall, 55% of all motorcyclists who had been involved in any crash cited loss of traction with the road surface due to gravel, potholes, slippery paint or tar. Eighty percent of all respondents who had been involved in a crash where they lost traction, reported that in the circumstances there was nothing they could have done to avoid the crash. The survey report (de Rome, Stanford and Wood, 2002) provides an extensive discussion of road-based hazards. They conclude that

> *"The essential argument comes down to the question of contributing responsibility. What is the responsibility of road authorities to provide a road environment that does not present such hazards without appropriate warning, and to what extent are motorcyclists responsible for anticipating the possibility of such situations." (de Rome, Stanford and Wood, 2002).*

3.3 HAZARDS ASSOCIATED WITH THE BEHAVIOUR OF OTHER ROAD USERS

Allardice's (2002) list of hazardous road configurations includes a number of situations that reflect the hazards associated with the behaviour of other road users:

- Roundabouts and intersections (other vehicles may fail to give way)
- Traffic lights (possible rear-end crashes and red-light runners)
- Motorways (high speeds close to "disinterested, inattentive, impatient, stressed and distracted vehicle drivers")
- Bridges (no escape route from potential head-on collisions)

In addition, he warns that "pedestrians are a potential hazard and should be respected in the same way as any other large animal on or near the road. Pedestrians are unpredictable, even more so than feral or domesticated animals, and can have impaired hearing and eyesight" (Allardice, 2002, p.69).

The hazards associated with the behaviour of other road users can be thought of as arising from failures of hazard perception by other road users. Thus, many of the factors that interfere with hazard perception by car drivers (e.g. distraction associated with mobile phone use) contribute to the behaviour of those road users being hazardous to motorcyclists. The extent to which this can and should be addressed by improving the hazard perception and responding skills of motorcycle riders, compared with the corresponding skills of car drivers is a matter for debate.

It is much easier to identify hazards related to the behaviour of other road users in the crash data than it is to identify the role of road based hazards. Therefore, relatively more is known about the extent of involvement of hazards relating to the behaviour of other road users in motorcycle crashes.

3.3.1 Failure to give way by other vehicles

The other vehicle is commonly judged at fault in multi-vehicle crashes involving motorcycles. In an early study of 900 motorcycle accidents in Los Angeles, Hurt, Ouellet and Thom (1981) found that the most common motorcycle accident involved another vehicle (75%) violating the right-of-way of the motorcycle at an intersection, usually by turning left in front of the oncoming motorcycle.

In Victoria, motorcyclists are commonly the vehicle going straight ahead in right-turn crashes, being in the rear in rear-end crashes and in the ongoing lane in sideswipes. New South Wales crash statistics for 2000 (data from RTA, cited in de Rome, Stanford and Woods, 2002) show that in 68% of crashes between a motorcycle and another vehicle, the other driver was responsible. In intersection crashes, the other driver was responsible in 74% of crashes.

A study of nearly 10,000 motorcycle crashes in the London area (Booth, 1989, cited in ROSPA, 2001) concluded that 62% of motorcycle crashes were primarily caused by the other road user. Half of the crashes were caused by car drivers and 10% by pedestrians. The report found that two-thirds of motorcycle crashes where the driver was at fault were due to the driver failing to anticipate the action of the motorcyclist. In contrast, studies of rural crashes find that most crashes are classified as "rider error", with losing control on a bend and overtaking being common (reported in ROSPA, 2001).

TRL in the United Kingdom has reported an analysis of police reports of 717 fatal crashes involving motorcycles that occurred between 1986 and 1995 (Lynam, Broughton, Minton and Tunbridge, 2001). The analysis used a system devised by TRL for identifying those factors that contributed directly to the occurrence of the crash.

'Failed to give way' and 'poor turn/manoeuvre' were common in crashes for which the non-rider was largely responsible and were associated with failure to observe satisfactorily, careless, thoughtless or reckless behaviour, or failure to judge the rider's path or speed.

The 48 crashes where 'poor turn/manoeuvre' by the other road user was the precipitating factor fell into two main categories:

- A vehicle turning right across the oncoming carriageway and failing to see an approaching motorcyclist (20 crashes)

- A vehicle performing a U-turn manoeuvre without sufficient care (12 crashes)

Other crashes involved vehicles turning into the path of motorcycles overtaking them, poor overtaking manoeuvres by vehicles and other poor manoeuvres by vehicles at junctions.

There were 70 crashes where the 'other vehicle failed to give way'. The majority of the crashes involved a vehicle turning right at a junction into the path of a motorcyclist. Most of these crashes were of two main types:

- A vehicle pulling out of minor roads into the path of the motorcyclist approaching from the right along the main road, and

- A vehicle making a right turn into a minor road across the path of a motorcyclist travelling in the opposite direction along the major road

None of the 345 motorcycle crashes examined in detail were filtering between traffic or waiting to overtake. Overall, 6 of the 345 crashes involved 'close following' – these were mostly riders in groups for pleasure or to a social event.

Lynam et al. (2001) report that there was little evidence that weather or road condition was an important factor in the majority of these crashes.

For those crashes that were judged to have been the principal responsibility of the motorcyclist, a high proportion involved 'loss of control', linked with excessive speed, alcohol impairment and careless/ thoughtless/ reckless behaviour. In the crashes where motorcyclists lost control, the three most common patterns were: running into another vehicle, going straight ahead at a bend or roundabout, or hitting a kerb or verge. In 15% of cases the motorcyclist lost control after trying to avoid a vehicle or an animal.

An analysis of causation factors for non-fatal crashes, using 1999 data, showed that similar factors were involved but that their importance differed. Excessive speed by motorcyclists was less commonly recorded in less severe crashes, and 'looked but did not see' was more commonly recorded where drivers were mainly responsible.

3.3.2 Pedestrians

Lynam et al. (2001) reported that in the TRL study of fatal motorcycle crashes, 65% of the crashes involving pedestrians were considered to be principally the fault of the pedestrian, mainly due to either failure to look or failure to judge the actions of the motorcyclist. They noted that two-thirds of the pedestrians involved in fatal motorcycle crashes in the United Kingdom were aged 60 and over. In fatal crashes of all types, about half of the pedestrians involved are of this age. This suggests that a failure by older pedestrians to detect or judge the speed of motorcyclists may be involved (in addition to the greater frailty of this group). It may be useful to include material on older pedestrians in training hazard perception and responding by motorcyclists.

3.4 SUMMARY OF HAZARDS FOR MOTORCYCLISTS

Hazards can be classified into those that are road based and those that arise from the behaviour of other road users. Motorcyclists are subject to the hazards faced by car drivers but are also at risk from situations not hazardous for car drivers, such as gaps in bridge decking wide enough to catch a motorcycle wheel but too narrow to effect a car tyre. The reactions required from riders also need to be different, as motorcycles handle differently to cars. The extent of potential harm associated with any given hazard is commonly greater for motorcyclists, given their comparative lack of protection.

The hazards associated with the behaviour of other road users can be thought of as arising from failures of hazard perception by other road users. The extent to which this can and should be addressed by improving the hazard perception and responding skills of motorcycle riders, compared with the corresponding skills of car drivers is a matter for debate.

It is much easier to identify hazards related to the behaviour of other road users in the crash data than it is to identify the role of road based hazards. Therefore, relatively more is known about the extent of involvement of hazards relating to the behaviour of other road users in motorcycle crashes.

4. HAZARD PERCEPTION AND RESPONDING IN VICTORIAN MOTORCYCLE CRASH DATA

Analyses of current Victorian motorcycle crash data were undertaken to identify those hazards and situations which pose a crash risk for motorcyclists and to assess the possible capabilities for riders to 'self-monitor' and 'risk compensate' for their skill deficiencies.

Previous published analyses of Victorian motorcycle data have found patterns indicative of the involvement of failures of hazard perception and responding. These include:

- differences in the risk and severity of crashes of novice riders and fully licensed riders (Cameron, 1992; Carr, Dyte and Cameron, 1995),

- differences in the crash rates per licence holder per year between novice riders and fully licensed riders (and between younger and older novices) (Haworth, Mulvihill & Symmons, 2002)

Given that the profile of motorcycle crashes (and particularly of riders) has changed considerably in the last decade, analyses of recent (1997-2001) Victorian crash data were undertaken to validate these conclusions.

The identification of the situations and conditions relevant to hazard perception and responding will help to show what situations and conditions need to be included in training programs.

4.1 ISSUES IN IDENTIFYING PROBLEMS IN HAZARD PERCEPTION AND RESPONDING FROM CRASH DATA

Two types of crash data are available: databases based on Police reports (such as the Victorian State Traffic Accident Record), and crash data collected as part of in-depth studies. This section focuses on the former and identifies some of the issues that must be considered in attempting to draw conclusions about hazard perception and responding from these data.

A number of studies have identified that many motorcycle crashes are not reported to Police and therefore are not included in the Police-based crash databases (e.g. Diamantopoulou, Brumen, Dyte and Cameron, 1995). The crashes that are least likely to be reported are those of low severity, single vehicle crashes and crashes involving some illegal behaviour (e.g. unlicensed riding, unregistered motorcycles, drink riding). Thus, the crash data not only underestimate the number of motorcycle crashes, but there is some bias in the crash data resulting from the pattern of under-reporting. If road-based hazards are relatively more important contributors to single vehicle crashes, then the under-reporting of single vehicle crashes is likely to result in crash data under-estimating the importance of road-based hazards.

In terms of hazard perception and responding, a more serious limitation on the usefulness of crash data is the extent to which information relevant to the presence of hazards and their role in the crash is recorded. Often the presence of hazards cannot be identified from crash data. Most hazards related to the road surface are not recorded in the crash data. For crashes involving running off the road on a curve, for example, there is no clear way of assessing whether there was a road surface hazard involved or whether the rider was travelling too fast or whether both factors contributed to the occurrence of the crash.

Hazards related to the behaviour of other road users are potentially easier to identify from the crash data than road-related hazards. However, there is no "road user at fault" coding in the Victorian crash data and overall assessments of legal right of way are complex, given the characteristics of the coding of crash types.

In addition, the crash data provides no information about circumstances in which the outcome was not a crash involving injury (or the successful avoidance of a crash). It raises many questions about why crashes occurred in some instances but did not in others.

The crash data provides useful information about the riding environments in which (at least reported) crashes occurred. Whether crashes occurred at intersections or not, the speed zone in which they occurred, the weather conditions etc are available for analysis. The identification of these riding environments and situations will help to identify what needs to be included in training in hazard perception and responding.

The relative lack of data regarding exposure to hazards makes it difficult to interpret crash data. If, for example, young riders are involved in twice as many recorded crashes as older riders in which a car failed to give way, what does this mean? Perhaps young riders ride more often in the situations in which that hazard occurs (e.g. urban arterials) and therefore their exposure to the hazard is higher. It may not necessarily mean that their ability to perceive and respond to the hazard is necessarily any worse than that of older riders (although this may very well be the case).

Crash data can provide some information about modifying factors such as alcohol (although much data are missing for less severe crashes) and the types of crashes that result. This provides some clues as to how alcohol might be affecting hazard perception and responding.

Some members of the motorcycling community believe that a substantial number of motorcycle crashes that are coded as "single vehicle crashes" were the outcome of motorcyclists attempting to avoid an oncoming car (or other car) and succeeding in avoiding the multi-vehicle crash, only to have a "single vehicle crash". While there is little evidence that is relevant to this claim, the Melbourne Case-Control Study (Haworth et al., 1997) found that 3% of crashes involved falling from the motorcycle as a result of trying to avoid an impact.

Hazards associated with road surface and geometry may be more likely to contribute to single vehicle crashes, while hazards associated with other road users may be more likely to contribute to multiple vehicle crashes.

It is likely that failures of hazard perception and responding per se are less of an issue in fatal crashes than in less severe motorcycle crashes (or in crashes involving "unriders" compared to those involving responsible riders). The effects of modifying factors such as speed and alcohol may be more common in fatal crashes than in less severe crashes.

These issues in the interpretation of motorcycle crash data mean that it cannot be relied upon as the sole source of evidence regarding hazard perception and responding by motorcyclists. Therefore, special purpose data collections and experimental studies are needed to gain a further understanding of these phenomena.

4.2 DESCRIPTION OF CRASH DATA SET

VicRoads maintains a database of crashes that occur in Victoria where an injury has occurred and the Police have been notified – the State Traffic Accident Record database (referred to hereafter as the STAR database). This database contains a large number of variables that includes information on the individuals involved in the crash (such as injury severity and blood alcohol concentration), the vehicles involved (such as the type and make of each vehicle involved), the location of the crash (such as street name and local government area), and the crash environment (such as whether the crash occurred at an intersection and whether it was raining).

For this analysis, data for motorcycle riders in crashes were extracted from a person-based version of the database, providing a description of each motorcycle-involved crash as well as a description of each motorcyclist involved. This approach yielded 9,273 records for the five-year period 1997-2001 inclusive. This means that 9,273 motorcycle riders were involved in crashes; there were actually 9,073 motorcycle-involved crashes (10.4% of the total number of crashes involving all vehicle types in this period). This difference of 180 (or just under 2%) indicates that 180 riders were involved in multiple-motorcycle crashes (although not necessarily that there were 180 multiple-motorcycle crashes – a particular crash may have involved more than two motorcycles). For the purposes of the following analyses, all riders were included and treated as though each was involved in a separate crash.

4.2.1 Approximating rider experience

The STAR database contains a "years driving experience" variable, but most values are missing or unreliable. Age and licence type are reliably coded. As discussed in an earlier section of this report, age can ordinarily be used as a reasonable proxy for driving experience for car drivers, as young adult drivers generally gain their licence as soon as they are legally allowed to and continue to drive. However, the relationship between age and motorcycling experience is weaker. Table 4.1 shows motorcycle licence level of crash-involved riders. As might be expected, learner permit holders and those with a probationary licence are more likely to be under 25 years of age. The largest number of fully licensed riders was 25-39 years old.

In order to provide a proxy measure of riding experience that also incorporated age effects (likely to affect both risk taking and increased car driving experience), age and licence type were combined into a new variable – age/licence group. Due to small sample sizes, for further analyses, motorcyclist age was limited to two categories – under 25 years of age and 25 and over. Likewise, licence type was restricted to learner and probationary together, and full licence. Learner and probationary riders were grouped together as novice riders. Motorcyclists aged less than 25 will henceforth be referred to as "young" and those aged 25 or more will be referred to as "older"; riders with learner or probationary licences will be called novice riders (although they may be novice car drivers) and those with a full licence are termed "fully licensed" – as such there are four classifications of riders in the following analyses: young novices, older novices, young fully licensed and older fully licensed.

Chi-square tests (χ^2) were used as a test of the degree of significance of any differences that occur within the analyses.

Table 4.1 Licence types and age groups of motorcycle riders involved in casualty crashes. Victoria 1997-2001

Licence type	Age categories (years old)					
	Under 25	25-39	40-59	60+	Missing/ unknown	Total
Learner	841	403	76	6	0	1,326
Probationary	588	119	15	1	0	723
Standard	895	3,964	1,649	108	7	6,623
Unlicensed	184	100	19	2	2	307
Unknown/missing	100	80	28	3	83	294
Total	2,608	4,666	1,787	120	92	9,273

4.3 CRASH TYPES

The database includes two variables that describe the “type” of crash that occurred. The “crash type” is selected by the police officer completing the paperwork on the crash; the distribution of crash types is included in Table 4.2. More than half of the crashes involved a collision between a motorcycle and another vehicle. A further quarter of the crashes were denoted “no collision and no object hit” – single vehicle crashes.

Table 4.2 Number of motorcycle riders involved in casualty crashes of each type. Victoria 1997-2001.

Crash type	Number	Percent
Collison with vehicle	4,849	52
No collision and no object hit	2,220	24
Collision with fixed object	851	9
Vehicle overturned	457	5
Collision with other object	306	3
Fell from/in moving vehicle	230	2
Struck animal	210	2
Struck pedestrian	149	2
Other accident	1	0
Total	9,273	100

The other variable used to specify the type of crash is the “Definition for Classifying Accident” (DCA) code. It is coded by VicRoads from all of the crash information provided by the police and indicates the interaction of the two primary vehicles involved (or single vehicle in a single-vehicle crash). There are 80 separate DCA codes, although they are grouped into ten categories (see Table 4.3). The most common type of crash as indicated by DCA category involves a motorcycle running off a straight section of road (23% of crashes), followed by a motorcycle running off a curved section of road (17%) – 40% of motorcycle-involved crashes occur when a motorcycle runs off the road.

An analysis by DCA code (see Table 4.4) found that the most frequent crash type involving a motorcycle was losing control on a straight carriageway (DCA 174, 16% of all crashes). The five most frequent crashes account for 39% of all crashes, and the ten most common crash types include 59% of all motorcycle-involved crashes.

Table 4.3 Number of motorcycle riders involved in casualty crashes of each DCA group. Victoria 1997-2001.

DCA group	Number	Percent
Run-off-road - straight	2,156	23
Run-off-road - curve	1,535	17
Travelling in same direction	1,377	15
Approach opposite directions	1,295	14
Approach from adjacent directions at intersection	1,038	11
Manoeuvring	739	8
Collision with object in path of vehicle	644	7
Overtaking manoeuvre	237	3
Involving a pedestrian	149	2
Miscellaneous	103	1
Total	9,273	100

Any of the crashes in the database may involve a failure on the part of the motorcyclist to detect a hazard, or an inappropriate or no response after detecting a hazard. Alternatively, as discussed earlier, the motorcyclist may detect the hazard, respond in a timely and appropriate manner, but still crash – such as braking heavily to avoid colliding with another vehicle and falling off, or making a conscious decision to run off the road with the possibility of a “softer landing” when the alternative option is to crash into a larger vehicle and likely fall onto the road. Additionally, as the database does not indicate where the fault for the crash lies, it is very difficult, if possible at all, to determine which party of a multi-vehicle is likely to have made an error in hazard perception or responding.

4.3.1 Crash types in different riding environments

As mentioned earlier, the crash data provides information about the types of situations and conditions in which crashes occurred. In order to examine these issues, a new variable was created, which is termed “riding environment”. Riding environment was created from a combination of speed limit and metropolitan versus rural crash location.

Table 4.4 DCA codes with the largest number of motorcycle riders involved in casualty crashes of these types. Victoria 1997-2001.

DCA code	Number of crashes	% of all crashes	DCA category	Crash description
174	1,441	16	Run-off-road - straight	Out of control on carriageway
121	853	9	Approach opposite directions	Opposing directions: Turning right through (not at intersection)
113	466	5	Approach from adjacent directions at intersection	Adjacent directions: right near (at intersection)
184	447	5	Run-off-road - curve	
120	424	5	Approach opposite directions	Head on (not overtaking)
130	413	4	Travelling in same direction	Rear end
140	412	4	Manoeuvring	U-turn
110	374	4	Approach from adjacent directions at intersection	Cross traffic
180	320	3	Run-off-road - curve	Off-carriageway right bend
181	316	3	Run-off-road - curve	Off right bend into object/parked vehicle

Three different riding environments were defined for these analyses. These were:

1. Roads with speed limits of 60 km/h or less in metropolitan Melbourne and the rest of Victoria. On these roads, it was expected that there would be a high density of intersections, many without traffic signals, and that there would be a large number of potential conflicts with other vehicles and pedestrians.

2. Roads with speed limits of greater than 60 km/h in metropolitan Melbourne. On these roads, it was expected that traffic densities would be relatively high, but that many intersections would have traffic signals. It was expected that both transport and recreational riding would occur on these roads.

3. Roads with speed limits of greater than 60 km/h in the rest of Victoria. On these roads, it was expected that traffic densities would be relatively low and that there

would be relatively few intersections, compared with Melbourne and that only a small proportion of these intersections would have traffic signals. It was expected that most of the riding on these roads would be recreational riding.

Metropolitan Melbourne was defined by postcodes. According to this definition, Geelong and other rural cities were included in the "Rest of Victoria".

The categorisation into three riding environments is supported by Lynam et al.'s (2001) finding that fatal motorcycle crashes on built-up roads and non-built-up roads (speed limit exceeded 40 mph) in the UK had different characteristics.

In terms of crash location, 67% of crashes occurred in the Melbourne metropolitan area and 33% in rural areas (this variable was defined in terms of local government area and Australian Bureau of Statistics definitions, which includes Geelong in the rural category). Analysing by speed limit zone, 59% of crashes occurred in a 60 km/h or less speed limit zone, 15% occurred in 70-90 km/h zones and 24% occurred in 100 or 110 km/h zones (the remaining 2% are unknown). The three levels of the riding environment account for the following elements of the total number of motorcycle crashes: 60 km/h and less metropolitan/rural – 59% (5,437 crashes); greater than 60 km/h metropolitan – 19% (1,766 crashes); and greater than 60 km/h rural – 20% (1,884 crashes). The remaining 186 crashes (2%) were missing values for speed limit of crash or their local government area (used to determine whether the crash occurred in a metropolitan or rural area).

Analysis of the crash data for 1997-2001 showed that the patterns of crashes involving motorcycles differed among the three riding environments (see Table 4.5). Crashes in speed zones of 60 km/h or less involved relatively more collisions with vehicles (63.5% versus 53.8% and 23.0%) and pedestrians. Crashes in speed zones of greater than 60 km/h in the Rest of Victoria involved relatively more single vehicle crashes in which there was no collision or object hit (35.1% versus 20.5% and 23.1%), collisions with animals (6.8% versus 1.2% and 1.5%), fixed objects and the vehicle overturning.

But clearly the extent to which riders are exposed to these hazards depends on their pattern of riding. Table 4.6 shows that the distribution of crashes among riding environments differs among younger and older novice and fully licensed riders ($\chi^2(6)=71.3$, $p<.001$). Older, fully-licensed riders have relatively fewer crashes in speed zones of 60 km/h and lower and relatively more crashes on roads with speed zones greater than 60 km/h in the Rest of Victoria than other riders. The simplest explanation of this is that it reflects differences in riding patterns.

Table 4.5 Numbers of crashes involving motorcycles in each of the riding environments. Victoria 1997-2001.

Crash Type	60 km/h or less	>60 km/h metro	>60 km/h rural
Collision with vehicle	3211	903	405
	63.5%	53.8%	23.0%
Struck pedestrian	111	8	2
	2.2%	.5%	.1%
Struck animal	59	26	120
	1.2%	1.5%	6.8%
Collision fixed object	274	180	267
	5.4%	10.7%	15.2%
Collision other object	70	50	152
	1.4%	3.0%	8.6%
Vehicle overturn	176	83	153
	3.5%	4.9%	8.7%
Fall from/in moving vehicle	123	41	43
	2.4%	2.4%	2.4%
No collision & no object hit	1035	387	617
	20.5%	23.1%	35.1%
Other accident	1	0	0
Total	5060	1678	1759
	100.0%	100.0%	100.0%

Table 4.6 Distribution of crashes among riding environments for young and older novice and fully licensed riders. Victoria 1997-2001.

Riding environment	Under 25 L or P	25 + L or P	Under 25 Full	25+ Full	Total
60- metro & rural	932	384	557	3187	5060
	66.5%	62.7%	63.4%	56.9%	59.6%
>60 metro	256	133	165	1124	1678
	18.3%	21.7%	18.8%	20.1%	19.7%
>60 rural	214	95	157	1293	1759
	15.3%	15.5%	17.9%	23.1%	20.7%
Total	1402	612	879	5604	8497
	100.0%	100.0%	100.0%	100.0%	100.0%

Crashes in the low speed riding environment

In the low speed riding environment (roads with speed limit of 60 km/h or less), the pattern of crashes differed among younger and older novice and fully licensed riders ($\chi^2(24)=65.2$, $p<.001$, see Table 4.7). Older novices appear to be less likely to have collisions with vehicles and to be more likely to have single-vehicle crashes (no collision, no object hit) than other riders. Types of crashes of full licence holders were similar for younger and older riders.

Similarly, the distribution of crashes by DCA category in low speed zones differed for young and older novice and fully licensed riders ($\chi^2(27)=64$; $p<0.000$). The primary differences would seem to be as follows (see Table 4.8):

- Young fully licensed riders have relatively more crashes in adjacent directions (at intersections).
- Older novices are less likely to be involved in crashes between vehicles travelling opposite directions.
- Young fully licensed riders are less likely to be involved in a crash between vehicles travelling in the same direction.
- Older novices are most likely to run off a straight section of road (even in low speed zones).

Table 4.7 Distribution of crash types involving motorcycles in the low speed riding environment (speed zones of 60 km/h or less) for young and older novice and fully licensed riders. Victoria 1997-2001.

Crash Type	Under 25 L or P	25 + L or P	Under 25 Full	25+ Full	Total
Collision with vehicle	625	220	353	2013	3211
	67.1%	57.3%	63.4%	63.2%	63.5%
Struck pedestrian	14	4	16	77	111
	1.5%	1.0%	2.9%	2.4%	2.2%
Struck animal	10	2	7	40	59
	1.1%	.5%	1.3%	1.3%	1.2%
Collision fixed object	74	25	31	144	274
	7.9%	6.5%	5.6%	4.5%	5.4%
Collision other object	6	7	8	49	70
	.6%	1.8%	1.4%	1.5%	1.4%
Vehicle overturn	29	22	16	109	176
	3.1%	5.7%	2.9%	3.4%	3.5%
Fall from/in moving vehicle	13	11	16	83	123
	1.4%	2.9%	2.9%	2.6%	2.4%
No collision & no object hit	161	92	110	672	1035
	17.3%	24.0%	19.7%	21.1%	20.5%
Other accident	0	1	0	0	1
	.0%	.3%	.0%	.0%	.0%
Total	932	384	557	3187	5060
	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4.8 Distribution of DCA groups of crashes involving motorcycles in the low speed riding environment (speed zones of 60 km/h or less) for young and older novice and fully licensed riders. Victoria 1997-2001.

DCA groupings	Age / licence				Total
	Under 25 L or P	25 + L or P	Under 25 Full	25+ Full	
Adjacent (intersections)	135	55	99	453	742
	14%	14%	18%	14%	15%
Opposing directions	178	38	88	486	790
	19%	10%	16%	15%	16%
Same direction	168	60	75	535	838
	18%	16%	13%	17%	17%
Manoeuvring	89	42	59	385	575
	10%	11%	11%	12%	11%
Overtaking	26	14	20	69	129
	3%	4%	4%	2%	3%
On path	46	17	27	170	260
	5%	4%	5%	5%	5%
Off path (straight)	185	110	119	752	1,166
	20%	29%	21%	24%	23%
Off path (curve)	87	40	51	230	408
	9%	10%	9%	7%	8%
Total	932	384	557	3,187	5,060
	100.0%	100.0%	100.0%	100.0%	100.0%

Note: The table includes only data of interest – where numbers of crashes are too small for meaningful analyses they have been removed. For this reason the totals at the bottom of each table will not be the true sum of each column.

Crashes in the higher speed metropolitan riding environment

There was no significant difference in the types of crashes in which the younger or older novices or fully licensed riders were involved in the higher speed (>60 km/h) metropolitan riding environment ($\chi^2(21)=22.9$, $p>.10$, see Table 4.9).

The pattern of crashes in terms of DCA groups did not differ significantly among young and older novice and fully licensed riders in higher speed zones (>60 km/h) in metropolitan areas ($\chi^2(27)=29$; $p>0.05$, see Table 4.10).

Table 4.9 Distribution of crash types involving motorcycles in the higher speed (speed zones greater than 60 km/h) metropolitan riding environment for young and older novice and fully licensed riders. Victoria 1997-2001.

Crash type	Under 25 L or P	25 + L or P	Under 25 Full	25+ Full	Total
Collision with vehicle	155	62	97	589	903
	60.5%	46.6%	58.8%	52.4%	53.8%
Struck pedestrian	0	1	1	6	8
	.0%	.8%	.6%	.5%	.5%
Struck animal	1	1	3	21	26
	.4%	.8%	1.8%	1.9%	1.5%
Collision fixed object	26	19	16	119	180
	10.2%	14.3%	9.7%	10.6%	10.7%
Collision other object	8	6	3	33	50
	3.1%	4.5%	1.8%	2.9%	3.0%
Vehicle overturn	10	4	8	61	83
	3.9%	3.0%	4.8%	5.4%	4.9%
Fall from/in moving vehicle	2	2	4	33	41
	.8%	1.5%	2.4%	2.9%	2.4%
No collision & no object hit	54	38	33	262	387
	21.1%	28.6%	20.0%	23.3%	23.1%
Total	256	133	165	1124	1678
	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4.10 Distribution of DCA groups in crashes involving motorcycles in the higher speed (speed zones greater than 60 km/h) metropolitan riding environment for young and older novice and fully licensed riders. Victoria 1997-2001.

DCA groupings	Age / licence				Total
	Under 25 L or P	25 + L or P	Under 25 Full	25+ Full	
Adjacent (intersections)	25	13	23	120	181
	10%	10%	14%	11%	11%
Opposing directions	40	20	18	130	208
	16%	15%	11%	12%	12%
Same direction	67	20	41	248	376
	26%	15%	25%	22%	22%
Manoeuvring	18	8	11	56	93
	7%	6%	7%	5%	6%
On path	10	6	5	56	77
	4%	5%	3%	5%	5%
Off path (straight)	52	32	31	239	354
	20%	24%	19%	21%	21%
Off path (curve)	40	31	32	224	327
	16%	23%	19%	20%	19%
Total	256	133	165	1124	1678
	100.0%	100.0%	100.0%	100.0%	100.0%

Note: The table includes only data of interest – where numbers of crashes are too small for meaningful analyses they have been removed. For this reason the totals at the bottom of each table will not be the true sum of each column.

Crashes in the higher speed Rest of Victoria riding environment

The distribution of crash types across young and older novices and fully licensed riders differed significantly ($\chi^2(21)=43.4$, $p<.01$) on roads with speed limit greater than 60 km/h in the Rest of Victoria (see Table 4.11). Older novices appear to be less likely to have collisions with vehicles and to be more likely to have single-vehicle crashes (no collision, no object hit) than other riders. Types of crashes of full licence holders were similar for younger and older riders.

The patterns of DCA crash types in speed zones greater than 60 km/h in the Rest of Victoria differed significantly among young and older novice and fully licensed riders ($\chi^2(27)=51$; $p<0.005$). The primary drivers of this difference would seem to be as follows (see Table 4.12):

- Older novices had relatively fewer crashes involving vehicles travelling in opposing directions, while young fully licensed riders had relatively more of these crashes
- Novice riders had relatively fewer on-path crashes than fully licensed riders
- Older novices were relatively more likely to run off a straight section of road
- Younger novices were less likely to run off the road on a curve than any of the other three groups.

Table 4.11 Distribution of crash types involving motorcycles in the higher speed (speed zones greater than 60 km/h) Rest of Victoria riding environment for young and older novice and fully licensed riders. Victoria 1997-2001.

Crash type	Under 25 L or P	25 + L or P	Under 25 Full	25+ Full	Total
Collision with vehicle	56	14	47	288	405
	26.2%	14.7%	29.9%	22.3%	23.0%
Struck pedestrian	2	0	0	0	2
	.9%	.0%	.0%	.0%	.1%
Struck animal	20	5	7	88	120
	9.3%	5.3%	4.5%	6.8%	6.8%
Collision fixed object	34	14	30	189	267
	15.9%	14.7%	19.1%	14.6%	15.2%
Collision other object	21	12	15	104	152
	9.8%	12.6%	9.6%	8.0%	8.6%
Vehicle overturn	12	8	7	126	153
	5.6%	8.4%	4.5%	9.7%	8.7%
Fall from/in moving vehicle	3	4	1	35	43
	1.4%	4.2%	.6%	2.7%	2.4%
No collision & no object hit	66	38	50	463	617
	30.8%	40.0%	31.8%	35.8%	35.1%
Total	214	95	157	1293	1759
	100.0%	100.0%	100.0%	100.0%	100.0%

4.4 SUMMARY OF ANALYSES OF CRASH DATA

Overall, about half of the motorcycle riders involved in casualty crashes in Victoria in 1997-2001 were involved in collisions with vehicles. These collisions comprised 64% of crashes in low speed areas, 54% of crashes in higher speed metropolitan areas and 23% of crashes in higher speed areas in the Rest of Victoria. The most common DCA codes for collisions with vehicles were:

- DCA 121 turning right through, not at intersection
- DCA 113 adjacent directions: right near (at intersection)
- DCA 120 head-on, not overtaking
- DCA 130 rear-end impact

- DCA 140 U-turn

Table 4.12 Distribution of DCA groups in crashes involving motorcycles in the higher speed (speed zones greater than 60 km/h) Rest of Victoria riding environment for young and older novice and fully licensed riders. Victoria 1997-2001.

DCA groupings	Age / licence				Total
	Under 25 L or P	25 + L or P	Under 25 Full	25+ Full	
Opposing directions	24	4	25	121	174
	11%	4%	16%	9%	10%
Same direction	13	6	12	65	96
	6%	6%	8%	5%	5%
On path	39	16	21	178	254
	18%	17%	13%	14%	14%
Off path (straight)	49	28	31	321	429
	23%	29%	20%	25%	24%
Off path (curve)	65	33	55	485	638
	30%	35%	35%	38%	36%
Total	214	95	157	1293	1759

Note: The table includes only data of interest – where numbers of crashes are too small for meaningful analyses they have been removed. For this reason the totals at the bottom of each table will not be the true sum of each column.

Given the results of earlier analyses, it is likely that the other road user failed to give right of way to the motorcyclist in the majority of these crashes.

Both age and licence status appear to affect the observed crash pattern of motorcycle riders. The crash data show that older fully-licensed riders have proportionally more of their crashes in higher speed zones outside of the metropolitan area (and perhaps in higher speed zones inside the metropolitan area), suggesting that this reflects their patterns of riding.

Even within a given riding environment, age and licence status appear to affect the crash pattern. Older novices were less likely to have collisions with vehicles and were more likely to have single vehicle crashes than other riders in low speed riding environments and in higher speed areas outside of the metropolitan area.

The interpretation of these crash data in terms of hazard perception and responding is difficult for the reasons outlined earlier in this section. While the crash data suggest that hazards associated with the behaviour of other road users are most important, the crash data system provides little scope for identifying the presence or role of road based hazards in crashes.

5.0 STUDIES OF HAZARD PERCEPTION AND RESPONDING

There has been extensive research into hazard perception by car drivers since about 1990. A large amount of research has been conducted since the preparation of our earlier report on Hazard Perception by Inexperienced Motorcyclists (Haworth et al., 2000) and much of it has been undertaken in the United Kingdom. This chapter reviews that research, and the extent to which it is likely to be relevant to hazard perception and responding by motorcyclists. The small number of studies that have addressed hazard perception and responding by motorcyclists are then described in more detail.

5.1 TYPES OF METHODS

The range of methodologies and stimuli that have been used to study hazard perception include; verbal ratings of the hazards concealed in textual descriptions of scenes, identification of hazards encountered on an actual drive, ratings of the riskiness of the events depicted in slides or videos of scenes (Finn & Bragg, 1986; Soliday, 1975) and motor responses to simulated risks (Currie, 1969; Pelz & Krupat, 1974; Watts & Quimby, 1981, cited in Groeger and Chapman).

The current UK HPT for drivers and riders is the result of extensive research by the Transport Research Laboratory (TRL) group and the National Foundation for Educational Research (NFER) and is based primarily on the early work by McKenna and Crick (1994) at Reading University in that the principles used by them were incorporated in the selection of scenarios for the NFER test (Grayson & Sexton, 2002).

5.2 GENERAL STUDIES OF HAZARD PERCEPTION AND RESPONDING

5.2.1 The relevance of hazard perception and responding skills

Among experience-related factors, deficient hazard perception skills have been found to make an important contribution to novice driver accident involvement. Compared to more experienced drivers, novice drivers are slower to detect and respond to hazards in the driving environment (Quimby & Watts, 1981) and are less likely to detect child pedestrians and cyclists in the driving environment (Egberink, Lourens & van der Molen, 1986). Quimby, Maycock, Carter, Dixon and Wall (1986) found that slow hazard detection (measured in a driving simulator) is associated with a history of greater self-reported accident involvement. Catchpole, Cairney and Macdonald (1994) and Catchpole (1998, cited in Catchpole & Leadbeatter, 2000) have shown that deficiencies in hazard perception skills account for a large proportion of the accidents in which novice drivers are involved.

However, Grayson et al. (2003) found no relationships between various measures they considered conceptually related to Hazard Detection (NFER and JOTS which are described later in this section, West's Decision-making Questionnaire) and crash involvement. This may have been because many of the participants were inexperienced drivers and therefore there were relatively few participants who had been involved in crashes. While there were no differences in crash involvement, subjects who scored highly on the NFER hazard perception test (in the sense that they had shorter response times to the filmed hazards) were assessed as being attentive, safe and skilful drivers, and as having good anticipation and good speed setting abilities by an expert observer on a test drive. The exception to this was speed, where the assessment of speed was unrelated to NFER hazard perception score.

5.2.1 McKenna and Crick's hazard perception test

McKenna and Crick (1994) used a simplified driving simulator which was based, in part, on that used by Watts and Quimby (1979) and Pelz and Krupat (1974). The simulator consisted of a television monitor and video recorder, interfaced with a computer and response button. The subject was instructed to respond to a sequence of various road and traffic situations, some of which were hazardous, by pressing a button as soon as a hazard is detected. The faster a subject is able to detect a hazard, the better the score.

The hazardous scenarios were chosen after receiving input from various police drivers and driving instructors about commonly occurring road hazards. On the basis of this information, in-car video recordings of various hazardous scenarios were taken from a perspective that approximated the driver's eye view of the road. Scenarios that were selected for testing were those that were least confounded with simple reaction time and that best discriminated between expert and novice car drivers.

5.2.2 Judgements of Traffic Scenes

Hazard perception skill as measured in hazard perception tests is defined operationally as the latency between making a discrete motor response (usually pressing a button on a computer) and the appearance of a hazard. However the measurement of simple reaction times does not provide information on how hazard perception develops and, therefore, how these skills can effectively be trained (Groeger and Chapman, 1996). Therefore, Groeger and Chapman used a different methodology, judgement of traffic scenes (JOTS), to determine whether different drivers use demonstrably different ways of assessing driving situations.

The stimuli were 24 video films taken from the driver's perspective during a drive through a set of junctions in Cambridge. All the videos used were filmed in dry, bright conditions, with relatively uncongested traffic. The films were selected to show a range of traffic conditions at each site. There were no particularly unusual or dangerous occurrences shown in any of the films. The types of junctions were: roundabout with vehicle/s performing right turn, unsignalised T-junction on left with vehicle/s travelling ahead, Unsignalised T-junction on right with vehicle/s travelling ahead, crossroads with traffic lights – vehicle/s performing left turn, roundabout with vehicle/s travelling straight ahead, T-junction with traffic lights on right – vehicle/s performing right turn, cross roads with traffic lights – vehicles performing right turn and roundabout with vehicle/s making a left turn.

The videos were projected onto a screen (1.7m x 1.3m) placed some 4 metres in front of participants, who sat at the steering wheel in front of half of a Vauxhall Astra. Films were watched through the windscreen of the vehicle from which the glass had been removed. After participants had watched each film, six questions were projected one by one onto the screen. There were 12 different questions, each of which required a response on a 7-point scale. Responses were made using a 7-key response box that was connected to a computer. The questions were designed to assess participants judgements of the traffic scenes on a number of dimensions; the level of risk they would have felt in the situation, how close they felt they were to vehicles and people in the film, how hard they would need to concentrate to drive safely in the situation, how well the film shows what normally happens at the junction, the extent to which they felt that an accident in the situation would have been serious, the level of stress felt if driving in the situation, the chances of something unexpected happening to make the situation more dangerous, the extent to which they felt they had control over danger in the situation, the amount of skill needed by the driver in the situation, the number of accidents they thought might occur at the junction, the speed at which the driver was travelling, and the level of 'busyness' of the situation.

Each participant was told that the experiment was intended to explore the way that drivers think about standard driving situations. Prior to seeing the 24 films, participants were shown the first six rating scale questions and asked to read through them. After each film had been shown, participants then answered the six questions, one at a time, at their own pace. The second six rating scales were then introduced as before. Each participant then saw the 24 films again in a different order and answered the new 6 questions for each film.

The results showed that drivers assess traffic situations using three different factors – the *difficulties* associated with driving, the *dangers* that are evident, and the extent to which the situation in which they drive is unlike what they would normally expect in the situation and the control they might have over events in it (*Abnormality*). These factors were highly consistent across a wide range of traffic situations but the relative importance of each varied as a function of the age and experience of the drivers.

Irrespective of experience, younger drivers tend to consider the potential for danger in a situation far more quickly than their older counterparts, but consider these dangers much less dangerous once they are found. For older drivers, again irrespective of experience, danger has less explanatory power. According to Groeger and Chapman (1996) this finding is evidence for what Jonah (1986) terms sensation seeking in the case of younger drivers. In terms of experience, older experienced motorists rely more on schema consistent aspects of the driving scene than younger experienced motorists. The authors suggest that the former group may simply drive more defensively seeking to recreate situations that have previously been safe or successful. The younger inexperienced group share the sensation seeking tendencies associated with youth, but tend to be less sensitive to aspects of a situation that may be outside of their control or that are unfamiliar to them.

Chapman and Groeger (1996) did not consider how their results correlate with crash involvement. However, the researchers detected differences in the way that drivers of varying age and driving experience levels judge traffic situations that may be predictive of future crash involvement or risky driving that could increase crash risk.

There may be some benefit in including a test of this kind as a part of a hazard perception test for motorcyclists. Although the JOTS did not measure reaction times to detect hazards as is done in most standard hazard perception tests, it provided useful information about what factors feed into and affect a driver's latency to detect hazards. As noted by Groeger and Chapman (1986), in the absence of knowing how or what drivers are learning as they gain driving experience, it is difficult to know how drivers can be trained such that they respond more safely to hazards while driving. Perhaps a more informative hazard perception test could measure latency to detect hazards *as well as* drivers' judgements of hazardous situations.

5.2.3 Studies undertaken for development of the UK Hazard perception test

Three out of four HPT tests initially developed by the National Foundation For Educational Research (NFER) were shown to discriminate between experienced and inexperienced drivers, and demonstrated high levels of psychometric reliability. However, while results showed that hazard perception test scores were significant predictors of self-reported near misses, they did not reach significance as predictors of crash involvement. It was suspected that the hazard perception items were too broad based which resulted in their not distinguishing between crash-involved and crash-free drivers and that they failed to adequately test those scanning and anticipation skills that form the basis of 'good' hazard perception ability.

Subsequent test development aimed to improve on previous work by including only those items that required good scanning techniques and an ability to anticipate potentially hazardous situations. The following criteria were defined and required for hazard perception items in the test:

- develops into an 'actual hazard';
- anticipation is possible for experienced driver or trained novice;
- scanning ahead and/or to the side necessary;
- clear and uncluttered scenario;
- not simply dependent on reaction time.

Analysis of test scores and questionnaire data revealed that experienced drivers scored higher and had lower response latencies than did novices, older drivers and higher mileage drivers had significantly higher scores, the average crash liability of novice drivers was significantly higher than experienced drivers and crash liabilities were significantly predicted by age and annual mileage. Driver response was predictive of crash liability in the expected sense, but was not significant.

On the basis of these results, new video material was developed. Filming was undertaken from the driver's perspective using a left-hand drive car. A reasonable view of the whole driving scene was provided. Both opportunistic and staged filming was used to generate 54 suitable video clips approximately 60 seconds in duration.

The new material was required to:

- include a little of the instrument panel to indicate that the view is from within a car;
- only show 'correct' driving, i.e. not too close, not too fast etc;
- be filmed in broadcast quality format;
- be filmed during daylight hours and fairly dry conditions.

A variety of driving situations was desirable. The scenarios were designed such that experienced drivers would know they should be alert for particular hazards, but which novices would be more likely to react to later when a situation had already developed. Some examples of the scenarios include;

a) dual carriageway:

- joining slip road with traffic on slip road and on nearside lane of dual carriageway;
- merging traffic from slip road driven vehicle in nearside lane;
- overtaking situations with driven vehicle in nearside lane, possibly boxed in and need to anticipate suitable gap.

b) country roads

- obstructed corners with oncoming traffic/cycles/horses/motorcycles;
- restricted roads due to parked vehicles and oncoming traffic – i.e. need to slow in order to round parked obstruction due to oncoming traffic.

c) urban roads

- pedestrians crossing from behind obstructions and using pedestrian crossing;
- pedestrians hesitating at the side of the road and maybe then crossing.

d) suburban roads

- cyclists having to overtake parked vehicles;
- children playing games;
- parked vehicles and on-coming traffic requiring anticipation and slowing down to avoid meeting adjacent to parked vehicle.

The subjects were grouped into three levels of car driving experience; learner, novice and experienced. The filmed scenarios were presented as video clips on a computer. The scenarios were presented as a continuous series of clips without a pause between them. After receiving on-screen instructions, subjects were told what the hazard was and that they should respond as soon as they had realised the potentially hazardous situation was developing. Subjects responded by touching a keyboard marked with a red arrow.

Those items that ‘perfectly’ distinguished between all three groups of drivers were then selected and two new tests developed for use in the pilot training program (see Chapter 6). When age and experience are used as proxy measures for driver skill in avoiding crashes, these variables can predict hazard perception scores.

5.3 STUDIES OF HAZARD PERCEPTION AND RESPONDING BY MOTORCYCLISTS

There have been relatively few studies that have measured hazard perception and responding by motorcyclists. These studies are reported here, followed by some more general studies of rider age and experience; factors that have been found to be associated with hazard perception ability in car drivers.

5.3.1 Types of hazards reported by motorcyclists

Armsby, Boyle and Wright (1989) reported a study that sought to compare the effectiveness of different techniques for assessing drivers’ perceptions of hazards (three types of interview methods, the Q-sort technique and several variants of the repertory grid method). All participants held a full driving licence. Regardless of whether nondirective, focussed or critical incident interviews were conducted, over 70% of the hazards mentioned by car drivers with no motorcycle riding experience arose from the behaviour of other road users, rather than features of the road environment. Car drivers who also rode (or had ridden) motorcycles, however, were able to identify specific features of the road, and specific actions of other road users, as hazards to motorcyclists. They conclude that “this might be expected, given that motorcyclists are more at risk from physical deficiencies in the road environment, such as a road surface with low skid resistance, and more vulnerable to injury if they are involved in an accident" (p.56).

5.3.2 Rider performance on car driver hazard perception test

In the United Kingdom, Horswill and Helman (2001) conducted a series of studies that attempted to assess the relative contributions of rider behaviour, car driver behaviour towards motorcycles and the physical vulnerability of motorcycles to the increased crash and injury rates of motorcycles compared to cars. The first of these studies is of relevance here, because one of the measures used was the hazard perception test developed by McKenna and his colleagues (McKenna and Crick, 1991, 1994).

The study compared the performance of three groups:

- Car drivers who had no (or almost no) motorcycle experience
- Motorcycle riders who were asked to respond as if they were riding their normal motorcycle
- Motorcycle riders who were asked to respond as if they were driving their usual car.

The three groups were matched in terms of age, gender, total distance travelled per year and the proportion having undergone advanced training. The average age was 40 years, there were more males than females and about 45 percent had undertaken advanced training. Unfortunately, the absolute or relative amount of motorcycling and car driving experience of the motorcyclists was not reported. It is likely, however, that participants were experienced in both car driving and motorcycle riding (unlike many other studies of hazard perception that have focused on inexperienced car drivers).

The participants completed a battery of video-based tests of driving behaviour and performance in the Reading University driving simulator. The simulator consisted of a blacked-out cubicle, in which participants were seated two metres from a back projection screen (1.4 x 1.1 m). Those participants who were asked to respond as if they were driving their usual car sat in a car mock-up (with seat, steering wheel, and pedals mounted on a platform). Those participants who were asked to respond as if they were riding their usual motorcycle sat on a Suzuki B120 motorcycle mounted in a stabilising frame. The eye level of participants was the same on the motorcycle and in the car mock-up. Digital video stimuli were presented on the back projection screen and, where appropriate, participants responded to events on the video with a hand-held button (which allowed reaction times to events to be measured). In the terms used in this report, the study measured hazard perception, but not the response selection or execution components of hazard perception and responding.

The video-based tests used were:

- McKenna's hazard perception test
- A close-following test
- A gap acceptance test
- An overtaking test
- A speed selection test.

After completing these tests, the participants completed a computer-based questionnaire that measured speed choice, driving violations, social motives, gap acceptance, close following and sensation-seeking.

The motorcyclists responding as if they were riding their normal motorcycles took more risks (chose faster speeds, overtook more often, and pulled out into smaller gaps) than the other groups. Motorcyclists responding as if they were driving their normal cars and car drivers did not differ on these measures. On the basis of these results, the authors concluded that the observed greater risk-taking by motorcyclists appears to be a function of riding a motorcycle rather than of the rider in general. The same pattern of results was found in both the video based measures and the simulation measures indicating that the findings were not likely to be artefacts of the testing media.

The three groups did not differ on the general personality or attitude measures.

Motorcyclists responding as if they were driving their normal cars reacted faster to hazardous situations than either car drivers or motorcyclists responding as if they were riding their normal motorcycles. This would suggest that motorcyclists had better hazard perception skills than car drivers. Given that the hazard perception test was intended for car drivers, the researchers argue that some of the hazards might be less relevant for motorcyclists and that this might explain why this group did not perform as well on motorcycles as they did in cars.

Based on these results, Horswill and Helman recommend that a separate HPT for motorcyclists with associated training should be introduced into licensing systems. This is discussed in more detail in Chapter 6.

5.3.3 Visual scanning patterns of riders and drivers

Nagayama, Morita, Miura, Watanabem & Murakami (1980) examined differences between car and motorcycle crashes and how this might be related to differences in the characteristics of the visual acquisition and processing patterns between drivers and riders. The researchers used an eye-marker method to examine how drivers and riders process visual information and to test for differences between this type of processing in car drivers and motorcycle riders.

Their first experiment involved three males aged between 24 and 36 years who possessed both car and motorcycle licences and had more than 8 and 4 years of driving and riding experience respectively. The subjects were required to both drive and ride for two kilometres at approximately 50 km/h and to acquire information as they ordinarily would. Subjects rode and drove on a section of an arterial road in a suburban area without median barriers. The recorder allowed for the subject's head movements.

Some important differences between drivers and riders were found in the pattern of acquisition and processing of visual information. A critical difference was in the structure of the foreground. The proportion of road surface in the visual field in riding a motorcycle is much larger than that in driving a car; in driving the car, the sky and the road surface that were filmed were in the ratio 71:29, whereas in riding the motorcycle they were in the ratio 31:69. The distribution of eye marks for car drivers were more frequently located at or above the horizon whereas in riding a motorcycle, they were more frequently located on the road surface.

The distribution of vertical fixation points was markedly different between drivers and riders. Vertical eye movements occurred less frequently and the more distant environment was looked at continuously in the case of car drivers. Motorcyclists however, had a wider vertical distribution of fixations and were found to look frequently at both near and far road surfaces. In terms of type of object looked at, 30 percent of motorcyclists' fixations were on the road surface, whereas car drivers looked relatively far ahead at objects such as traffic lights, and seldom at the road surface.

Overall, the differences in the visual scanning patterns between motorcyclists and car drivers seem to be consistent with the types of crashes they have and with the nature of the riding/driving task itself. The authors noted that motorcyclists ride on the outside of the road where they are more likely to encounter hazards such as uneven pavement surfaces and trash that could hinder their balance. Consequently, they are required to focus a large proportion of their attention on road conditions in order to ensure smooth riding. The researchers found that the major focus of motorcyclists' attention was on the road surface. Motorcyclists also had difficulty scanning the distant foreground and the efficiency of their peripheral vision in acquiring information was found to be poorer than that of car drivers'. Given that safe riding also involves scanning ahead to acquire distant information, it would seem that there is a trade-off for motorcyclists between scanning the immediate and distant environment that could potentially lead to negative safety outcomes.

Car drivers were found to look far ahead with relatively stable eye movements. The authors suggested that it is reasonable to infer that drivers have more time to look aside. In contrast, they suggest that based on the results of the motorcyclists' scanning patterns that they search and scan the road surface fairly frequently, it is reasonable to infer that they have less spare capacity to look aside. They conclude that this is consistent with the finding that crashes caused by looking aside are more frequent for car drivers than for motorcyclists.

A second experiment similar to the first was conducted to examine the additional effects of vehicle type (car, motorcycle and light motorcycle) and vehicle speed (30km/h, 45km/h and 60 km/h). There were no significant differences between types of motorcycles used. However, the differences between the acquisition and processing of visual information found in car drivers and motorcyclists in Experiment 1 were further supported in Experiment 2.

The proportion of road surface in the visual field was smaller for car drivers and they were looking further into the distance than were motorcyclists. The authors suggest that the relatively compact dispersion of their fixation points and the fact that they were looking well into the distance would make it relatively unnecessary to acquire information with frequent and divergent eye movements in order to cover the foreground. In contrast, motorcyclists were looking more often at the foreground and the proportion of the road surface in their visual field is larger. The conflict between scanning the immediate and more distant environment seemed to be reflected in the finding of larger variance in vertical horizontal lines and divergent eye movements. Also, they were found to have a shorter duration of fixations suggesting that they were scanning poorly but more extensively. These findings suggest that motorcyclists might fail to acquire information necessary for safe riding.

In terms of the effect of speed, it was found that, for both drivers and riders, the distribution of fixation points were more divergent and shorter as speed increased. The authors suggest that under conditions of lower speed, there is more attentional capacity available whereas under conditions of higher speeds, workload increases leaving available less spare attentional capacity.

Differences in the characteristics of the visual acquisition and processing patterns between drivers and riders seems to be consistent with the types of crashes characteristic of these road users and may also have implications for the types of training they receive.

A similar study by Tofield and Wann (2001) found the opposite results to those of Nagayama et al (1980). Tofield and Wann compared the scanning patterns of a group of 12 car drivers who had a mean of 8.5 years of driving experience with a group of 12 motorcyclists who had a mean of 20 years of driving experience using a virtual reality simulation of driving a car. Participants sat in a viewing booth with a large screen display with interactive steering control. They were required to steer around a computer-generated course comprising photo-realistic textures including bends, hills, buildings, trees and road signs. Participants were not informed of the aims of the study but were instructed to complete the course as quickly and as safely as possible without veering off the road.

There were two conditions; a no traffic condition in which participants completed 10 laps without other vehicles (and without knowing that there would be no other vehicles on the road), and a traffic condition in which they completed 5 laps of the same circuit with 7 other vehicles travelling in the opposite direction and sometimes on a collision course. An optics system was used to record participants' gaze and their looking behaviour was digitally recorded with an emphasis given to where they looked on approaching bends and obstacles that might conceal oncoming traffic.

As the consequences of not scanning ahead into the distance are more detrimental for motorcyclists than for car drivers, the researchers predicted that the former group would show greater attention than the latter with regard to the road ahead. The results were consistent with predictions; motorcyclists looked significantly further down the road than car drivers; a finding that was even more pronounced in the no-traffic condition but still maintained in the more hazardous traffic condition. Motorcyclists were looking 2.06 seconds ahead in the no-traffic condition and 2.98 seconds in the traffic condition. Car drivers looked 1.13 seconds ahead in the no-traffic condition and 2.13 seconds ahead in the traffic condition.

Tofield and Wann (2001) suggest that motorcyclists exhibited a pattern of scanning that is consistent with safe driving, whereas the pattern by car drivers could potentially lead to hazardous outcomes.

The inconsistency in the findings of Nagayama et al (1980) and Tofield and Wann (2001) suggest that further research is needed to clarify any differences in scanning patterns between motorcyclists and car drivers. The discrepant results may reflect differences in the methods and design used by the two studies. In the Nagayama et al study, the *same* participants were tested and compared under real world conditions of *both* driving a car and riding a motorcycle suggesting that their study might be a better and more realistic test of potential differences in scanning patterns than that used by Tofield and Wann.

Nagayama et al (1980) found that when riding a motorcycle, motorcyclists had scanning patterns that were less safe than those exhibited by car drivers driving cars, while Tofield and Wann (2001) found that motorcyclists driving cars exhibited better performance than car drivers driving cars. Notwithstanding their superior performance compared to car drivers, a further possible explanation for these discrepancies is that motorcyclists exhibit a scanning pattern consistent with safe driving *whilst in a car* but that their experience when riding a motorcycle is different given the additional demands of this type of vehicle. This is consistent with Tofield and Wann's suggestion that motorcyclists need to exercise greater caution on the roads and with Nagayama et al's finding that motorcyclists have additional demands that make the task of riding more difficult compared to driving a car. It would be informative to repeat this experiment using the methodology employed by Nagayama et al.

5.3.4 Lane positioning to reduce the risk of collision

Ouellet (1990) wrote a paper with the aim of shifting the focus of collision avoidance away from emergency braking and swerving to other strategies to reduce the risk of collision. He proposed that lane positioning as the rider approaches a potentially threatening situation is a simpler, more reliable and more effective means of reducing collision risk than reliance on emergency braking. A mathematical reconstruction was used to determine whether a crash occurs as a function of two factors: 1) where the motorcycle is when the car begins the manoeuvre that will take it across the path of the oncoming motorcycle, and 2) the kind of braking done by the motorcycle.

He recommends a simple avoidance strategy – 'when faced with a potential right-of-way threat ahead, the motorcycle rider should move away laterally from the threat. That is, move to the right for a left-turning car or one crossing from the left. Or, move to the left for a car threatening from the right. And slow down and get ready when a potential threat is observed up ahead' (p22). Ouellet suggests that these principles could also apply in situations when a specific threat is not obvious. For example, a rider could choose a lane position that balances the risks of where various potential threats might come from. In riding down a residential street, the rider might choose to ride down the centre of the street to avoid cars or pedestrians that might be emerging from either side.

Ouellet points out that optimum lane positioning is not a substitute for effective braking, but is a very useful adjunct to skilled braking. Conversely, effective braking is not a substitute for good lane positioning. Effective braking should not be performed at the expense of conspicuity. For example, a rider should not position him/herself in lane two if doing so means that a large vehicle in lane one obstructs the view of the motorcycle from other traffic waiting to turn left.

Ouellet concludes that "lane positioning is essentially nothing more than defensive driving. It is simply a habit that each rider needs to develop: to think about what is up ahead, where the threats might come from and to be in the best position to deal with them" (p.23).

5.3.5 Failures of responding

A number of studies have examined the role that failures in responding to hazards has played in motorcycle crashes. ROSPA (2001) states that braking, especially in an emergency, is one of the most difficult tasks encountered when riding a motorcycle. Errors in braking can easily lead to skidding, capsizing or the vehicle becoming unstable. Front and rear motorcycle brakes are usually operated separately (unlike a car's which are linked) and so the rider has to decide which brake to apply, when and what proportion of front and rear braking to use according to the situation and road surface (some motorcycles do have coupled brakes).

They report that incorrect use of motorcycle brakes is considered a factor in many crashes. In their data, over a third of riders used only the rear brake and 11% used only the front brake. Even in an emergency, 19% of riders used only their rear brakes and 3% only used their front one. One study they cite estimated that correct braking, using the full capacity of the motorcycle, could prevent 30% of motorcycle crashes, although this study was conducted before ABS was available for motorcycles.

The Hurt study of motorcycle crashes in the Los Angeles area (Hurt, Ouellet and Thom, 1981) concluded that the riders showed significant collision avoidance problems. Most riders would overbrake and skid the rear wheel, and underbrake the front wheel greatly reducing collision avoidance deceleration. The ability to countersteer and swerve was essentially absent. They noted that the typical motorcycle crash allows the motorcyclist less than 2 seconds to complete all collision avoidance action.

The analysis of fatal single vehicle motorcycle crashes in the US found that 22% of the motorcyclist fatalities in 1999 were related to either braking or steering manoeuvres (National Center for Statistics and Analysis Research and Development, 2001). The involvement of braking manoeuvres has not changed, but the involvement of steering manoeuvres has increased from 3% in 1990 to 9% in 1999. However, almost half of the fatal crashes did not report any crash avoidance manoeuvre during the crash investigation (either not reported by police or information reported is inconclusive). About 30% of the fatalities were attributed to no manoeuvre in the crash.

A limited re-examination of crash data collected for the Case-Control Study of Motorcycle Crashes (Haworth, et al., 1997) was undertaken to identify specific rider and crash characteristics that relate to deficiencies in hazard perception and responding (reported in Haworth et al, 2000). Failure to respond was more common in multi-vehicle crashes than single vehicle crashes, as might be expected of a factor reflecting a failure of hazard perception. However, the proportion of crashes which were multiple-vehicle crashes did not differ between experienced and inexperienced riders. Similarly, the pattern of type of crash (impact with object or vehicle, fell avoiding impact, and loss of control) did not vary between experienced and inexperienced riders. Failure to respond was a little more common in crashes of inexperienced riders than experienced riders but the difference was not large.

5.3.6 Other research relevant to hazard perception and responding by motorcyclists

The research reported in this section relates to patterns of motorcycle crash involvement as a function of age and experience (both as a motorcycle rider and as a car driver). While this is not directly relevant to hazard perception and responding, it provides some input to the issues of the extent that crash risk is affected by these variables and may be useful in deciding which age and experience categories of motorcyclists require training in hazard perception and responding.

Age and inexperience

It might be expected that lack of experience will be as important for motorcycle riders as it is for car drivers. A large number of studies have shown that young riders have more crashes than older riders (Kraus, Riggins and Franti, 1975; Bragg, Dawson and Jonah, 1980; Hurt, Ouellet and Thom, 1981; Broughton, 1988; Rutter, Quine and Chesham, 1995; Lin, 1998; Mullin, Jackson, Langley and Norton, 2000) but many of these studies do not separate the effects of age and experience, or possible changes in the type or amount of riding with age. Recent statistics show that young motorcyclists are more likely than older motorcyclists to be killed or seriously injured on the roads. Based on 1998, 1999 and 2000 data, riders aged 17-25 years had the highest rate of fatalities per 100 million motorcycle kilometres travelled (47.0) (ATSB, 2002). This age group was found to have a risk of fatal injury 9 times higher than the lowest risk group comprising older riders aged 50-54, who had a rate of 4.9.

Lin (1998) studied a sample of 4,729 motorcycle riders and found that past crash history and lack of experience were both positively related to an increase in risk of a motorcycle crash.

Hull (1981) found that the exposure-adjusted accident rate for motorcyclists in New Zealand with less than six months riding experience was significantly higher than the rates for riders with 6-11 months experience or those with over a year of experience. The exposure-adjusted accident rate was also substantially and significantly lower for riders aged 20 years old or older compared with those aged 19 or less. The accident rate for the youngest group was exceeded only by that for the group with less than 6 months riding experience.

Bragg, Dawson and Jonah (1980) found that, after controlling for exposure, age was the more important factor in discriminating crash involved from crash free riders. Riders aged 15 to 19 years had 5.47 crashes per 100,000 km while riders aged over 25 had 2.29 crashes per 100,000 km.

In New Zealand, Mullin, Jackson, Langley and Norton (2000) found a strong relationship between increasing age of rider and decreasing risk of moderate to fatal injury from a motorcycle crash. Riders aged over 25 years had less than half the risk of 15 to 19 year olds. However, they found little evidence that increasing years of regular motorcycle riding or car driving reduced the risk of moderate to fatal injury from a motorcycle crash, once the age of the driver and other confounding factors are controlled for. Familiarity with the motorcycle was the only experience measure associated with a strong protective effect.

Similarly, Rutter and Quine (1994) conducted a longitudinal study of 4,000 motorcycle riders in the UK to determine the relative contributions of age and inexperience in crashes involving young riders and to determine whether crashes may be associated with particular patterns of behaviour. They found that youth played a much greater role than inexperience, and that crashes were associated with a willingness to break the law and violate the rules of safe riding. The latter finding was shown to be predictable from riders' beliefs measured 12 months earlier. Rutter and Quine argue that beliefs about riding play a mediating role between age and behaviour such that youth produces particular beliefs which in turn produces particular behaviours. They suggest that training courses which focus primarily on skills fail to adequately deal with higher order cognitive processes which impact on safe riding.

Rutter, Quine and Chesham (1995) found that both age and experience predicted breaking laws and rules, but that age was the most reliable predictor.

In their study of motorcycle crashes, Hurt et al., (1981) found that the rider was usually inconspicuous in traffic, inexperienced, untrained, unlicensed, unprotected, uninsured, and did a poor job of avoiding the collision. Also, 16-24 year olds were over-represented in the crash statistics, as were those with a recent history of traffic violations and/or accidents.

Lack of attention to the driving task was a significant factor for the rider. Alcohol was involved in almost half of the fatalities. Collision avoidance skills were lacking (a typical accident allows the rider less than 2 seconds to complete any avoidance actions).

A limited re-examination of crash data collected for the Case-Control Study of Motorcycle Crashes (Haworth et al., 1997) was undertaken to identify specific rider and crash characteristics that relate to deficiencies in hazard perception and responding (reported in Haworth et al, 2000). The study compared injured riders and pillion passengers from 222 crashes in Melbourne, with 1200 motorcyclists riding through the crash sites at the same time of day and week. After adjusting for the greater tendency of more experienced riders in crashes to have positive BAC readings, there was a statistically significant reduction in crash risk as a function of years of on-road riding experience. The magnitude of the reduction was small, however, equating to a rider with ten years experience having about a 25% lower risk than a rider with one year of on-road riding experience.

In order to examine the issue of inexperienced riders who are not novices, Haworth et al. (1997) defined inexperienced riders as those who had ridden on the road for less than three years or rode less than three days or less than 100 kilometres per week. While inexperience was widespread (40% of fully licensed riders in crashes and 37% of fully licensed control riders), this factor was not associated with a statistically significant increase in crash risk.

As part of their study, Haworth et al. (1997) asked riders a series of questions about their riding skills and strategies. In general, younger and less experienced riders were more likely to report behaviours consistent with good hazard perception techniques than older and more experienced riders. The greater likelihood that younger riders, many of whom were not fully licensed, had completed at least one training course complicates the interpretation of the observed differences somewhat. Interpretation is also more difficult given the lack of ability to validate these self-report responses.

Haworth et al. (2002) found that the crash involvement rate per 10,000 licences held by novice riders (learner and restricted licence holders) aged under 30 was more than double that of novice riders aged 30 and over. If the amount and nature of riding of the two novice groups is similar (and there is no clear available data to address this), this suggests that either experience as a car driver leads to improved hazard perception and responding skills or that some characteristics of riding by older riders (speed choice, choice of riding environments etc.) lead them to be involved in fewer crashes.

Compared to riders aged under 30, riders aged 30 and over:

- were involved in relatively fewer serious injury crashes and relatively more other injury crashes
- had crash involvement rates per licence holder that were about one-third of those for licence holders aged under 30
- were involved in relatively more rural than metropolitan crashes
- were involved in relatively more crashes in higher speed zones (in both metropolitan and rural areas)
- were involved in relatively fewer crashes at intersections (in both metropolitan and rural areas)
- were involved in slightly more crashes in warmer months

- were involved in relatively more crashes on weekends
- were involved in relatively more daytime crashes
- were involved in relatively more single vehicle crashes (except among fatal crashes where the reverse was true) in both metropolitan and rural areas
- were involved in relatively more crashes coded as "on path" and "off path-on straight" and "off path-on curve" (which are single vehicle crashes)
- were involved in relatively more crashes in which they were carrying pillions (except among fatal crashes)
- were more likely to hold standard (full) licences
- were less likely to be unlicensed
- were more likely to have a blood alcohol concentration exceeding 0.05 (but this conclusion is clouded by missing data)

Mullin et al. (2000) note that many studies that have examined the contribution of age and inexperience to motorcycle crashes, have reported only univariate results and have not controlled for potential confounding variables in their analyses. If this is the case then youth, not inexperience, may be the more crucial factor in motorcycle crashes.

Effect of car-driving experience

As a motorcycle is often a secondary mode of transport, many novice riders already possess a car licence and some experience driving a car. A number of studies have examined whether experience as a car driver improves the safety of novice motorcycle riders. One reason for this could be that hazard perception skills learned as a car driver can be used in motorcycle riding. Another reason may be that these novices are older and their safety has improved as a result of increased maturity, rather than experience.

After controlling for exposure, Taylor and Lockwood (1990) found that driving a car reduced the frequency of motorcycle crashes for riders until they reach their early thirties, with the magnitude of the reduction being greatest for young riders. For older riders, the effect was reversed and its magnitude smaller. They comment that this may be because the skills required for driving safely on the road are developed whilst driving a car and these skills are also useful when riding a motorcycle. But the effect was found to vary with age, rather than riding experience, and so it is possible that young riders who also drive a car may represent a different, and perhaps more mature, group than those who do not. Socioeconomic status may also affect access to other vehicles.

In a New Zealand study, Mullin (1997) found no reduction in risk of involvement in a motorcycle crash associated with driving other vehicles regularly over some years or in the previous year. There was a possible association with a small increase in risk among motorcyclists driving another vehicle more than three days per week in the last year (age-adjusted RR=1.26, 95% CI 0.95-1.66). After adjustment for a range of factors (including socioeconomic status) the association disappeared.

Self-monitoring and risk compensation

Rider surveys and other published sources were examined for evidence of self-monitoring and risk compensation strategies adopted by motorcyclists. The mostly daytime and fine weather pattern of riding helps to reduce exposure to hazards such as failure to give way by drunken or fatigued car drivers and reduces the exposure to wet road surfaces. However, it is likely that these patterns of riding may have more to do with comfort and the purpose of riding than with risk reduction.

The NSW Motorcycle Safety Council Survey of Motorcyclists (de Rome et al., 2002) reported that 57% of respondents answered yes to the question "Do you ever put-off or cancel riding your motorbike in wet weather?" Only 9% rode mainly on weeknights. It should be noted that the survey sample was older and rode larger motorcycles than the distribution of owners of registered motorcycles in NSW and it is unclear whether younger or novice riders would have given the same pattern of responses.

Allardice (2002) cautions against riding at night because it is very difficult to see the road surface. He also recommends against riding if the rider is tired, stressed, depressed, angry, thirsty, hungry, pre-occupied with problems or upset after a quarrel. He advises against riding if the rider has been drinking or taking drugs or debilitating medication.

5.4 SUMMARY OF STUDIES OF HAZARD PERCEPTION AND RESPONDING

There has been a lot of research into hazard perception by car drivers since about 1990 but only a small number of studies have addressed hazard perception and responding by motorcycle riders. The research has shown that novice drivers are slower or less likely to detect and respond to hazards and that drivers who are slower at detecting hazards in a driving simulator report having more accidents.

A number of studies have demonstrated that failures in responding (particularly failure to respond, or braking ineffectively) play a role in motorcycle crashes. One study suggests that correct lane positioning may be more important in crash avoidance than emergency braking. Another study found that riders spend more of their time looking at the road surface and less time looking at objects further away and this may interfere with the detection of vehicle-based hazards. However, a later study with a different methodology found the opposite results.

6. STUDIES OF HAZARD PERCEPTION TRAINING

The development of safe hazard perception and responding skills is important in lowering crash risk for all road users. However, teaching appropriate response execution may be more critical for riders than for drivers given their greater likelihood of serious injury and death in the event of a crash and the extent to which failures in response execution may result in failure to avoid the initial hazard or a different type of crash. If hazard perception and appropriate responding skills are necessary for safe riding, then an important question is whether their development can be accelerated by training. This chapter describes the research that has been undertaken in this area for both car drivers and motorcycle riders. The best methods for training hazard perception and responding in the Victorian context are the focus of the second report (Wallace et al., 2005).

6.1 TYPES OF METHODS USED TO PRESENT TRAINING

Most studies of hazard perception training have focussed on improving these skills in car drivers and have placed little emphasis on the response phase of hazard perception and responding. This has been largely due to the types of methodology used. There may also have been a view that skills in responding did not need to be trained, but this has not been articulated in the research reports.

Off-road training and testing has generally involved a classroom situation with an instructor using videotape and photos. In these settings, hazard perception is measured in terms of reaction times to hazards depicted in video footage taken from a driver's point of view. Clearly, the nature of the task does not permit an assessment of how well a driver would *react* to a hazard in the event that it could lead to a crash.

On-road training may involve an instructor travelling with the learner and directing his/her attention to likely hazards and discussing potential avoidance techniques. However, it is neither safe nor ethical to deliberately drive in hazardous and accident-producing situations. In that sense, a driver's hazard perception and responding behaviour can be successfully trained and assessed to some extent, but not in truly hazardous situations.

Simulation is a more recent technology that allows an in-depth analysis of hazard perception *and* responding behaviours by drivers and riders in a safe environment. The technique has been successfully used to assess and train hazard perception skills in drivers although there appears to be little research involving the use of riding simulators designed to assess and train these skills in motorcyclists (see Chapter 8). Also, the disadvantage of simulation is that it is relatively expensive and resource intensive as (in most applications) only one candidate can be trained at a time. PC-based training programs are another recent innovation designed to train hazard perception and appropriate responding skills in novice drivers. While the programs have lower fidelity than simulators, they are a much less expensive alternative and can be accessed by a wider market. The potential role for simulation in improving motorcyclist hazard perception and responding is discussed in more detail in the second Stage 1 report (Wallace et al., 2005).

6.2 EXPERIMENTAL STUDIES OF HAZARD PERCEPTION TRAINING FOR CAR DRIVERS

McKenna and Crick were the first to demonstrate the 'trainability' of hazard perception. A study conducted by the researchers in 1992 (cited in Crick & McKenna, 1991) found that their test of hazard perception discriminated between a group of expert police drivers and a group of experienced drivers. They considered that this difference most likely resulted from the difference in the quality and quantity of training received by the two groups. They concluded that "this implies that hazard perception skills are amenable to modification and improvement through advanced training courses, which, given the established link between hazard perception and accident involvement, suggests in turn the potential value of advanced training courses as a means of countering road accidents" (Crick & McKenna, 1991, p.100).

Crick and McKenna (1991) ascribe the lack of evidence for the benefits of advanced training in road safety to a lack of methodological soundness in previous evaluations and to the content of the courses: "it may be the case that the [advanced] courses assessed have focused very little on the acquisition of hazard perception skills. The same might be said of basic, pre-licensure training courses, which if true, may explain other puzzling or paradoxical findings in the literature" (p.104).

They examined the hazard perception skills of a group of experienced drivers before and after an advanced training course. Hazard perception was measured in terms of reaction times to hazards depicted in video footage taken from a driver's point of view. For those who did not notice particular hazards a maximum latency was recorded. The course participants were matched for both age and exposure with control drivers who did not participate in the course. The post-test was carried out 8-9 months after the course. Results indicated that the untrained group showed no significant change in hazard perception times, while the trained group responded significantly more quickly to hazards.

McKenna and Crick found that a group of drivers showed significant improvements in hazard perception after participation in an advanced RoSPA (Royal Society for the Prevention of Accidents) driving course compared to a group of matched controls who did not undertake the course. In a further experiment, McKenna and Crick (1997) found that a group of novice drivers achieved an average hazard perception score that equalled that of experienced drivers after completing three hours of classroom training using video material.

Classroom training in hazard perception has typically involved students watching video footage of driving through an area where hazards exist. Mills et al. (1998) had groups of 4-5 drivers watch a video of hazards for approximately two hours. A local driving instructor taught them how to identify the hazards and assess them. The aim was for the drivers to begin to learn some of the characteristics of moving vehicles and pedestrians, which would allow them to predict future hazards. "Emphasis was placed on the subjects looking ahead, using critical scanning areas and anticipating hazards in order to identify them as early as possible" (Section 3.6).

In the on-road training reported by Mills et al. (1998), subjects drove on selected routes in the local area for two one-hour sessions, a week apart. They were accompanied by a driving instructor and were required to continuously describe the road situation and to nominate and explain changes in road speed and direction in advance. This technique was used to help the driver learn to identify potential hazards on the road. At the end of the first training period, the instructor discussed areas that needed improvement and set the driver goals to aim toward and practice during the following week.

Mills et al. (1998) found that the combination of on-road and classroom hazard perception training led to the greatest reduction in reaction times to perceive hazards. The second greatest reduction was for on-road training, followed by classroom training. On the second assessment, all groups responded more quickly to hazards in which they could be a threat to others. The group who had both on-road and classroom training and the group who only had on-road training responded more quickly on the second assessment to hazards that could be a threat to them.

Mills et al. (1998) caution against interpreting their findings in terms of on-road training or combined on-road and classroom training being more effective than classroom training. On-road training was not statistically significantly better than classroom training in most analyses. The combined training was found to be better but this may have resulted from it comprising four hours of training, rather than the two hours for on-road or classroom training alone.

A study conducted by Horswill and McKenna (1998) found that drivers' risk taking propensity could be reduced through training in hazard perception. The researchers also found that hazard perception training has a differential influence on speed choice. It was concluded that the reduction in risk taking as a result of training could not be accounted for by drivers simply choosing slower speeds in order to present themselves in a positive light to the experimenter. Trained participants were found to choose slower speeds in scenes that were hazardous, but in identical scenes with the hazards removed, this effect was not observed. It is not known whether these findings would transfer to the on-road environment.

6.2.1 Evaluation of UK Driving Standards Agency training package

The Transport Research Laboratory group (Grayson and Sexton, 2002) undertook an evaluation of whether training could improve performance on the new Hazard Perception Test that was being developed for introduction into the UK licensing system in late 2002 (which is described in Section 7.2.2 of this report). A training package was created by the Driving Standards Authority (DSA) Training Establishment, to a specification supplied by TRL Limited. The training package had the following characteristics:

- Candidates received a minimum of one session and a maximum of three sessions of training;
- Each session lasted a maximum of one hour; candidates received approximately one session per week;
- A one-hour session based upon approximately 20 minutes of video material;
- Candidates received training at the stage when they had mastered the basic vehicle control skills – the timing of this depended on the individual, but it was generally after about 10 hours of driving lessons;
- The training was delivered in a 'classroom' type setting in small groups, and was interspersed with their regular on-road tuition.

The training package consisted of three modules; one for basic training, and two for more advanced training. The purpose of the modules was to improve learner driver awareness of developing traffic situations and to make their performance in this respect more like that of experienced drivers.

Each module was designed to last about 60 minutes and was able to be delivered by non-professional driver trainers to groups of between 5 and 10 students. The video depicted on-road situations that showed possible hazardous situations and freeze frame techniques were used to encourage interaction between the students and the instructor to help participants to identify particular situations. For example, students were asked to identify where the hazards were and were also asked 'what if ….happened ?"and to think about what would happen and what they would do next. The students used a workbook afterwards to summarise and consolidate the material covered during training. The advanced module was designed to expand on the basic module but with a greater emphasis on dynamic situations. It appears that the training focussed on both hazard perception and responding but the latter task was theoretical given that subjects did not learn how to respond to hazards in practice.

The efficacy of the hazard perception training material was evaluated by comparing the hazard perception performance of three groups of learner drivers who were recruited at the time they presented for their Theory test; Group A (control group – no training) who had undertaken one hazard perception test on recruitment and a second two months later; Group B who received the same treatment plus one hour of basic hazard perception training one month after the first test, and Group C who received the same treatment as Group B plus 2 hours of more advanced training.

Performance outcomes as measured by the gains in hazard perception scores over a two-month period between the first and second tests showed that test scores increased with the level of training. The net gain due to training was significantly higher in the training groups than in the control group and was three times greater for basic plus advanced training than basic training alone (as measured by HP scores). The general conclusion was that hazard perception skills as measured by the newly developed tests could be trained in learner drivers using the training material developed.

6.2.2 Does improved performance on tests of hazard perception mean improved safety?

While research has shown that hazard perception training in novice drivers leads to improved performance on hazard perception tests, it is not yet known whether these drivers go on to be safer drivers and have fewer accidents (McMahon & O'Reilly, 2000). Harrison (2002) queries the effectiveness of hazard perception training:

> *The role for education and training in this context is limited. The acquisition of hazard detection and response skills does not rely on conscious knowledge of the type that can be taught explicitly, but is rather built on automatic processes that evolved to provide lower animals with simple cue-response skills in complex situations. It is unlikely that an education or training approach will have any significant impact on the basic information processing mechanisms that underlie hazard-related behaviours.*
>
> *One implication of this view is that teaching specific responses to specific hazards is only likely to be successful if combined with extensive and ongoing practice…. Thus a training approach to developing responses will need to be experience based rather than knowledge based. (p.6)*

Harrison (2002) also makes the point that experience may serve to undo what is taught in hazard perception training. For example, the everyday experience of not crashing despite travelling too close to the vehicle in front may overrule training in leaving a safe following distance.

Groeger (2000) maintains that individuals learn associations between particular types of hazards and particular ways of responding in a given environment such as in traffic. When the *response requirements* are changed, the same stimuli responded to in one environment may be responded to more slowly/faster in another environment. Also, the stronger the relationship between a given stimulus and a given response, the more difficult it becomes to relearn a new way of responding to the stimulus.

Those who really do respond safely to hazards in actual driving conditions may respond more slowly in hazard perception tests because they have learned, for example, to decelerate rather than to press a button in response to hazards. Groeger (2000) points out that simply detecting hazards while watching video tapes may reveal strong anticipatory effects but will only confer a safety advantage in traffic where the additional time available to these people is used to choose the appropriate way of responding to the hazard. He concludes that "although tests of hazard perception may relate to the individual's actual driving, and the assessments experts might make of his or her driving, it is at best unclear whether these relationships merely reflect broader relationships between age and the measures taken" (p.141).

6.3 HAZARD PERCEPTION TRAINING PROGRAMS FOR CAR DRIVERS

In the United Kingdom, USA and Victoria, training programs have been developed to improve the hazard perception skills of novice car drivers. Development of a training package for use in the European Union is progressing. By encapsulating the whole process of an instructor, video footage and interactive activities such as driving tasks using the mouse to steer a virtual car, these programs enable hazard perception training to be accessed by a larger market of novice drivers than might otherwise be possible using other training media.

6.3.1 Official Guide to Hazard Perception - UK

The UK Driving Standards Agency has produced a training video accompanied by a trainee workbook and trainer guide to ensure that suitable resource material is available to all novice drivers and riders who are preparing for the UK Hazard Perception Test (described in Section 7.2.2). An 'Official Guide to Hazard Perception' called RoadSense has also been developed by the DSA to help candidates prepare, with their instructor, for the new theory test. It is a modular, multi-media training resource developed on the basis of extensive research into hazard perception training and testing. RoadSense consists of a:

- Video – used to illustrate key principles and initiate discussion.
- Student workbook – accompanies the video and poses questions to be discussed with the trainer and highlights key messages. It also contains stills from the video.
- Trainer guide – A guide for the trainer covering material in the video and workbook. It is designed to enable concepts demonstrated in the video to be discussed during practical driving lessons.

- Handouts – A series of handouts based on stills from the video to enable the trainer to test key concepts.

The package is designed for use by both the learner driver and his/her instructor so that the learner can obtain guidance from the instructor where needed. It is not intended as a teach-yourself product. The package was initially launched on video to ensure that as many learners as possible can have access to it. It was stated that it will also become available on DVD. It is not known whether motorcycling instructors use the package and to what extent those that do use it find it helpful.

6.3.2 DriveSmart - Victoria

Another recent innovation for training HP skills in novice drivers is an interactive CD-ROM based computer application. Two products, namely, DriveSmart (Regan, Triggs & Godley, 2000) and Driver ZED (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002) have been designed to train novice drivers in higher order cognitive skills including hazard perception. While there has not been an evaluation of the effectiveness of these products in reducing crashes, both have been effective in training hazard perception skills to novice drivers as measured in a driving simulator.

The DriveSmart CD-ROM was developed for Victoria's Traffic Accident Commission (TAC) to train novice drivers in the skills identified as major contributors to their crash involvement, namely; hazard perception, attentional control, time sharing and calibration. The performance of a group of participants (aged between 17 years and 17 years and 9 months) was tested using an advanced motion based driving simulator both immediately after a training session and four weeks post-training and compared to a matched control group.

The results showed that trained participants performed significantly better than controls on a range of tasks at both testing points. The researchers concluded that, compared to controls, trained participants performed significantly better on hazard perception tasks and attentional control tasks.

Assessments of drivers' confidence both prior to training and at completion showed that there were no differences in the confidence ratings of both groups either before or after training. This is an important finding given that previous training programs have largely been ineffective in reducing young driver crashes because they can inadvertently induce overconfidence and, in turn, an increased tendency to engage in risky driving behaviours. DriveSmart is currently distributed, along with other learning materials, to Victorian learner drivers as part of the TAC's HELP campaign.

6.3.3 Driver Zed - US

The Driver Zed CD-ROM was developed for the AAA Foundation for Traffic Safety in the US and evaluated by Fisher et al. (2002). The aim of the product is to train hazard perception skills in young drivers by means of commentary driving techniques that teach learners to scan the driving environment for potential hazards by breaking it into separate zones. The emphasis is on training learners to articulate what they are doing while driving (i.e, to provide a running commentary) and then feedback and an evaluation of the commentary is provided.

Using a fixed-platform driving simulator, the performance of trained 16-17 year old high-school students who were learning to drive was compared at 1-2 weeks post-training with a group of fully-licensed college students who spent a number of hours (10-12 per week) driving a college bus. The results showed that trained participants performed more similarly to the experienced drivers in ways that were likely to reduce their exposure to risk. It was concluded that the program has the potential to reduce novice driver crashes. The researchers plan to conduct a further evaluation six months post-training.

6.3.4 TRAINER – European Union

The TRAINER (The system for driver **Tr**aining and **A**ssessment using **In**teractive **E**valuation tools and **R**eliable methodologies) Project currently underway in Sweden looks at using computer based interactive multimedia and simulator technology to train vehicle handling skills as well as higher order cognitive skills including hazard perception and responding to learner car drivers (Falkmer & Gregersen, 2001). Three different simulation tools are currently being developed; a multi-media info-box to familiarise drivers with the basic principles of steering and driving a vehicle, a low-cost driving simulator and a medium cost driving simulator to train more complex skills such as hazard perception and responding.

Four sets of TRAINER tools are to be developed and installed at Belgium, Spain, Sweden, and Greece. The development of scenarios for the training simulators will be based on the skills that are deemed most critical for learner drivers. They have been structured according to the four hierarchical levels of the GADGET matrix: Level 4- Goals for life and skills for living, Level 3-Goals and context of driving, Level 2-Mastering traffic situations, and Level 1-Vehicle manoeuvring. The TRAINER Project is not yet fully developed so an evaluation of its effectiveness cannot be provided. However, the program is likely to be effective given the success of previous simulator and PC-based training programs and its emphasis on factors which encompass a more holistic view of the driving task.

6.4 OTHER TRAINING APPROACHES TO IMPROVING HAZARD PERCEPTION AND RESPONDING

6.4.1 Moderating illusory beliefs

Drivers have been found to incorrectly rate themselves as more skilful, safer and slower, and less likely to have an accident than the average driver, a finding that has been observed to a greater extent in young novice drivers (Svenson, 1981; McKenna, 1993; Horswill, Waylen & Tofield, 2002). This phenomenon was originally termed ‘unrealistic optimism’ (Weinstein, 1980, cited in Rutter, Quine and Albery, 1998) and is also referred to as ‘illusory beliefs’ (Horswill et al., 2002). The finding may be problematic for road safety if drivers who believe they are less likely to crash have less incentive to protect themselves by driving safely (McKenna, 1993).

Horswill et al. (2002) found that the superiority bias was even greater for ratings of hazard perception skills than for vehicle control skills. Farrand and McKenna (2001) reported that drivers’ ratings of their own hazard perception ability did not correlate with their speed of response in a video hazard perception test. Thus, drivers may not be motivated to undertake hazard perception training because they consider that their hazard perception skills are already better than those of their peers.

Rutter et al. (1998) demonstrated that unrealistic optimism was present in motorcyclists. On average, riders believed themselves to be less at risk than other riders of an accident needing hospital treatment in the next year. However, the optimism was reduced by 'relative realism' – riders were young and inexperienced (and riders who reported risky behaviours on the road) saw themselves as more at risk than other riders. There was some evidence that having a friend or relative killed or injured on the roads affected their perceptions of absolute risk of injury or death. Surprisingly, a higher perception of risk in the initial questionnaire did not result in safer behaviour being reported in the second questionnaire – the reverse was true.

There may be some benefit in reducing risky driving behaviours among riders by means of cognitive interventions designed to moderate illusory beliefs. By asking drivers to imagine their involvement in a serious crash for which they were to blame, McKenna and Myers (1997) found that drivers no longer regarded themselves as better than average and also indicated their intentions to reduce driving speeds. It was found that these changes persisted for a reasonable length of time. While it is not known whether these changes produced safety benefits on the road, it might be worthwhile investigating whether similar patterns exist among motorcyclists and, if so, whether these patterns can be modified through intervention.

Gregersen (1996) suggests that simply making drivers realise their own limitations and that there will be situations that they cannot handle may make them safer drivers. Simpson and Mayhew (1990) discuss taking a "health promotion" perspective – how a person drives may be no more important than how a person chooses to drive – i.e. take into account lifestyle factors rather than simply concentrating on skills improvement. Deliberate risk taking, such as drink driving, can be targeted in this manner. This is one of the aims of the TRAINER project (see Section 6.3.4).

6.4.2 Providing information about hazards

Another way of improving hazard perception may be to simply provide hazard information, such as identifying accident blackspots or providing statistics of the increased risk of driving at night. However, such information does not mean that a particular situation is hazardous for a particular driver. The risk at a blackspot intersection is based on the number of accidents that have happened there without regard for the number that have not occurred. Also, as many drivers consider themselves to be safer and more skilful than the average driver, they are likely to consider the risk information to be irrelevant to them, and this view is reinforced when they pass through the intersection without being involved in an accident (Brown & Groeger, 1988).

6.4.3 Improving scanning strategies

A potential approach to speeding up the detection of hazards by novice drivers is to train them in visual scanning strategies. Chapman, King and Underwood (2001) express concern that this may be ignoring a deeper problem, that poor scanning strategies may be the inevitable outcome of slow processing of information at any particular location. They state that there is no point in training drivers to scan more rapidly if this prevents them fully processing information from the locations that they have already fixated.

Harrison (2002) also questions the potential benefits of training to improve visual scanning strategies. He states that teaching scanning skills assumes that where drivers look is determined by their knowledge about the locations of potential hazards. He cites research that shows that overt visual attention may be more controlled by stimulus characteristics rather than top-down attentional processes. Thus, the benefits of training in visual scanning may be limited.

6.5 HAZARD PERCEPTION IN MOTORCYCLE TRAINING

A number of authors have concluded that the apparent lack of success of rider training in reducing accident risk or number of violations may stem from the content of the training programs (Chesham, Rutter & Quine, 1993; Crick & McKenna, 1991; Haworth, Smith & Kowadlo; 1999; Reeder, Chalmers & Langley, 1996; Simpson & Mayhew, 1990). The rider training programs currently in use focus mainly on the development of vehicle control skills. This is not necessarily through choice but is often brought about through time constraints and the need to prepare a rider for an end test that is skill-based.

There is considerable room for the important attitudinal concepts of cognition, perception and reaction to be more effectively delivered. Rothe and Cooper (1988) concluded that "the lack of riding skill is not the major problem. Attitudes, personality and awareness of others are". They went on to recommend that "motorcycle rider training courses should be more attentive to education than training" and these courses "should use instructors who are better prepared to implement the education-oriented programs" (p.203). Chesham et al. (1993) concluded that "training courses concentrate on riding technique and pay little attention to why safe riding is important. That is, they offer little by way of cognitive underpinning for the behaviours they promote." (p.428).

Jonah, Dawson and Bragg (1981) attributed the failure of the Motorcycle Operator Skill Test (MOST) to predict accident involvement to the absence of testing for danger perception and risk-taking. "The focus of the MOST test and indeed most licensing tests is still primarily geared towards the acquisition of basic vehicle control, a fact which inevitably influences the content of elementary training courses aimed essentially, whether consciously or unconsciously, at equipping novices to pass the test" (Crick & McKenna, 1991, p.104).

Simpson and Mayhew (1990) speculate that some riders may benefit from skills training while others will not. They posit that perhaps trainees who begin with a relatively low level of skill development could benefit from training while others who are more skilled in vehicle control may find little safety benefit in completing such a course. Rider motivations are also important, such as the reason for enrolling in the course (e.g. to satisfy parental requests).

They also point to some 'well designed' studies that have actually found that formally trained riders had the same risk of being involved in an accident as riders who did not receive the instruction. Some studies have even found that formally trained riders had higher accident rates (per miles ridden).

Simpson and Mayhew (1990) also point out that much of the outcome data analysed is simply number of crashes. If severity and type of crash were analysed the data may reflect more favourably on training programs. For example, a rider may avoid an obstacle and slide or fall off as opposed to crashing into the obstacle. This would indicate a heightened hazard perception ability, but lack of practice in avoidance actions. While number of crashes is often the ultimate assessment of improved rider ability, some weighting of the crash based on severity as measured by injury (e.g. number of days of hospitalisation) may be more appropriate.

Many motorcycle training courses state that they teach “roadcraft” and there is often an implict assumption that roadcraft equates to hazard perception and responding. But roadcraft is rarely clearly defined. Allardice (2002) defines roadcraft as “riding ‘nous’, the ability to recognise and react to surrounding influences and your environment” (p.41).

For motorcyclists, hazard perception requires knowledge of both the physical hazards associated with the road layout and the hazards associated with the behaviour of other road users. The draft new course for proceeding to a licence without a learner permit (Haworth & Smith, 1999), includes material on “coping with the road”, which identifies road-related hazards, and “coping with other road users” to help riders to predict what other road users are likely to do. In order to identify a vehicle as a hazard or potential hazard, there is a need to be able to predict what it is likely to do. This is also covered in the session on “roadsense” (road rules).

There can be deterrents to enrolling in a training course, such as the cost and availability in some areas. The Australian Transport Safety Bureau (ATSB) has released a new motorcycle rider training video and booklet called “Ride On” that can be purchased or ordered via the internet. The video runs for 43 minutes and provides instruction in “bike control skills plus mental skills to anticipate danger as well as skills for self control” (FORS, 2000). Rather than simply demonstrating examples of riding safely, the video includes four camera angles with zoom-ins, split screens and inserts to provide detailed information throughout the production. The video and accompanying booklet were produced with collaboration from experienced motorcyclists and instructors. While it is stressed that neither the booklet nor the video are meant as replacements or substitutes for personal training, these self-paced and accessible materials should be a useful addition.

6.6 CONCLUSIONS AND IMPLICATIONS FOR MOTORCYCLIST HAZARD PERCEPTION TRAINING

While research has shown that hazard perception training in novice drivers leads to improved performance on hazard perception tests, it is not yet known whether these drivers go on to be safer drivers and have fewer accidents (McMahon & O’Reilly, 2000).

Some of the methods used for hazard perception training for car drivers may not be feasible for motorcyclists. For example, while instructors travelling with novice car drivers and providing feedback on hazards (or listening to commentaries) has been used, it may not be appropriate (and it would be illegal) for an instructor to travel as a pillion with a novice rider.

Many of the approaches to hazard perception training for car drivers require only detection of the hazard and response by pressing a button. Thus, they do not train improved execution of responses to hazards, an area that the crash data suggest is of greater importance to riders than drivers.

Standard motorcycle training courses leading to standard motorcycle tests have not been shown to result in reductions in crash involvement. There has been little evaluation of the effectiveness of products designed to improve hazard perception and responding by motorcycle riders. The lack of a good test of hazard perception and responding by motorcycle riders has prevented research to evaluate the effectiveness of motorcycle training programs and products in enhancing these skills.

Horswill and McKenna (1998) found that hazard perception training for car drivers reduced their risk-taking propensity. Given that motorcyclists have been found to engage in more behaviours known to increase crash risk (e.g. Horswill & Helman, 2001), it might be expected that the potential benefits of a hazard perception training program designed specifically for motorcyclists would be even more critical for this group.

An important factor in assessing when training in hazard perception and responding should be provided to riders is rider attrition. While most novice car drivers go on to become experienced car drivers, this is not the case for motorcyclists. Many riders who obtain a learner permit do not go on to obtain a licence.

The implications for motorcycle safety are both conceptual and practical. Firstly, what contributes to the attrition factor and what implications does it have for the safety of the resulting population (i.e. do the less safe drop out or the more safe?). Secondly, any motorcycle-specific hazard perception and responding training that is delivered very early in the learning process (e.g. at the time of obtaining a learner permit) may be delivered to many more people than eventually end up riding motorcycles. This is an apparent waste of resources. Related to this issue, is whether the hazard perception and responding training would influence the attrition rate. If it increased rider confidence, then it might act to reduce the attrition rate (this would be bad if it did so without increasing skills in hazard perception and responding). If it decreased rider confidence (as they became more aware of hazards and the difficulties of avoiding them successfully), then the attrition rate might increase.

7. HAZARD PERCEPTION TESTING

In light of the reported associations between crash involvement and poor hazard perception ability (e.g. Quimby et al., 1986), some jurisdictions have developed tests to measure hazard perception skills among novice drivers at the probationary stage of licensing. The inclusion of a hazard perception test in the procedure for acquiring a licence to drive is deemed to be the most effective way of ensuring that hazard perception training is taken on a voluntary basis.

It should be noted, however that most of the available tests do not measure response selection or execution – the focus is really on the hazard perception component only. This may limit the extent to which they are able to predict the crash liability of motorcyclists.

7.1 ON-ROAD TESTING OF HAZARD PERCEPTION AND RESPONDING

An alternative to using a computerised test of hazard perception is to incorporate hazard perception measures into the on-road test. Careful planning of test routes can help to standardise the static hazards such as roundabouts that candidates might meet during the practical on-road test. However, standardising for moving hazards is more difficult.

Christie, Cummins, Fabre, Harrison, Hill, Johnston, Newland and Robertson (1998) describe the design and testing of a new full licence test (FLT), introduced in May 1999 as part of New Zealand's graduated licensing scheme. The FLT is the riding test that holders of a restricted motorcycle licence must pass before graduating to a full licence.

The test was designed based on the crash profile of novice New Zealand drivers and a search of international practice. The crash profile was similar between novice car drivers and novice motorcycle riders in that there were greater problems with left/right turns, U-turns and loss of control (perhaps due to speed control) than for more experienced drivers. The FLT was designed to assess cognitive factors such as hazard perception, gap selection, and higher speed zone driving on both straight and curved roads.

The FLT is carried out in real traffic conditions and consists of three parts. The first part is a basic drive to ensure that the candidate has very basic driving skills. Part 2 is "detecting and responding to hazards in built up areas", and is 15 minutes in duration. Part 3 lasts for 20 minutes and is in higher speed zones. In Part 2, as the candidate approaches a particular driving situation the tester asks them to note and remember all of the hazards they see as they perform a particular driving manoeuvre. They then pull over and describe the hazards and how they responded to them – this must match the tester's assessment of the situation. Part 3 is similar except that the speed zones are higher (70-100 km/h) and they must describe the hazards and how they are responding at the same time as they negotiate the situations. The FLT motorcycle test is also split into three parts, where the only major difference between it and the car test is that the rider is followed by the tester in another vehicle.

The test was trialled with car drivers and motorcycle riders, but not analysed separately (only 5 riders participated in the testing). The FLT received a positive response from the testers and candidates and seemed to have a good degree of reliability and validity.

One of the issues that has arisen in the implementation of the FLT for motorcyclists is that many testers cannot ride a motorcycle and therefore follow in a car. It is possible that the tester may not be aware of the hazards seen by the motorcyclist or vice versa. While the developers of the test suggested the use of voice-activated communications between the candidate rider and the assessor, this does not appear to have been implemented.

7.2 COMPUTERISED HAZARD PERCEPTION TESTS

McKnight and Stewart (1990, cited in Staysafe, 1997) argue that perceptual skills cannot be readily tested in practical tests due to the non-uniformity of the traffic environment and the difficulty in distinguishing what drivers fail to perceive from what they may perceive but feel no need to respond to. Computerised HPTs are designed to overcome these limitations. Some of the advantages of computerised tests include removing differences between different examiners (in terms of bias), and removing the ethical problem of exposing drivers to potential accident-producing scenarios (McKenna & Horswill, 1998, cited in Catchpole & Leadbeatter, 2000). Candidates can also be tested on a far greater range and severity of hazardous situations than would be possible to expose them to on public roads. Also, the driver's response to hazards can be analysed in greater detail than would be possible during an on-road test (McKenna & Crick, 1997).

It should be noted, however, that all of the current computerised hazard perception tests measure only the hazard perception component and the response is merely to indicate that the hazard has been detected. Thus, there is no measurement of the individual's ability to choose and implement the correct response. This is potentially a greater drawback for motorcycle riders than for car drivers.

7.2.1 VicRoads Hazard Perception Test

According to Congdon and Cavallo (1999), the VicRoads Hazard Perception Test (HPT) was one of the first tests of its kind implemented as part of a licensing system. It was introduced in 1996 as part of testing applicants for a probationary licence in Victoria (Fitzgerald & Harrison, 1998). The purpose of the HPT is to screen drivers on their ability to assess traffic situations and to make safe driving decisions. The HPT is designed such that only applicants with extensive driving experience should be able to pass it. As such, it aims to promote the acquisition of hazard perception skills by encouraging novice drivers to undertake more practice and experience prior to licensing (Congdon, 1999). It is hoped then, that the standard of driving among novices should be higher once they are licensed.

Originally, it was proposed that the HPT be implemented at the end of the three-year probationary licence period. Those who passed would graduate to a full licence, while hazard perception training would be provided to those who repeatedly failed the test (I-Cubed@RMIT, 2002). Thus, one of the original purposes of the HPT was to encourage drivers to continue to learn and develop hazard perception skills during the probationary period. It is interesting to note that a HPT based on the Victorian test has been implemented as an exit test in New South Wales. In Western Australia drivers must pass a hazard perception test to gain entry into the provisional stage of licensing.

The HPT was derived from Witkin's Embedded Figures Test (WEFT) (Bailey, 1994). The test items were devised on the basis of classifications of Victorian road crashes during 1986-88 in which pedestrians, intersections, rear-end crashes and single vehicle crashes all featured highly (Hull, 1991, cited in Bailey, 1994). The scenarios were selected on the grounds that they represent the types of situations that lead to accidents in which young novice drivers are over-represented (Congdon & Cavallo, 1999).

The HPT is a multimedia presentation that incorporates video-footage of traffic scenarios filmed from the drivers' perspective. The scenarios are presented to test applicants on a computerised touch-screen. They are required to respond to each one by touching (or abstaining from touching) the screen to indicate when it is safe to make one of four manoeuvres; slow down, overtake, make a turn, or move off, where it may be necessary to prevent a potential accident.

Congdon and Cavallo (1999) examined casualty-related crash data where the HPT scores of any of the individuals were known. They found that drivers with lower scores on the HPT were more likely to be involved in crashes within the first 18 months following licensing (driving time or distance travelled was not found to differ between the groups). Experienced drivers have also been found to perform better on the HPT than inexperienced drivers (Hull & Christie, 1992, cited in Congdon & Cavallo, 1999). However, the HPT was found to have low reliability. This was due in part to the relatively short length of the test and in part to some items eliciting responses that were inconsistent with responses to other items (Catchpole & Leadbeatter, 2000).

The HPT was updated in 2002 in response to some of the limitations in the earlier tests. At the time of its inception, technological constraints limited the test to 12 traffic scenarios each of seven-seconds duration only. The HPT now includes 90 traffic scenarios. There are longer video sequences to better simulate real world driving and allow for a greater range of correct response windows across test item types. Applicants must now complete 28 question items which are randomly selected from one of 15 different test forms. Test instructions have been improved to maximise comprehension for licence applicants and the video quality and graphic interface design have also been improved.

The HPT does not directly measure skills such as attentional control or time taken to detect a hazard, and is actually more a test of risk than hazard perception according to the definitions suggested earlier. There is also a "primacy of expectancy" effect (Evans, 1991, cited in Bailey, 1994), where it is to be expected that reaction times may be shorter for those individuals who have primed themselves for the test. Once driving on the road it is unlikely that the drivers will maintain the same level of alertness for hazards as they did while completing the HPT.

The term 'hazard perception' when applied to the Victorian test appears to be a different concept to that used in the UK. McKenna and Horswill (1999) argue that the some of the skills measured in the Victorian HPT (namely close following, overtaking and gap acceptance) should be regarded as measures of skills or behaviours separate to general hazard perception. This claim was based on the results of a factor analysis of the performance of subjects on computerised tests of close following, overtaking, gap acceptance, and a short version of McKenna's hazard perception test (McKenna and Horswill, 1997).

7.2.2 UK Hazard Perception Test

In late 2002, the United Kingdom introduced a HPT as a requirement for candidates applying for car, motorcycle, lorry and bus licences. Applicants for non-car licences must pass the HPT even if they already hold a full car drivers licence. The test is taken by candidates who already possess a Provisional UK or Northern Ireland (NI) Driving Licence (a provisional licence in the UK and NI would appear to be equivalent to the Victorian learner permit). Thus, its role in the licensing system is similar to that of the Victorian HPT. The UK HPT is part of, and taken subsequent to, the current touch screen knowledge test and takes about 25 minutes to complete. Car drivers and motorcyclists must score at least 38 out of 75 marks to pass the hazard perception element. It is planned to increase the pass score to 44 in increments of 2 by 1 September 2003 (http://members.aol.com/sjelz/theory.htm).

The test items involve dynamic hazards where there is an interaction between two or more road users and where there are clues that an experienced driver might detect that indicate that a risky situation might develop. There are 14 video clips featuring road scenes and potential hazards of various types, such as vehicles, pedestrians and road conditions. Examples include looking for events occurring in front of the car such as a stray dog by the kerb, looking for something joining the car's path such as a car emerging from the left, and looking for an event occurring in the opposite traffic such as a car stopping in the road to collect a passenger. Little information was available regarding the extent to which road-based hazards, which are more relevant for motorcycle riders, are included.

7.3 HAZARD PERCEPTION TESTING FOR MOTORCYCLE RIDERS

7.3.1 Current practice

The search of the literature and specific contacts made for this project failed to find any motorcyclist specific hazard perception test that had been developed or introduced anywhere in the world. In the Netherlands a licensing system for moped riders is being instituted that uses a slide-based test (Wijnolst, 1995), but there does not seem to be an equivalent of the test specifically for motorcycle riders. At the time the Hazard Perception Test was being implemented in Victoria, it was planned to develop a testing and training module specifically aimed at motorcyclists but this was not carried out (I-Cubed@RMIT, 2002). At present, it appears that there are no plans to introduce a separate version of the test designed specifically for motorcyclists in the UK or in any other jurisdiction.

While candidates for a motorcycle licence in the UK are required to pass the HPT, candidates applying for a motorcycle licence in Victoria, Western Australia and New South Wales NSW (the only jurisdictions other than the UK that include a HPT as part of the licensing system) are not required to sit the HPT for car drivers. As mentioned in Section 1.4, most of the Victorian applicants for a motorcycle licence already hold a car licence and those who obtained their car licence after 1996 would have passed the car Hazard Perception Test.

One of the arguments for hazard perception testing is that it encourages licence applicants to attempt to improve their hazard perception skills, either informally or by undertaking formal hazard perception training. The current motorcycle learner and licence tests in Victoria arguably do not measure hazard perception, although they measure some components of the ability to respond (e.g. application of counter-steering techniques to swerving around obstacles, quick stops on straight and curved paths). Performance on tests similar to those used in Victoria has not been found to predict a rider's total number of crashes, the number of reportable crashes involving the rider (those that resulted in a certain amount of property damage), or the number of crashes recorded in the rider's police file (Chesham et al., 1993). The relationship between performance on car driver tests and later crash involvement is also weak or non-existent.

7.3.2 The potential usefulness of car hazard perception tests for motorcycle riders

Given that candidates for a motorcycle licence in Victoria are not required to pass the HPT, the issue arises of whether car hazard perception tests are useful for motorcycle riders.

Horswill and Helman (2001) claim that the current UK licensing system that requires learners applying for their motorcycle licence to pass the HPT designed for car drivers may disadvantage riders. Their simulator study (discussed in detail in Section 5.3.2) found that motorcyclists (who were older and also held full car licences) performed better on McKenna's hazard perception test when they were asked to respond as if they were driving their normal cars than when they were asked to respond as if they were riding their normal motorcycles. Given that McKenna's test was intended for car drivers, the researchers argue that some of the hazards might have been less relevant for motorcyclists and that this might explain why this group did not perform as well on motorcycles as they did in cars. For example, squeezing through a narrow gap in traffic would be less of a problem for motorcyclists than for drivers of cars. Horswill and Helman consider that similar results could occur with the UK HPT and recommend that a separate HPT for motorcyclists with associated training should be introduced into licensing systems. Helman (personal communication, 2003) has advised that he intends to develop a motorcyclist hazard perception test.

It is also questionable whether the HPTs developed for car drivers give sufficient emphasis to hazards specific to motorcyclists such as road surface hazards. This would limit their ability to be able to predict later crash involvement.

8. MOTORCYCLE SIMULATORS AND THEIR USE IN RESEARCH AND TRAINING

An extensive search of the motorcycle safety literature and the simulation literature was undertaken to identify any motorcycle simulator research that has been undertaken and to assess the relevance of that research for the current project. In addition, contacts were made with the following organisations:

- the Simulation Industry Association of Australia (SIAA)
- the Transportation Safety Board (TRB)
- the Surface Transport Transportation Group of the Human Factors and Ergonomics Society (HFES)
- the International Standards Organisation Committee
- the University of Michigan Transportation Research Institute
- TRL Limited

and a range of driving simulation and road safety experts from around the world.

8.1 ISSUES IN SIMULATION AND ITS APPLICATION TO MOTORCYCLE TRAINING

Two documents have specifically addressed issues in simulation and their application to motorcycle training: a report commissioned by the US Motorcycle Safety Foundation (Hancock, undated) and an article by Tatsuhiko Awane of the Driving Safety Promotions Centre of Honda Motor Company (Awane, 1999).

8.1.1 Transfer of training from simulation to the real world

Hancock (undated) summarises the advantages and disadvantages of simulation. The advantages he identifies are:

- Safety (particularly in rider training)
- Flexibility in creating, testing and re-testing scenarios
- Controllability enabling confounding variables and test-test variability to be minimised
- The ability to replay performance to learners to highlight areas for further training
- Observability (being able to directly and closely observe participants in an unobtrusive manner)
- Comparative cost of simulation (given that motion based systems are unlikely to be used for rider training or even motorcycle research, the costs of simulation are liable to be low. Simulation is used to augment other training methods)

The disadvantages that he identifies are:

- Behavioural and motivational issues – different attitudes and motivations to real world where no risk of injury or loss of life.
- Observer presence known and close by.

- Simulation sickness (not just as an inconvenience but may influence behaviour, response biases and ultimately training effectiveness)
- Technological limitations – Auditory and visual environments have greatest promise in emulating real world environments but incorporating haptic visual interfaces is more difficult.
- Costs – the need to evaluate cost-fidelity trade-off.

Hancock identifies two main types of simulators

1) Fixed base system

2) Motion based system (includes all the components of 1) in addition to a motion platform (pitch, yaw and roll).

He concludes that "what is clear from past experience and is evident from the intrinsic problems associated with motorcycle simulation, is that such high-fidelity, wrap-around motion systems are very unlikely to represent a cost effective method of motorcycle rider training."

He points out that it is not always necessary to add all cues necessary for motion for example, when the human sensory systems needs only a critical few to create the feeling of movement. Optimal positive training transfer is said to occur when all of the elements of a training task are identical to the target task. However, high fidelity does not necessarily ensure effective training and transfer. In fact, some studies have shown that some high fidelity features can decrease rather than increase training transfer (Lintern, 1991, cited in Hancock, undated). It is possible that lower fidelity virtual environments can actually provide enhanced training platforms over high fidelity environments. Instead of investing in high cost high fidelity environments, designers of virtual environments should concentrate on what elements of a task and task environment will ensure that a positive transfer of training will occur from the training task to the target task.

The understanding of which elements of a training task require high similarity for positive transfer to occur is complex. The big challenge is to identify the critical transfer elements of a task so as to ensure that a positive transfer of training will occur. There is a need to carefully validate any simulator to ensure that there is correspondence between the actual results obtained and the set of outcomes which are desired in order to fulfil the implementation objectives of having used the simulation system.

Hancock concludes that

- High-level motion based systems are not cost-effective for motorcycle training and research.
- Home-based PC systems can be used to provide rules based training strategies.
- Simulation should be used as part of a battery of training tools.
- There is a greater need to focus on those elements which will ensure a positive transfer of training rather than on maximizing realism and high fidelity.

8.1.2 Issues for simulation in motorcycle training arising from the Japanese experience

Awane (1999) contends that "the best way to teach drivers real skills, including sound judgment and control, is to give them direct experience of controlling a vehicle....an effective approach to driver education is to allow people to vividly experience the unfortunate consequence of careless driving with a systematic way of helping them to understand the cause of such errors and to reflect on their driving performance. Simulators are a type of tool well suited to this kind of education method" (p.26).

He notes that some rider re-education programs have started to include danger anticipation training using simulators in their regular curricula. This is in line with the suggestions that the emphasis in simulator training should be on recognition of 'accident configurations' rather than 'last-second collision avoidance measures' (Hancock, Wulf, Thom, & Fassnacht, 1990).

Awane maintains that classroom teaching of what he terms "danger anticipation" cannot provide training in all the activities involved in riding and, in particular, does not teach trainees to develop the moment-to-moment awareness and judgment necessary to control a motorcycle. On-road training is also constrained for motorcycle riding because it is difficult for the instructor to notice important details like the delays in the responses of trainees. With a simulator, however, these behaviours can be noted immediately, or on replay of the recorded riding sequence.

He stresses the importance of replaying exercises to trainees from different angles to teach them to recognise problems that they failed to notice when riding. As part of this process, the instructor encourages the trainee to observe how the problem occurred, reflect on why it occurred, and determine what should be done to correct it. Awane believes that the role of the instructor in simulator training is different to that in real vehicle training, but is still important.

Awane notes that the use of a checklist of trainee behaviour during simulated riding can help to establish common items by which to assess riding performance and minimise the role of the instructor's own personal views. The checklists can function as a personal performance record for each trainee and monitor whether specific problems have been overcome.

Several problems have arisen with the use of simulators, however (Awane, 1999). Motion sickness affects some trainees, a certain time is needed for familiarisation with the simulator, and often there is insufficient time available for trainees to gain enough practice on the simulator to take full advantage of the training (due to a shortage of simulators).

Awane proposes that a comprehensive rider education system should include classroom training, skills practice using real vehicles and simulation training to learn to handle situations that are too dangerous to practice using a real vehicle. He maintains that for inexperienced trainees, the simulator should be used first for teaching basic motorcycle handling skills, before moving on to practice with real vehicles. Danger anticipation training can be deepened at each stage of training using a real vehicle and simulator in turn.

According to Awane, it is not necessary to use simulators prior to real vehicles for experienced riders. The simulator can be used as a diagnostic tool to identify bad riding habits in experienced riders. Then they can practice riding real motorcycles to correct any bad riding habits revealed during their simulator sessions. It is also possible to go back to the simulator to check that their riding technique has indeed been corrected.

Awane notes that the most objective criterion for evaluating the effectiveness of simulator education is accident reduction. He notes, however, that it is currently too early to be able to conduct such an evaluation accurately. Instead, he reports the results of a survey of graduates of a large number of driving and riding schools. The purpose of the study was to find out whether the graduates found the simulator exercises to be useful in practice. The response rate was very low – less than 2% – and therefore the results may not be reliable. Another survey by the Automobile Safety Driving Centre, a public organisation, found that many people reported that they found simulator training a valuable opportunity to face dangerous situations that cannot be practised using real vehicles. Awane concludes that the use of simulators in training has highlighted to trainees the importance of danger anticipation.

A partly translated Japanese document supplied by the Honda Australia Roadcraft Training complex in Sydney shows that the death rate per 10,000 motorcycle riders has decreased substantially since the introduction of simulator training in September 1996. It states that "understanding of other traffic's characteristics and the ability of hazard prediction are the factors believed to have contributed to this, and these were mainly done by using the driving simulators".

The main challenge that Awane has identified for the future is to increase the amount of time that each trainee can spend on the simulator. One option to allow more widespread use of simulators is that simulator equipment be designed and manufactured to be less expensive. Better utilisation of simulators may be possible by dividing trainees into groups and having some undertake training using real motorcycles while others are using the simulator(s) and then rotating.

Awane also notes that the lack of time for repetitive practice in motorcycle training at the licensing stage may be constraining training in danger anticipation (a point also relevant in Victoria, e.g. see Haworth & Smith, 1999). He identifies the potential to make danger anticipation training compulsory at driving/riding schools or special traffic education facilities within six months or perhaps one year after obtaining a motorcycle licence.

8.2 MOTORCYCLE SIMULATION IN JAPAN

Most of the use of simulators in motorcycle rider training has occurred in Japan, where driving and riding schools and driving and riding licensing centres have started to use simulators for training and education. This has occurred in the context of a licensing system in which learning to drive or learning to ride must occur off-road. There is very little description of these programs and evaluations available in English.

An early paper (Yuhara, Oguchi and Ochiai, 1993) stated that a variety of riding simulators were being developed ranging from a fixed-base simulator for basic riding training to a simulator equipped with a visual system to allow different traffic environments to be presented.

The use of simulators in motorcycle training began in Japan in 1996 with the use of simulation exercises for training prior to obtaining a licence to ride a large-sized motorcycle (over 400 cc). Training sessions with simulators were made a compulsory part of training for a motorcycle licence prior to 1998.

8.2.1 Honda riding simulator

The Honda Motor Company developed a riding simulator for "learning by experience for danger prediction and forecast". Some of the simulation issues relating to the motion systems that needed to be addressed in the first two prototypes are discussed by Miyamaru, Yamasaki and Aoki (2002). In 1992 it began to be used for research into safe driving education for beginner riders at the Suzuka Traffic Training Centre. Commercial versions of the simulator were first marketed in 1996. More than 200 of these riding simulators have been used by traffic education centers and riding schools in Japan and overseas, providing risk-prediction training in situations where on-road rider training is difficult to obtain (see Figure 8.1). A description and assessment of the Honda driving simulator currently situated in Melbourne is provided as an appendix to the second Stage 1 report (Wallace et al., 2005).

Figure 8.1 The first generation Honda motorcycle riding simulator. Image from http://www.ssdcl.com.sg/simulatorlhonda_motorcycle.asp

A press release from Honda Corporate News (April 17, 2001) announced that a new second generation riding simulator has been developed (shown in Figure 8.2). The press release states that it retains the original concept with improvements in the functions necessary for rider education at a lower price. The main features of the new riding simulator are

1) Further evolution of the lean-sensor which helps to reproduce more natural handling and cornering feel.

2) The size of the video display screen has been expanded to create a more natural field of vision. Image processing has been improved.

3) The system can simulate a variety of motorcycles ranging from a 50cc scooter to a large-sized motorcycle.

4) The overall size has been made considerably more compact and a lower price has been achieved.

Figure 8.2 The second generation Honda motorcycle riding simulator. Image from http://world.honda.com/news/2001/c010417_1.html

8.2.2 Kawasaki simulator

Limited (and undated) information has been obtained regarding the Kawasaki simulator (see www.phrixus.com). Kawasaki Heavy Industries was approached by the Japanese National Police Agency to develop a better, more realistic riding simulator which would allow potential riders to take their rider training at a riding school. It is the world's first motorcycle riding simulator using a head mounted display (HMD). The rider sits on a motorcycle and by using the HMD is able to look side-to-side, use rear view mirrors and lean forward at intersections to check traffic (see Figure 8.3). The riders also learn the use and feel of a clutch, throttle etc. The simulation can depict different riding courses. Users can choose between "street" and "specific condition" (sic) riding. Student and instructor communicate via a built in microphone and earphones. After simulation, problem areas can be instantly reproduced and viewed from several angles.

8.3 DEVELOPMENTS OUTSIDE OF JAPAN

The internet-based search revealed a number of patents for motorcycle simulators (e.g. US3686776: Motorcycle Riding Simulator) but it is unclear whether the simulators are developed or suitable for motorcycle hazard perception training or testing. The PERCRO organisation in Italy has developed a motion-based simulator (termed MORIS) that aims to reproduce the dynamics of a real motorcycle (http://percro.sssup.it/projects/moris/html). The final goal of the MORIS project is to develop a tool to assist the design and development process of two-wheeled vehicles and, particularly, to reduce the number of road tests currently required after prototype fabrication.

Figure 8.3 The Kawasaki motorcycle simulator incorporating a head mounted display. Image from www.phrixus.com/training.htm

Dr-Ing Reiner Foerst GmbH, a German company that is part of the TRAINER consortium (see Section 6.3.4), has developed a range of simulators, including a motorcycle simulator (see Figure 8.4). The simulator comprises an actual motorcycle (the type can be chosen by the customer) in front of a rear-projection screen. Riding around curves may be undertaken by steering or by the rider shifting his weight. The company has patented a method of calculating the forces acting on the motorcycle in curves and the motorcycle that forms part of the simulator is mechanically inclined in curves. The road and landscape image is also inclined to create what they claim to be a "real motorcycle driving feeling". The simulator can present an obstacle appearing suddenly on the road and measure the braking forces, reaction time and braking distance.

Figure 8.4 The motorcycle simulator developed by Dr-Ing Reiner Foerst GmbH. Image from http://www.drfoerst.de/e_n8m.htm

The US-based Motorcycle Safety Foundation has developed a PC-based motorcycle simulation challenge as part of its rider training resources. It is noted that the Transport

Accident Commission is developing a motorcycle equivalent of the RideSmart CD-based training package for young drivers.

In Britain, TRL Limited may possibly develop a motorcycle simulator in the future (Andrew Parkes, personal communication, 2003).

8.4 VICTORIAN HIGH TECHNOLOGY OPTIONS REPORT

A report on high technology options for motorcycle rider testing and training in Victoria was prepared for the Transport Accident Commission by I-Cubed@RMIT (2002). The report describes three formats that could be used for rider training, each with its own advantages and limitations.

1) Small vision station with spherical screen, enabling immersive training and testing of a single individual with 180° field of view in all directions.

2) Large vision station with spherical screen, enabling immersive training and testing of up to 10 individuals at a single showing with 180° field of view in all directions.

3) An “I-Max” type format with a cylindrical screen, enabling immersive training and testing of up to 30-50 individuals at a single showing with 130° field of view horizontally.

The report states that these options are now available. The technology was originally used (and is still used) in military training.

The report states that all of these options are superior to the technology used in the current hazard perception test which was specifically designed for operators of motor cars rather than motorcycles. While some of the concepts used in the existing HPT for novice car drivers will be relevant to motorcyclists, the newer technology described above provides the capacity to realistically portray motorcyclist behaviour and therefore offers the capacity to provide an appropriate training and testing facility e.g., can provide realistic experience for such operator behaviours as “leaning” into corners.

The costs of providing an immersive training and testing environment by providing ‘wrap-around’ vision have reduced substantially. The report concludes that although the new technology may not be practical for universal application to car drivers, the small number of motorcycle licences issued and the limited number of locations at which motorcyclist testing and training is undertaken mean that this technology can reasonably be used for motorcycle training and testing.

9. SUMMARY AND CONCLUSIONS

This project is the first stage of a larger program of research into hazard perception training for motorcyclists. Future stages of the project will investigate what type of environment can be used to teach hazard perception and responding, for example a simulator environment or combination of off-road and simulator training.

This is the first report of Stage 1 of the research program. The second Stage 1 report investigates the best training methods for teaching hazard perception and responding skills to motorcycle riders. It provides an analysis of training methods and examines the potential usefulness of simulation and other training methods in motorcycle rider training.

This report has attempted to consider the extent to which the findings of research into hazard perception and responding (mostly conducted with car drivers) are relevant to motorcyclists, given the different vehicle control skills required for safe riding and given the additional or different hazards relevant to motorcycling (see Haworth et al., 2000).

Another issue considered important for this project is the extent to which the findings are relevant to Victorian motorcyclists, given their age and experience profiles (both in car driving and motorcycle riding). Much of the research in hazard perception and hazard perception training has focussed on young novice car drivers. This group is both young and inexperienced. The research has demonstrated that their hazard perception skills are poorer than older, more experienced drivers. It has also shown that hazard perception training can improve their performance on hazard perception tests to a level similar to older, more experienced drivers. However, many Victorian motorcyclists are not young and many have more car driving experience than motorcycling experience. Little is known about the relationship between age and experience and ability in hazard perception and responding for motorcyclists. There is a need to assess for which categories of motorcycle riders – younger, older, novice, experienced, returning – hazard perception and responding needs to be improved and how this could be done.

9.1 DEFINITIONS AND THEORETICAL APPROACHES

For the purposes of this report, a *hazard* was defined as “any permanent or transitory, stationary or moving object in the road environment that has the potential to increase the risk of a crash. Hazards exclude characteristics of the rider or the vehicle, which are classed as modifying factors." *Hazard perception* is defined here as “the process whereby a road user notices the presence of a hazard” (from Evans and Macdonald, 2002, p.93). Hazard perception is the first stage in a chain of processes linking the existence of physical hazards to outcomes.

Modifying factors are defined as characteristics of the rider or the motorcycle that modify the level of risk of a hazard. They can be long-term characteristics of the individual such as rider experience and rider skill in executing responses (real or perceived) or more transitory characteristics such as travel speed, type of protective clothing worn and mechanical condition of the motorcycle. The concept of *defensive riding*, as described by riders, appears to place more emphasis on the modifying factors and less on the perception of hazards.

A number of different theoretical frameworks have been used to explain hazard perception by car drivers including recognition-primed decision making (Klein, 1989, 1993), situational awareness theory (Endsley, 1995) and evolutionary psychology (Harrison, 2002). The four-component model of responding to risk (Grayson et al., 2003) does not directly mention motorcycling, but the model's inclusion of a response execution phase (Implementation) makes it potentially the most useful for understanding motorcyclists' responses to hazards. Analyses of motorcycle crashes have demonstrated that response implementation may be where the process of hazard perception and responding fails in some crashes (e.g. Haworth et al., 2000). It is likely that modifying factors such as alcohol would affect several components of the model, including threat appraisal and implementation (e.g. by lengthening reaction time). However, the model does not specifically deal with transient modifying factors that influence the potential severity of the outcome such as speed and it is unclear how the model accounts for improvement with experience. Thus, it needs more work before it can serve as a comprehensive model of hazard perception and responding by motorcyclists.

9.2 TYPES OF HAZARDS

Hazards can be classified into those that are road based and those that arise from the behaviour of other road users. Motorcyclists are subject to the hazards faced by car drivers but are also at risk from situations not hazardous for car drivers, such as gaps in bridge decking wide enough to catch a motorcycle wheel but too narrow to affect a car tyre. The reactions required from riders also need to be different, as motorcycles handle differently to cars. The extent of potential harm associated with any given hazard is commonly greater for motorcyclists, given their comparative lack of protection.

The hazards associated with the behaviour of other road users can be thought of as arising from failures of hazard perception by other road users. The extent to which this can and should be addressed by improving the hazard perception and responding skills of motorcycle riders, compared with the corresponding skills of car drivers is a matter for debate.

It is much easier to identify hazards related to the behaviour of other road users in the crash data than it is to identify the role of road based hazards. Therefore, relatively more is known about the extent of involvement of hazards relating to the behaviour of other road users in motorcycle crashes.

9.3 HAZARDS AND HAZARDOUS SITUATIONS INDICATED BY THE CRASH DATA

Data for Police reported crashes have a number of shortcomings in terms of identifying the role of hazards and hazard perception and responding. There is significant under-reporting of crashes that are of low severity, single vehicle crashes and crashes involving some illegal behaviour (e.g. unlicensed riding, unregistered motorcycles, drink riding). If particular hazards are relatively more important contributors to any of these types of crashes, then their importance is likely to be underestimated in the crash data.

A serious limitation on the usefulness of crash data is the extent to which information relevant to the presence of hazards and their role in the crash is recorded. Most hazards related to the road surface are not recorded in the crash data. Hazards related to the behaviour of other road users are potentially easier to identify from the crash data than road-related hazards. However, there is no "road user at fault" coding in the Victorian crash data and overall assessments of legal right of way are complex, given the characteristics of the coding of crash types. In addition, the crash data provides no information about circumstances in which the outcome was not a crash involving injury (or the successful avoidance of a crash). It raises many questions about why crashes occurred in some instances but did not in others.

Given these constraints, the crash data provides useful information about the riding environments (e.g. as defined by intersections, speed zones, weather conditions) in which (at least reported) crashes occurred. The identification of these riding environments and situations will help to identify what needs to be included in training in hazard perception and responding.

Overall, about half of the motorcycle riders involved in reported casualty crashes in Victoria in 1997-2001 were involved in collisions with vehicles. These collisions comprised 64% of crashes in low speed areas, 54% of crashes in higher speed metropolitan areas and 23% of crashes in higher speed areas in the Rest of Victoria. The most common DCA codes for collisions with vehicles were:

- DCA 121 turning right through, not at intersection
- DCA 113 adjacent directions: right near (at intersection)
- DCA 120 head-on, not overtaking
- DCA 130 rear-end impact
- DCA 140 U-turn

Given the results of earlier analyses, it is likely that the other road user failed to give right of way to the motorcyclist in the majority of these crashes.

Both age and licence status appear to affect the observed crash pattern of motorcycle riders. The crash data show that older fully-licensed riders have proportionally more of their crashes in higher speed zones outside of the metropolitan area (and perhaps in higher speed zones inside the metropolitan area), suggesting that this reflects their patterns of riding.

Even within a given riding environment, age and licence status appear to affect the crash pattern. Older novices were less likely to have collisions with vehicles and were more likely to have single vehicle crashes than other riders in low speed riding environments and in higher speed areas outside of the metropolitan area. This needs further investigation. It may be that older novices are relatively better at perceiving and responding to hazards arising from the behaviour of other road users or relatively poorer at dealing with road-based hazards than other riders.

9.4 HAZARD PERCEPTION RESEARCH

There has been extensive research into hazard perception by car drivers since about 1990 but only a small number of studies that have addressed hazard perception and responding by motorcyclists. Studies have shown that novice drivers are slower or less likely to detect and respond to hazards in the driving environment (Quimby & Watts, 1981; Egberink, Lourens & van der Molen, 1986) and that slow hazard detection (measured in a driving simulator) is associated with a history of greater self-reported accident involvement (Quimby, Maycock, Carter, Dixon and Wall, 1986).

A number of studies have demonstrated the role that failures in responding (particularly failure to respond, or braking ineffectively) play in motorcycle crashes (ROSPA, 2001; Hurt, Ouellet and Thom, 1981; National Center for Statistics and Analysis Research and Development, 2001; Haworth, et al., 1997). Ouellet (1990) argues that correct lane positioning may be more important in crash avoidance than emergency braking.

The two studies of the visual scanning patterns of riders and drivers (Nagayama et al., 1980; Tofield & Wann, 2001) found different results. Nagayama et al. found that riders spent more time looking at the road surface, whereas car drivers looked relatively far ahead at objects such as traffic lights, and seldom at the road surface. Tofield and Wann reported that experienced riders looked further ahead than experienced car drivers in a car driving simulation. The inconsistency in the findings of Nagayama et al (1980) and Tofield and Wann (2001) suggest that further research is needed to clarify any differences in scanning patterns between motorcyclists and car drivers. The discrepant results may reflect differences in the methods and design used by the two studies. In the Nagayama et al study, the *same* participants were tested and compared under real world conditions of *both* driving a car and riding a motorcycle suggesting that their study might be a better and more realistic test of potential differences in scanning patterns than that used by Tofield and Wann. It would be informative to repeat this experiment using the methodology employed by Nagayama et al.

The development of safe hazard perception and responding skills is important in lowering crash risk for all road users. However, teaching appropriate response execution may be more critical for riders than for drivers given their greater likelihood of serious injury and death in the event of a crash and the extent to which failures in response execution may result in failure to avoid the initial hazard or a different type of crash. If hazard perception and appropriate responding skills are necessary for safe riding, then an important question is whether their development can be accelerated by training. While research has shown that hazard perception training in novice drivers leads to improved performance on hazard perception tests, it is not yet known whether these drivers go on to be safer drivers and have fewer accidents (McMahon & O'Reilly, 2000).

Some of the methods used for hazard perception training for car drivers may not be feasible for motorcyclists. For example, while instructors travelling with novice car drivers and providing feedback on hazards (or listening to commentaries) has been used, it may not be appropriate (and it would be illegal) for an instructor to travel as a pillion with a novice rider. It is noted that the Transport Accident Commission is developing a motorcycle equivalent of the DriveSmart CD-based training package for young drivers which it intends to call "RideSmart".

Many of the approaches to hazard perception training for car drivers require only detection of the hazard and response by pressing a button. They do not train improved execution of responses to hazards, an area that the crash data suggest is of greater importance to riders than drivers.

Standard training motorcycle training courses leading to standard motorcycle tests have not been shown to result in reductions in crash involvement. There has been little evaluation of the effectiveness of products designed to improve hazard perception and responding by motorcycle riders. The lack of a good test of hazard perception and responding by motorcycle riders has prevented research to evaluate the effectiveness of motorcycle training programs and products in enhancing these skills.

Horswill and McKenna (1998) found that hazard perception training for car drivers reduced their risk-taking propensity. Given that motorcyclists have been found to engage in more behaviours known to increase crash risk (e.g. Horswill & Helman, 2001), it might be expected that the potential benefits of a hazard perception training program designed specifically for motorcyclists would be even more critical for this group.

An important factor in assessing when training in hazard perception and responding should be provided to riders is rider attrition. While most novice car drivers go on to become experienced car drivers, this is not the case for motorcyclists. Many riders who obtain a learner permit do not go on to obtain a licence. Thus, any motorcycle-specific hazard perception and responding training that is delivered very early in the learning process (e.g. at the time of obtaining a learner permit) may be delivered to many more people than eventually end up riding motorcycles. This is an apparent waste of resources. Related to this issue, is whether hazard perception and responding training would influence the attrition rate. If it increased rider confidence, then it might act to reduce the attrition rate (this would be bad if it did so without increasing skills in hazard perception and responding). If it decreased rider confidence (as they became more aware of hazards and the difficulties of avoiding them successfully), then the attrition rate might increase.

9.5 HAZARD PERCEPTION TESTING

In light of the reported associations between crash involvement and poor hazard perception ability (e.g. Quimby et al., 1986), some jurisdictions have developed tests to measure hazard perception skills among novice drivers at the probationary stage of licensing. The inclusion of a hazard perception test in the procedure for acquiring a licence to drive is deemed to be the most effective way of ensuring that hazard perception training is taken on a voluntary basis. It should be noted, however, that most of the available tests do not measure response selection or execution – the focus is on the hazard perception component only. This may limit the extent to which such tests are able to predict the crash liability of motorcyclists.

The search of the literature and specific contacts made for this project failed to find any motorcyclist-specific hazard perception test that had been developed or introduced anywhere in the world. At present, it appears that there are no plans to introduce a separate version of the test designed specifically for motorcyclists in any jurisdiction.

In the UK, candidates for a motorcycle licence are required to pass the HPT, but this is not the case in Victoria, Western Australia and New South Wales. Most of the Victorian applicants for a motorcycle licence are not required to sit the car HPT because they already hold a car licence and it is assumed that they would have passed the Test (those who obtained their car licence after 1996) or would have developed hazard perception skills from years of driving cars.

Given that most candidates for a motorcycle licence in Victoria are not required to sit the HPT, the issue arises of whether car hazard perception tests are useful for motorcycle riders. Horswill and Helman (2001) claim that the current UK licensing system that requires learners applying for their motorcycle licence to pass the HPT designed for car drivers may disadvantage riders and recommend that a separate HPT for motorcyclists with associated training should be introduced into licensing systems. Helman (personal communication, 2003) has advised that he intends to develop a motorcyclist hazard perception test.

It is also questionable whether the hazard perception tests developed for car drivers give sufficient emphasis to hazards specific to motorcyclists, particularly road surface hazards. This would limit their ability to be able to predict later crash involvement.

9.6 MOTORCYCLE SIMULATORS

An extensive search of the motorcycle safety literature and the simulation literature was undertaken to identify any motorcycle simulator research that has been undertaken and to assess the relevance of that research for the current project.

Most of the use of simulators in motorcycle rider training has occurred in Japan, where training sessions with simulators were made a compulsory part of training for a motorcycle licence prior to 1998. This occurred in the context of a licensing system in which learning to drive or learning to ride must occur off-road. There is very little description of these programs and evaluations available in English.

Riding simulators have been developed by the Honda Motor Company, by Kawasaki (a head mounted display unit) and some European companies. In Britain, TRL Limited may possibly develop a motorcycle simulator in the future. The Honda simulator was developed for "learning by experience for danger prediction and forecast" and appears to be the most relevant to hazard perception and responding. Little information was available regarding the Kawasaki simulator. A description and assessment of the first generation Honda driving simulator currently situated in Melbourne is provided as an appendix to the second Stage 1 report.

In a report prepared for the US-based Motorcycle Safety Foundation, Hancock (undated) concludes that

- High-level motion based systems are not cost-effective for motorcycle training and research.
- Home-based PC systems can be used to provide rules based training strategies.
- Simulation should be used as part of a battery of training tools.
- There is a greater need to focus on those elements which will ensure a positive transfer of training rather than on maximizing realism and high fidelity.

Awane (1999), on the basis of Japanese experience, proposes that a comprehensive rider education system should include classroom training, skills practice using real vehicles and simulation training to learn to handle situations that are too dangerous to practice using a real vehicle. He maintains that for inexperienced trainees, the simulator should be used first for teaching basic motorcycle handling skills, before moving on to practice with real vehicles. Danger anticipation training can be deepened at each stage of training using a real vehicle and simulator in turn. According to Awane, it is not necessary to use simulators prior to real vehicles for experienced riders. The simulator can be used as a diagnostic tool to identify bad riding habits in experienced riders which can then be corrected by practice riding real motorcycles (and potentially checked on the simulator).

9.7 CONCLUSIONS

The following key issues were identified in this report:

- Motorcycle riders must deal with the same hazards as car drivers, as well as the additional hazards of failure by car drivers to give way and road surface hazards.
- Hazard perception and responding is more crucial for motorcyclists than car drivers, because motorcyclists cannot rely on the other road user seeing and avoiding them.
- The potential severity of crashes, regardless of the type of hazard, is greater for motorcyclists.
- The vehicle control skills involved in riding a motorcycle are more complex than driving a car and failure to correctly implement a response to a hazard may in itself be dangerous.
- Attention sharing between the vehicle control skills and hazard perception and responding may be problematic for novice riders.
- Any test of hazard perception that does not include a response implementation component may underestimate the difficulties in hazard perception and responding shown by motorcyclists and may, in particular, underestimate any differences between novice and experienced riders.

This report has identified that very little research has investigated hazard perception and responding by motorcycle riders. For car drivers, the research has shown that experienced drivers are quicker to detect hazards and that slower responses to hazards are associated with higher self-reported crash involvement – but this has not been tested for motorcycle riders.

While it is clear that road based hazards are relatively more important for motorcycling than for car drivers, it is unclear what factors affect perception and responding to these hazards. These factors could include characteristics of the rider, of lighting and visibility, of travel speed and of the traffic circumstances.

The small number of studies measuring hazard perception and responding by motorcycle riders has found that:

- Riders are more likely to nominate road-based hazards than car drivers
- In a simulator, experienced riders react faster to hazards when acting as car drivers than when acting as riders
- Responding is a relatively more crucial part of the process for riders than for drivers
- Most novice riders are experienced car drivers and are older than novice car drivers
- Riders and car drivers differ in where they look. One study found that riders spend more time looking at the road and less further away but another study disagrees.

The following recommendations are made:

1. Research should be undertaken to investigate whether experienced riders are faster at perceiving hazards than novice riders and whether this depends on the type of hazard (vehicle-based or road-based) and the level of car driving experience of the rider.

2. The results of the research outlined in 1. should be used to determine the relative emphasis given in training to the two types of hazards and who the training should target (novice car and motorcycle operators, novice motorcycle riders who are experienced car drivers etc.).

3. Hazard perception training products (or a hazard perception test) for motorcycle riders cannot be developed until more is known about what affects hazard perception, how this varies among the different classes of hazards, and the extent to which hazard perception can be trained.

4. Research should be undertaken to resolve whether training should focus on addressing hazard perception or responding or the modifying factors. It may be that addressing the modifying factors could be more useful than improving hazard perception or responding.

5. Any hazard perception training that is developed should fit the needs of the Victorian riders. Different approaches may be needed for younger and older novices. There is a need to assess for which categories of motorcycle riders – younger, older, novice, experienced, returning – hazard perception and responding needs to be improved and how this could be done.

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