The University of Nottingham

**Centre for Motorcycle Ergonomics
& Rider Human Factors**

**Advanced Training & Rider Performance
(Final report)**

**Prepared for the
Institute of Advanced Motorists**

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Advanced Training and Rider Performance

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Executive summary

Motorcyclists typically constitute less than 4% of the total number of licensed vehicles on UK roads, however they account for 21% of all UK road fatalities. Motorcycles therefore account for a disproportionate number of road traffic accidents, being in the order of 51 times more likely to be killed or seriously injured than car drivers (Department for Transport, 2009a). There is evidence that many of these accidents occur on unfamiliar roads (Department of Transport, 2005), with 65% of fatalities occurring in rural areas and greater than 70% involving learner or inexperienced riders (Department of Transport, 2009a). Previous research (Clarke, et al, 2004) has shown that the three most common types of motorcycle accidents are:

- **Right of way violations** – typically occur when motorists fail to see a motorcyclist approaching a junction and pull out on them, even though they were looking the direction the motorcyclist came from (Clarke, et al, 2004). This phenomenon is also referred to as a 'looked but did not see' accident (Brown, 2002).

- **Loss of control on a bend, corner or curve** – these accidents are usually regarded as primarily the fault of the motorcyclist rather than other road users, with accidents more associated with riding for pleasure involving only the motorcyclist and no other traffic (Clarke, et al, 2004). There is also evidence that left-hand bends appear to feature more in these kinds of motorcycle accidents than right-hand bends.

- **Motorcycle manoeuvrability accidents** – where riders are judged to be at fault, 16.5% of accidents involved a motorcyclist overtaking other vehicles (Clarke, et al, 2004). Other accidents occur when the motorcyclist is passing slow moving or stationary traffic (often referred to as 'filtering').

Against this backdrop, the Centre for Motorcycle Ergonomics and Rider Human Factors was commissioned by the Institute of Advanced Motorists (IAM) to conduct one of the first in-depth rider behaviour studies of its kind. From the outset, in order to identify good on-road skills and strategies, it was important to compare groups of road users who have fundamentally different skills, attitudes and behaviours. While an obvious approach might compare groups who are more likely to have, or have had, an accident with those who have a safer on-road record, this can prove remarkably difficult. Accidents are relatively infrequent and easily contaminated with exposure issues and environmental factors making it very difficult to make comparisons. For this reason, a study was designed to compare Novice, Experienced and Advanced trained riders across a battery of motorcycle related tests. However, in order to do this a new integrated experiment approach had to be developed using an innovative motorcycle simulator to capture a range of measures without the danger of bias, priming or experimental factors such as order, practice and fatigue effects.

Within the integrated experiment approach, a main riding scenario was developed incorporating common accident situations. Additional tasks were designed in order to explore a wide range of skills, attitudes and behaviours across the three rider groups. Within the main riding scenario were a number of mini-experiments in their own right. The research followed a 'between-subjects' design as participants were assigned to specific rider groups based on their training profile. Some aspects of the scenario were also developed as a 'mixed' design allowing for analyses 'between' the rider groups as well as 'within' specific sections of the scenario.

An opportunistic sample of 62 participants was recruited for the research. However, 1 participant dropped out as a result of simulator sickness. The remaining 61 participants included:

- **20 Novice riders** (i.e. riders who were post-CBT and preparing to take the standard Driving Standards Agency motorcycle test, or who had passed their test within the last 12 months)
- **21 Experienced riders** (i.e. riders who had passed their test, with riding experience over 3 years, but with no further training)
- **20 Advanced riders** (i.e. riders who had passed their IAM riding test in the last 3 years).

The results indicate that IAM training shows clear benefits for urban riding. In 40mph zones IAM riders held better road positions to anticipate a variety of hazards and responded accordingly. IAM riders also performed better in rural situations on 60mph roads. They were quickest through bends and generally rode in a more defensive position, closer to the centre line of the road. IAM riders did not use their brakes as much as the other riders in the 60mph zones and as they were already travelling slower in the 40mph zone, they could brake harder.

IAM riders were generally smoother in their riding style, making better progress into, around and out of a variety of bends. When outside furniture was present (and in particular, trees close to the roadside) rider behaviour was more cautious with slower speeds and road position surrendered.

When negotiating hazards on left- or right-hand bends, Novice and Experienced riders both appeared to respond late to the hazards and adopt road positions which left them vulnerable to oncoming traffic. Advanced riders were smoother at negotiating the hazards and appeared to be able to ride 'through' the bends by preparing for the next bend earlier than the Novice and Experienced riders.

When approaching a hazard on a bend the general tendency was to slow down first and then alter road position. When approaching a hazard on a straight road, riders tended to alter position before braking.

Experienced riders illustrated some behaviours similar to Advanced riders (e.g. lateral variance in 60mph zones and entry speeds into bends) but also reverted to behaviours more aligned to Novice riders (e.g. lateral variance in 40mph zones).

It would appear that Novice riders may not have fully developed their road awareness and perhaps adopted behaviours similar to Advanced riders without commensurate skills. Experienced riders appeared to be over cautious in bends compared to either the Novice or Advanced riders, whilst the Advanced riders showed clear advantages in their riding behaviour across a number of sub-scenarios. They were generally better able to recognise potential hazards and with a better initial road position, they did not have to alter their riding lines as much as the other rider groups. Coupled with the specific hazard perception task, the Advanced riders were quicker at perceiving hazardous situations and adopted a more responsible approach to hazard avoidance.

The research represents on of the first in-depth and systematic motorcycle simulator studies into rider behaviour. It has demonstrated clear differences between the three rider groups and potential benefits of advanced training above and beyond general rider experience and basic training. Whilst experience seems to help develop rider skills to an extent, advanced training appears to develop deeper levels of awareness, perception and responsibility. It also appears to make riders better urban riders and quicker, smoother and safer riders in rural settings. When taken together the results of this novel integrated experiment approach offer not only a perspective on the behaviour and skills of the rider groups, but also a tantalising insight into the attitudes and mindsets of Novice, Experienced and Advanced riders.

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1.   Introduction

1.1. Research background

This report presents the findings of an independent investigation by the Centre for Motorcycle Ergonomics & Rider Human Factors. This Centre comprises a number of researchers drawn from different University Departments in response to motorcycle research requirements. For this research the services of the Human Factors Research Group, School of Psychology and Dimax Technologies Ltd were used to investigate aspects of rider performance and behaviour on behalf of the Institute of Advanced Motorists (IAM). The outline for the study was based on the outcomes of meetings between the University of Nottingham and the IAM. These meetings helped to develop the focus of the investigation, clarify aspects of rider performance and behaviour based on differing levels of rider training, and the effectiveness of IAM 'Skills for Life' motorcycle rider training.

1.2. Timescale

The main study was timetabled to run between August and October 2010 with the findings being prepared for an official launch at 'Motorcycle Live 2010' (29 November, 2010).

1.3. Rationale

Motorcyclists are grossly over-represented in accident statistics (as of June 2010 they only constituted less than 4% of the total number of licensed vehicles on UK roads, they accounted for 21% of all UK road fatalities). While it would be unfair to place the blame for all these accidents solely with motorcyclists (as car drivers typically cause 2 of the 3 most common motorcycle accidents in the UK), it must still be recognised that there are skill and attitudinal gaps in rider behaviour that contribute to a large proportion of accidents (Clarke, et al, 2007). Consequently, just as important research must continue to focus on the role of car drivers in the high fatality rate of motorcyclists (Crundall, et al, in press), it is equally important to focus upon the abilities and strategies of motorcyclists themselves.

In order to identify good on-road skills and strategies, it is important to compare groups of road users who have fundamentally different skills, attitudes and behaviours. One tactic might be to compare groups of road users who are more likely to have, or who have had, an accident with those who have a safer on-road record, although this can actually prove remarkably difficult. Accidents are still relatively infrequent, and are contaminated with exposure issues and environmental factors making it very difficult to make comparisons across different groups.

In many studies of car driving, researchers resort to proxy measures of crash liability, such as experience. This is one of the more robust measures with the longer someone has been driving relating to a decreased likelihood that they might be involved in an accident. For instance, UK novice drivers (within a year of passing a driving test) are three times more likely to be involved in crash than more experienced drivers, and it has been argued that this is due to a change in risk taking behaviour and an improvement in driving skills after that first year (Gregersen & Bjurulf, 1996; Clarke, et al, 2005; Horswill & McKenna, 2004; Underwood, 2007).

If this proxy is extended to motorcycling, it would be plausible to predict that a comparison of novice riders with more experienced riders should identify those skills and strategies that are more likely to be indicative of safer rider behaviour. However, it would be a mistake to imagine that the typical pattern of expertise and behaviour in car drivers can be automatically transferred to motorcyclists. Considering the different underlying motivations for riding a motorcycle compared to driving a car, and the very different skill sets required to perform riding and driving tasks, it is possible that experience, *per se*, may not be related to an obvious decrease in accident liability.

Indeed, with car driving it has been noted that some negative attitudes take time to develop (Crundall, Humphrey & Clarke, 2008) and some of the skills and strategies that become entrenched with experience may be sub-optimal in certain situations (Crundall, et al, in press).

It would potentially be an error to merely compare a novice group of riders with an experienced group of riders, for even if differences were found between the two groups on a variety of sub-behaviours, it is likely that the differences represent superior behaviour for the experienced group in some instances, but possibly inferior behaviour in other instances. With this in mind, a comparison of three rider groups (including those who have received advanced training) would provide a richer assessment and more sensitive investigation. Through a comparison of these three groups of riders it should then possible to identify what skills and strategies might be considered optimal; which of them improve with experience; and which might deteriorate with experience as over-reliance on false expectancies and bad habits lead to sub-optimal behaviours.

1.4. Aim and objectives
The aim of this research was to investigate the differences in rider performance according to different levels of training that riders have received. In order to achieve this, the following objectives were identified:
- Develop an integrated experimental approach
- Build a bespoke riding scenario
- Recruit and conduct the study across the three rider groups
- Analyse and disseminate the findings

1.5. Overview of work programme
A number of key activities were undertaken in order to provide the scientific basis of the study and motorcycle simulator riding scenario:
- **Literature review –** there is a general lack of published literature on motorcycle human factors but there is a body of literature detailing rider characteristics, safety figures and accident data. A detailed review was conducted to provide the scientific context for the study.
- **Expert elicitation of scenario attributes –** using the preliminary IAM stakeholder meetings and discussions with subject matter experts, key attributes were developed to define riding environment characteristics which were then incorporated into the simulator riding scenario.
- **Scenario build –** using 'STI-SIM Drive' software it was possible to control many variables in a riding scenario in order to develop an empirical and repeatable approach to investigating rider behaviour. A bespoke scenario was built for the research based on the IAM's 'IPSGA' riding principles to assess rider information, position, speed, gear and acceleration. The main riding scenario was designed in a manner which tested what riders saw rather than what they expected to see. Embedded within the main scenario were a number of sub-scenarios designed to investigate specific aspects of rider behaviour and/or key accident scenarios.
- **Integrated experimental approach –** in addition to the main simulation scenario, an integrated experimental approach was developed incorporating a number of tasks which were designed to test different aspects of rider skills, attitudes, and behaviour.
- **Experiment and analysis –** the full study was executed and the data analysed across three participant groups to investigate differences between Novice riders, Experienced riders without advanced training and IAM advanced riders.
- **Report, presentation, dissemination –** research findings are presented in this report, a formal presentation of the results was conducted on 11 November 2010 and an overview report was launched on 29 November at Motorcycle Live 2010. Further dissemination activities are planned (media opportunities and academic journal publications).

1.6. Structure of the report

The report is presented in four broad sections:
- **Context** (introduction and literature review)
- **Methodology** (integrated experiment approach)
- **Results** (for each aspect of the integrated approach)
- **Review** (general consideration of results and future research)

The structure is illustrated in Figure 1.1

Section 1	Section 2	Section 3	Section 4
Context	**Methodology**	**Results**	**Review**
Introduction & Literature Review Advanced riding IPSGA principles Accident rates Simulator research MotorcycleSim	**Integrated Experiment Approach** Participants Design Hardware Ethics Procedure	**Demographics** **General riding** **Side roads** **Urban riding** **Bends with barriers** **Left hand bends** **Right hand bends** **Rider Hazard perception**	**Discussion** General discussion Future research Dissemination

Figure 1.1: Overview of report structure

More specifically, the following chapters are presented:
- **Chapter 2 (Literature review)** – presents key literature on aspects of rider behaviour, simulation studies and a description of MotorcycleSim. The relevant literature for each aspect of the integrated experiment is introduced at the start of each chapter.
- **Chapter 3 (Integrated experiment approach)** – this section of the report provides an overview of the common aspects of the integrated experimental approach, detailing the participant groups, hardware, design and overall procedure.
- **Chapter 4 (Demographics)** – compares the rider groups sampled in this study against official statistics.
- **Chapter 5 (General riding, attitudes & workload) –** provides an overview of rider data for 60mph and 40mph zones; straights and curves; rider attitudes and workload across the whole scenario.
- **Chapter 6 (Side roads) –** looks at the phenomenon of vehicles pulling out of a side road and their effects on rider behaviour.
- **Chapter 7 (Urban riding) –** considers how riders behave in an urban environment and perceive the potential hazards of pedestrians and parked vehicles.
- **Chapter 8 (Bends with barriers) –** investigates how the three rider groups rode a series of identical left-hand bends with only the outside roadside characteristics altered according to different furniture features.

- **Chapter 9 (Left-hand bends) –** examines the effect of encountering a hazard around an obscured left-hand bend. More specifically, any group effects of anticipating the hazard and subsequent behaviours after encountering it were investigated.
- **Chapter 10 (Right-hand bends) –** as with the left-hand bends, this chapter examines the effect of encountering a hazard around an obscured right-hand bend.
- **Chapter 11 (Hazard Perception) –** this aspect of the study explored how the different rider groups identified and perceived hazards from video footage.
- **Chapter 12 (Discussion) –** each of the results chapters presents a focused discussion for that topic, this chapter draws together observations from across the research, considers issues of simulator fidelity and identifies future research areas.

2.   Literature review

2.1. Introduction

Motorcycles offer a compact, agile and fuel efficient means of transport (McInally, 2003). For example, on 40mph roads motorcycles have the highest average 'free flow' speed of all vehicles (Department for Transport, 2007). However, riding them is a relatively complex and risky activity (McInally, 2003).

With road vehicles there are many aspects common to their use in the context of the overall road system (Helander, 1976). The motorcycle and rider do, however, have fundamentally different person-machine interfaces and can also interact with the road and traffic system in different ways to other motor vehicle types (Martin, Phull & Robertson, 2001; Robertson 2003; McInally, 2003; Lee, Polak & Bell, 2007). In particular, a number of studies indicate that motorcyclists appear to have faster braking responses than car drivers, but that their braking capability is less than that of cars (Lee, Polak & Bell, 2007). They also utilise the road space in a different way to other types of vehicle (Robertson 2003). What other road users may perceive as risky or aggressive behaviours may be due to the differences in the capabilities of motorcycles and other vehicle types (Robertson, et al, 2009).

The motorcycle and rider can be understood in terms of an interactive system operating within a very demanding safety critical environment (Stedmon, 2008). This interplay of the human-motorcycle interaction (HMI) between the rider, motorcycle and environment means that research should focus on many aspects such as how the rider processes the vast array of information around them (directly or indirectly from the motorcycle and environment); what impact experience and training has on the rider's ability to control the motorcycle and interact with the ever-changing environment; and what factors affect a rider's ability to ride safely or push their limits (and what happens when things go wrong). A lot of research has concentrated on the causes of road traffic accidents and although motorcycle manufacturers are beginning to take the physical design of motorcycles more seriously with some, albeit limited, adjustability in their models, virtually no human factors research has been conducted on rider behaviour.

2.2. Advanced riding and 'IPSGA' principles

Advanced riding consists of a system of applied techniques to improve the skill and safety of riding a motorcycle. There is an assumption that rider safety and riding skill are aspects of the same ability: to control the speed and position of the motorcycle relative to everything else on the road (IAM, 2009). An accident, or near-miss, usually represents a loss of control, a lapse in riding skill or an aspect of rider distraction. Advanced training may help riders improve their skills by increasing their awareness of the range of factors that can affect riding experience and improve the performance of the HMI, through the rider's own capabilities, the characteristics of the motorcycle, and the wider road and traffic conditions.

The IAM's 'Skills for Life' advanced training focuses on a system of motorcycle control as a way of approaching and negotiating potential hazards in a methodical, safe, manner that reduces, as far as possible, the effects of chance. It is formed upon a principle that encompasses five factors of safe riding: Information, Position, Speed, Gear and Acceleration or the 'IPSGA' system of motorcycle control (IAM, 2009):

- **Information** – the taking, using and giving of information is the primary factor to safe riding. The rider needs to be constantly seeking information to plan their riding and information should also be provided by the rider whenever other road users might benefit from it.
- **Position** – the rider should always position themselves so that hazards can be passed safely and smoothly, taking full account of any other road users.

- **Speed** – the rider must adjust their speed as necessary, using throttle, brake and gears to ensure the appropriate speed required to complete various manoeuvres. For these activities to be completed in a smooth and steady manner, it is essential that riders anticipate any hazards as early as possible.
- **Gear** – once the correct speed for a situation is achieved, the correct gear for that speed must be engaged.
- **Acceleration** – having taken account of their speed, other road users, and the road and traffic conditions ahead, the rider must then decide whether it is appropriate to accelerate away from a hazard. An appropriate point to accelerate safely and smoothly must be chosen, and the amount of acceleration must always be adjusted to the circumstances.

Using these principles, the IAM's advanced training aims to make motorcycling more enjoyable and safer for the rider and other road users. It still remains, however, that motorcyclists are a vulnerable user group within the wider the road system and more likely to be involved in accidents.

2.3. Motorcycle accident rates

Motorcycles account for a disproportionate number of road traffic accidents being in the order of 51 times more likely to be killed or seriously injured (KSI) than car drivers (Department for Transport, 2007). According to the latest UK figures (Department for Transport, 2009a) between 2007 and 2008 motorcycle traffic increased by 33% compared to the 1994 to 1998 baseline although the KSI rate for motorcyclists during this period fell by 30%. Despite this, the motorcyclist population still has an especially poor safety record compared to other road user groups. Latest figures reveal that over 21,000 motorcyclists (including moped and scooter riders) and pillion passengers were injured and 493 motorcyclists were killed in reported accidents for Great Britain in 2008 (Department for Transport, 2009a). Motorcyclists continue to have the highest fatality rate of any road user group as well as the highest rates for slight injuries (per 100 million vehicle kilometres) (Department for Transport, 2009a).

In relation to where accidents occur, 65% of motorcycle fatalities occurred in rural areas and 70% of motorcycle fatalities occurred on machines with engines over 500cc (Department for Transport, 2009a). Considering the contributory factors, motorcyclist accidents had a notably higher percentage for loss of control and learner or inexperienced riders when compared with other road users. When considering riders of machines with engines sizes above 50cc, casualties peak in the 30 to 39 year old age range (Department for Transport, 2009a). This finding may be related to the changing profile of motorcycling and the typical age of motorcycle riders being between 35 years to 49 years old.

Previous research at UNott (Clarke, et al, 2004) has shown that the three most common types of motorcycle accidents are:
- **Right of way violations** – characterized by the problem of other road users not seeing motorcyclists and assuming a right of way. It should be noted that although these are referred to as right of way violations in the literature, technically these violations should be termed as failures to give way. In many observation failure cases of this type, the motorcycle that the driver had failed to see was so close to a junction that there appeared to be no explanation as to why it had not been seen (Clarke, et al, 2004). This phenomenon is also referred to as a 'looked but did not see' (LBDNS) accident (Brown, 2002) or the more colloquial 'sorry mate I didn't see you' (SMIDSY) accident.   If these accidents were to be eliminated, there would be an approximate 25% fall in the total UK motorcycle accident rate (Clarke, et al, 2004).

- **Loss of control on a bend, corner or curve** – these accidents are usually regarded as primarily the fault of the motorcyclist rather than other road users, with accidents more associated with riding for pleasure involving only the motorcyclist and no other traffic (Clarke, et al, 2004). There is also evidence that left-hand bends appear to feature more in these kinds of motorcycle accidents than right-hand bends.
- **Motorcycle manoeuvrability accidents** – a sub-group of accident cases appear to be related to the way motorcyclists manoeuvre their motorcycles. Taking all accident cases where riders were judged as blameworthy, 16.5% involved a motorcyclist overtaking other vehicles and causing an accident (Clarke, et al, 2004). These at-fault riders tend to be younger and riding higher engine capacity machines than other accident involved riders. However, motorcycle accidents also occurred when riders took the opportunity to pass slow moving or stationary traffic, which is often referred to as 'filtering' (Clarke, et al, 2004).

There is also evidence that a proportion of motorcycle accidents involve larger capacity machines on roads some distance from where the rider resides, indicating that accidents often take place in unfamiliar areas and on unfamiliar roads (Department for Transport, 2005).

2.4. Simulators

Capturing riders' experiences in the real 'context of use' is extremely valuable and underpins the applied nature of ergonomics and human factors within human-machine interaction. However, it is not always practical, or indeed ethical, to capture real world user experiences especially in situations which could compromise personal or public safety (Stedmon, et al, 2009). As a result, simulators have emerged and continue to be developed as a major research tool.

Simulators offer a level of abstraction from the real world by providing an artificial environment in which users can experience characteristics of a real system (Stedmon, Young & Hasseldine, 2009). Historically simulators evolved primarily as training tools ranging from basic part-task trainers to high specification applications that mimic almost every aspect of a real system (e.g. advanced aircraft simulators). In the more conventional sense of a simulator, there is usually an integration of underlying hardware (usually taken from or mimicking the original system) coupled with a computer-generated projected image for an interactive task. However, a simulator does not have to consist of full replica equipment and can include non-technology applications (such as paper-based schematics and cardboard mock-ups, group work, or face-to-face role play) through to simple computer based desktop simulations, situation or equipment emulations and basic trainer systems (Stedmon, et al, 2009). Simulations can also include real equipment used in a non-operational setting to familiarise users with processes in a safe environment. Motion platforms in simulators can enhance the user experience if implemented effectively however if the motion cues are inaccurate, symptoms of simulator sickness can develop. This is a phenomenon with similar symptoms but different aetiology to motion sickness and affects approximately 5% of the population (Kennedy, et al, 1993).

With any simulator there are limits to the degree of realism that can be achieved and it is important, when developing them, to ensure that they do not become a slavish attempt to recreate a real world system (Stedmon, et al, 2009). A key human factors question is the degree of realism that is required in order that simulators serve the purpose for which they are intended (e.g. training, research, product development, etc) based on a fundamental understanding of user requirements, user expectations and the intended user experience.

2.5. Driving simulators and driver behaviour

Driving simulators have been used to examine the effectiveness of training on drivers' reactions to hazardous scenarios. For example, in a study that investigated the effects of experience and training on young drivers' performance, inexperienced drivers who had undergone hazard perception training drove differently to untrained inexperienced drivers (Fisher, et al, 2002). Research using driving simulators has also had some success in identifying performance differences in reaction to hazards across apparently homogenous groups. In an investigation into hazard detection in subgroups of young novice drivers, differences were observed in the way they responded to an emergency situation and to several potential traffic hazards in the simulator (Deery & Fildes, 1999).

Other driving simulator research has illustrated differences in cognitive workload levels between inexperienced and experienced drivers with trained and experienced drivers being able to automate the driving task more effectively than inexperienced drivers (Patten, et al, 2006). It appeared that experienced drivers had more spare mental capacity and were therefore able to focus spare resources on assessing peripheral information. This argument was used to support the finding that experienced drivers spotted more hazards than the inexperienced drivers (Patten, et al, 2006). This research provided a basis for understanding the differences between experienced and professionally trained drivers, and drivers who have little or only modest driving experience, but who were not unqualified or novice drivers (Patten, et al, 2006).

Driving simulators have also been used to assess the behavioural effectiveness of road engineering factors such as the speed choice for drivers negotiating bends. Drivers approaching bends demonstrated improved speed adaptation if the curve radius was highlighted, either implicitly (e.g. with hazard marker posts or chevrons) or explicitly (e.g. with an advisory speed sign or flashing warning) (Jamson, Lai & Jamson, 2010). This study also investigated the placement of trees by the roadside but found no effect on driver speed for straight road sections. This was perhaps because the trees did not present an immediate hazard, however, when the road width was narrowed using peripheral hatching, drivers were forced to position themselves closer to oncoming traffic and this had the effect of lowering driving speeds. A similar result was observed when simulated pedestrian refuges were introduced in an urban setting (Jamson, Lai & Jamson, 2010).

Simulator studies help to investigate and explain the theoretical background of safety interventions that have been shown to work effectively in the real world (Lewis-Evans & Charlton, 2006; Jamson, Lai & Jamson 2010). The introduction of hazard marker posts that accentuated vanishing point information throughout a rural curve in Buckinghamshire (UK) appeared to reduce a previously high motorcycle KSI rate observed for the previous eight years to zero in the three years following the introduction of actual hazard marker posts (James, 2005).

2.6. Motorcycle simulator research

In comparison to driver behaviour, motorcycle simulation research is a newer and less developed area of investigation. However, differences between novice, inexperienced, and experienced motorcyclists has been demonstrated where experienced riders crashed less often, achieved better rider performance scores after each hazardous event, and were more likely to approach hazards at an appropriate speed than inexperienced or novice riders (Liu, Hosking & Lenne, 2009; although Shahar, et al, 2010 failed to replicate these results using the same type of simulator and software). Furthermore, young motorcycle riders tended to be overconfident in their hazard perception abilities but this did not translate into better performance in a hazard perception task (Liu, Hosking & Lenne, 2009). This finding builds on earlier motorcycle simulator research in which experienced riders has superior hazard perception skills than novice riders (Bastianelli, Spoto & Vidotto, 2008). From this study, it was suggested that novice riders are both unable to allocate sufficient cognitive resources to visual search activities, and have an inadequate mental model for detecting traffic

hazards. It was also suggested that increased skill might be associated with an increase in the ability for acquiring information from traffic events and developing more specific mental models of a variety of hazards (Bastianelli, Spoto & Vidotto, 2008).

More recently, research has investigated hazard perception and visual scanning patterns using a motorcycle simulator (Hosking, Liu & Bayly, 2010). Results indicated that experienced motorcyclists were faster to respond to hazards than inexperienced riders, and that the faster response times might be due to experienced riders having a visual search pattern that is more flexible than that of inexperienced riders (Hosking, Liu & Bayly, 2010). Within this study, prior car driving experience led to some improvements in hazard perception skills of inexperienced riders illustrating that some of the hazard perception skills learned in car driving seem to transfer across to motorcycle riding (Hosking, Liu & Bayly, 2010). More specifically, inexperienced motorcyclists who were experienced car drivers were faster to respond to hazards, and had more flexible search patterns, than riders who were inexperienced users of both forms of transport. Nevertheless, further improvements would still be required in order for the hazard perception skills of these inexperienced riders to reach the levels attained by experienced riders (Hosking, Liu & Bayly, 2010).

2.7. MotorcycleSim

Whilst many areas of transport simulation have developed over the last 20 years there has been one notable exception: motorcycles. As a result (and the information is hard to find) motorcycle simulation technology is virtually non-existent with perhaps less than five different types around the world in the public domain (Stedmon, et al, 2008). Of the known motorcycle simulators, apart from MotorcycleSim, none have been developed primarily for rider behaviour research.

At UNott, MotorcycleSim has been designed and built with the main aim of conducting human factors research. It is an innovative project (development is ongoing) for which there was little prior knowledge or expertise to draw from. This has been a major challenge but the result is a simulator which is the first of its kind in the world. A schematic diagram of MotorcycleSim is represented in Figure 2.1, below.
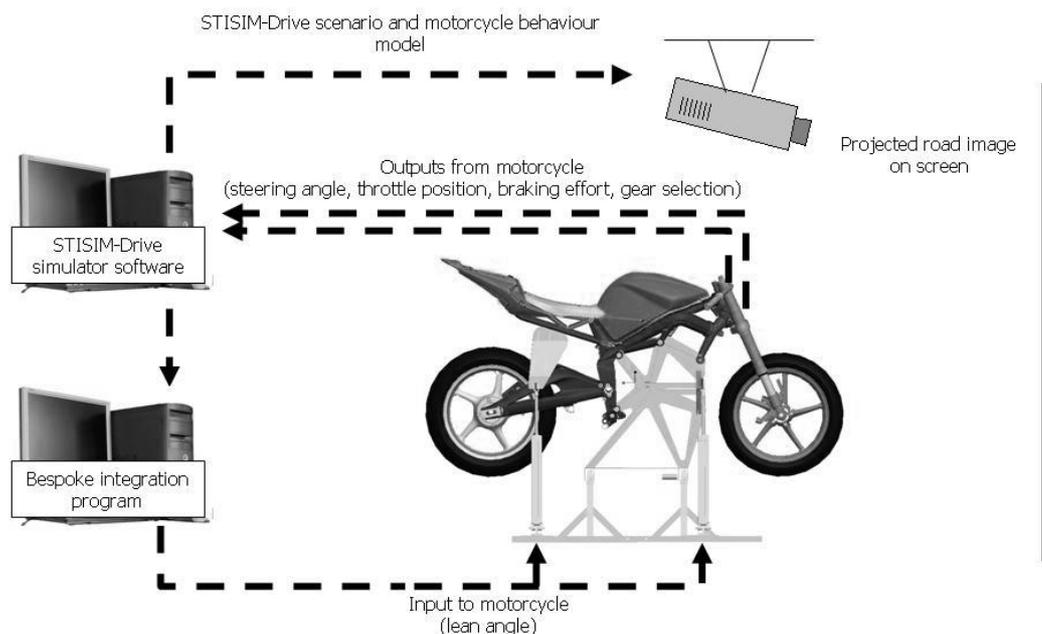
Figure 2.1: An overview of the MotorcycleSim system

MotorcycleSim consists of the hardware (a full size motorcycle, two pairs of pneumatic actuators and user input controls) providing data to the 'STISIM-Drive' software which is then used to provide visual feedback via a projected riding scenario directly in front of the user. The simulator has been built using a full size and fully equipped Triumph Daytona 675 motorcycle (kindly supplied by Triumph Motorcycles). The existing motorcycle controls of the motorcycle (throttle, brake lever, brake pedal, gear selector, clutch lever) were modified or adapted to work with the simulation software and work in a realistic manner. The brakes work on distributed ratios between the front and rear brakes (75:25 to simulate dry conditions or 50:50 to simulate wet weather riding). The functional fidelity of the brakes is preserved however, as the user is required to use both brakes to input the maximum braking effort (as would be expected on a real motorcycle). Surround sound speakers provide feedback of engine noise. The visual representation can be manipulated in a number of ways:

- enhanced acceleration and braking effects can be presented by altering the degree of dynamic pitch in the visual scene as the motorcycle accelerates and slows down.
- the scenery tilts as the user steers in a particular direction to enhance the perception into leaning into a corner.
- the rider's field of view can be increased to take account of peripheral visual cues.

The simulator works in either a static or dynamic mode. In the static mode, both pairs of pneumatic actuators are pressurised (at approximately 10bar) and the motorcycle does not lean. This static pressure provides a high degree of stability but not total stability and users have to balance a proportion of their weight on the motorcycle as they would in a real riding situation (with the motorcycle in motion). In the dynamic mode, the actuators operate in reciprocal pairs (on each side of the motorcycle) to control the lean angle of the motorcycle. The actuators are set in pairs to help control stability and enable the lean of the rider to be changed from -25 to +25 degrees in 0.8 seconds (based on an 80kg rider).

MotorcycleSim uses commercially available 'STISIM-Drive' software which is an industry leader in simulation software and has a worldwide support community. The software can be used to build interactive riding scenarios with different weather conditions, traffic, cyclists, pedestrians (adults and children) as well as typical hazards such as vehicles pulling out at junctions, braking suddenly, etc. As a result, it is possible to model all the scenario attributes including the position of street furniture, buildings, trees, etc. MotorcycleSim allows for strictly controlled experimental repeatability in a laboratory setting as riders experience identical scenarios which are not possible on the road (where traffic, weather and even lighting conditions can vary on the same route between different rides). It is also possible to present real video footage (although this is not interactive in the same way as the 'STISIM-Drive' scenario software). MotorcycleSim in use is illustrated in Figure 2.2.

Figure 2.2: MotorcycleSim

MotorcycleSim provided the basis for this research given its unique ability to test rider behaviour in a controlled environment. Within the main riding scenario a number of sub-scenarios were developed and additional tasks were designed within the integrated experiment approach in order to explore a wide range of skills, attitudes and behaviours across the three rider groups.

3.   Integrated Experiment Approach

The research was designed as an integrated experiment consisting of a number of key tasks within which were a number of sub components. Within the main riding scenario there were a number of sub-scenarios which represented embedded mini-experiments in their own right. It was important to develop an integrated experimental approach so that data could be captured in an unbiased, systematic manner and so that participants were not primed about the research focus.

3.1. Participants

An opportunistic sample of 62 participants was recruited through local and national adverts at rider training schools, local motorcycle meetings and the national IAM newsletter. All participants were members of the public who held at least a provisional UK motorcycle license, had normal or corrected to normal vision and did not suffer from migraines, epilepsy or motion sickness. From the sample, 61 participants completed the whole evaluation and their data were used for analysis (one participant withdrew with simulator sickness symptoms). Participants were filtered for excessive driving experience and so anyone with a typical annual mileage over 17,000 miles per annum or who held any other type of driving licence (e.g. public service vehicle, light or heavy goods vehicle) were excluded from the study. Across the rider groups the following participants were recruited:

- **20 Novice riders** (i.e. riders who had completed their compulsory basic training and were preparing to take the standard Driving Standards Agency (DSA) motorcycle test, or who had passed the standard DSA test within the last 12 months);
- **21 Experienced riders** (i.e. riders who had passed the standard DSA motorcycle test, with riding experience over 3 years, but with no further training);
- **20 IAM riders** (i.e. riders who had passed their IAM advanced riding test in the last 3 years).

3.2. Design

The research followed a 'between-subjects' design as participants were assigned to specific rider groups based on their rider training profile (e.g. Novice, Experienced, IAM-trained riders). This meant that statistical analyses could be conducted to investigate any differences 'between' the different groups. Some aspects of the main riding scenario were also developed as a 'mixed' design allowing for analyses 'between' the rider groups as well as 'within' specific sections of the scenario. Three main tasks were given to the riders:

- **Main riding scenario –** required riders to complete two circuits of a simulated route through rural (60mph) and urban (40mph) zones. Measures included speed, braking, lateral position within the lane, and variation of position in the lane.
- **Rider hazard perception –** in this part of the experiment, participants viewed videos of riding scenarios in order to identify different hazards on the road.
- **Battery of questionnaires –** were designed to collect demographic, rider attitudes and subjective workload data.

Embedded within the main riding scenario were a number of sub-scenarios. These were designed in such a way that baseline data were collected in Lap 1 upon which comparisons could be drawn from Lap 2. For some of the sub-scenarios, specific hazards were modelled in Lap 2 which allowed for finer grained analyses to be conducted. The sub-scenarios included:

- **Side roads –** whilst riding through a suburban area, participants passed four side roads. Two side roads were obscured by buildings, while the other two had a more open aspect. One obscured and one un-obscured side road also contained a car, triggered by the proximity of the rider, which approached the

give way line of the main carriageway and then stopped. These vehicles posed potential give way violations, but did not actually enter the main carriageway. On the second lap a vehicle pulled out from a different side road so that rider behaviour could be compared between the laps and for different junction characteristics.

- **Urban riding –** in this sub-scenario a busy urban environment was represented with zones of pedestrians, cars, pedestrians and cars, and empty areas. On the second lap a pedestrian emerged from between two parked cars in order to investigate how riders might perceive and react to the potential hazards of pedestrians and parked vehicles.
- **Bends with barriers –** four left bends of equal curvature and distance had two types of furniture (Armco or trees) and two levels of proximity to the outside edge of the road (near and far). This allowed for an investigation of how furniture type and proximity between the rider groups.
- **Left-hand bends –** a succession of joined up left and right bends were encountered on each lap. In this sub-scenario only left-hand bends were analysed and on the second lap a stationary vehicle was present on a bend blocking the path of the rider. Banked verges and trees prevented the rider from perceiving this car until they were part way around the bend and this was used to assess any group effects of anticipating the hazard and subsequent behaviours after encountering it.
- **Right-hand bends –** these were similar to the left-hand bends, except only the right-hand bends were analysed in a second series of left and right bends. On the second lap the riders encountered an on-coming car close to the centre of the road, risking a collision with a rider, especially if they were taking the racing line. This sub-scenario, therefore, examined the effect of encountering a hazard around an obscured right-hand bend.

3.3. Hardware

The main apparatus for the study was the MotorcycleSim simulator which has been described above. The simulator was used in the static mode throughout the research with the pneumatic actuators pressurised to stabilise the motorcycle and rider. A bespoke scenario was developed for the research, modelled in the 'STISIM-Drive' simulation software with bends, traffic, pedestrians, junctions, and traffic lights that riders interacted with. The software was used to define the characteristics of the Triumph Daytona 675 motorcycle (e.g. steering input, gear ratios, rev ranges, engine noise). For this study, improvements were made to the handling characteristics of the motorcycle (gears and steering), the clutch and front brake levers and improvements to the audio feedback of engine noise. Participants wore a helmet whilst on the simulator (for ecological validity). They were given the choice of wearing their own or an open face Arai helmet. A laptop running E-Prime software was used to collect participant responses for a battery of PC-based questionnaires and video files used in the hazard perception task were presented on a 20 inch iMac PC. A checklist was used to code the responses to the hazard perception task. Other questionnaires were used throughout the evaluation including: consent form, demographic questionnaire, personal comfort questionnaires, NASA-TLX subjective workload questionnaire, and a debrief form (further details and copies of these materials are available from the authors on request).

3.4. Ethics

Any study involving human participants is subject to ethical approval at some level. Within UNott human factors studies are governed by the Engineering Faculty Ethics Committee and permission was obtained prior to the start of the simulation trials. Ethics approval safeguards participants from any undesirable aspects of study methods, as well as safeguards the researchers against any recourse from participants after the study. No major issues were identified by the Committee although good practice was observed on monitoring any potential negative effects of simulator sickness which typically affect 5% of the population.

3.5. Procedure

Each participant session lasted for approximately 68 to 75 minutes and participants were paid for their time. An overview of the procedure is detailed in table 3.1.

Activity	Time (mins)
Welcome & consent form	2
Rider demographics	4
Rider comfort check	1
Simulator practice sessions (x2)	8 to 10
Rider comfort check	1
Simulator main session	20 to 25
Rider workload (NASA-TLX)	3
Rider comfort check	1
Hazard perception task	15
Motorcycle rider behaviour questionnaire (MRBQ)	6
'Locus of control' questionnaire	4
Debrief & payment	3
Total	**68 to 75**

Table 3.1: Overview of the integrated experimental procedure

Participants completed a consent form, demographic questionnaire, and a short comfort questionnaire (which was repeated at stages through the practice and main simulator sections) to monitor any potential symptoms of simulator sickness.

Participants were shown the main controls of MotorcycleSim and conducted two practice sessions. The purpose of the first practice scenario was to familiarise participants with the simulator controls (e.g. steering, throttle response, gears, and braking inputs). At a random point in the first practice scenario, they were instructed to perform an 'emergency stop' under full braking so that they could gauge the braking effects of MotorcycleSim. The second practice scenario took place with slow moving vehicles in the rider's lane and oncoming traffic in the opposite lane. This allowed participants to gain further experience of the simulator controls whilst performing overtaking manoeuvres around the slow moving vehicles. The two practice sessions lasted between 8 to 10 minutes. Upon completion, participants completed a second comfort questionnaire.

Participants then completed the main riding scenario. Participants were instructed that the route would take 20 to 25 minutes to complete along a mixture of urban and rural roads and that the route would repeat itself half way through. Participants were also instructed to ride as they would in the real world. If participants left the road (by more than 1ft on either side of the road) an accident was recorded and they were placed back on the road and continued the simulated route from that point.

After completing the main riding scenario participants completed a NASA-TLX subjective workload questionnaire and a final comfort questionnaire. Participants then took part in a hazard perception task in which a series of 14 randomly-ordered short video clips were presented on a computer. Participants completed a Motorcycle Rider Behaviour Questionnaire (MRBQ) and 'locus of control' questionnaire. Participants were finally briefed on the purpose of the study, paid for their time and encouraged to give feedback and comments regarding their simulation experience and the study in general.

Chapters 4 to 11 report the findings of the research. Given the complexity of the integrated experimental design each sub-scenario is organized in a separate chapter and provides an overview of supporting literature, research approach adopted, results and focused discussion. The results are presented in the following order:

- **Chapter 4 (Demographics)** – compares the rider groups sampled in this study against official statistics.
- **Chapter 5 (General riding, attitudes & workload) –** provides an overview of rider data for 60mph and 40mph zones; straights and curves; rider attitudes and workload across the whole scenario.
- **Chapter 6 (Side roads) –** looks at the phenomenon of vehicles pulling out of a side road and their effects on rider behaviour.
- **Chapter 7 (Urban riding) –** considers an urban environment and how riders perceived the potential hazards of pedestrians and parked vehicles.
- **Chapter 8 (Bends with barriers) –** investigates how the three rider groups rode a series of identical left-hand bends with only the outside roadside characteristics altered according to different roadside furniture features.
- **Chapter 9 (Left-hand bends) –** examines the effect of encountering a hazard around an obscured left-hand bend.
- **Chapter 10 (Right-hand bends) –** this chapter examines the effect of encountering a hazard around an obscured right-hand bend.
- **Chapter 11 (Hazard Perception) –** this aspect of the study explored how riders across the different rider groups identified and perceived hazards from video footage.

Data were analysed using SPSS statistical analysis software. Parametric data were analysed using Analysis of Variance (ANOVA) procedures which are detailed in each sub-section. Where appropriate planned comparisons were conducted on significant interactions and post-hoc Scheffe or Tukey HSD tests performed. Due to the small numbers of female riders in the study, no formal analyses were conducted for gender, however some measures report their data for descriptive purposes.

> **Where appropriate, text boxes are used to highlight key findings before detailed statistical analyses are reported.**

4.   Rider demographics

4.1. Introduction

The Department for Transport surveyed UK rider demographics as part of a study into older motorcyclists. The findings suggested that there has been a widespread change in the motorcycling population since the 1950s (Department for Transport, 2005). The age at which riders gain their motorcycle licence (and purchased their first motorcycle) has changed steadily over the decades, as those who currently pass their test are, on average, 13 years older than their counterparts in the 1970s (Department for Transport, 2005). National UK statistics (Department for Transport, 2009b) indicate that almost half of all registered motorcycles in the UK are usually owned by men aged between 35 years and 49 years old. Of the 105,000 standard DSA motorcycle tests taken between 2008 and 2009, 85% were taken by male riders (Department for Transport, 2009b).

The Department for Transport also reported that the manner in which motorcyclists build up their riding experience has changed. More recent recruits to motorcycling tend to move up through motorcycle engine sizes more quickly than their counterparts did in the past (Department for Transport, 2009b). This finding was supported by a review of motorcyclists who had taken up riding in recent years that showed a similar trend for progressing to larger engine sizes more quickly than riders in the past (Jamson & Chorlton, 2009). Of all licensed motorcycles in 2008 the most common engine size was between 501cc and 700cc (e.g. medium sized engines). The Department for Transport has postulated that there is a cohort of riders who have progressed to large capacity machines relatively quickly, without the same gradual build up of riding and machine handling skills through a range of lower engine sized motorcycles than was previously allowed for (Department for Transport, 2009b).

Half of the 2005 Department for Transport sample were categorised as new or returning riders. This in turn suggested that the UK roads have a significant proportion of motorcyclists who are either using newly learned skills or relying on old skills that were developed some years ago and which may have subsequently degraded through a period of non-use (Department for Transport, 2005). The results of the survey also suggested that it is more likely that long-term riders attend voluntary riding improvement courses, which may provide scope for returning riders to be encouraged to participate in further training (Department for Transport, 2005).

Given that motorcyclists might progress more quickly to larger capacity motorcycles, it is interesting to note that motorcycle purchasing is often influenced by styling and image. Riders sampled in the 2005 Department for Transport survey quoted aspects of styling and top speed as important factors in their purchasing choice (Department for Transport, 2005). According to the Motorcycle Industry Association (MCIA) 'naked' motorcycles were the most popular style of motorcycle registered as new in 2009 (MCIA, 2010). These motorcycles, which represented 22% of total sales, are built with no fairing or only a small handlebar fairing, an upright riding position, and medium to large engine capacities (MCIA, 2010). Traditionally, 'SuperSport' motorcycles have been the most popular motorcycles in the UK. These motorcycles, which represented 20% of total sales in 2009, are styled and designed to mimic or directly replicate racing machines, normally with full fairings, low handlebars, in medium to large engine capacities (MCIA, 2010).

The MCIA have developed a motorcycle classification scheme (MCIA, 2010). Categories are shown in rank order of their numbers of new registrations in 2009 in Table 4.1.

Motorcycle type	Brief description	New registrations in 2009
Naked	Basic specifications, no (or small) fairing, upright riding position. Engines large/medium. Often known as 'retro'.	21,268
SuperSports	Mimic or replicate racing motorcycles. Full fairing, dropped handlebars. Often know as 'race replicas'.	18,930
Scooters	Engine integral to rear suspension, step-through chassis.	16,939
AdventureSports (inc. Supermoto)	Styled similar to Trail/Enduro, but for road use; similar features as Tourers.	10,416
Custom	Low seat, forward footrests, high handlebars; chromed features; often called 'cruisers'.	9,255
Sports Touring	Full/part fairings, practical rider/pillion seat; low/medium handlebars; medium/large capacity.	8,338
Trail Enduro	Trials or Enduro styled, with off-road/x-country capability.	5,476
Touring	Designed for long-distance; comfort seats for rider/pillion; luggage and fairings.	3,663
Unspecified	Not fitting into above descriptions.	789

Table 4.1: New registrations 2009 by motorcycle style (MCIA, 2010)

The 2005 Department for Transport survey also found evidence of a shift in the nature of motorcycle use becoming more of a leisure activity (Department for Transport, 2005). It has been argued that for many riders in the UK, motorcycling is more of accessory than a primary means of transport (Jamson & Chorlton, 2009). When categorised as commuters, leisure riders or a combination of the two, 85% of riders engaged in some form of leisure riding (Department for Transport, 2005). Leisure riders tend to consist of long-term and returning riders owning larger capacity motorcycles and leisure rides tended to take place on aesthetic roads with wide sweeping curvature, impressive views and little other traffic (Department for Transport, 2005). Related to this is the finding that the distance ridden by motorcyclists is highly seasonal. Motorcyclists, as a total population, tend to ride more through the summer months (April to September) than in the winter months (January to March) (Department for Transport, 2005).

4.2. Method
Rider demographics were collected in a short questionnaire at the start of the experimental procedure.

4.3. Results

> **The majority of participants in the study were male riders and the Experienced and IAM riders were generally older than the Novice riders.**
>
> **Novice riders tended to have the least riding experience, and whilst IAM and Experienced riders were similar, IAM riders tended to have higher weekly riding hours and reported higher annual mileages than the other two rider groups.**
>
> **Motorcycles were generally used for pleasure and commuting activities with all groups reporting they rode in darkness, wet weather and throughout the year. However, fewer Novices rode at night or in wet weather.**
>
> **Novice and Experienced riders generally rode Naked or SuperSports motorcycles. IAM riders had a more varied ownership of motorcycle types.**
>
> **In relation to car driving behaviour, although the IAM riders had more driving experience and larger annual mileages, they appeared relatively similar in profile to the Experienced riders.**
>
> **Actual accident rates were extremely low and did not show any differences between the rider groups.**
>
> **IAM riders reported more licence endorsements than the other two rider groups.**

4.3.1. Rider gender and age

The majority of riders in the study were male (88.5%, n=54) compared to a smaller sample of women riders (11.5%, n=7). The rider groups are represented in Table 4.2.

Rider Groups	Rider gender		
	Male	Female	Total
	% (n)	% (n)	% (n)
Novice	80 (16)	20 (4)	100 (20)
Experienced	95.2 (20)	4.8 (1)	100 (21)
IAM	90 (18)	10 (2)	100 (20)
Total	**88.5 (54)**	**11.5 (7)**	**100 (61)**

Table 4.2: Gender data for the rider groups

Both the IAM (mean = 47.4yrs old; range = 34yrs old to 67yrs old) and Experienced riders (mean = 40.6yrs old; range = 21yrs old to 56yrs old) were generally older than the Novice riders (mean = 26.5yrs old; range = 17yrs old to 38yrs old). The rider groups are represented in Table 4.3.

Rider Groups	Rider age (years)		
	Male	Female	Total
	Mean (SD)	Mean (SD)	Mean (SD)
Novice	25.5 (8.4)	30.5 (6.5)	26.5 (8.2)
Experienced	39.8 (8.8)	56.0 (n/a)	40.6 (9.3)
IAM	48.0 (9.4)	42.0 (5.7)	47.4 (9.2)
Total	**38.3 (12.6)**	**37.4 (11.1)**	**38.2 (12.4)**

Table 4.3: Age data across the rider groups

4.3.2. Riding experience
The IAM (mean = 16.6yrs) and Experienced riders (15.6yrs) reported more riding experience than Novice riders (1.0yrs). The rider groups are represented in Table 4.4.

Rider Groups	Rider experience (years)		
	Male	Female	Total
	Mean (SD)	Mean (SD)	Mean (SD)
Novice	1.0 (0.9)	0.9 (0.9)	1.0 (0.9)
Experienced	16.0 (9.9)	7.0 (n/a)	15.6 (9.9)
IAM	17.2 (12.2)	11.1 (8.5)	16.6 (11.9)
Total	**12.0 (11.6)**	**4.7 (6.1)**	**11.1 (11.3)**

Table 4.4: Rider experience across the rider groups

4.3.3. Annual mileage
An outlier in the female Novice rider group was excluded from the data as it was reported the rider did 20,000 miles per annum (this was larger than 3 standard deviations from the mean). The IAM riders (mean = 7400 miles per annum) reported a higher annual mileage than both the Experienced (mean = 4318.2 miles per annum) and Novice riders (3710.5 miles per annum). The rider groups are represented in Table 4.5.

Rider Groups	Annual mileage (miles per year)		
	Male	Female	Total
	Mean (SD)	Mean (SD)	Mean (SD)
Novice	4031.3 (3090.1)	2000.0 (2000.0)	3710.5 (2996.8)
Experienced	4650.0 (3285.1)	2000.0 (n/a)	4318.2 (3318.6)
IAM	7250.0 (4281.5)	8750.0 (6717.5)	7400.0 (4357.7)
Total	**5333.3 (3793.0)**	**6500.0 (7376.8)**	**5379.0 (4298.0)**

Table 4.5: Annual mileage across the rider groups

4.3.4. Riding hours per week
The IAM riders (mean = 8.8hrs per week) rode more hours per week than both the Experienced (mean = 7.3hrs per week) and Novice riders (7.7hrs per week). The rider groups are represented in Table 4.6.

Rider Groups	Hours per week		
	Male	Female	Total
	Mean (SD)	Mean (SD)	Mean (SD)
Novice	8.6 (5.0)	4.3 (5.6)	7.7 (5.3)
Experienced	7.5 (6.0)	4.0 (n/a)	7.3 (5.8)
IAM	9.1 (6.4)	6.0 (4.2)	8.8 (6.2)
Total	**8.4 (5.8)**	**4.7 (4.4)**	**7.9 (5.7)**

Table 4.6: Riding hours per week across the rider groups

4.3.5. Patterns of motorcycle use

All 3 groups reported a similar pattern of use for their motorcycles. Motorcycles were used primarily for pleasure rides (96.7%), then commuting (63.9%), with only a small proportion of riders reporting that they used their machines for work purposes (14.8%). More Experienced riders (23.8%) used their motorcycles for work compared to IAM riders (15%) and Novice riders (5%). The rider groups are represented in Table 4.7.

Rider Groups	Patterns of motorcycle use			
	Pleasure	Commuting	Work	Total
	% (n)	% (n)	% (n)	% (n)
Novice	90.0 (18)	70.0 (14)	5.0 (1)	55.0 (33)
Experienced	100.0 (21)	57.1 (12)	23.8 (5)	60.3 (38)
IAM	100.0 (20)	65.0 (13)	15.0 (3)	60.0 (36)
Total	**96.7 (59)**	**63.9 (39)**	**14.8 (9)**	**65.6 (107)**

Table 4.7: Patterns of motorcycle use across the rider groups

4.3.6. Riding at night, in wet weather and through the year

In general more riders across the groups rode throughout the year (78.8%) than at night (23%). More Experienced riders appeared to ride in these extreme conditions (50.8%) than either the Novice riders (40.0%) or IAM riders (46.7%). The rider groups are represented in Table 4.8.

Rider Groups	Riding at night, in wet weather and through the year			
	At night	Wet weather	Through the year	Total
	% (n)	% (n)	% (n)	% (n)
Novice	15.0 (3)	25.0 (5)	80.0 (16)	40.0 (24)
Experienced	28.6 (6)	42.9 (9)	81.0 (17)	50.8 (32)
IAM	25.0 (5)	40.0 (8)	75.0 (15)	46.7 (28)
Total	**23.0 (14)**	**36.1 (22)**	**78.7 (48)**	**45.9(84)**

Table 4.8: Riding in different conditions across the rider groups

4.3.7. Type of motorcycle ridden

Riders from all 3 groups were asked about the make and model of motorcycle they rode most often. These answers were then coded, and applied to categories used by the MCIA. The most popular motorcycles across the Novice and Experienced rider groups were naked or SuperSports motorcycles. SuperSports motorcycles were popular with the IAM rider group, but these riders also had a higher proportion of Sports Tourers and Tourers than the other two rider groups. Figures 4.1, 4.2 and 4.3 represent the proportions of riders from each group owning different styles of motorcycle.
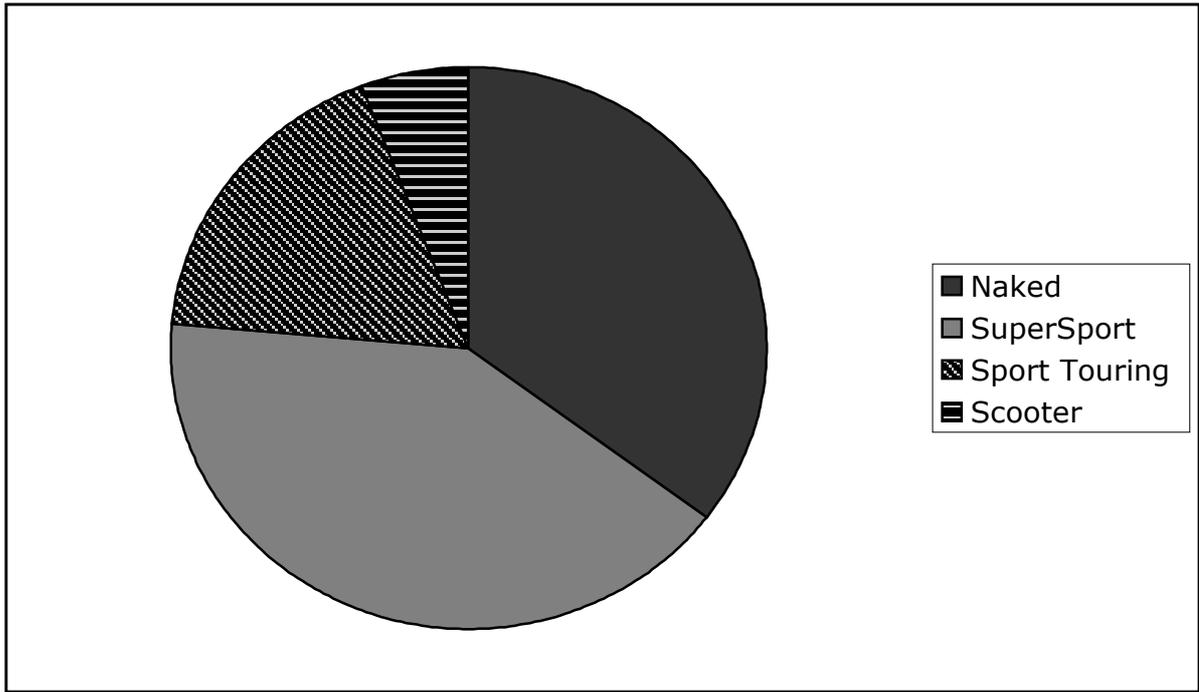
Figure 4.1: Motorcycle styles ridden by the Novice rider group
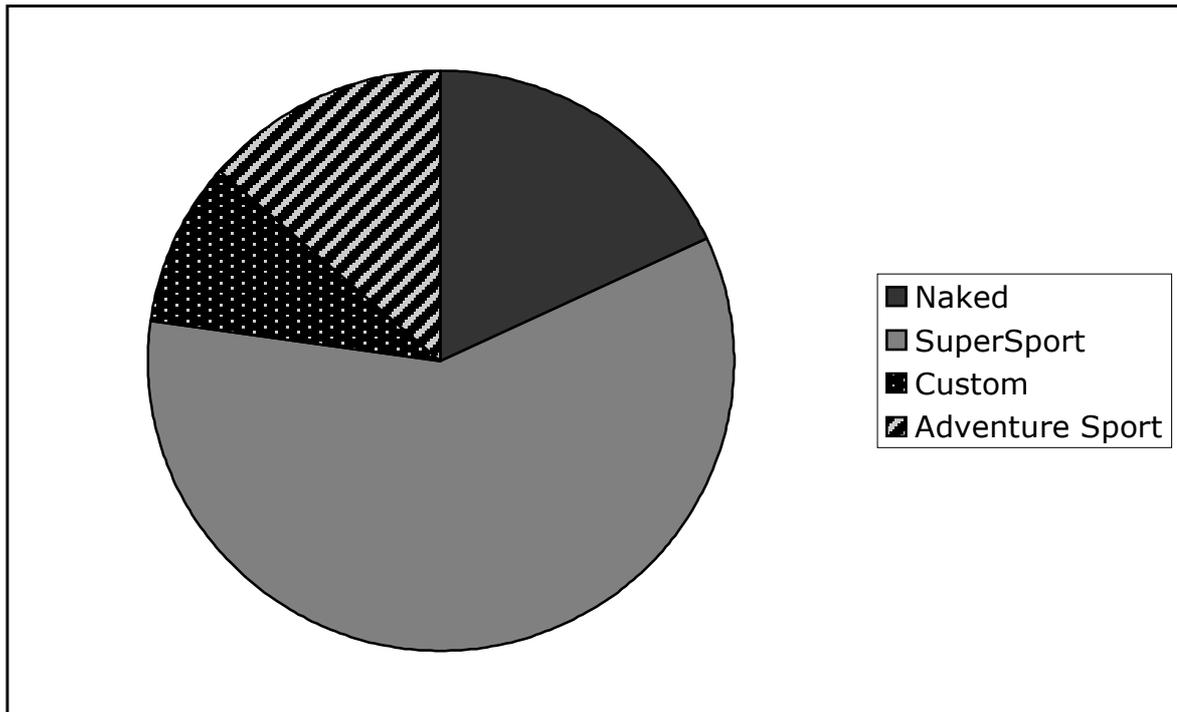
Figure 4.2: Motorcycle styles ridden by the Experienced rider group
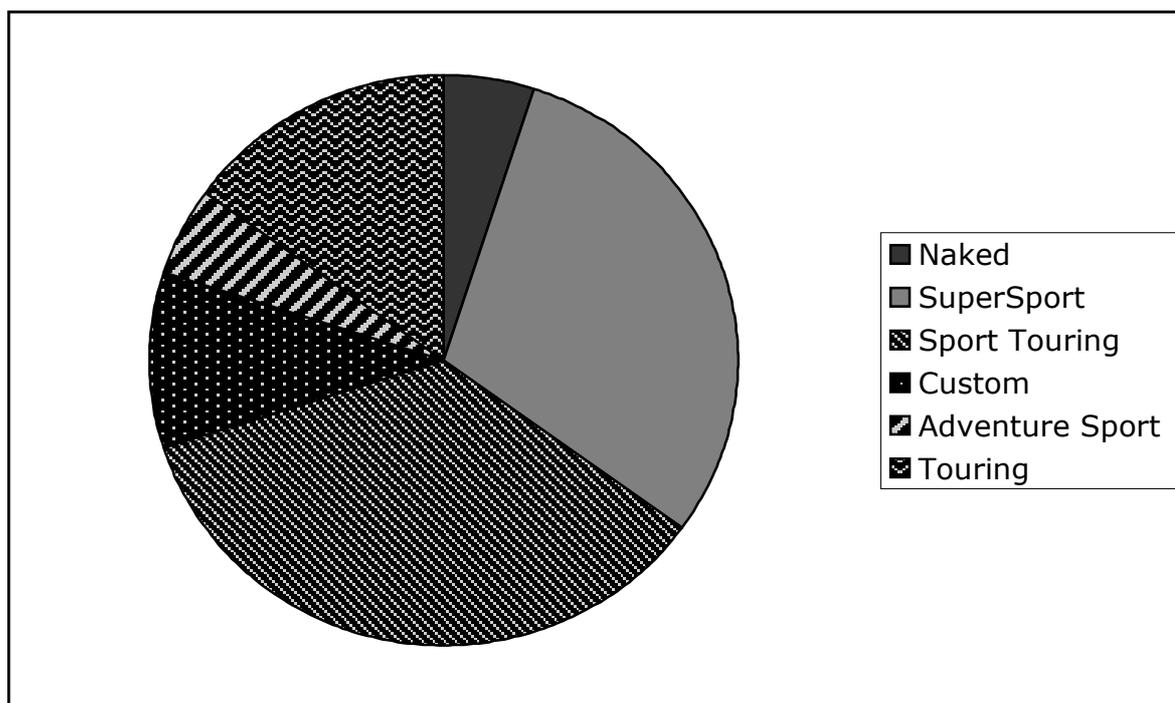
Figure 4.3: Motorcycle styles ridden by the IAM rider group

4.3.8. Car driving experience

The IAM-trained riders (mean = 26.4yrs) had more car driving experience than Experienced riders (mean = 19.0yrs), who in turn had more car driving experience than Novice riders (mean = 7.8yrs). Given the large standard deviations for the Experienced and IAM-trained riders these two groups would appear to be relatively homogenous. In relation to annual mileage, the IAM (mean = 7875.0 miles) riders reported more miles per year than Experienced riders (mean = 6022.7 miles), who in turn reported more miles per year than Novice riders (mean = 5957.9 miles). Again, similar large standard deviations were apparent for the Experienced and IAM-trained riders, indicating that these two groups were relatively similar. The rider groups are represented in Table 4.9.

Rider Groups	Car driving experience	
	Years	Annual mileage
	Mean (SD)	Mean (SD)
Novice	7.8 (7.9)	5957.9 (5717.4)
Experienced	19.0 (12.2)	6022.7 (4526.3)
IAM	26.4 (11.8)	7875.0 (5137.3)
Overall	**17.8 (13.1)**	**6599.3 (5122.8)**

Table 4.9: Rider experience across the rider groups

4.3.9. Accidents & license endorsements

The average reported crash rate was similar across all 3 groups for the last 12 months with 11.1% of riders reporting an accident in which they were to blame to some degree. This was slightly higher for Novice riders (15.0%) and lowest for Experienced riders (9.5%). In relation to endorsement points more of the IAM riders reported having received points (17.5%) compared to the Experienced riders (9.5%) or Novice riders (2.5%). The rider groups are represented in Table 4.10.

Rider Groups	Accidents & endorsement points % (n)	
	Accidents	Endorsement points
Novice	15.0 (3)	2.5 (1)
Experienced	9.5 (2)	9.5 (4)
IAM	10.0 (2)	17.5 (7)
Overall	**11.1 (7)**	**19.7 (12)**

Table 4.10: Rider experience across the rider groups

4.4. Discussion

Of the 105,000 standard DSA motorcycle tests taken between 2008 and 2009, 85% were taken by male riders, supporting the trend that motorcycling is a predominantly male pursuit (Department for Transport, 2009b). As expected, the male sample in this study accounted for the majority (88.5%) of participants. However, the Novice group contained the largest proportion of female riders (20%) however, like the Experienced and IAM-trained groups, they appeared to follow the expected demographic trends.

National UK statistics (Department for Transport, 2009b) reveal that nearly half of all registered motorcycles in the UK are owned by people aged between 35 years and 49 years old. The average age of sample in this study (38.2 years old) followed this trend although, perhaps as expected, Novice riders were generally younger than the Experienced or IAM rider groups. The IAM group was also generally older than the other two rider groups. As an opportunistic sample was recruited for the study it could be argued that the Novice group just happened to be younger riders and that fewer older new riders (typically 'born again bikers') took part in the study. However, within this rider group, 8 riders out of the 20 were 33yrs or older and so this sample had a roughly equal mix of older and younger riders. That the IAM rider group was the oldest sample seemed to fit Department for Transport survey which suggested that it is more likely that long-term riders attend voluntary riding improvement courses (Department for Transport, 2005).

Perhaps as expected, Novice riders tended to have the least riding experience. IAM and Experienced riders were similar which was encouraging as it meant that the opportunistic samples did not happen, by chance, to have an IAM group that were a lot more experienced than the other riders which could have confounded other data. IAM riders tended to have higher weekly riding hours and reported higher annual mileages than the other two rider groups which meant they were getting more regular experience than the other groups.

It has been argued that for many riders in the UK, motorcycling is more of an accessory than a primary means of transport (Jamson & Chorlton, 2009). When categorised as commuters, leisure riders or a combination of the two, 85% of riders engaged in some form of leisure riding (Department for Transport, 2005). The results from this study indicate that almost all riders rode their motorcycles for pleasure (96.7%) with all groups reporting they rode in darkness and wet weather. These findings are possibly explained by the high proportion of riders across all three rider groups (78.7%) who reported using their motorcycle all year round. Experienced riders reported riding for work more than the other rider groups and also for riding in extreme conditions, perhaps indicating that they could not always choose when they rode their motorcycles.

According to the Motorcycle Industry Association the most popular style of motorcycle registered as new in 2009 were 'naked' motorcycles (22% of sales) and 'SuperSports' (20% of sales) (MCIA, 2010). It was not surprising, therefore that Novice and Experienced riders generally rode these styles of motorcycle. IAM riders had a more varied ownership of motorcycle types which, coupled with being older than the other two rider groups possibly reflected a more diverse progression of motorcycle riding and styles through their riding career.

In relation to car driving, IAM-trained and Experienced riders had similar profiles. Perhaps because of their relative ages, IAM riders had generally held their full car licence longer than the Experienced riders, who in turn, had held their full car licence longer than the Novice riders. That said, the reporting of similar annual driving mileages would seem to indicate that driving behaviour was similar across the groups.

Actual accident rates were extremely low and did not show any differences between the rider groups. However, in this study, IAM riders reported more licence endorsements than the other two rider groups. Perhaps due to a combination of their greater number of years licensure for driving cars, the IAM rider group reported a higher number of licence endorsement points than the other two rider groups. This finding, by itself must be treated with caution as it was collected at the start of the study and may have been influenced by social conformity issues with the other two rider groups misrepresenting their true level of endorsements. It could be that the IAM-trained riders felt more confident and responsible, and were therefore more honest from the outset.

5.   General riding, attitudes & workload

5.1.   Introduction

Does motorcycling experience lead to an improvement in the skills and strategies of motorcyclists? Or might some negative riding behaviours actually develop with increasing experience? By comparing the three rider groups the aim of this investigation was to identify which attitudes, skills and strategies improved through experience of motorcycle riding, and which measures required advanced training before an improvement was noted. Furthermore, assuming that the IAM-trained riders provide a benchmark of optimum riding behaviour, this aspect of the research aimed to identify those behavioural differences between Novice and Experienced riders that represent a worsening of behaviour with increased experience rather than an improvement. In such cases, it might be expected to find greater agreement in attitudes or behavioural measures between the Novice and the IAM-trained riders, rather than between the Experienced and IAM-trained riders.

As noted in Chapter 3, the current approach is primarily based on measures taken from MotorcycleSim supplemented with questionnaire measures and a hazard perception test. Within the simulated route specific hazards and road configurations were designed to test particular hypotheses regarding the changes in riding behaviour that might occur with increased experience and advanced training. Subsequent chapters will deal with these specific hypotheses and will provide detailed analyses of the sub-scenarios. The current chapter however focuses on an overview of the general measures that arose from the main riding scenario, along with some of the general questionnaire measures. It was important to assess whether there were any high-level differences between the rider groups across the whole route, before taking a more fine-grained perspective arising from the sub-scenarios.

In order to assess car driver behaviour the Driver Behaviour Questionnaire (DBQ) has been widely used in road safety research, differentiating errors from violations (Reason, et al, 1990). For example, the DBQ has shown that drivers that score high on the violation scale are statistically more likely to have been involved in both past and future accidents (Parker, et al, 1995; Quimby, et al, 1999). Drawing on this work, a Motorcycle Rider Behaviour Questionnaire (MRBQ) has been developed that measures motorcyclist behaviours that might predict accident risk (Elliot, Baughan & Sexton, 2007). From a 43 item checklist, five key factors are identified:

- **Traffic errors** (e.g. 'attempt to overtake someone that you had not noticed to be signalling a right turn')
- **Control errors** (e.g. 'brake or throttle-back when going round a corner or bend')
- **Speed violations** (e.g. 'exceed the speed limit on a country/rural road')
- **Performance of stunts** (e.g. 'attempt to do, or actually do, a wheelie')
- **Use of safety equipment** (e.g. 'wear protective trousers')

In research findings when the effects of age, experience and annual mileage were controlled for, traffic errors were the main predictor of overall accident risk. Where riders accepted a degree of blame, control errors and speed violations were also significant predictors of accident risk (Elliot, Baughan & Sexton , 2007).

A theoretical distinction can be drawn between motorcycle riding violations that are cognitively driven behaviours versus affectively driven behaviours. The MRBQ speed violation items can be considered as cognitive behaviours, reflecting an underlying tendency to deliberately deviate from safe rules and procedures (Elliot, Baughan & Sexton, 2007). Violations on the performance of stunts factor can be considered as affective behaviours performed in order to satisfy sensation-seeking motives. A similar dichotomy in violations was observed in another rider behaviour study, where behaviours were classified as aggressive violations and ordinary violations (Shu-Kei Cheng & Chi-Kwong Ng, 2010). An ordinary violation, such as 'drove above the speed

limit in order not to be late for an appointment' could be considered as a cognitively driven violation while an aggressive violation such as 'participated in unofficial races' might be considered as an affectively driven violation to satisfy sensation seeking motivations.

It is important to note that speed-related riding violations for motorcyclists do not necessarily follow the same pattern as the speed-related violations for car drivers. For example, older motorcyclists (above 35 years old) reported themselves as more likely to speed on rural roads and less likely to speed on urban roads and more likely than drivers to speed in the daytime rather than at night (Broughton, et al, 2009).

5.2. Method

All 61 participants completed the main riding scenario. Participants were instructed that they would ride a mixture of urban and rural roads and were asked to ride as they would in the real world. Participants were required to complete two laps of the simulated route. The route covered a total distance of 101,000ft (30,793m) and was balanced, in as far as possible, so that riders spent an equal time riding in 60mph and 40mph zones. The road design comprised 2 lanes divided by a dashed centre-line. The lanes were 12ft wide with a hard shoulder or pavement that was 4ft wide. If the rider left the road more than 1ft from the nearside or offside road edge, a crash would result.

Several measures were taken across the whole route (both laps combined) in order to assess whether there were any general differences between the three groups in their riding behaviour. The primary measure was whether the rider crashed into one of the pre-defined hazards. Other, more continuous, measures included average speed, average throttle, average braking duration, the average number of braking episodes, the average maximum braking effort, the average lateral position of the motorcycle (e.g. position in the lane), and the average variance in lateral position (how much the motorcycle changed its position in the lane). These measures were analysed in two ways:

- **Differences between the rider groups according to the speed limit of the road they were travelling on** - all roads in the route were either 40mph or 60mph limits and it was reasonable to predict that behaviour which might differentiate between the rider groups in a 60mph zone might not differentiate them in a 40mph zone, or vice versa. Accordingly the first set of analyses compares measures of speed, throttle, braking, and lateral position across the two speed limit zones.
- **Differences between rider groups according to road curvature.** As the majority of curves occurred within the 60mph zones, the analyses were restricted to road segments within this zone. All 60mph roads were then divided into 4 classifications: straight roads, slight curves (with a curvature of 0.001 or less) medium curves (with curvature up to 0.002) and tight curves (none of which had curvatures greater than 0.003). Slight curves tended to be 'spirals', whilst medium and tight curves tended to be full bends in the road. A spiral is a transition section of roadway from a straight section of road to a curve. The spiral linearly changes the roadway curvature from zero (straight) to the curvature of the curve over the spiral length. Spirals are used in real carriageway engineering to ease the road user's transition into a bend from the preceding road design

As this chapter focuses on overall measures of performance, it seemed appropriate to also detail the results of the MRBQ and rider workload. As noted previously, the MRBQ is a 43 item questionnaire that is reported to produce a five-factor structure, including traffic errors, speed violations, engagement in stunts, use of safety equipment, and control errors (Elliot, Baughan & Sexton, 2007). In this study it was assumed that between the rider groups differences would be observed for scores on these self-reported measures.

5.3. Results

5.3.1. Analysis of the Motorcycle Riding Behaviour Questionnaire

> **Participants were given a motorcycle questionnaire about their riding behaviour. Statistically, three self-reported measures emerged as important:**
> - **riding errors in traffic**
> - **speed violations**
> - **involvement in stunts**
>
> **All riders reported very little involvement in stunts. However IAM-trained riders reported fewer traffic errors and fewer speed violations than Novices and Experienced riders.**

Prior to the analysis of the simulator data, the scores from the Motorcycle Behaviour Questionnaire were collated. Cronbach's alpha was calculated for the five factors identified by Elliot, Baughan & Sexton, (2007). The alphas are presented in Table 5.1. Only three of these factors reached the 0.7 criterion threshold for acceptance, therefore only traffic errors, speed violations and stunts were analysed further.

MRBQ factors	Cronbach's Alpha	Mean score		
		Novice	Experienced	IAM
Traffic Errors	0.74	1.96	1.88	1.62
Speed Violations	0.75	3.09	3.13	2.42
Stunts	0.77	1.48	1.69	1.29
Safety Equipment	0.50			
Control Errors	0.39			

Table 5.1: Cronbach's alpha for the five factors of the MRBQ

The mean factor scores for the rider groups were analysed using 1x3 ANOVAs for each of the three MRBQ factors. A significant main effect was observed for rider group in the traffic errors factor $[F(2,58) = 6.2, p<0.01]$. A significant main effect was also observed for rider group in the speed violations factor $[F(2,58) = 8.4, p<0.001]$. In both instances post-hoc Tukey HSD tests identified that the IAM-trained riders had lower ratings than both the Experienced riders and the Novice riders (all at $p<0.05$ or lower). There was no differentiation between rider groups in relation to the factor of Stunts, however all participants' ratings were extremely low on this factor. No other significant effects were observed ($p>0.05$).

5.3.2. Rider Accidents

> **Accidents were too few and far between to offer statistical differences between the rider groups. However, the actual number of crashes did appear to show a trend which suggested IAM riders had the fewest.**

The most pertinent data from the simulator was considered to be whether the riders crashed into the four specific hazards that were placed on the second lap of the main scenario. These hazards were a parked car hidden on a blind bend, an oncoming car close to the centre-line when approaching around a blind bend, a pedestrian stepping out from between two parked cars, and a vehicle pulling out from a side road into the path of the motorcyclist. All riders successfully negotiated both hazards that were

situated on blind bends. For the side road hazard, one Novice and three Experienced riders collided with the emerging car. For the pedestrian hazard 11 Novices, 10 Experienced riders and five IAM-trained riders collided with the pedestrian. While these absolute numbers are too small to generate significant values in typical analyses (such as Chi Square), when they are expressed as percentages of the total possible number of crashes into the pre-defined hazards that could have occurred, there is a strong trend that the IAM had fewer accidents (Figure 5.1).
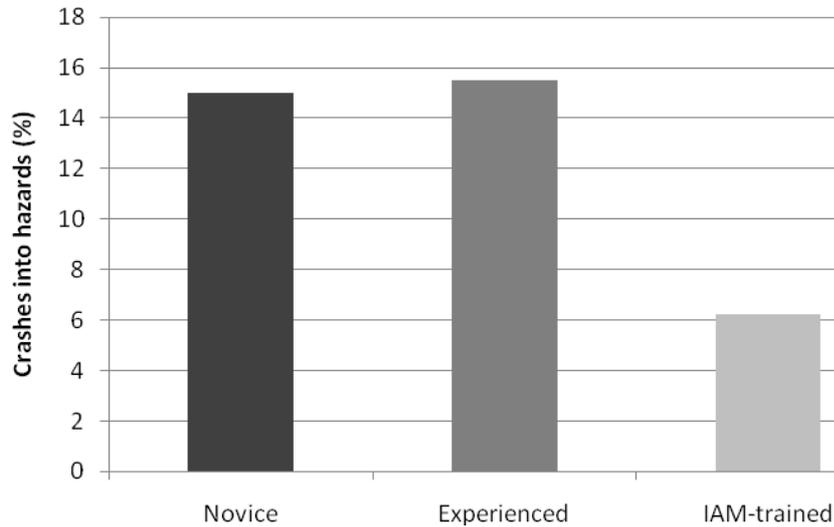
Figure 5.1: Number of crashes across the rider groups

Reliance upon crash data is notoriously difficult for researchers interested in identifying why some riders or drivers are safer than others. As real world (and simulator) crashes are relatively infrequent events, they do not lend themselves to statistical processes of identifying group differences. The advantage of the current research was that, even though the pattern of crashes across the rider groups is encouraging, the multitude of measures taken from the motorcycle simulator provided an opportunity to assess group differences with more sensitivity than coarse records of crashes. The following sections will detail the analyses of some of the measures taken across the whole duration of the simulated route.

Before leaving the crash statistics however, it should be pointed out that although it appeared that the IAM-trained riders had fewer accidents involving the pre-defined hazards, there were a further five instances of IAM-trained riders losing control of the simulated motorcycle and crashing on bends that did not contain hazards. For the other groups one Experienced rider and three Novice riders also crashed in similar circumstances.

5.3.3. A comparison of rider behaviour in 60mph and 40mph zones

The following section details the analysis of all riding as a function of which speed limit zone the rider was in, while the subsequent section details the comparisons of straight roads with the three classifications of bends.

> **All riders tended to ride at similar speeds in the 60mph zone.**
>
> **IAM riders tended to have lower speeds in the 40mph zone, and applied greater brake pressure in these zones.**
>
> **In both speed zones IAM riders kept closer to the centre-line of the road, while Novices were closest to the left-hand edge of the road. IAM riders did however make greater use of the whole lane, changing position more frequently that Novice riders.**
>
> **Experienced riders also varied their position in the lane, but only in the 60mph zones.**
>
> **The results suggest that while general motorcycle experience does improve rider behaviour, especially in the 60mph zone, specific IAM training is associated with further improvements in 40mph zones**.

Average speed - 2x3 ANOVA was performed on data for the average speed of riders in the two different speed limit zones. While it was anticipated that riders had a higher average speed in the 60mph zone (mean = 55mph) compared to the 40mph zone (mean = 37mph) a significant interaction was observed between rider group and the speed limit zone $[F(2,58) = 3.6, p<0.05]$. As represented in Figure 5.2 all rider groups tended to ride at similar speeds in the 60mph zone, although in the 40mph zone, the speed for IAM-trained riders (mean = 35.0mph) was lower than the Novice riders (mean = 37.6mph) and Experienced riders (mean = 37.1mph).
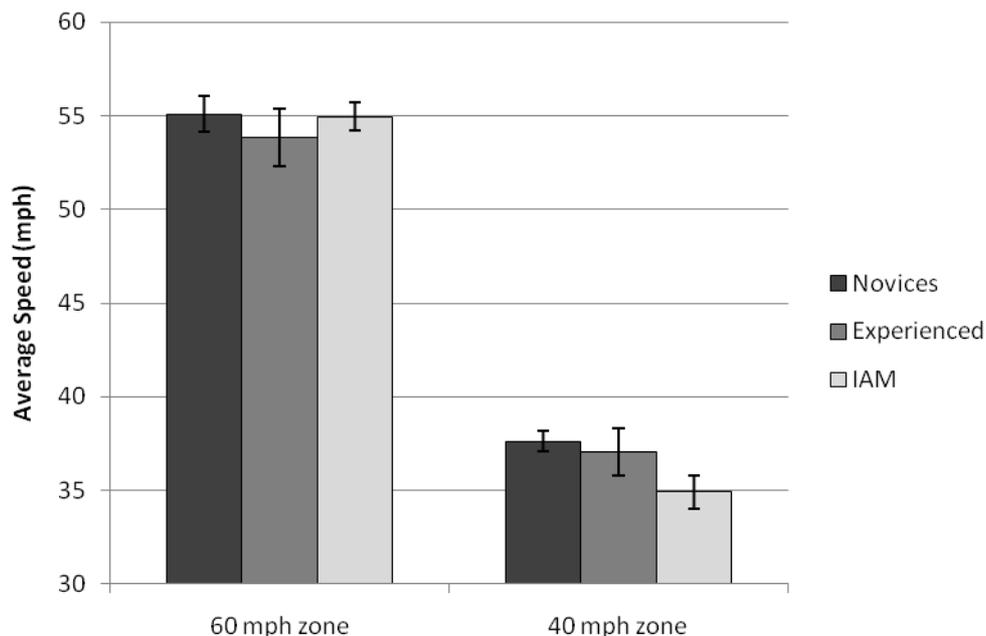
Figure 5.2: Average speeds in 60mph and 40mph zones

Throttle rotation - the measure of throttle rotation followed a similar pattern to that of average speed, with more throttle rotation in the 60mph zones than the 40mph zones. A significant interaction was observed between rider group and throttle position [$F_{(2,58)} = 5.1$, $p<0.01$], illustrating that IAM-trained riders used less throttle input in the 40mph zone compared to both the Novice and Experienced rider groups.

Speeding offences - while average speed measures were generally within the specific speed limits for the respective zones, there were periods of time when riders exceeded these limits. The average duration that a participant spent above the speed limit in the 60mph and 40mph limit zones was analysed using a 2x3 ANOVA. An interaction fell short of conventional statistical acceptance of $p<0.05$ [$F_{(2,58)} = 2.6$, $p=0.08$] although it would seem to indicate a trend in the data that fits with the average speed data. As can be seen in Figure 5.3, there is a suggestion that the IAM riders exceeded the speed limit the least, while the Novices speeded the most, but only in the 40mph zone. This fits with the idea that IAM training raises awareness of potential hazards in urban zones and riders are therefore particularly cautious regarding their speed when travelling in these zones.
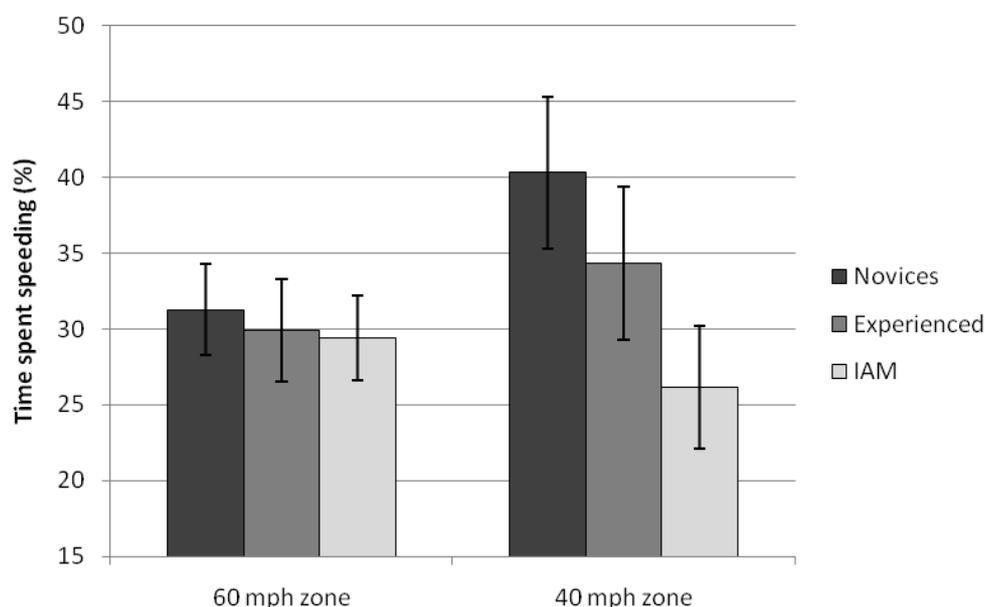
Figure 5.3: Average time spent speeding in the 60mph and 40mph zones

Average lateral position - the simulator also recorded the lateral position of the motorcycle in the lane. The width of the lane was 12ft and the software attributed the centre-line of the road (the dividing line between the two lanes of traffic) with a lateral position score of zero. If riders remained in their lane they varied in lateral position between 0ft and -12ft (with a greater negative value reflecting a position that was further away from the centre-line), while positive numbers represented excursions over the centre-line into the opposite lane.

The average lateral position for the three groups of riders were analysed using a 2x3 ANOVA. A significant main effect for speed limit was observed [$F_{(2,58)} = 18.0$, $p<0.001$] indicating that all riders tended to position themselves further from the centre-line in 60mph zones (mean = -5.2ft) compared to 40mph zones (mean = -4.1ft). A significant main effect was also observed for rider group [$F_{(2,58)} = 18.0$, $p<0.001$]. Post-hoc Tukey HSD tests illustrated that all three rider groups were significantly different to each other. Figure 5.4 illustrates that Novice riders were the furthest to the left (-5.19ft from the centre-line) whilst the IAM riders were closest to the centre-line (-4.09ft from the centre-line).
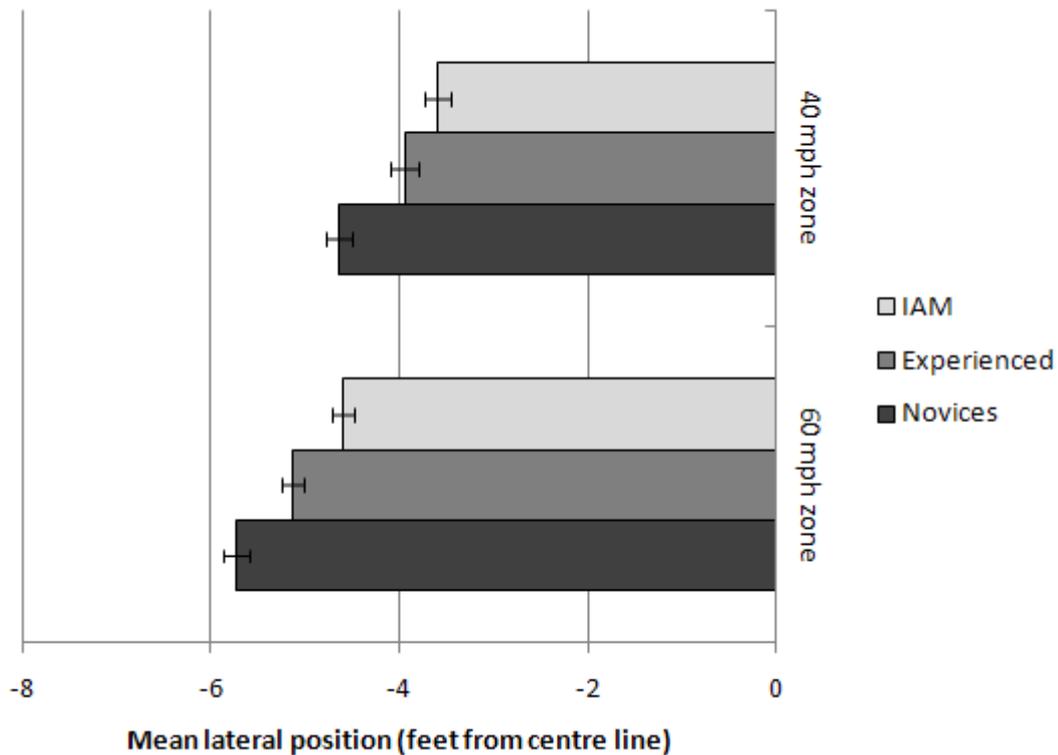
Figure 5.4: Average lateral positions of riders in the 60mph and 40mph zones

Variance in lateral position - in addition to the average lateral position, the variance in lateral position was also analysed. This measure referred to the extent that riders changed their lateral position whilst riding, with the assumption that a greater overall variance in lateral position suggested that a rider was more flexible in their lane maintenance, and tended to vary their lane position according to circumstances. A 2x3 ANOVA was performed on the data and a significant main effect for speed limit zone $[F(1,58) = 148.9, p<0.001]$ indicated that across all the groups, riders varied their lateral position more in the 60mph zones (mean = -7.00ft^2) compared to the 40mph zones (mean = -3.10ft^2). A significant main effect was also observed for rider group $[F(2,58) = 9.2, p<0.001]$ and an interaction between rider group and speed limit zone $[F(2,58) = 3.8, p<0.05]$. Post-hoc analyses revealed the IAM-trained riders had a greater overall variance in lateral position than the Novice riders $(p<0.001)$. Experienced riders were placed in-between both rider groups and did not differ significantly from the other rider groups. The reason for this becomes apparent when viewing the interaction (Figure 5.5). The graph shows that the Experienced riders behaved more like the IAM-trained group in the 60mph zones, but more like the Novices in the 40mph zones, which would support the argument that advanced training provides the IAM riders with specific skills in 40mph zones.
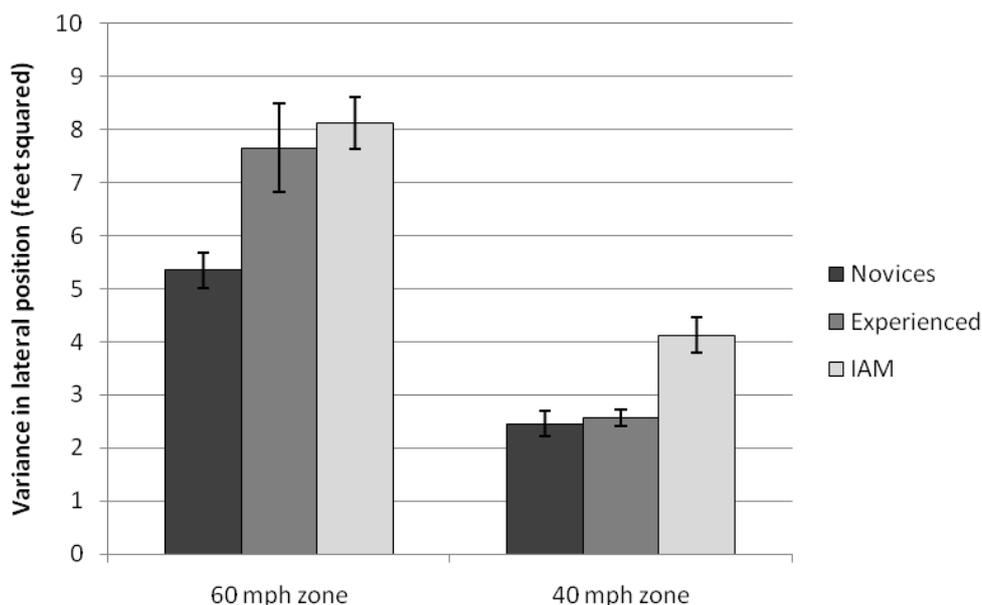
Figure 5.5: Variance in lateral position of riders in 60mph and 40mph zones

Braking behaviour - several measures of braking were recorded in the simulation software, however only the average maximum braking effort illustrated any differences between the rider groups. Average maximum braking effort was calculated by recording the maximum pressure applied to both the front and rear brakes during any one braking episode, and then averaging across them for each rider within the 60mph and 40mph speed limit zones. These data were analysed using a 2x3 ANOVA and a significant interaction was observed [$F(2,58) = 6.7$, $p<0.01$] indicating that whilst all groups have similar maximum braking scores in the 60mph zone, all riders increased their braking effort in the 40mph zone, with the IAM riders having the lowest braking effort in the 60mph zone but the highest in the 40mph zone (Figure 5.6). This is again congruent with the suggest that IAM training has had greater impact on riding behaviour in the 40mph zone than in the 60mph zone.
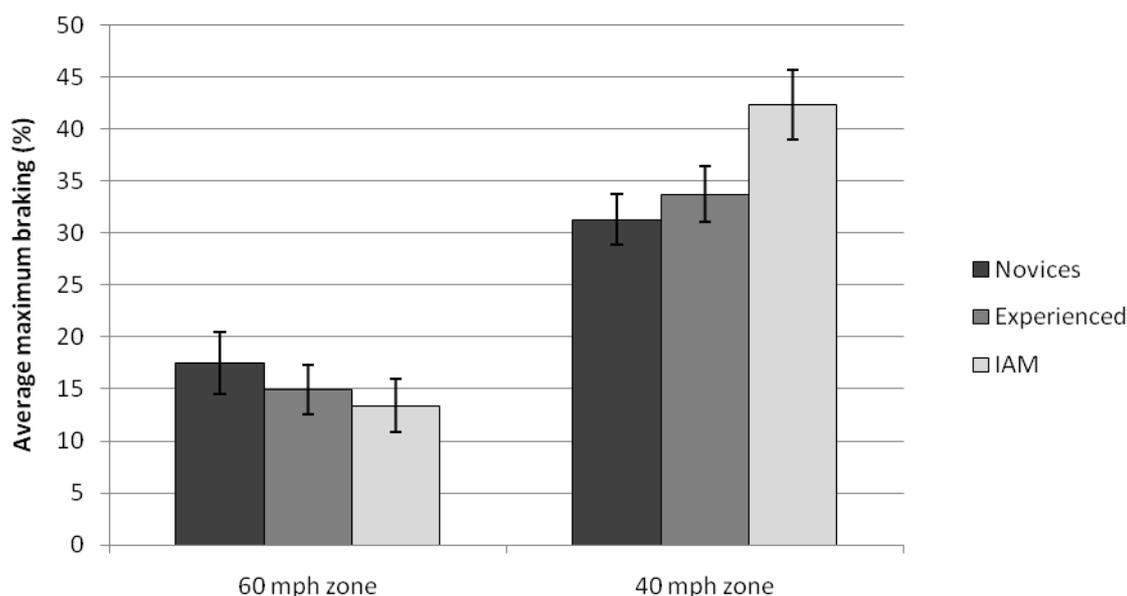
Figure 5.6: Braking effort of riders in the 60mph and 40mph zones

5.3.4. Straight and curved road sections

> **The three rider groups were compared across 4 types of roadway:**
> - **straights**
> - **slight curves**
> - **medium curves**
> - **tight curves**
>
> **IAM riders had the highest speed through the curves, closely followed by the Novice riders. Experienced riders tended to take all the curves at lower speeds than the other two rider groups.**
>
> **An analysis of lane positioning on straights and through curves suggested that the IAM riders tended to prepare for tight and medium bends by altering their lane position early. Novice and Experienced riders however tended to alter their position more in the medium curves than they did in the slight curves.**

Average speed - a 3x4 ANOVA was performed on the average speed data, which compared the three rider groups with the four classifications of road geometry. Across all riders speed was the greatest on the straights (mean = 59.7mph), reducing on the slight curves (mean = 49.9mph) as riders prepared for tighter curves ahead. Medium curves required no further adjustment in speed (mean = 50.2mph), although tight curves tended to provoke a further decrease in speed (mean = 47.4mph). The reduction in speed across these four road types varied across the rider groups [$F_{(6,174)}$ = 45.1, $p<0.001$]. Planned repeated contrasts revealed a significant interaction in two places, between straights and slight curves and between slight curves and medium curves. As can be seen in Figure 5.7 all riders reduced their speed from straights to slight curves, but Experienced riders reduced their speed to a greater extent than the other two groups. Between slight curves and medium curves the Novice and Experienced riders maintained their speed however the IAM riders had a slight but significant increase in their speed on medium curves.
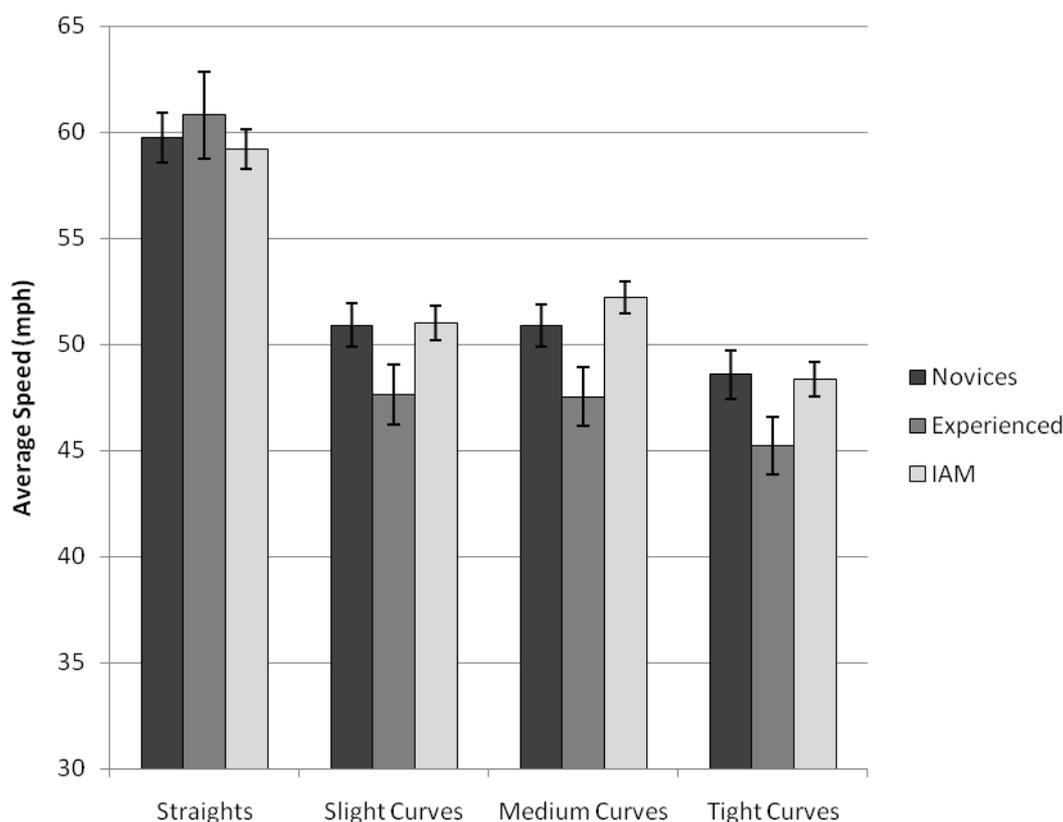
Figure 5.7: Average speed across the four classifications of road geometry

Throttle rotation - average throttle rotation mirrored the average speed results.

Average lateral position – a 3x4 ANOVA was conducted on the average lateral position data. A significant main effect was observed for rider group [$F_{(2,58)} = 7.2$, $p<0.001$]. Post-hoc tests revealed that all three rider groups were different to each other ($p<0.01$) with IAM-trained riders riding closest to the centre-line (mean = -4.9ft), followed by the Experienced riders (mean = -5.5ft), and Novices being furthest from the centre-line (mean = -6.1ft). A significant interaction was also observed between rider group and the four classifications of road geometry [$F_{(6,174)} = 5.0$, $p<0.001$]. Repeated planned contrasts revealed that the IAM riders stayed closer to the middle of the road, especially so on the medium bends where the Novice and Experienced riders tended to move away from the centre of the road. It should be noted however that this measure of average lateral position is averaged over left and right curves. For analysis of lane position on specific curves see chapters 8, 9, and 10.

Variance in lateral position – a 3x4 ANOVA revealed a significant main effect for rider group [$F_{(2,58)} = 5.2$, $p<0.01$]. Post-hoc tests revealed that Novice riders had much less variance in their lateral position compared to the IAM riders ($p<0.01$). This effect was further qualified by a significant interaction between rider group and road segment [$F_{(6,174)} = 9.2$, $p<0.001$]. Repeated planned contrasts illustrated that the interaction lay partially in the comparison of straights to slight curves [$F_{(2,58)} = 4.5$, $p<0.05$] with both the Experienced and IAM riders changing their position in the lane more so on these slight curves than the Novice riders. As already noted, the slight curves tend to be spirals that lead on to either medium curves or tight curves, and this therefore makes logical sense: the riders were positioning themselves during the spiral in order to optimally navigate an up-coming medium or tight curve. While Novices also changed their lane position in a spiral, this change was less pronounced. A further significant interaction was observed in the comparison of slight curves with medium curves [$F_{(2,58)} = 18.7$, $p<0.001$]. As shown in Figure 5.8 the pattern of results indicated that the peak variance in lateral position for Novice and Experienced riders

appeared in medium curves, whilst for IAM riders the peak variance in lateral position occurred in the slight curves. Essentially it appears that the IAM-trained riders made all of their preparations in regard to lane position for medium and tight bends during the preceding spirals. Both Experienced and Novice riders however showed greater adjustment to their lane position while actually negotiating the medium curves. Although their lane variance peaked in medium curves, the Experienced riders still made more adjustments to their lane position in tight curves than the IAM riders. This suggests that the IAM-trained riders were more prepared for medium and tight bends due to more flexibility in their lane positioning on the approach to these bends.
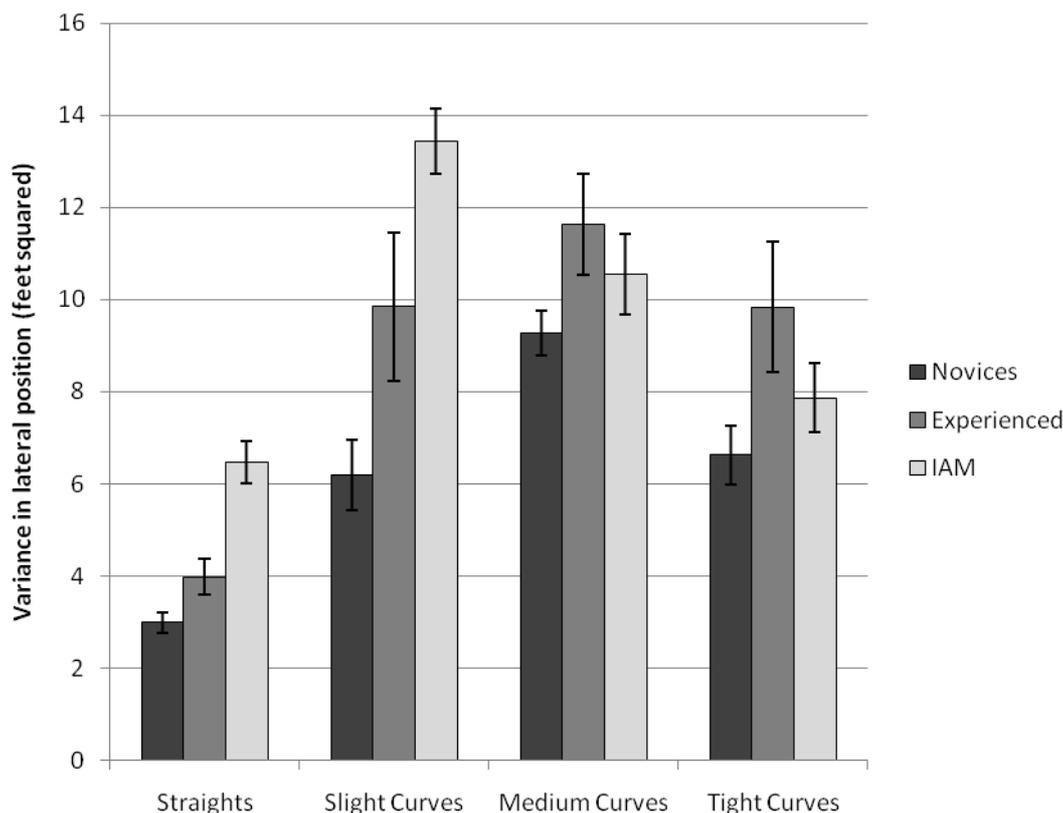
Figure 5.8: Lateral position across the four classifications of road geometry

Braking behaviour - when measures of braking were analysed using 3x4 ANOVAs, no significant effects were observed ($p>0.05$) for braking duration, the number of braking episodes, or the average maximum braking effort.

5.3.5. Rider workload

Participants completed a NASA-TLX subjective workload questionnaire after the main riding scenario. Participants rated how demanding the riding task had been based on six workload factors: mental demand, physical demand, temporal demand, performance effort and frustration. From the factor sub-scales an overall workload score was calculated (Byers, Bittner & Hill, 1989). Workload was analysed using 1x3 ANOVA but no significant effects were observed ($p>0.05$). The pattern of results indicated that IAM riders reported the highest workload (mean = 45.6) and Novice riders reported the lowest workload (mean = 41.6).

5.4. Discussion

On the basis of the above analyses, the three rider groups behave significantly differently on a number of behaviours and across a variety of measures. For certain behaviours it was clear that the three groups followed what might be considered the naive hypothesis of experience and training, with Novices ostensibly performing worst and the IAM-trained riders performing best. On some measures however it could be seen that the advanced training provided little advantage over that of general riding experience. On yet other measures, however, it was clear that the Novices and IAM-trained riders were more similar and that experience in itself did not provide specific benefits to riding.

The first set of analyses focused on the data from the MRBQ. Whilst Elliot, Baughan & Sexton (2007) reported a five-factor structure, only three of these factors in the current data set (traffic errors, speed violations and propensity to engage in stunts) were reliable measures of the underlying constructs. There are two important things to note before progressing. First, that the current data did not support the full five factor structure does not invalidate the findings of Elliot, Baughan & Sexton (2007). Their questionnaire approach was the primary reason for their study, and as such they were able to use a much larger sample. The current study took a behavioural approach, and the questionnaire was embedded within the integrated experiment approach and therefore did not have the same power of analysis in this respect. From this study, it can be concluded that the most prominent factors in Elliot, et al's, study, are also reliable here, and were used to compare the three rider groups.

The second point to note is that obtaining a reliable factor from the MRBQ does not mean that factor is interesting in isolation. The 'stunts' factor is just such a case. While the measure is reliable, none of the riders rated themselves as very likely to engage in stunts, and there was no difference across the groups. With this result, however, it could be argued that the riders in this study are more focussed on cognitive or ordinary behaviours, rather than affective or aggressive behaviours performed in order to satisfy sensation-seeking motives (Elliot, Baughan & Sexton, 2007; Shu-Kei Cheng & Chi-Kwong Ng, 2010).

The traffic errors and speed-violations did, however, show differences between the groups with the IAM-trained riders showing a decrease in self-reported traffic errors and speed violations compared with the other groups. There was no difference between the Novice and Experienced riders. IAM-trained riders from this study might indeed commit fewer traffic errors and speed violations, (although from the demographic data in Chapter 4, they reported more license endorsements) but the Novice and Experienced riders reported a higher tendency to commit such errors and violations and perhaos have not yet experienced the legal consequences of this behaviour.

The accident data appeared to uphold these group differences. Again, the IAM-trained riders appeared to be safer than the Novices in regard to accidents with the pre-determined hazards, but the Experienced riders appeared to crash as often as the Novices. Unfortunately accident data is always an impoverished source to conduct analyses with (due to their infrequent nature). Despite the obvious trend for IAM-trained safety, a Chi Square test did not illustrate any significant differences between the rider groups. The benefit of undertaking a simulator study however is the wealth of sensitive data that is gathered at a more fine grain level of behaviour (and which is reported in later Chapters).

In the comparisons of rider behaviour across the 60mph and 40mph zones, the measures of speed, throttle and braking, illustrated that IAM-trained riders appeared to ride more defensively in 40mph zones than the other groups. In the 60mph zones however there was very little difference between all three groups and so it would appear that mere riding experience does not result in riders changing their coarse behavioural signatures above Novice riders. Equally, the IAM-trained riders concur with

the other two groups in the 60mph zone, suggesting that their advanced training imparted more sensitivity in the 40mph zone. When taken together, these findings suggest that the IAM riders were riding more defensively in an urban environment (and to an extent in the rural environment) and able to brake harder due to travelling at a slower speed then other rider groups in the 40mph zones.

A more general effect of experience and training was noted on the measure of absolute lane position, with Novices, Experienced and IAM-trained riders generally choosing different lane positions: the Novices were the closest to the inside edge of their lane and the IAM-trained riders were the closest to the centre-line. This effect was present regardless of speed zone. It appears that the move towards a more central road position develops with experience and is enhanced with advanced training. A more central road position may provide greater viewing distances around left bends, more flexibility in manoeuvring when faced with potential hazards, greater distance between the rider and certain hazards such as parked cars, and help avoid road surface features associated with road edges (soft verges, drains, etc).

The argument that a central position provides flexibility is further supported by the increased variance in lateral position shown by the IAM-trained riders. Essentially, this suggests that they were more likely to move within their lane, adopting different positions according to the circumstances. It was interesting to note that the Experienced riders behaved in a similar fashion with the IAM-trained riders in regard to flexibility of position within their lane, but only in the 60mph zones. In the 40mph zones the Experienced riders behaved more like the Novices, with a restriction in the amount of lateral movement. This suggests that riding experience can make riders aware of the benefits of changing position within the lane, but that it requires advanced training to extend this to 40mph zones. It is likely that the increased variation shown by Experienced riders in the 60mph zone occurred for a different reason to that of the IAM-trained riders in the 40mph zones. For instance, the increased variance in 60mph zones may reflect a greater tendency to take a racing line on bends (which indicates a lack of advanced skills) whereas increased variance in 40mph zones might relate more to hazard management and avoidance (which is learned through advanced training). Regardless of the underlying reasons for the differences, these results reinforce the suggestion that IAM-trained riders have specifically benefitted in their rider awareness manifested in how they approach slower speed urban and suburban areas.

The analysis of straight road sections compared to three types of curve also revealed interesting patterns. In regard to speed, IAM-trained riders and Novice riders were both faster than the Experienced riders through the bends. Experienced riders decelerated significantly more than both the other groups in all types of curve. Novices could not keep up with the IAM-trained riders in the medium curves however, as the interaction revealed a tendency for the advance riders to speed up once they had the measure of the curve.

Two interesting points need to be raised here. First, why would the Novices enter bends faster than the Experienced riders? Extrapolating from the car driver research on novice drivers, it is possible that novices have exaggerated confidence in their own abilities (Finn & Bragg, 1986; Matthews & Moran, 1986) or are unaware of the hazards associated with bends. It is known that loss of control on bends is a major cause of motorcycle crashes (Clarke, et al, 2007) and it is likely that the Experienced riders may have previously encountered bends that have made them reconsider their entry speeds as a consequence. The IAM-trained riders however were equally happy to ride into bends at speeds equal or even greater than those of the Novices. Does this mean that they are equally over-confident? It is likely that the two groups have considerable confidence in their ability to take bends, and that this confidence derives from the same place (having recently undertaken training, albeit one at a basic level and the other at an advanced level), however the training received by the IAM riders makes them faster throughout the bends and so any derived confidence is more justified.

This leads to a second point: is the speed or confidence of the IAM group really justified? It was mentioned earlier that there were a number of IAM crashes on bends in the simulator. These crashes were not precipitated by the pre-determined hazards and were simply loss of control accidents. While it remains a possibility that misplaced confidence still plays a role in causing accidents even after advanced training (Katila, Keskinen & Hatakka, 1996) who found that advanced skid pan training for car drivers led to an increase in crashes), it is also possible that this represents a limitation of the simulator. The current version of MotorcycleSim does not allow for counter steering and it is possible that the IAM-trained riders might be more practiced at this technique and therefore found themselves at a disadvantage having to overcome their natural inclination to steer in a different direction to that required by the simulator. As the number of IAM-trained crashes on bends was extremely low, other rider groups also behaved in a similar fashion and no significant effects were observed, it does not threaten the validity of the overall results.

A further finding of note from the comparison of bends was the variation with the bends across the groups. IAM-trained riders changed lane position most during slight curves (typically these were spirals preparing for medium and tight curves). Once into a tight or medium curve, the IAM-trained riders became more stable in their lane positions. The results from the other two groups however suggested that they were less prepared in terms of lane position, and were still increasing their lane variance while negotiating medium curves. The variance of lateral position across the four road segments was of greater interest than absolute position as some riders may have considered the racing line to be the most appropriate way to take a bend. IAM training offers an alternative perspective that by taking bends on a wide line, the rider has a much better view around the bend in order to be better able to anticipate hazards, as well as accelerate out the bend earlier. It also makes them more visible to oncoming traffic earlier than if they take a racing line.

The lack of any significant differences for subjective workload between the rider groups suggests that neither group perceived the main riding scenario to be more difficult than the other rider groups. This provides a level of consistency across the groups in the effort it took to conduct the riding task. There was a trend in the data which suggested that the IAM-trained riders rated their workload the highest and Novice riders rated their workload the lowest. Looking at the sub-scales in detail, IAM riders rated the task higher for cognitive load and general effort. Further research would need to be conducted in order to explore this trend but it suggests that IAM rider felt the riding task was more demanding than Novice riders, perhaps due to a higher level of cognitive effort in assessing the road conditions, assessing their speed and negotiating curves.

In conclusion, it appears that the general measures have identified a number of differences between the three rider groups. The IAM-trained riders report fewer traffic errors and speed violations, and the results from the simulator seem to corroborate this (there was a trend for fewer crashes into hazards, and they did have slower speeds at least in 40mph zones). The effect of advanced training on behaviour within the 40mph zones was quite marked, suggesting that these riders have developed particular skills and strategies for dealing with urban and suburban environments. At the very least they treat these environments with more caution and appear to ride more defensively. The benefits of training are not completely restricted to the 40mph zones however (in the curve analysis IAM-trained riders made faster progress through bends). Taken together the results display a complex patchwork of skills and strategies, some of which can benefit from experience, whereas others need advanced training to evoke them. With the caveat of counter steering acknowledged, these results make a compelling case for the validity of the simulator, and a clear case for the benefits of advanced training.

6.   Side roads

6.1. Introduction

Research has shown that one of the three main causes of accidents involving motorcycles occur with car drivers failing to give way at T-junctions (Clarke, et al, 2007). In relation to accidents, 54.3% of motorcycle accidents took place at an intersection and, in these cases, 60% were reported with passenger cars as the collision partner (MAIDS, 2009). These accidents are characterized by other road users pulling out from a side road onto a main carriageway into the path of an approaching motorcycle. In many cases, the driver reports having failed to see the motorcycle, despite looking in the direction of the motorcycle. This phenomenon has been termed a 'Look But Fail To See' (LBFTS) error (Brown, 2002).

Some studies have attempted to determine what causes LBFTS errors. It is likely that expectations and cue salience of other road users play a role: drivers expect to see other cars rather than motorcycles and therefore the threshold required for detecting motorcycles is much higher. In support of this, drivers who also ride motorcycles are less likely to cause motorcycle crashes (Magazzu, Comelli, & Marinoni, 2006). These dual drivers have greater exposure to motorcycles and are more aware of the potential dangers at T-junctions. Furthermore, Brooks & Guppy (1990) have found that drivers who have ridden pillion with family members or close friends who ride motorcycles show better observation for motorcycles, and are less likely to collide with motorcycles than drivers who did not have similar experiences. It is possible that a greater exposure to motorcycles reduces the threshold required to notice them.

Another possible reason for these right of way violations is that drivers notice the motorcycle, but fail to make a correct appraisal of the situation. For example, it has been suggested that drivers make an incorrect estimation of the amount of time that it will take for the motorcycle to reach the junction, since time-to-contact estimations tend to be less accurate for smaller objects. This is known as the size-arrival effect (DeLucia, 1991). However, Crundall, Humphrey & Clarke (2008) argue that right of way violations involving motorcycles are likely to result from drivers failing to perceive the motorcycle rather than from incorrect appraisal. Experienced drivers were presented with pictures of T-junctions containing a car, a motorcycle, or neither. The pictures were only presented for 250ms, which is roughly equivalent to one fixation (i.e. when the eyes fix on an image and process visual information). Drivers were less likely to detect a motorcycle than a car when the vehicle was far away, but when the vehicles were close or mid-distance, detection of motorcycles was similar to that of cars. In a second experiment, drivers had as long as they wanted to look at the same pictures and were asked to judge whether or not it was safe to pull out. In this case, car drivers did not differentiate between cars and motorcycles and it can be argued that right of violations result from errors in perception rather than speed judgement (Crundall, Humphrey & Clarke, 2008).

More recently, Crundall, et al, (in press) conducted an eye-tracking study while drivers watched videos recorded from a driver's perspective. The study showed that drivers looked at motorcycles for shorter durations than cars at T-junctions. Such short gaze durations are linked with reduced or no processing, and are therefore symptomatic of a LBFTS error.

While it is important to investigate why drivers fail to see motorcyclists at T-junctions, as yet, no studies have looked at this issue from the perspective of the motorcyclist. Given the prevalence of accidents involving motorcycles at these junctions, it is likely that many motorcyclists would recognise T-Junctions as a potential source of danger. As a result, one might expect riders to slow down on approach to these junctions and to select a road position that decreases the likelihood of being hit should a car pull out.

Furthermore, experience of accidents or near misses at T-Junctions is likely to increase the perceived risk associated with these junctions. It would be logical to expect Experienced and IAM riders to behave differently from Novice riders on approach to T-Junctions, since experienced riders have been riding for longer and are therefore likely to be more aware of, potential hazards emerging from side roads. Also, if advanced training increases awareness of potential sources of hazard, it would be anticipated that IAM riders might perform differently from Novice and Experienced riders. If training and experience leads to anticipation of the hazard, then IAM riders and Experienced riders should not need to alter their speed and road position as much as the Novices when the same hazard occurs.

If riders experience a hazard, then this could have a more localised effect on riders' perception of risk, even if this is short-lived. Shinoda, Hayhoe and Shrivastava (2001) suggest that car drivers perform an active search of the environment, which is influenced by a learnt probabilistic structure. Thus, a car pulling out from a side road is likely to increase the rider's perceived probability of cars pulling out from other side roads, resulting in a change in speed and road position on approach to all subsequent side roads.

There were two main questions underlying this study:
- How do Novice, Experienced and IAM-trained riders respond when a car pulls out from a side road in a typical LBFTS scenario?
- Does the experience of this hazard modify rider behaviour when approaching subsequent side roads?

In order to answer these questions, a sub-scenario was designed in which riders rode past the same side roads in two laps of the main riding scenario route. Lap 1 was used to collect baseline data regarding speed and lateral position. On Lap 2, a car pulled out from the first side road in front of the rider. This allowed for the measurement of direct responses to the hazard in terms of changes in speed and lateral position. It was also possible to investigate if riders modified their behaviour after experiencing the hazard by comparing speed and lateral position at the other junctions on Lap 1 (before the hazard) and Lap 2 (after the hazard).

If the occurrence of a hazard modified a rider's subsequent behaviour, then what triggers were responsible for this change? Might riders modify their behaviour only when they can see a car approaching a junction, or might they modify their behaviour when they can't see a car? To test this, rider behaviour was compared when approaching junctions with a car pulling up as well as with junctions that did not contain a car. Furthermore, if riders are guided by a learned probabilistic structure, does the certainty with which the rider can assume that there is or isn't a car influence their behaviour? To test this, the visibility of the junctions was systematically varied: half of the junctions were obscured by a building (decreasing the certainty of there being a car present or not), and half of the junctions had a more open aspect (increasing the certainty of there being a car present or not).

6.2. Method
In this sub-scenario the roadway was designed as a suburban area with residential buildings set back on either side of the road. There were five side roads to the left-hand side, set a minimum of 628ft apart. Each side road represented a give way junction onto the main road along which the rider was travelling. There were dashed lines at the end of each side road to indicate a give way junction. At the beginning of the sub-scenario, 526ft before the first side-road, there was a crossroads with traffic lights which turned to red as the rider approached. This ensured that all riders began the scenario from a stationary position. The speed limit for this sub-scenario was 40mph, indicated by a speed limit sign placed 687ft before the crossroads. The first side road was empty on the first lap and was not analysed. However on the second lap this side road contained a hazard (a car approached the give way line, but then failed to give way, pulling out in front of the motorcyclist) and is henceforth referred to as the

'hazard side road' (Figure 6.1). The car hazard was triggered when the rider was 5 seconds away (based on the rider's current speed) and started travelling at 10.2mph from a distance of 58ft from the junction (i.e. the car was initially out of the view of the rider). The car then continued at the same speed and finally stopped with the centre of the vehicle 1.8ft over the give way line. The car came into view approximately 218ft before the junction if the rider was travelling down the centre-line at 40mph.

Figure 6.1: Rider view of side road hazard

The remaining four side roads did not contain actual hazards, but measures were recorded on both laps to test 3 separate hypotheses:

- whether the open or obscured nature of the side road affected rider behaviour
- whether the presence or absence of a car approaching the give way line (but not crossing it) affected rider behaviour
- whether the occurrence of the hazard affected subsequent approaches to side roads (comparing Lap 1 side roads with those on Lap 2).

Each car was triggered when the rider was 5 seconds away and travelled at 10mph from a distance of 68ft from the junction (i.e. initially out of the rider's view). In order to avoid any practice, anticipation or learning effects, during Lap 1 the second and fifth side roads contained cars, and during Lap 2 the third and fourth side roads contained cars. Therefore, excluding the hazard side road, there were two obscured side roads (one with a car pulling up and one without a car, Figure 6.2, left panel) and two open side roads (one with a car pulling up and one without a car, Figure 6.2, right panel) on each lap.

Figure 6.2: Obscured and open side roads as observed by riders

Two variables were investigated in this sub-scenario:
- side road (clear or obscured)
- vehicle approaching junction (present or not present)

As a result a 2x2 matrix was developed based on the presence of an approaching vehicle and whether the junctions were clear or obscured. This is represented in Table 6.1.

	Side road (clear or obscured)	
Vehicle approaching junction	Vehicle present, side road clear	Vehicle present, side road obscured
(present or not present)	Vehicle not present, side road clear	Vehicle not present, side road obscured

Table 6.1: 2x2 matrix of characteristics for the side roads

6.3. Results

Participants behaviour in the side roads sub-scenario was analysed in two ways:
- **Direct responses to the car hazard –** average speed, average lateral position and variance in lateral position were calculated across five distance bins from the hazard: 500ft to 400ft; 400ft to 300ft; 300ft to 200ft; 200ft to 100ft; and 100ft to 0ft. This was analysed using a 3x5 mixed ANOVA with rider group as a between subjects variable and distance bin as a repeated measures variable.
- **Modification of rider behaviour -** on the approach to the four other (non-hazard) junctions, average speed, average lateral position and variance in lateral position were compared. Mean scores were calculated for the measures when the rider was 300ft before each junction up to when the rider reached the near edge of the junction. These measures were compared for the two types of junction (obscured or open) with and without a car pulling up. Furthermore, comparisons were made between Lap 1 (before the hazard) and Lap 2 (after the hazard).   These data were analysed using a 3x2x2x2 mixed ANOVA with rider group as a between subjects variable and lap (Lap 1 vs. Lap 2), junction type (obscured vs. open), and presence of car pulling up (car vs. no car) as repeated measures variables.

6.3.1. Response to hazard

Riders reduced their speed most in the last 100ft before the hazard.

Riders started moving towards the centre-line on approach to the hazard junction before they reduce their speed.

Riders make the greatest lateral movement in the last 100ft before the hazard.

IAM trained riders ride closer to the centre-line than Novices.

Average speed - there was a main effect of distance from hazard [$F_{(4,228)}$ = 187.488, $p < 0.001$], shown in Figure 6.3. Riders significantly increased their speed between the first three adjacent distance bins ($p < 0.01$). There was no significant change in speed between 300/200ft and 200/100ft from the hazard, but then riders significantly decreased their speed between 200/100ft and 100/0ft from the hazard ($p < 0.001$).
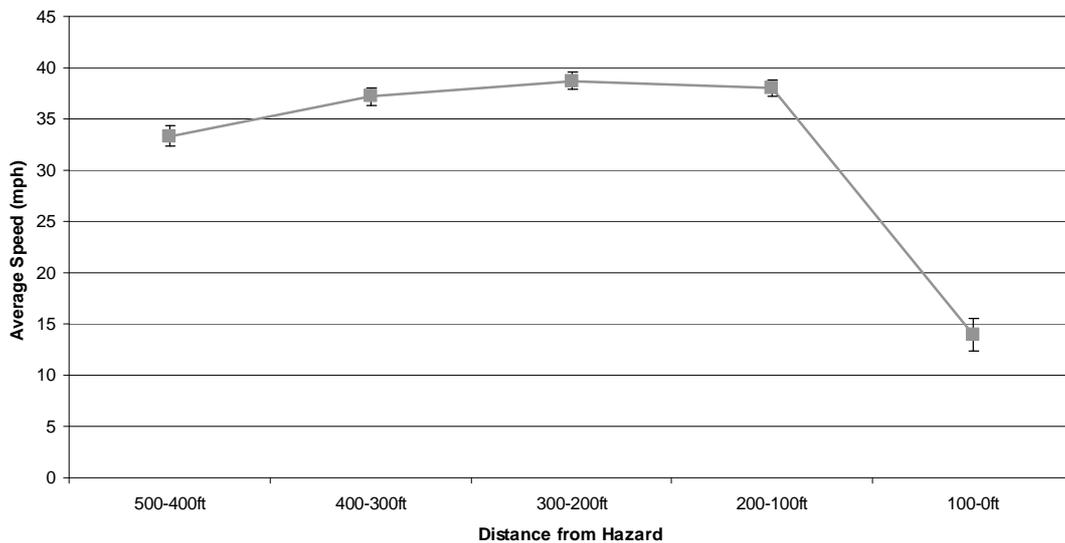
Figure 6.3: Average speed across the five distance bins

Lateral Position - there was a main effect of rider group [$F_{(2,57)}$ = 3.616, $p < 0.05$]. Scheffe tests revealed that IAM riders (mean = -4.08 ft) rode significantly closer to the centre-line than Novice riders (mean = -5.05 ft; $p < 0.05$). Experienced riders (mean = -4.58 ft) did not significantly differ from either of the other two rider groups. There was also a main effect of distance [$F_{(4,228)}$ = 56.465, $p < 0.001$], shown in Figure 6.4. Repeated contrasts revealed that, as they approached the hazard, riders made a significant change in lateral position towards the centre-line between each of the five adjacent bins ($p < 0.05$ for comparison between 500/400ft and 400/300ft; $p < 0.001$ for all other comparisons).
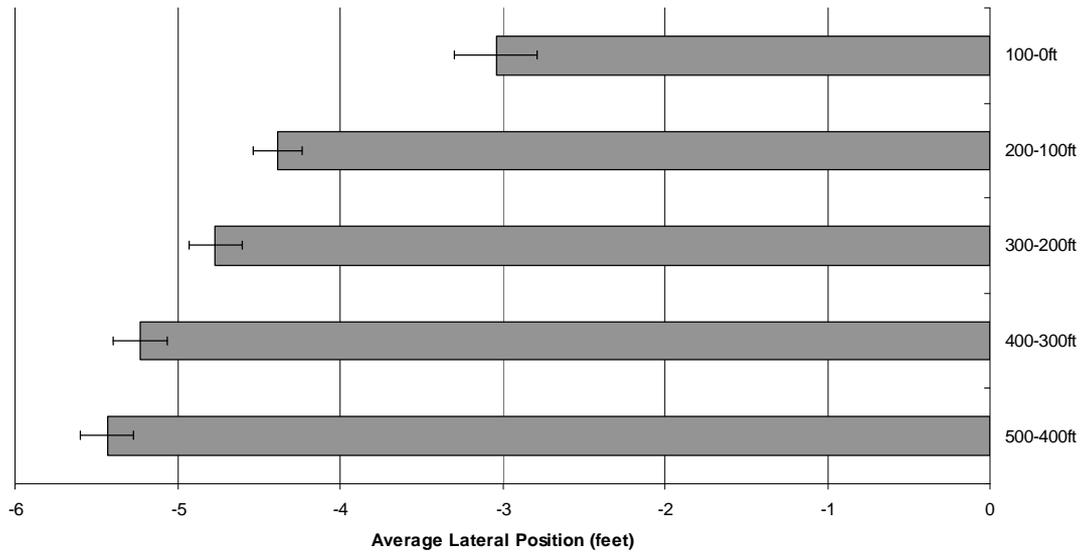
Figure 6.4: Average Lateral Position across 5 distance bins

Variance in Lateral Position - there was a main effect of distance [$F_{(4,228)} =$ 36.880, $p<0.001$], shown in Figure 6.5. Repeated contrasts revealed that riders only significantly increased the variance of their lateral position between the 200/100ft (mean = 0.11ft^2) and 100/0ft distance bins (mean = 1.86ft^2; $p<0.001$).
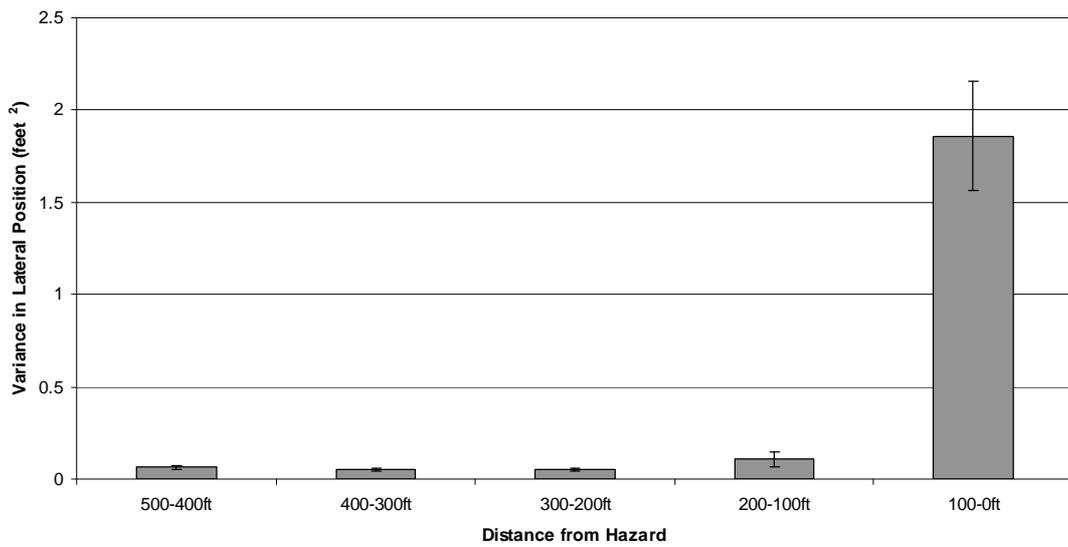
Figure 6.5: Variance in lateral position across 5 distance bins

6.3.2. Lap comparison

> **IAM-trained riders approached open junctions more slowly than Experienced riders.**
>
> **IAM-trained riders approached junctions with no car more slowly than Experienced riders.**
>
> **IAM-trained riders rode closer to the centre-line than Novices when approaching obscured junctions, and rode closer to the line than both Novices and Experienced riders when approaching open junctions.**
>
> **Riders rode closer to the centre-line when approaching open junctions than when they approached obscured junctions (although this was only significant for Novices and IAM trained riders).**
>
> **Before the hazard, IAM riders rode closer to the centre-line than both the Novices and Experienced riders when approaching junctions where a car pulled up. After the hazard, the IAM riders rode closer to the centre-line than both Novices and Experienced riders when approaching junctions without a car.**
>
> **After the hazard, IAM trained riders made more lateral movement than Experienced riders when approaching junctions where a car pulled up.**

Average speed - there was a significant main effect for rider group [$F_{(2,57)} = 3.283$, $p<0.05$]. Scheffe tests revealed that IAM riders (mean = 36.8mph) rode more slowly than Experienced riders (mean = 41.8mph). Novices (mean = 40.0mph) did not significantly differ from either of the other two rider groups. There was also a main effect junction type [$F_{(1,57)} = 10.928$, $p<0.01$], which illustrated that riders approached obscured junctions more slowly than open junctions (mean obscured = 38.8mph; mean open = 40.2mph). However, an interaction between junction type and rider group [$F_{(2,57)} = 4.339$, $p<0.05$] suggested that this was driven by the Experienced riders who chose faster speeds at open junctions (Figure 6.6). Simple main effects confirmed this, revealing that only the Experienced riders were affected by junction type [$F_{(1,20)} = 22.626$, $p<0.001$], riding significantly faster when they were approaching open junctions than when they were approaching obscured junctions.
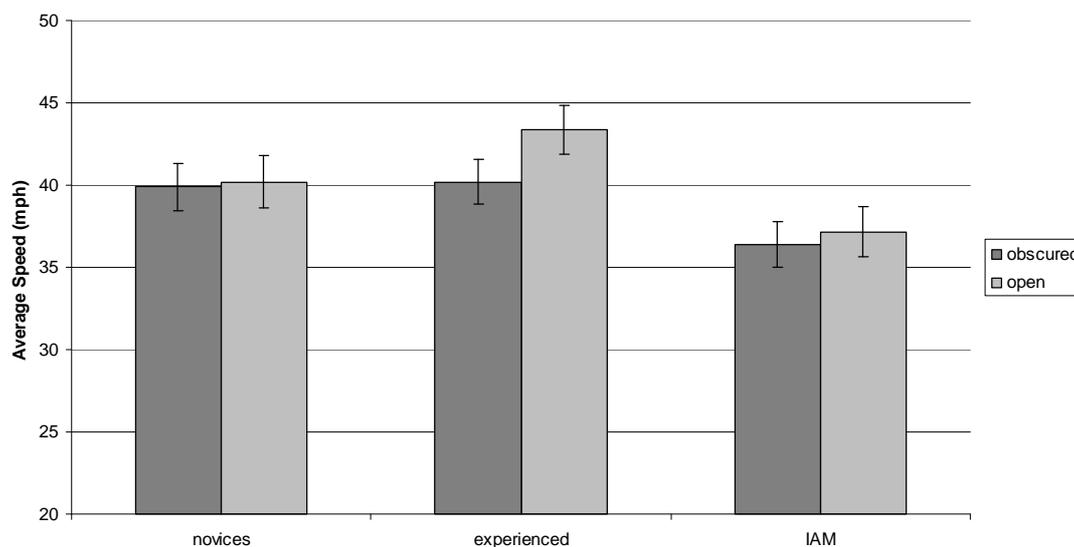
Figure 6.6: Average speed of riders approaching obscured and open junctions

There was also a main effect of car presence [F(1,57) = 51.271, p<0.001], which revealed that riders approached side roads with a car present more slowly than those without cars. As can be seen from the interaction in Figure 6.7 [F(2,57) = 6.158, p<0.01), this effect was primarily driven by the Experienced riders choosing a faster speed in the less dangerous situations (i.e. when no car is present).
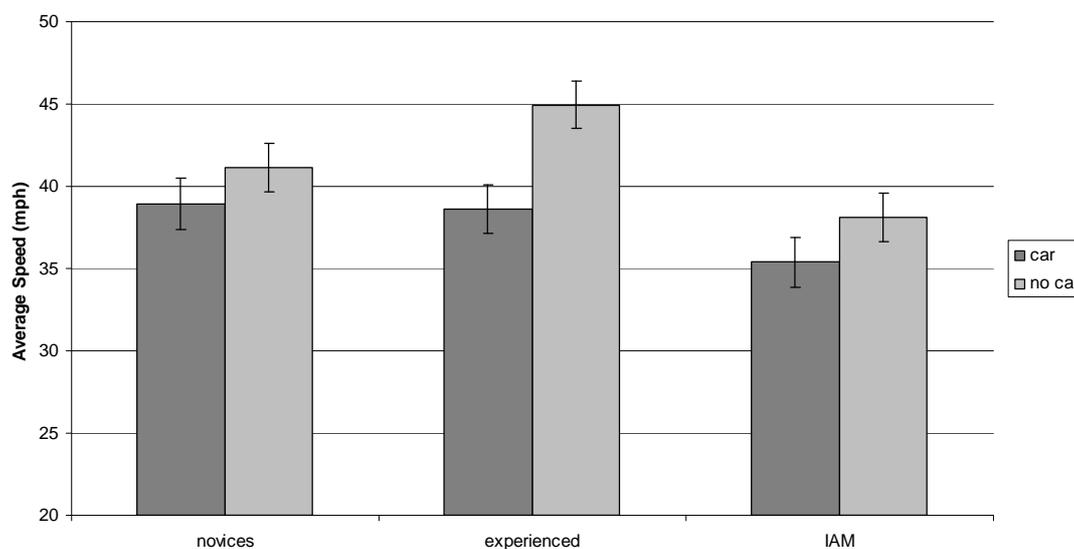
Figure 6.7: Average speed of riders approaching junctions with and without an approaching car

However, the presence or absence of a car pulling up also interacted with lap [F(1,57) = 37.158, p<0.001], and junction type [F(1,57) = 18.854, p<0.001], which also resulted in a 3-way interaction between car x lap x junction type [F(1,57) = 15.492, p<0.001], shown in Figure 6.8.
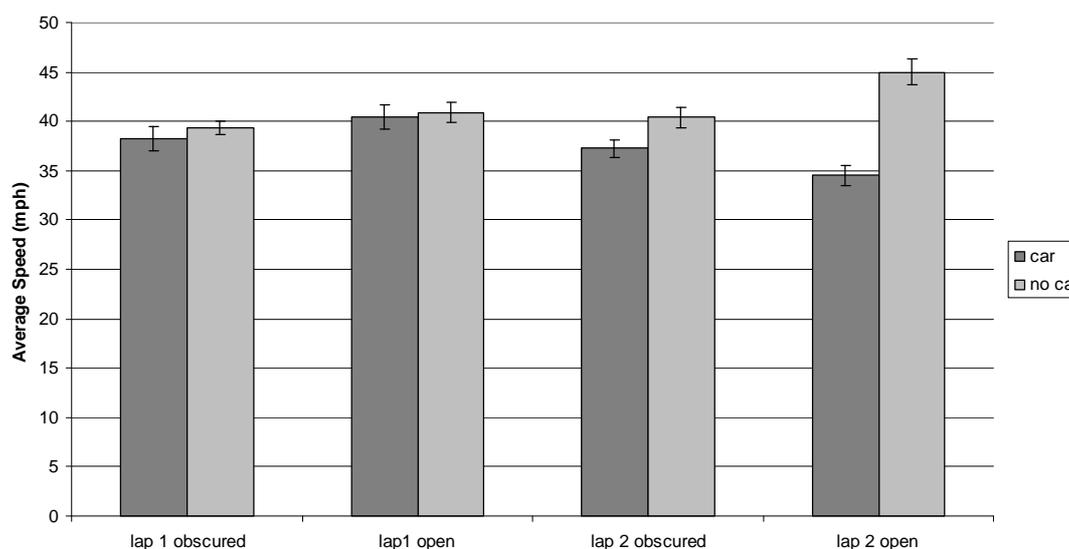
Figure 6.8: Average speed when approaching obscured and open junctions, with and without an approaching car during Lap1 and during Lap 2

Simple main effects revealed that riders approached junctions where a car pulled up more slowly than junctions with no car present, but only on the second lap. This was significant for both obscured junctions ($p<0.01$) and open junctions ($p<0.001$), although the difference was much greater for open junctions. On Lap 1, riders were significantly slower when approaching obscured junctions than when approaching open junctions, regardless of whether or not a car was pulling up ($p<0.05$). On Lap 2, riders were also slower approaching obscured junctions, but only when there was no car pulling up ($p<0.001$). At junctions were a car pulled up on Lap 2, riders were slower when approaching open junctions ($p<0.001$). Since the approaching car was visible earlier at open junctions, the results are likely to be a reflection of riders reducing their speed earlier when approaching these junctions. Finally, simple main effects analysis revealed that, when approaching open junctions where a car pulled up, riders were significantly slower on Lap 2 than on Lap 1 ($p<0.001$). However, when approaching open junctions where a car did not pull up, riders were significantly faster on Lap 2 than on Lap 1 ($p<0.01$).

Lateral Position - there was a main effect of rider group [$F_{(2,57)} = 8.898$, $p<0.001$], which showed that IAM riders rode significantly closer to the centre-line (mean = -3.87ft) than Novices (mean = -5.10ft). The Experienced riders (mean = -4.50ft) did not significantly differ from either the IAM or Novice group. There was also a main effect of lap [$F_{(1,57)} = 13.760$, $p<0.001$]. Riders were positioned closer to the centre-line in Lap 2 (mean = -4.28ft) than in Lap 1 (mean =-4.70ft). A main effect of junction type [$F_{(1,57)} = 40.775$, $p<0.001$] suggested that riders were closer to the centre-line when they were approaching open junctions (mean = -4.16ft) than when they were approaching obscured junctions (mean = -4.82ft). However, an interaction between junction type and rider group [$F_{(2,57)} = 3.583$, $p<0.05$] revealed that only the IAM-trained and, to a lesser extent, Novices, illustrated this effect (Figure 6.9). Furthermore, when junctions were obscured, the IAM riders were positioned closer to the centre-line than Novices ($p<0.01$), but were not significantly different from the Experienced riders. However, when junctions were open, the IAM riders were positioned closer to the centre-line than both the Novice ($p<0.001$) and the Experienced riders ($p<0.05$).
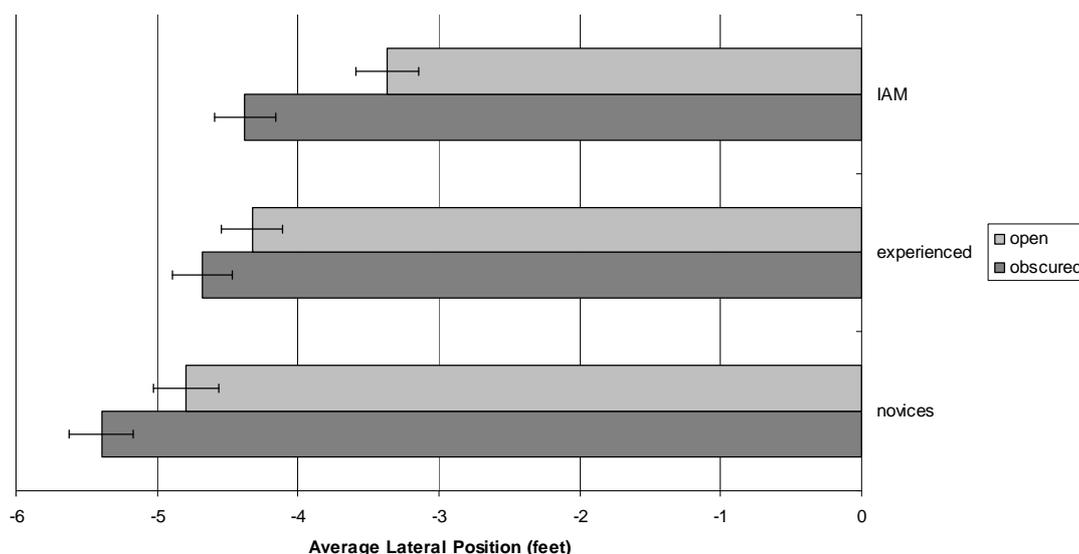
Figure 6.9: Lateral position of riders approaching open and obscured junctions

There was a main effect of car [F(1,57) = 7.078, p<0.05], which revealed that riders rode closer to the centre-line when approaching junctions where a car pulled up (mean = -4.37ft) compared with junctions where there was no car (mean = -4.61ft). However, there was an interaction between car and lap [F(1,57) = 23.924, p<0.001] and an interaction between car x lap x rider group [F(2,57) = 12.283, p<0.001] as shown in Figure 6.10. Simple main effects analysis revealed that on Lap 1, IAM riders rode closer to the centre-line than both the Novices (p<0.001) and the Experienced riders (p<0.01), but only when approaching junctions where a car pulled up. On Lap 2, IAM riders rode closer to the centre-line than both Novice (p<0.001) and Experienced riders (p<0.01), but only when approaching junctions with no car.
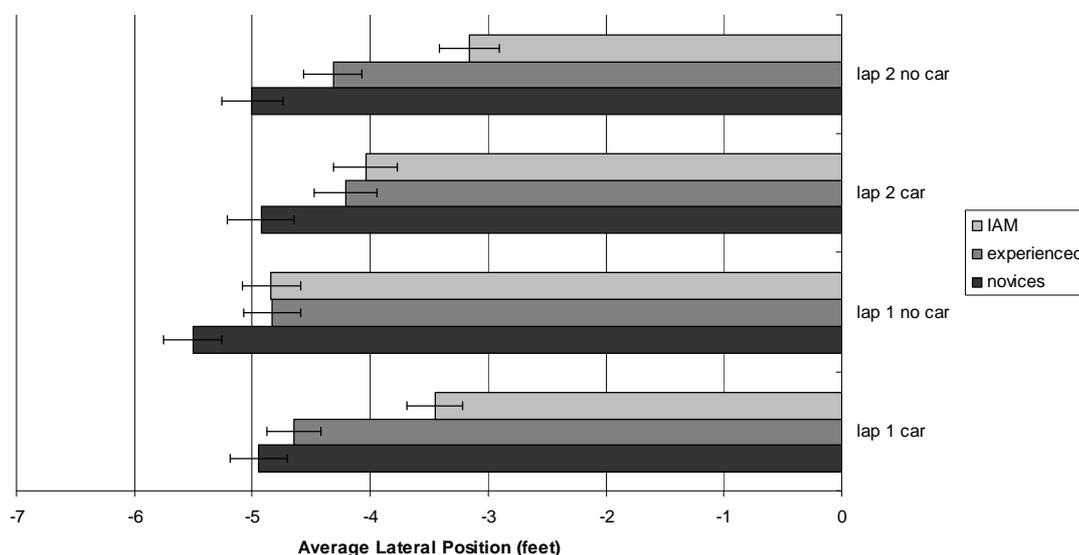
Figure 6.10: Lateral position of riders approaching junctions with and without approaching cars during laps 1 and 2

Novices also showed an interesting sensitivity to the presence of cars in the side roads. On Lap 1 they were positioned closer to centre-line when a car pulled up in the side road, compared to their position when passing an empty side road [F(1,18) = 7.817, p<0.05]. In Lap 2 however, regardless of whether a car was present or not, they adopted the same position as in Lap 1 when a car was present. This suggests that on Lap 2 they approached empty side roads with the same degree of caution as side roads

that contained a car. It is possible that this sensitisation to side roads was evoked by the car hazard they experienced between the Lap 1 and Lap 2 side roads.

There was no effect of car presence for Experienced riders, but, as with the Novices, they also rode closer to the centre-line on Lap 2 than on Lap 1 when approaching junctions with no car [$F(1,20) = 5.221$, $p<0.05$]. IAM riders rode closer to the centre-line when a car pulled up in Lap 1 [$F(1,19) = 37.714$, $p<0.001$], but on Lap 2 they rode closer to the centre-line when there was no car present [$F(1,19) = 13.382$, $p<0.01$]. Furthermore, at junctions with no car, IAM riders rode closer to the centre-line on Lap 2 than on Lap 1, but at junctions where a car pulled up, IAM riders actually rode further from the centre-line on Lap 2 than on Lap 1.

Finally, there was an interaction between car x proximity x lap [$F(1,57) = 37.988$, $p<0.001$], which suggested that riders were closer to the centre-line on open junctions than obscured junctions only when a car pulled up and only on the second lap.

Variance in Lateral Position

There was a trend towards an effect of rider group [$F(2,57) = 3.087$, $p=0.053$]. Scheffe tests revealed that this was due to the IAM riders making more lateral movement than the Experienced riders, but this difference was not statistically significant (IAM mean = 1.04ft^2; Experienced mean = 0.52ft^2; $p=0.08$). There was a significant main effect of car [$F(1,57) = 25.880$, $p<0.001$] which showed that riders varied their lateral position more when a car pulled up (mean = 1.16ft^2) than when there was no car (mean = 0.26ft^2).   However, there was also a lap x car x rider group interaction which approached statistical significance [$F(2,57) = 3.120$, $p=0.052$] and is shown in Figure 6.11.
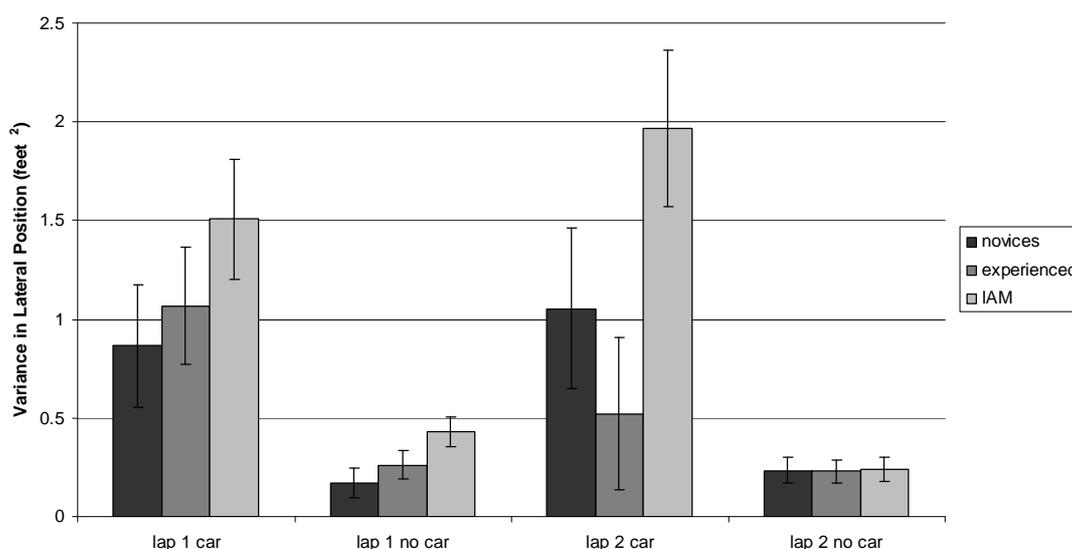
Figure 6.11: Variance in lateral position of riders approaching junctions with and without approaching cars during laps 1 and 2

Simple main effects analysis revealed an effect of rider group only on Lap 2 when riders were approaching junctions where a car pulled up [$F(2,57) = 3.503$, $p<0.05$]. On these junctions, the IAM riders varied lateral position more than the Experienced riders ($p<0.05$) while the Novice riders did not significantly differ from either of the other two groups. All 3 groups of riders varied their lateral position more when approaching junctions with a car than junctions without a car on Lap 1 ($p<0.05$ for Novice and Experienced; $p<0.01$ for IAM), but only the IAM riders did the same on Lap 2 ($p<0.01$). None of the groups of riders showed any significant effects of lap for junctions with cars or junctions without cars.

6.4. Discussion

The results of this sub-scenario show that riders increased their speed on approach to the hazard junction before the car hazard appeared (they were accelerating to the speed limit after having stopped at a red traffic light designed to make sure that all riders started this phase from a stationary point). When the hazard became visible (approximately 218ft before the junction), riders responded by changing their lane position and decreasing their speed. Initially, this decrease in speed was only slight (and statistically non-significant) but as they got nearer to the junction and the car appeared not to decelerate, riders made a significant decrease in speed within the last 100ft. While riders increased speed on approach to the junction, they started to move towards the centre-line between 500 to 400ft and the 400 to 300ft before the hazard appeared. This suggests that riders were exercising caution on approach to the side road by moving towards the centre-line before they chose to decrease speed. This is particularly true of IAM-trained riders who rode closer to the centre-line than the Novices.

Although lateral movement towards the centre-line was initially more gradual riders made a much greater lateral movement within the last 100ft (after the hazard had appeared) in an attempt to avoid a collision with the car. Since there were no statistical interactions with rider group, the results suggest that all three groups responded to the hazard in a similar fashion by braking and adjusting lateral position.

In relation to the other junctions, IAM-trained riders generally approached them more slowly than the other two rider groups. However, this difference was only statistically significant between IAM riders and Experienced riders when the riders were approaching open junctions. Furthermore, Experienced riders were faster on approach to open junctions than obscured junctions, while IAM riders displayed the same level of caution on both types of junction. A similar pattern was found regarding the presence or absence of cars. Experienced riders were significantly faster than IAM riders when no cars were present, but there was no difference between IAM and Experienced riders when approaching junctions containing a car. Whilst all three groups were faster passing junctions with no cars than when cars were present, this difference was much greater for Experienced riders. Therefore, the Experienced riders exercised the same level of caution as the IAM group (with regard to speed) when the junctions were obscured or when there was a car pulling up. However, for open junctions or junctions with no car, the Experienced riders exercised less caution than the IAM riders. This suggests that Experienced riders regarded such junctions as less risky than the IAM riders did. In other words, IAM riders exercised caution regardless of whether they could see a potential hazard or not, whereas Experienced riders only reduced their speed when they could see a potential hazard or if they were not confident that they would be able to see a potential hazard if it was there (i.e. obscured junctions). Interestingly, this effect did not interact with lap, suggesting that the Experienced riders failed to reduce their speed at open junctions, even after the hazard car had pulled out of an open junction.

Whereas the Novice riders did not differ from the IAM riders in terms of speed, the IAM riders rode closer to the centre-line than the Novices. The IAM riders also rode closer to the centre-line than the Experienced riders but only at open junctions. When junctions were obscured, Experienced riders displayed a similar level of caution to the IAM riders, riding closer to the centre-line. Interestingly, all riders tended to position themselves closer to the centre-line when approaching open junctions rather than obscured junctions (although this was only significant for IAM and Novice riders). However, an interaction with car and lap revealed that this effect was greatest when there was a car present (particularly on the second lap), indicating that the effect was largely due to riders noticing cars pulling up earlier, and therefore heading for the centre-line earlier, at open junctions.

After experiencing the car hazard, when approaching empty junctions, all three rider groups positioned themselves closer to the centre-line compared with their positions on Lap 1. However, the Novice and Experienced groups did not modify their behaviour when approaching junctions with a car, since they already approached these junctions closer to the centre-line than empty junctions. This suggests that having experienced the car hazard riders exercised more caution when they could not see a car. Interestingly, when approaching junctions containing a car, the IAM riders were actually further from the centre-line after experiencing the hazard. However, after the hazard, they also increased the variance of their lateral position when approaching junctions containing cars. The reason for this increase in lateral movement is unclear, but it might have been an attempt to reduce motion camouflage. This refers to a specific phenomenon where an object, moving directly towards an observer, may not appear to move at all (Srinivasan and Davey, 1995). It is of great importance to give-way accidents at T-junctions if a car driver at a T-junction is looking down the main carriageway and spots an approaching motorcycle. If the alignment of the motorcycle and the driver is maintained throughout the approach, then the only cue to motion that the driver perceives (at least in the early stages) is an increase in the size of the motorcycle. Normally one would also have optic flow disparities to aid in the detection of motion, but in this case such cues are initially absent, leaving only the cue of retinal expansion (i.e. the expanding size of the image on the retina). Crundall, Humphrey & Clarke (2008) argue that this is a particular problem for relatively small objects such as motorcycles due to the threshold limits of the retinae.

The IAM (IAM, 2009) and Motorcycle Action Group (MAG, 2006) have suggested specific strategies for overcoming motion camouflage. These focus on increasing 'x-motion' (i.e. lateral angular motion) to an observing driver at a junction, by adjusting lateral position slightly, usually towards the centre-line, which will add in additional motion cues beyond mere retinal expansion. It is possible that the increased variance in lane position shown by the IAM-trained riders was such an attempt to use lateral motion to increase their potential visibility to the car driver. Of course the simulator cannot use such cues to determine whether a car should pull out, but it is unlikely that such considerations are uppermost in the minds of riders when negotiating the virtual route.

7. Urban riding

7.1. Introduction

Whilst riding a motorcycle is a risky pursuit (McInally, 2003) and motorcyclists are often killed in collisions with other road users, there is evidence that they, themselves, pose a risk to others (especially pedestrians). Given their power, acceleration and relatively small size and profile on the road, motorcycles may be particularly difficult objects for pedestrians to spot and judge speeds for. Coupled with pedestrians often appearing from behind parked vehicles, giving road users little time to react and often being poorly protected, pedestrians are one of the highest 'at risk' categories of road users. Within the UK, 1,312 pedestrians and cyclists were hit by motorcyclists, of which 21 were killed, and 264 were seriously injured (Department for Transport, 2005). More recent figures within Great Britain in 2009 (Department for Transport, 2010) illustrate that for all accidents involving pedestrians:

- 58% of accidents reported that the pedestrian failed to look properly
- 23% reported the pedestrian was careless, wreckless or in a hurry
- 18% of accidents in which a pedestrian was injured or killed reported that the pedestrian failed to look properly and was careless, wreckless or in a hurry
- 17% of pedestrians failed to judge a vehicle's path or speed
- 16% of accidents occurred when a pedestrian crossed the road from a position masked by a stationary or parked vehicle.

With this focus on pedestrian hazards, it was particularly interesting to investigate any potential differences in rider behaviours and attitudes. In a simplistic manner, looking at purely pedestrian hazards would only illustrate gross differences between the rider groups. In order to investigate how riders perceive pedestrian hazards they were combined with parked vehicles so that any combined effects of pedestrians and vehicles could be identified.

7.2. Method

In this sub-scenario, a straight road section, 6500ft in length, represented urban street scene with shops, streetlights and tall office block on either side of the road. There was a 40mph speed limit sign positioned at the beginning of the sub-scenario.

The sub-scenario began with a 1000ft long section of straight road. This section of road was then followed by four further sections of road that were designed to investigate differences in rider behaviour according to different hazard combinations.

On the first lap, the initial road section was clear of parked vehicles and pedestrians. However, on Lap 2, a female pedestrian stepped out from between two cars parked on the left-hand side. The point at which the pedestrian walked out was 500ft away from the 40mph speed limit sign. The pedestrian was triggered to start moving when the rider was 2 seconds away (based on the rider's current speed) and moved at a constant speed of 4.8mph. This meant that a rider positioned on the centre-line of the road travelling at the speed limit would not hit the pedestrian. Furthermore, for a rider travelling near the centre-line at the speed limit, the pedestrian was visible from 116ft away (Figure 7.1). However, for riders who positioned themselves nearer to the kerb and/or rode above the speed limit, the pedestrian was visible for a shorter amount of time, leaving the rider with less time to plan and execute an appropriate response.

Figure 7.1: Rider view of shopping area hazard

Two variables were investigated in this sub-scenario:
- Pedestrians walking along the pavement (present or not present)
- Parked vehicles on left-hand side of the road (present or not present)

As a result a 2x2 matrix was developed based on the presence of pedestrians and/or parked vehicles. This is represented in Table 7.1.

	Pedestrians (present or not present)	
Parked vehicles (present or not present)	No pedestrians or parked vehicles	Pedestrians only
	Parked vehicles only	Pedestrians and parked vehicles

Table 7.1: 2x2 matrix of characteristics for the shopping area

The sections were arranged in the following order: pedestrians only; parked vehicles only; no pedestrians or parked vehicles; and pedestrians and parked vehicles (Figure 7.2). Each section was 1000ft long and did not contain any hazards on either Lap1 or Lap 2. However, measures were taken for these sections on both laps to investigate if riders modified their behaviour after the initial hazard on Lap 2.

Figure 7.2: Rider view of pedestrians and parked vehicles in the shopping area

Rider behaviour shopping sub-scenario was analysed in 2 different ways:
- **Responses to the hazard -** measures were calculated across five distance bins from the hazard (i.e. 250ft to 200ft, 200ft to 150ft, 150ft to 100ft, 100ft to 50ft, and 50ft to 0ft). This was analysed using a 3x5 mixed ANOVA with rider group as the between groups variable and distance bins as the within groups variable.
- **Modification of behaviour** – average speed, average lateral position and variance in lateral position was analysed using a 3x2x2x2 mixed ANOVA with rider group as a between measures variable and lap (Lap 1 vs. Lap 2), presence of pedestrians (pedestrians vs. no pedestrians), and presence of parked cars (parked cars vs. no parked cars) as within measures variables.

7.3. Results

7.3.1. Response to hazard

> **Within the distance analysed, all three rider groups moved closer to the centre-line of the road as they approached the hazard.**
>
> **Experienced riders reduced their speed more sharply than the other rider groups as they got closer to the hazard.**
>
> **Experienced riders reduced their speed and changed their lateral position early in the approach to the hazard and then when they were very close to the hazard.**
>
> **IAM riders were generally travelling at a lower speed than the other rider groups.**
>
> **Novice and IAM riders changed their lateral position throughout their approach to the hazard.**
>
> **IAM riders generally rode closer to the centre-line than the other rider groups.**
>
> **Although the Experienced and IAM riders were initially positioned similarly, the IAM riders moved towards the centre-line more than the Experienced riders on approach the hazard.**
>
> **Riders tended to make much more lateral movement when they were less than 50ft from the hazard.**

Average speed - although there was no main effect of rider group, a significant interaction between rider group and distance from hazard was observed [$F(8,232) = 2.982$, $p<0.01$]. Analysis of simple main effects revealed that only the Experienced riders significantly reduced their speeds as they got closer to the hazard [$F(4,80) = 14.508$, $p<0.001$], by reducing their speed between the 250ft/200ft and 200ft/150ft distance bins ($p<0.05$) and between the 100ft/50ft and 50ft/0ft distance bins ($p<0.01$). These findings are illustrated in Figure 7.3.
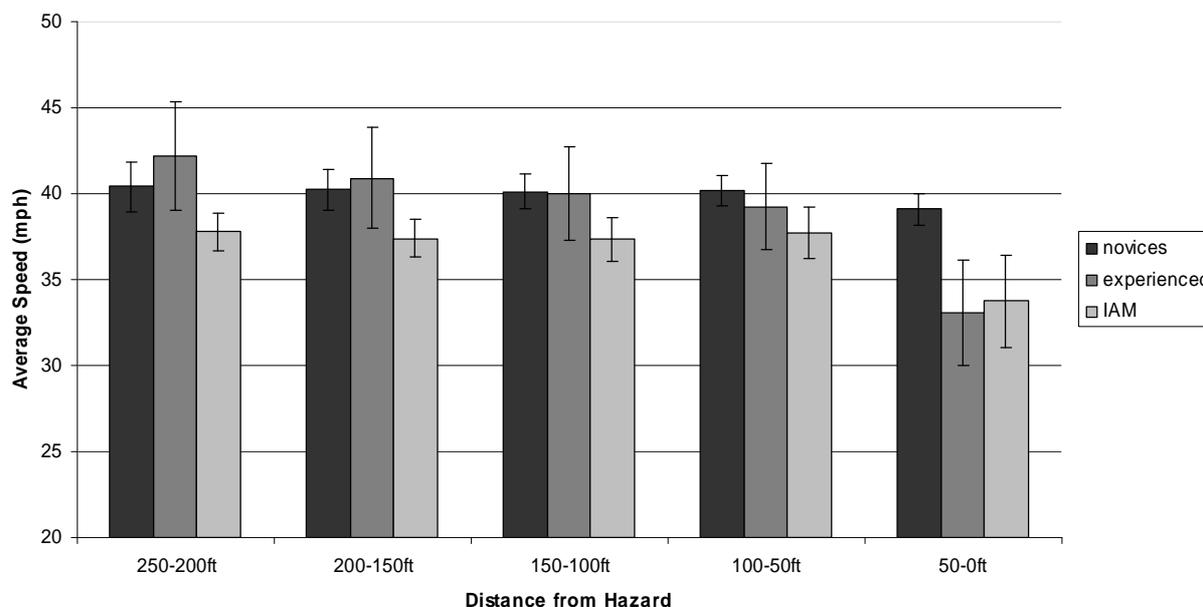
Figure 7.3: Average speed for rider groups approaching the hazard

Lateral Position – a significant main effect was observed for distance from hazard [$F_{(4,232)}$ = 126.575, $p<0.001$]. Repeated contrasts revealed that there were significant changes in lateral position between all five distance bins (mean scores at 250ft/200ft = -4.097ft; 200ft/150ft = -3.564ft; 150ft/100ft = -3.079ft; 100ft/50ft = -2.714ft; 50ft/0ft = -2.031ft; $p<0.001$).

A significant interaction was observed between rider group and distance from hazard [$F_{(8,232)}$ = 3.421, $p<0.01$]. Simple main effects analysis revealed that all three groups of riders changed their lateral position on approach to the hazard:
- [$F_{(4,76)}$ = 33.184, $p<0.001$] for Novice riders
- [$F_{(4,80)}$ = 23.354, $p<0.001$] for Experienced riders
- [$F_{(4,76)}$ = 89.446, $p<0.001$] for IAM riders

However, whilst Novice and IAM riders changed their lateral position between all five distance bins, Experienced riders did not change their lateral position between the 150/100ft and 100/50ft bins). Furthermore, simple main effects analysis revealed group differences for the 100/50ft distance bin [$F_{(2,58)}$ = 3.718, $p<0.05$] and the 50/0ft distance bin [$F_{(2,58)}$ = 3.901, $p<0.05$]. In both cases, the IAM riders were significantly closer to the centre-line than the Novices ($p<0.05$). Repeated contrasts were also carried out to isolate the interaction, which showed that the interaction was only significant between the 200ft/150ft and 150ft/100ft bins ($p<0.05$) and between 150ft/100ft and 100ft/50ft bins ($p<0.01$). Therefore, the interaction illustrated that although the Experienced and IAM riders were initially positioned similarly, the IAM riders moved towards the centre-line more than the Experienced riders on approach the hazard.

Figure 7.4 illustrates the mean lateral position of all three rider groups for the five distance bins. Within the distance analysed, all three rider groups moved closer to the centre-line of the road as they approached the hazard.
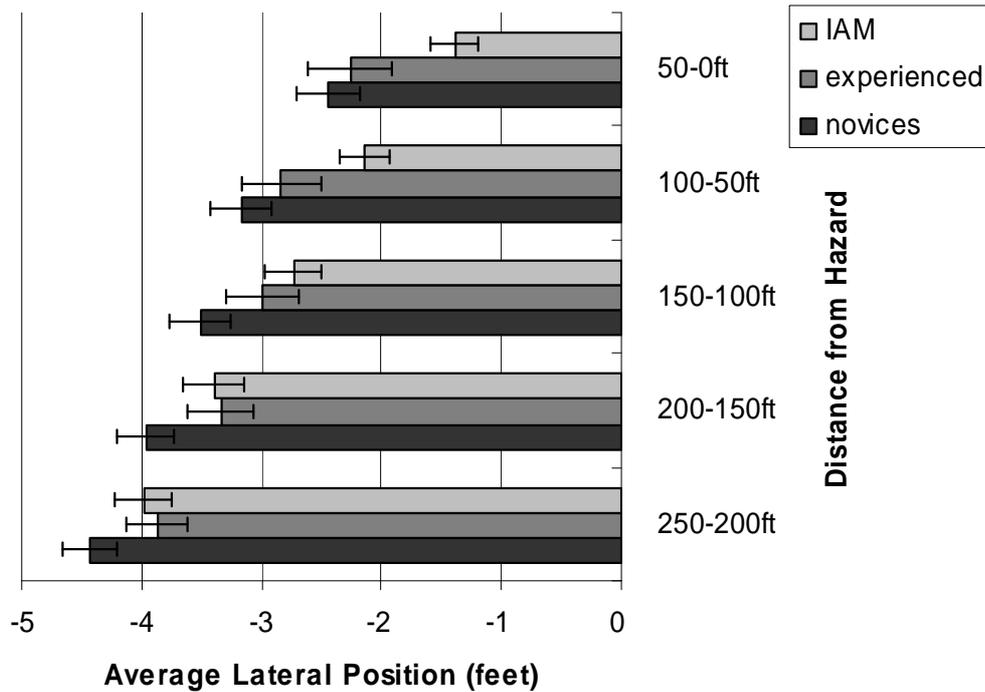
Figure 7.4: Mean lateral position for rider groups approaching the hazard

Variance in Lateral Position – a significant main effect was observed for distance from hazard $[F_{(4,232)} = 17.285, p<0.001]$ but no effects for rider group were observed. Repeated contrasts revealed that there was only a statistically significant change in variance of lateral position between 100ft/50ft and 50ft/0ft from the hazard ($p<0.001$). As illustrated in Figure 7.5, riders made more lateral movement when they were less than 50ft from the hazard.
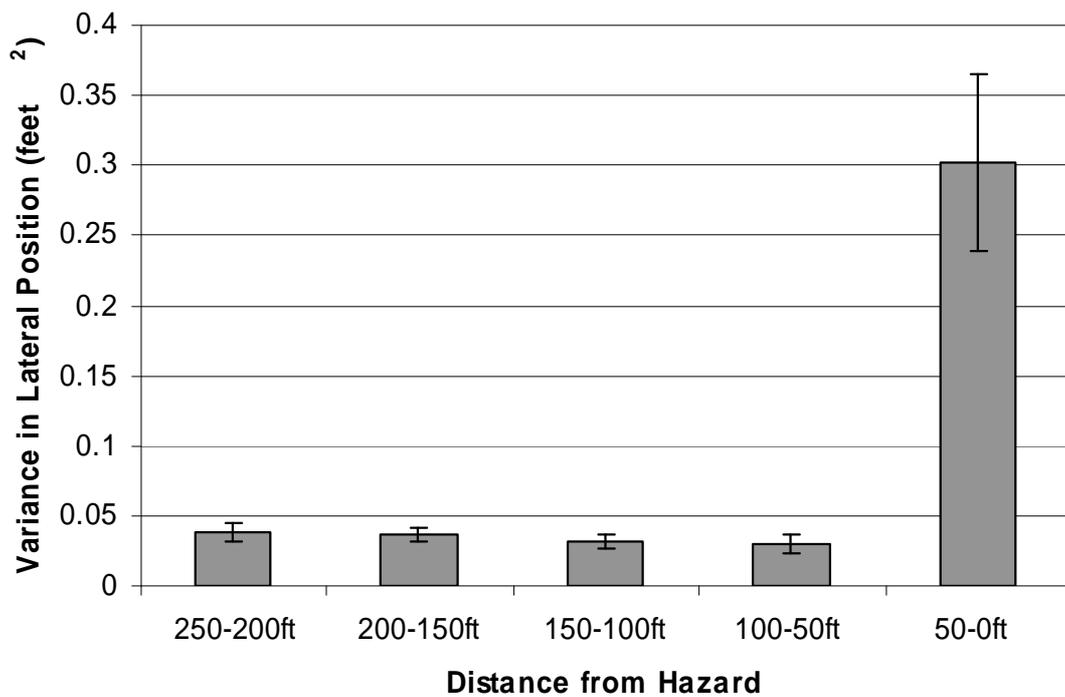
Figure 7.5: Variance in lateral position for the five distance bins

7.3.2. Lap Comparison

> **In this study, motorcyclists rode faster when pedestrians were present and slower when parked cars were present.**
>
> **On Lap 1, participants rode faster when pedestrians were present, regardless of whether there were parked cars.**
>
> **On Lap 2, participants rode faster when there were no pedestrians, but only when there were also no parked cars.**
>
> **Novices rode further from the centre-line than Experienced riders and IAM riders. All rider groups rode closer to the centre-line in Lap 2 (after the hazard) than Lap 1.**
>
> **Riders rode closer to the centre-line when cars were present. IAMs riders rode closer to the centre-line of the road than both the Novice and Experienced riders.**
>
> **Riders rode closer to the centre-line when there were no pedestrians compared to when pedestrians were present.**
>
> **In zones containing parked cars, riders rode closer to the centre-line when pedestrians were absent than when they were present.**
>
> **In zones containing parked cars, participants made significantly more lateral movement when pedestrians were present than when they were absent.**
>
> **In zones containing no parked cars, riders made more lateral movement when pedestrians were absent than when they were present.**

Average speed - there was a main effect for pedestrians [$F_{(1,58)} = 5.241$, $p<0.05$] which revealed that riders were faster when pedestrians were present (mean = 37.95mph) than when there were no pedestrians (mean = 37.36mph). There was also a main effect of cars [$F_{(1,58)} = 29.079$, $p<0.001$], which revealed that riders were slower when there were parked cars present (mean = 36.91mph) and rode faster when no cars were present (mean = = 38.40mph). A 3-way interaction between pedestrians x cars x lap was observed [$F_{(1,58)} = 4.630$, $p<0.05$]. Simple main effects revealed that on Lap 1, participants rode faster when pedestrians were present, regardless of whether there were parked cars [$F_{(1,60)} = 15.008$, $p<0.001$] or no parked cars [$F_{(1,60)} = 6.272$, $p<0.05$]. Also on Lap 1, participants slowed down in the presence of parked cars, regardless of whether there were pedestrians [$F_{(1,60)} = 9.770$, $p<0.01$] or no pedestrians [$F_{(1,60)} = 19.608$, $p<0.001$]. On Lap 2, participants rode faster when there were no pedestrians, but only when there were no parked cars [$F_{(1,60)} = 8.671$, $p<0.01$]. Similarly, participants slowed down when there were parked cars, but only when there were no pedestrians [$F_{(1,60)} = 19.024$, $p<0.001$]. This interaction is illustrated in Figure 7.6.
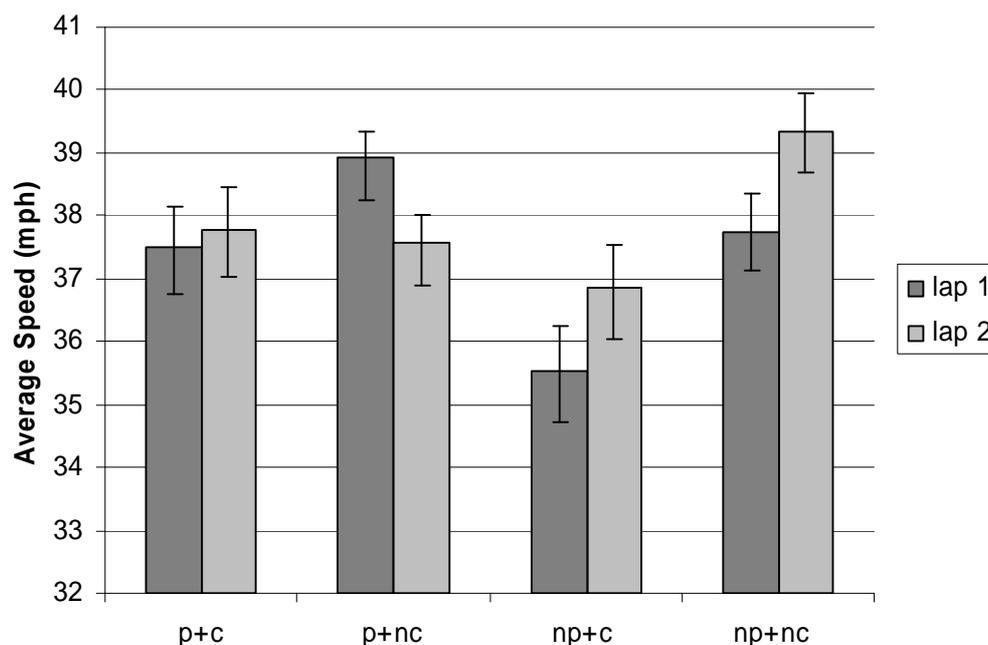
Figure 7.6: Average speed for Laps 1 & 2 in the four shopping area sections
(p+c = pedestrians and cars; p+nc = pedestrians and no cars; np+c = cars and no pedestrians; and np+nc = no pedestrians and no cars).

Lateral Position - there was a significant main effect for rider group $[F_{(2,58)} = 16.572, p<0.001]$. Novices rode further from the centre-line (mean = -3.90ft) than Experienced riders (mean = -3.28ft) and IAM riders (mean = -2.57ft). Scheffe tests revealed significant differences between Novice and Experienced riders (p<0.05); Novice and IAM riders (p<0.001) and Experienced and IAM riders (p<0.05). There was also a significant effect of lap $[F_{(1,58)} = 14.082, p<0.001]$, which showed that riders rode closer to the centre-line in Lap 2 (mean = -3.11ft) than in Lap 1 (mean = -3.39ft).

A main effect was also observed for cars $[F_{(1,58)} = 290.475, p<0.001]$, which illustrated that riders rode closer to the centre-line when cars were present (mean = -2.45ft) than when there were no parked cars (mean = -4.05ft). However, there was also an interaction between rider group and car $[F_{(2,58)} = 4.856, p<0.05]$. Simple main effects analysis revealed that rider group was significant when cars were present and when cars were absent (p<0.001). Scheffe tests revealed that when cars were present, IAMs riders (mean = -1.72ft) rode closer to the centre-line of the road than both the Novice (mean = -2.95ft; p<0.001) and Experienced riders (mean = -2.67ft; p<0.01). There was no significant difference between Novice and Experienced riders when cars were present (p=0.542). In contrast, when there were no parked cars, both Experienced riders (mean = -3.88ft) and IAM riders (mean = -3.43ft) rode closer to the centre-line of the road than Novice riders (mean = -4.84ft; p<0.01 for Novices vs. Experienced; p<0.001 for Novices vs. IAM), but there was no significant difference between Experienced and IAM riders (p=0.231). This interaction is illustrated in Figure 7.7.
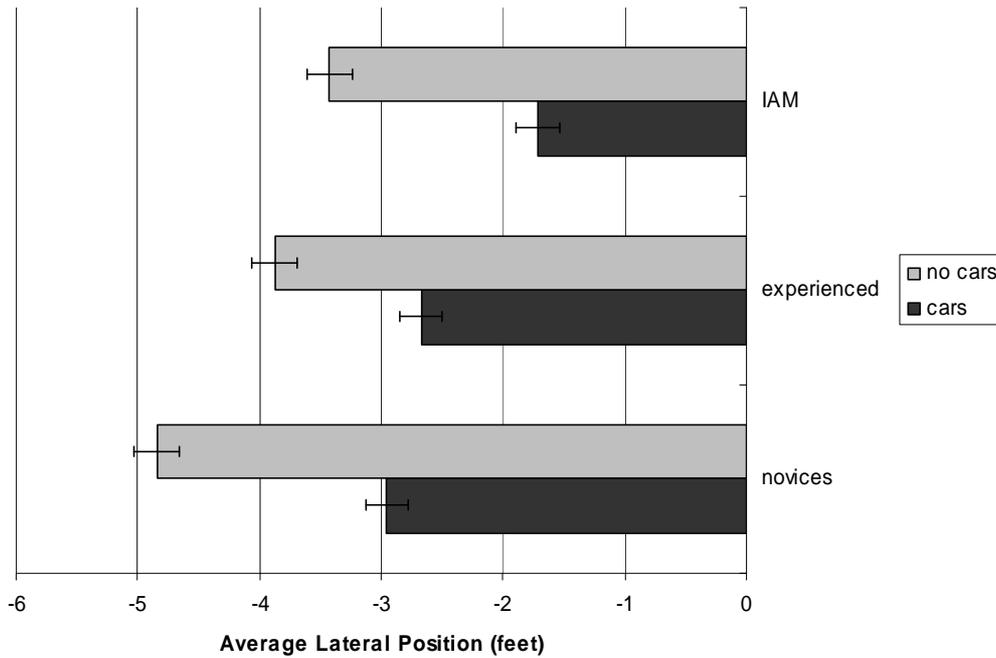
Figure 7.7: Lateral position of rider groups for cars and no cars present

A significant effect was observed for pedestrians [$F_{(1,58)}$ = 23.516, $p<0.001$] illustrating that riders rode closer to the centre-line when there were no pedestrians (mean = -3.10ft) than when pedestrians were present (mean = -3.40ft). However, there was also an interaction between pedestrians and parked cars [$F_{(1,58)}$ = 22.185, $p<0.001$]. Simple main effects analysis revealed that when there were no parked cars, there was no difference in the lateral position between the rider groups. However in zones containing parked cars, riders rode closer to the centre-line when pedestrians were absent (mean = -2.14ft) than when pedestrians were present (mean = -2.76ft; $p<0.001$). Simple main effects analysis also indicated that riders rode closer to the centre-line in the presence of parked cars in both pedestrian and no-pedestrian zones ($p<0.001$). This interaction is illustrated in Figure 7.8.
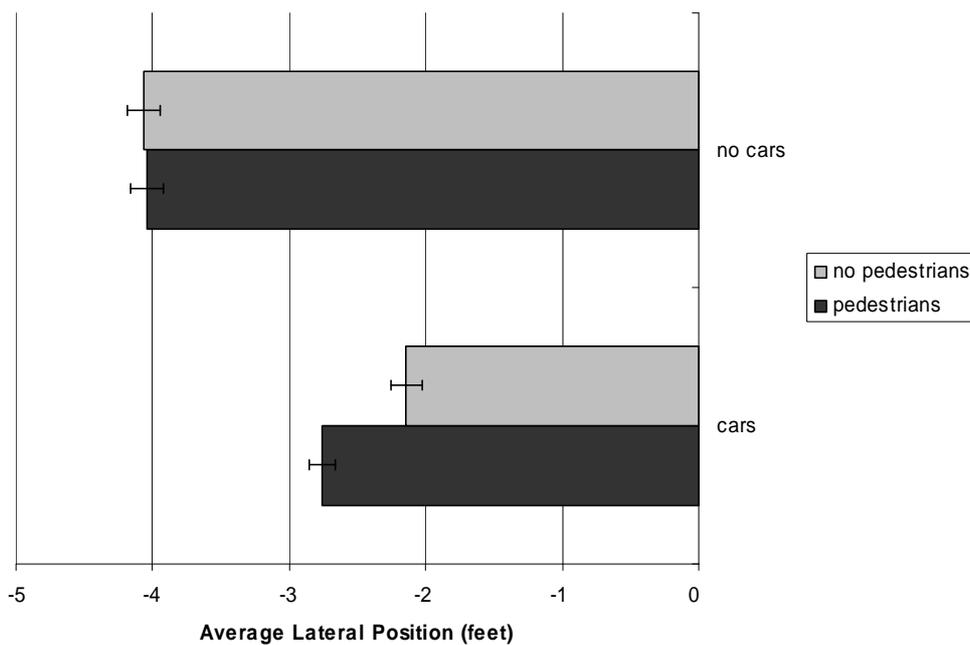
Figure 7.8: Lateral position of rider groups for pedestrian and cars

Variance in Lateral Position – a significant interaction was observed between cars and pedestrians [$F(1,58) = 26.866$, $p<0.001$]. Simple main effects analysis revealed that in zones containing parked cars, participants made significantly more lateral movement when pedestrians were present (mean = 0.71ft^2) than when pedestrians were absent (mean = 0.50ft^2; $p<0.01$). However, in zones containing no parked cars, riders made more lateral movement when pedestrians were absent (mean = 0.94ft^2) than when pedestrians were present (mean = 0.47ft^2; $p<0.001$). Furthermore, in zones containing pedestrians, riders made significantly more lateral movement in the presence of parked cars ($p<0.01$), while in non-pedestrian zones riders made significantly more lateral movement in the absence of parked cars ($p<0.001$). This interaction is illustrated in Figure 7.9.
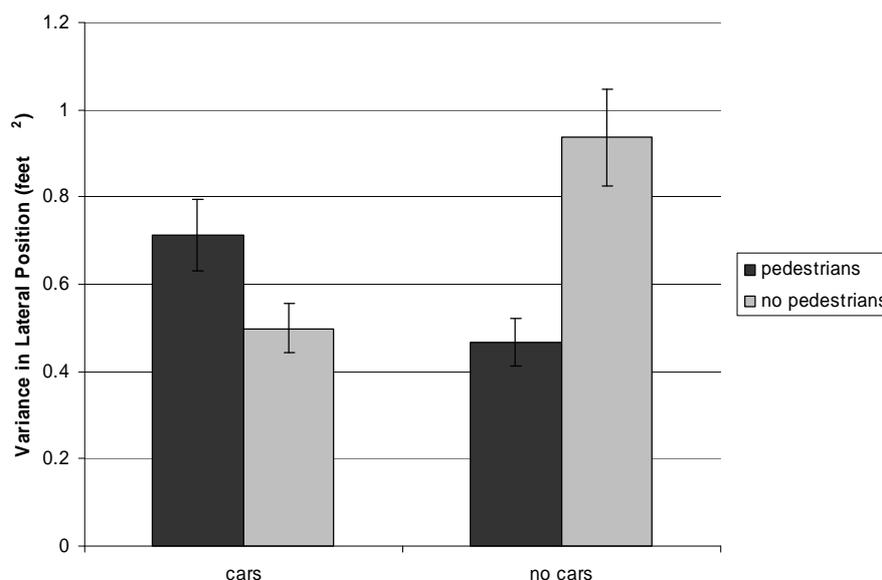
Figure 7.9: Variance in lateral position of rider groups for pedestrians and cars

7.4. Discussion

As all three rider groups approached the hazard, they tended to move closer to the centre-line of the road, but their general avoidance behaviours were different. In relation to average speed, Experienced riders reduced their speed more sharply than the other two rider groups as they got closer to the hazard. Whether they were unaware of the potential hazard or reacted later by braking harder is unclear. The Novice riders did not respond to the hazard by reducing their speed as dramatically but appeared more likely to swerve away from the hazard in the final moments before impact. Across all three rider groups, the IAM-trained riders appeared to have the most advantageous strategy. They did not need to reduce their speed as much as the other groups as they were already riding more slowly (albeit not significantly). Whether they anticipated the hazard or not they were already riding more defensively in the urban environment.

Experienced riders reduced their speed and changed their lateral position early in the approach to the hazard and then when they were very close to the hazard. They appeared to react early and/or respond later than the other rider groups. IAM riders generally rode closer to the centre-line than the other rider groups and were therefore better placed to see the hazard and make minor adjustments to their lateral position and speed in order to avoid the hazard. They continued to move towards the centerline (the opposite lane had no oncoming traffic) in an apparent attempt to put as much space between them and the primary hazard (pedestrian crossing the road). This is illustrated in Figure 7.10.
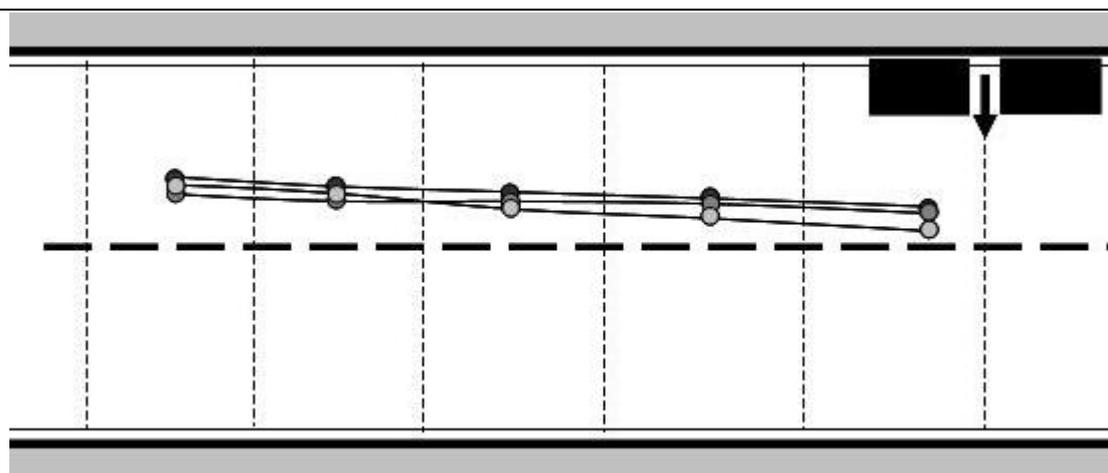
Figure 7.10: Lateral position plot as riders approach the pedestrian hazard
(the same colour coding is used as in the graphs with Novices as the darkest markers, Experienced riders as the mid-tone markers, and IAM-trained riders and the lightest markers)

Novice and IAM riders changed their lateral position throughout their approach to the hazard. Although the Experienced and IAM riders were initially positioned similarly, the IAM riders moved towards the centre-line more than the Experienced riders on approaching the hazard. Riders tended to make much more lateral movement when they were less than 50ft from the hazard. The nature of the hazard was dynamic, in that the pedestrian became visible and then proceeded to across the road. This late deviation in lateral position could have been a responsive mode to the hazard rather than a late awareness of the hazard.

In this study, motorcyclists rode faster when pedestrians were present and slower when parked cars were present. It may have been that they perceived the cars as more of a hazard (e.g. pulling out or opening doors) than the pedestrians who mainly walked along the pavement in a uniform manner (e.g. they did not randomly cross the road).

On Lap 1, participants rode fastest when pedestrians were present, regardless of whether there were parked cars. On Lap 2, participants rode fastest when there were no pedestrians or parked cars. Coupled with the previous findings, this would seem to indicate that the sample of motorcyclists in this study perceived the cars to be more hazardous than the pedestrians. However, after having had the hazard encounter with the pedestrian crossing the road, all rider groups altered their behaviour by riding slower than they had previously. This could indicate an effect for the pedestrian hazard that occurred, leaving riders aware of the danger of pedestrians and cars, so that when neither were present, they felt able to ride faster.

Novices rode further from the centre-line than Experienced riders and IAM riders. All rider groups rode closer to the centre-line in Lap 2 than Lap 1. This supports the idea that some form of adaptive behaviour occurred after the hazard.

An interesting finding was that riders rode closer to the centre-line when there were no pedestrians than when pedestrians were present. Whilst it may have been expected that riders would try to keep a distance from pedestrians, this may reflect a limitation of the scenario as programmed pedestrians in this scenario moved along the pavement in a uniform manner. With pedestrians moving in a random fashion or with others crossing the road further ahead of the rider, this may have been more ecologically valid. In zones containing parked cars, riders rode closer to the centre-line when pedestrians were absent than when pedestrians were present. This may have indicated a concern that unseen pedestrians (such as the pedestrian hazard) may be more salient than pedestrians that are in view.

There were some clear effects that arose when parked vehicles were present. Riders made significantly more lateral movement when pedestrians were present than when pedestrians were absent which could indicate that the combined aspects of pedestrians and parked cars prompted more use of the lane to move out from cars to get a better view of any pedestrians that might be about to cross the road. In zones containing no parked cars or pedestrians, riders made more lateral movement than compared to when pedestrians were present.

Riders rode closer to the centre-line when cars were present. Again, it must be noted that no opposing traffic was present so this effect may not have occurred to the same degree if other traffic was present. More specifically, IAM-trained riders rode closer to the centre-line of the road than both the Novice and Experienced riders. It would appear that advanced training provides benefits to riders in an urban environment by raising their awareness of potential hazards so that they ride more defensively. The IAM riders were, therefore, in a better position to see and respond to the hazard. This finding would seem to support other research into experience and professionally trained drivers. In a study of 54 police trained drivers and a sample of 56 non-police trained drivers, results indicated that police drivers reduced their speed on approach to pedestrians at the roadside and adopted a more central lane position compared with non-police trained drivers on urban roads (Dorn & Barker, 2005).

8.   Bends with barriers

8.1. Cue salience in driving

Investigation of vision in the natural world has shown that the pattern and duration of eye fixations are highly specialized according to the specific situation. For instance, Land and Lee (1994), in a study of car steering and eye fixations, found that drivers regard the 'tangent point' on the inside a curve as particularly salient, and seek this point 1 to 2 seconds before entering the bend, then returning to it throughout the bend as they steer through it.

Shinoda, Hayhoe & Shrivastava (2001) have argued that visual saliency in driving operates in a 'top-down' fashion (i.e. saliency is driven by expectations). They examined drivers' abilities to detect 'Stop' signs in a virtual environment when the signs were visible for restricted periods of time. Detection of these signs was heavily modulated by the local visual context. They suggested that visibility of the signs required active search, and that the frequency of this search was influenced by learnt knowledge of the probabilistic structure of the environment. Participants more reliably fixated on the signs at intersections, even though they were presented for a restricted period, than they did when the signs were presented 'mid-block'. Saliency therefore applies to schemas or mental models of the environment, by looking for features that are expected in certain contexts. Related to this is change blindness where people often find it hard to discern changes in the visual field even if they are obvious in retrospect.

Driving simulator research has focussed on the saliency of 'edge rate' information (i.e. objects appearing close to the road edge in a moving scene). Van der Horst and de Ridder (2007) conducted a driving simulator study that incorporated roadside features including trees, guardrails, barriers, panels, and emergency lanes. They found that drivers tended to move away laterally from safety barriers on first approach, and that they also slowed down. The type and size of a safety barrier appeared unimportant; the presence of any barrier caused the effect. Trees were not found to affect the speed of the driver unless they were close (approximately 2m) to the road edge on a rural road, and this effect faded rather quickly. There was no influence on driver speed if the trees were more than 4.5m from the lane edge. Van der Horst and de Ridder commented that as drivers did not adjust their behavior, they possibly did not perceive trees to be dangerous, however this actually made trees potentially more dangerous as drivers ignored them.

8.2. Optic flow and simulators

The relative angular speed of objects during forward movements changes with their distance from the observer. This optic flow provides information about absolute distance to an object and travel speed. Optic flow has been shown to be a reliable cue to estimate distance of travel as participants can be very accurate (with an overall error of less than 3%) in discriminating travel distances (Bremner & Lappe, 1999). Similarly, it has been demonstrated that humans can use optic flow to estimate distance travelled when appropriate scaling information is provided (Redlick, Jenkin & Harris, 2001). However, it has also been illustrated that people can sometimes overestimate distances traveled when velocity is constant or if acceleration is below 0.1m/s (Redlick, Jenkin & Harris, 2001).

In a study using a dynamic driving simulator with a large field of view, subjective speed perception and the lack of dashboard information was investigated (Kemeny & Paneral, 2003). The results indicated that subjective speed perception in full scale driving simulators were highly correlated (r=0.88) to real road conditions. From this it was reasoned that as driver and environmental object speeds determine velocities in the optic flow pattern, knowledge of road markings or other scale factors (such as roadside furniture or trees, for instance) help drivers make good estimates of speed (Kemeny &

Paneral, 2003). In related phenomena, psychophysical studies on motion perception have shown that observers can underestimate speed when image contrast, texture or luminance are reduced and these same mechanisms might lead to underestimations of driving speed in foggy weather or during night driving (Kemeny & Paneral, 2003).

Shrivastava, et al, (2005) investigated the influence of reduced spatial structure from the flow field on perceived speed in a virtual driving environment. In order to examine the effects of reduced spatial structure they removed road texture and line markings, and changed the density of roadside objects. These experimental manipulations substantially reduced the accuracy of speed perception, both in an immersive environment with a head mounted display, and when participants simply viewed the scene on a monitor display. It was argued that the change in the visual field from which optic flow information was available was at least partially responsible for reduced ability to judge speed of self-motion and that optic flow plays a substantial role in judgments of speed of self-motion in the natural environment (Shrivastava, et al, 2005).

Human factors experts and psychologists have known for some time that the closer roadside elements are to the side of the roadway, the faster they appear to be travelling in a driver's peripheral vision (Fuller & Santos, 2002). This increased flow of visual stimuli increases the subjective perception of speed and encourages the driver to slow down (Charlton, 2004). Narrow roads or a hedgerow by the roadside can induce an exaggerated sense of speed, whereas situations with reduced edge-rate information, such as open highways with broad lanes and high verge widths can decrease the sense of speed (Charlton, 2004). Perceptual countermeasures such as simulated peripheral hatching and pedestrian refuges (Jamson, Lai & Jamson, 2010) function at an implicit or automatic level in the sense that drivers need not explicitly attend to them or consider their meaning in order for them to be effective (Charlton, 2004; Lewis-Evans and Charlton, 2006).

8.3. Introduction

In order to investigate aspects of optic flow, the main riding scenario comprised a sub-scenario of bends with barriers in which the outer edge of the bend had different furniture characteristics. It was hypothesized that with furniture closer to the roadside, optic flow would be increased and this would affect rider behaviour. In this sub-scenario, cue salience was manipulated across natural and man-made barriers (such that riders may have perceived the Armco barrier as more salient because it had been put there for a reason, rather than trees naturally occurring in a rural landscape).

Clarke, Ward & Bartle (2010) analysed over 1000 fatal road collisions and one of the patterns to emerge was that the majority of collisions involving young drivers were categorized as a loss of control on bends. This reinforces an earlier finding that the most common motorcycle accident, where the rider was to blame, involved loss of control on a bend (Clarke, et al, 2007).

When negotiating bends, there is evidence to suggest that car drivers make extensive use of the tangent point to guide their steering (Land & Lee, 1994). Encouraging drivers to stare at the tangent point may even promote smoother steering (Mars, 2008). On this basis the furniture on the outside of a UK left-hand bend is unlikely to receive many direct glances from a driver. However drivers also make use of peripheral vision in maintaining steering (Land & Horwood, 1995) and the extent to which drivers can extract peripheral information from a driving scene is dependent upon driving experience (Crundall, Underwood & Chapman, 1999; 2002). On this basis, it is possible that motorcyclists may attend to the outside road furniture through peripheral vision.

Previous evidence has reported that drivers underestimate the curvature of tight bends (Fildes & Triggs, 1985; Milleville-Pennel, et al, 2007). This may be due to a failure to extract pertinent information prior to the bend. Milleville-Pennel, et al, (2007) suggest that while the tangent point may provide useful information once inside the bend, very

little pertinent information is available prior to entering. This means that riders, who might be travelling relatively fast, might be unable to prepare for the curvature of a bend in advance.

One other possibility that relates to curvature perception is the possibility that drivers or riders fail to appropriately appraise the level of risk presented by the bends. The theory of risk homeostasis suggests that if perceived risk is lower than one's preferred level of risk, then the driver or rider might increase the risk associated with their actions to ensure optimum arousal (Wilde, 1998; 2001). If risk is too high, an individual might seek to alter their behaviour to reduce the danger associated with a task; if it is not high enough, an individual might look for ways to stimulate more risk. If information regarding the level of risk a bend might pose is not available until the rider has entered the bend, it might be too late to change the behavior without negative consequences (e.g. braking on a bend).

One potential source of guidance to curvature is the placement of outside bend furniture. Any roadside furniture will generate additional optic flow that may provide guidance for a car driver (De Ridder, et al, 2006). For a motorcyclist however, any guidance information might be outweighed by the increased risk of collision. To assess the impact of different furniture on the three rider groups, trees and Armoc barriers were compared. Furthermore, the distance of roadside furniture was investigated as the proximity of the furniture might improve guidance through additional optic flow information, but it could also increase the risk of collision and injury.

De Ridder, et al's, study (2006) is perhaps the closest to the current sub-scenario. De Ridder used car drivers in a Dutch driving simulator navigating a series of curves with different road furniture (varying the proximity of different types of furniture to the road edge). Their study revealed that the proximity of bend furniture had a slowing effect on speed, and drivers tended to position themselves further away from close-proximity furniture. However there were very few effects due to the presence of trees per se. In fact they concluded that "trees along the road do not seem to influence driving behaviour that much and are not considered to be a serious hazard by road users," (De Ridder, et al, 2006, p42). However, the generalisability of these results to a motorcycling population is debatable.

It was predicted that the current study would show that riders have a respect for trees and that proximity would also play a role in moderating rider behaviour. More specifically, it was anticipated that experience and advanced training would also improve sensitivity to external road furniture.

8.4. Method

All 61 participants contributed data to these analyses. This sub-scenario comprised a sequence of four left-hand bends. The speed limit was 60mph. Each of the bends were 700ft long, comprising a 500ft section with constant curvature of 0.0015 (1/radius in feet) preceded by a 100ft entry spiral and followed by a 100ft exit spiral.

The bends were all preceded by a standard warning sign for a left-hand bend ahead. This was positioned 500ft before each bend. Two variables were investigated in this sub-scenario:
•   type of furniture (trees or an 'Armco' style barriers)
•   distance of furniture from the road edge - 'near' (3ft to 5ft) or 'far' (33ft to 35ft)

As a result a 2x2 matrix was developed according to the type of furniture and distance from the outside edge. This is represented in Table 8.1.

Distance from outside edge (near/far)	Type of furniture (trees and Armco)	
	Trees near (3ft to 5ft)	Armco near (3ft to 5ft)
	Trees far (33ft to 35ft)	Armco far (33ft to 35ft)

Table 8.1: 2x2 matrix of characteristics for bends with furniture

The first bend that was encountered contained near trees, the second bend included far Armco barriers, the third bend contained far trees, and the final bend included near Armco barriers. All four bends were encountered twice (once on each lap). All of the bends occurred prior to any of the hazards which followed in the subsequent sub-scenarios on Lap 2. Screenshots of the 4 left-hand bends are shown in Figure 8.1.
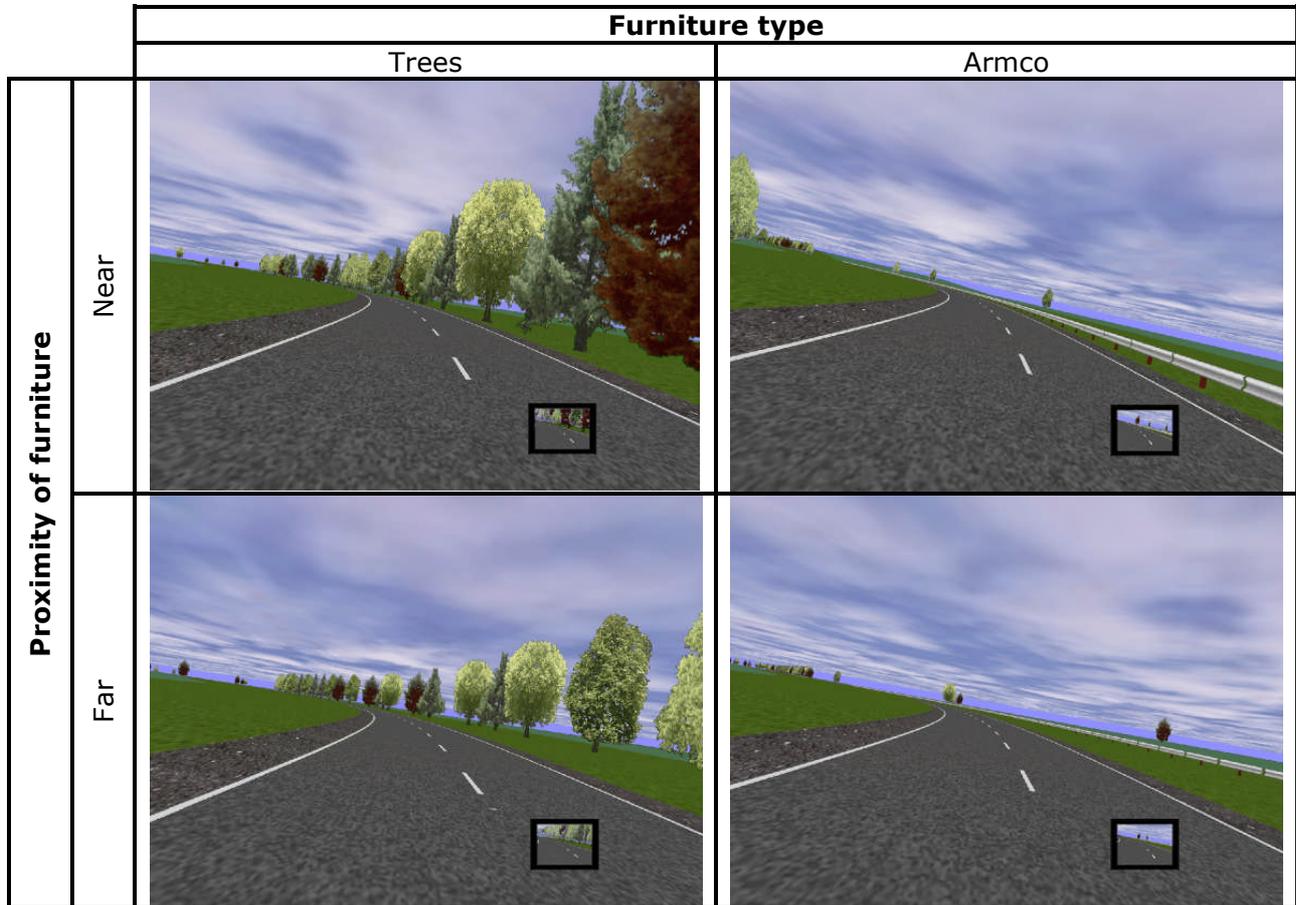
Figure 8.1: Screenshots of the four conditions of left-hand bend

Any effects between the three rider groups (Novice, Experienced and IAM-trained riders) for furniture (tree or Armco), proximity (near or far) and lap number (Lap 1 or Lap 2) were analysed through a series of 3x2x2x2 mixed ANOVAs. These analyses were conducted for measures of average speed, lateral position and the variance in lateral position. Where appropriate, further analyses were conducted in the form of planned comparisons and post-hoc tests.

8.5. Results

8.5.1. Assessing the impact of furniture type and proximity on riding behaviour

> **IAM riders rode faster around the bends than the other rider groups; Experienced riders were generally slowest around the bends.**
>
> **The average speed of all riders was slower when furniture was placed near to roadside, but more exaggerated when trees were placed in close proximity to the roadside.**
>
> **All rider groups rode further from the centre-line when the furniture was near to the roadside, but more so when trees were present on the bends.**
>
> **IAM-trained riders positioned themselves significantly closer to the centre-line than the other rider groups.**
>
> **All rider groups rode closer to the centre-line in Lap 2 than in Lap 1.**
>
> **Riders tended to make more adjustments to their lane position when negotiating bends with barriers close to the roadside. Only the Novice and IAM riders reduced their lateral variance when the furniture was further away. Experienced riders maintained a high level of lane variance regardless of the proximity of the furniture and had a greater variation in lateral position than the Novice riders.**

Average speed - a significant main effect was observed for group [$F(2,58) = 4.90$, $p<0.05$]. Post-hoc analyses revealed that the IAM riders (mean = 55.9mph) negotiated the bends faster than the Experienced riders (mean = 50.4mph; Tukey HSD $p<0.01$), while Novices fell in-between (53.3mph). Furthermore, a significant interaction between rider group and furniture was observed [$F(2,58) = 7.06$, $p<0.01$]. As illustrated in Figure 8.2, IAM-trained riders travelled faster on the bends than either the Novice or Experienced riders.
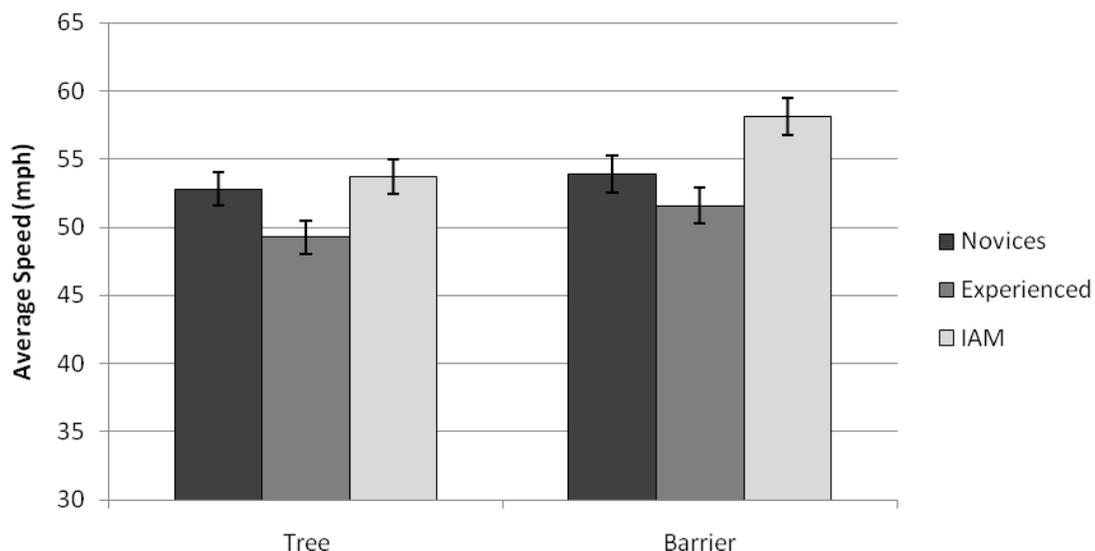
Figure 8.2: Average speed for on bends with barriers across the rider groups

Both the type of furniture on the outside of the bends [F(1,28) = 50.96, p<0.001] and the proximity of the furniture to the roadside produced significant main effects [F(1,28) = 18.74, p<0.001]. These effects were further qualified by a significant interaction between the two [F(1,58) = 21.88, p<0.001]. As illustrated in Figure 8.3, the average speed of all riders was relatively slower for trees than Armco barriers and more exaggerated when trees were placed in close proximity to the bend. This condition resulted in a significant reduction in speed for all riders.
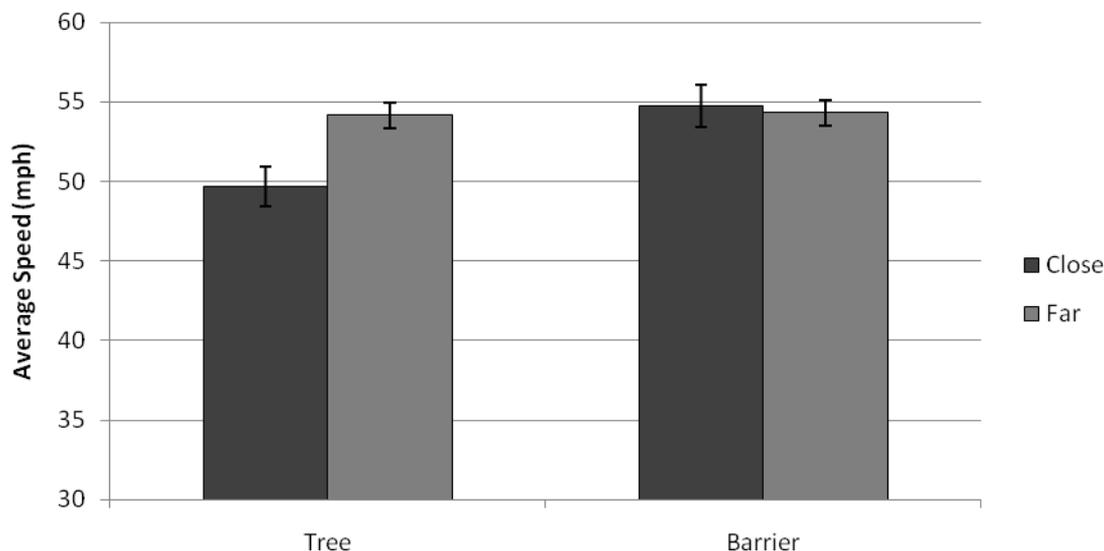
Figure 8.3: Average speed for type and proximity of furniture

A significant main effect was also observed for average speed around the left-hand bends in Lap 1 and Lap 2 [F(1,58) = 4.35, p<0.05], illustrating that riders rode faster around the bends in Lap 2 (mean = 54.19mph) than Lap 1 (mean = 52.58mph). A three-way interaction between rider group, proximity of the furniture to the bend, and lap number was also observed [F(2,58) = 3.18, p<0.05] (Figure 8.4). A series of simple main effect analyses with post-hoc tests compared the three rider groups for each level of the other two factors. When furniture was in close proximity to the bend on Lap 1, IAM riders rode faster than Experienced riders [F(2,58) = 3.22, p<0.05]. With furniture further from the side of the road, on Lap 1, IAM riders again rode faster than Experienced riders [F(2,58) = 2.10, p<0.01]. On Lap 2, close furniture evoked greater speeds in both the Novice and IAM riders compared to the Experienced riders [F(2,58) = 4.32, p<0.05]. However, on Lap 2 when furniture was placed further away from the roadside, by this point the Novice and Experienced rider speeds were close to those of the IAM group, removing any statistical differences.
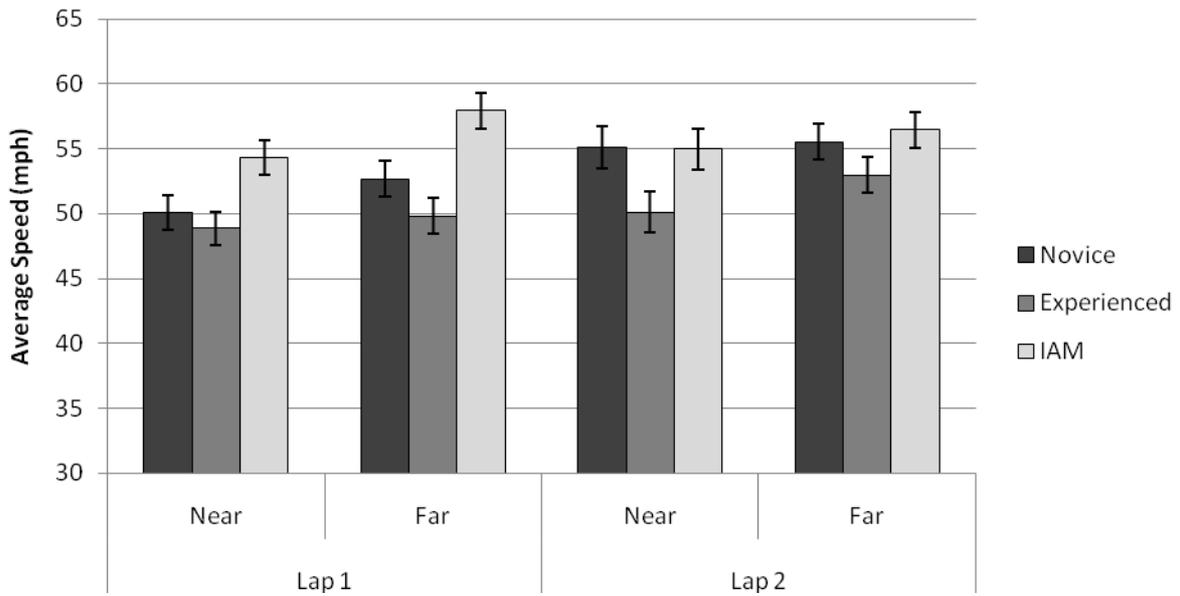
Figure 8.4: Interaction between group, lap and proximity of furniture on average speed

Average lateral position – a significant main effect was observed for furniture [$F_{(1,58)}$ = 7.63, $p<0.01$] indicating that all rider groups rode further away from the centre-line (and therefore further away from the furniture) when trees were present on the bends (mean = -6.31ft) rather than Armco barriers (mean = -6.10ft). A significant main effect for proximity was also observed [$F_{(1,58)}$ = 4.03, $p<0.05$], illustrating that all rider groups rode further from the centre-line when the roadside furniture were near to the roadside (mean = -6.23ft) than when it was placed further from the roadside (mean = -6.13ft). A main effect for rider group was also observed [$F_{(2,58)}$ = 25.19, $p<0.001$] suggesting that IAM riders positioned themselves significantly closer to the centre-line (mean = -4.82ft) than Novice (mean = -7.01ft) or Experienced riders (mean = -6.79ft). Post-hoc tests confirmed that the IAM riders rode closer to the centre-line than Novice riders and Experienced riders ($p<0.001$) (Figure 8.5). Finally, a significant main effect between the average lateral position in Lap 1 and Lap 2 was observed [$F_{(1,58)}$ = 16.29, $p<0.001$], illustrating that riders rode closer to the centre-line in Lap 2 (mean = -6.03ft) than in Lap 1 (mean = -6.39ft).
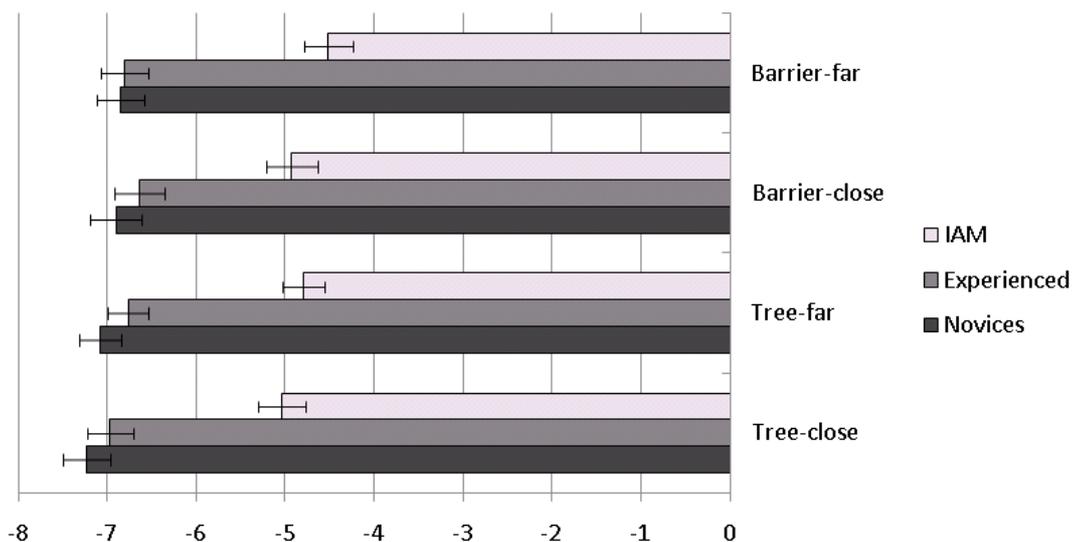
Figure 8.5: Average lateral position across furniture and proximity

Variance in lateral position – a significant main effect of rider group was observed [$F(2,58) = 3.42$, $p<0.05$], illustrating that Experienced riders had a greater variation in lateral position (mean = 0.20ft^2) than the Novice riders (mean = 0.13 ft^2) ($p<0.05$). A significant main effect for proximity was observed [$F(1,58) = 4.86$, $p<0.05$] suggesting that all riders tended to make more adjustments to their lane position when negotiating bends with barriers close to the roadside. A significant interaction between rider group and proximity was also observed [$F(2,58) = 3.53$, $p<0.05$]. As can be seen from Figure 8.6, it was only the Novice and IAM riders who reduced their lateral variance when the furniture was further away. Experienced riders maintained a high level of lane variance regardless of the proximity of the furniture.
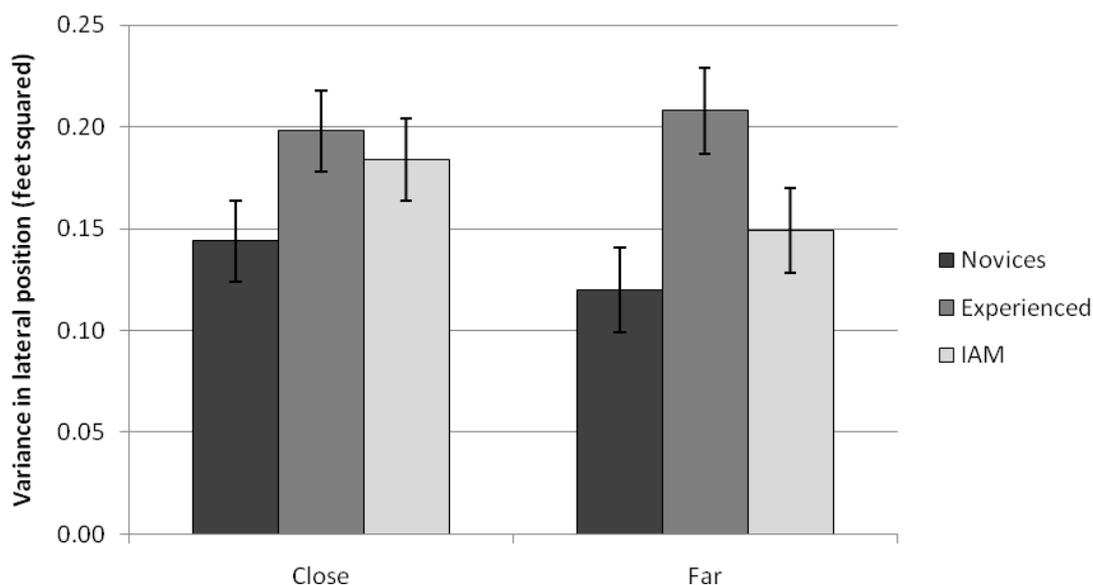
Figure 8.6: Variance in lateral position for proximity of furniture

8.5.2. Assessing the variation of measures within a bend

All riders slowed down into bends and then picked up speed on the way out – the results demonstrated the general advice of 'slow in – fast out'

The different rider groups had different profiles through the bends:
*   **IAM riders tended to be faster throughout the bends**
*   **Novice riders tended to approach bends slowly and build up their speed**
*   **Experienced riders tended approach bends at a similar speed to IAM riders, but slowed down more before building up their speed**

Compared to the Novice or Experienced riders, IAM riders maintained a more central road position through the majority of the bend sub-sections. Their position altered upon exiting the bend and was similar to the other rider groups.

While the above measures provided a comparison of the four different bends of interest, the measures that were analysed reflected data for the whole curve. It was possible however that group differences could be more specific to certain portions of the bends. Analyses were conducted in order to investigate if riders negotiated particular sub-sections of a bend differently. To achieve this, each bend was divided into seven sub-sections. The first and last sections represented the 100ft spirals. Sections 2 to 6 represented the full bend partitioned into equal sectors. In order to analyse any differences between the three rider groups and seven bend sub-sections, a series of 3x7

ANOVAs were conducted on each curve using the dependent measures of speed, lateral position and variance in lateral position. Laps 1 and 2 were examined separately.

Average speed within the bends - a significant main effect was observed when the trees were placed close to the bend [$F_{(6,348)} = 22.84$, $p<0.001$]. Repeated contrasts suggested that average speed differed in bend sub-sections 1 and 2 [$F_{(1,58)} = 10.01$, $p<0.01$], sub-sections 3 and 4 [$F_{(1,58)} = 6.96$, $p<0.05$], sub-sections 4 and 5 [$F_{(1,58)} = 17.76$, $p<0.001$], sub-sections 5 and 6 [$F_{(1,58)} = 36.64$, $p<0.001$] and finally sections 6 and 7 [$F_{(1,58)} = 61.73$, $p<0.001$]. A significant interaction was observed for rider group and bend section [$F_{(12,348)} = 2.46$, $p<0.01$] (Figure 8.7).
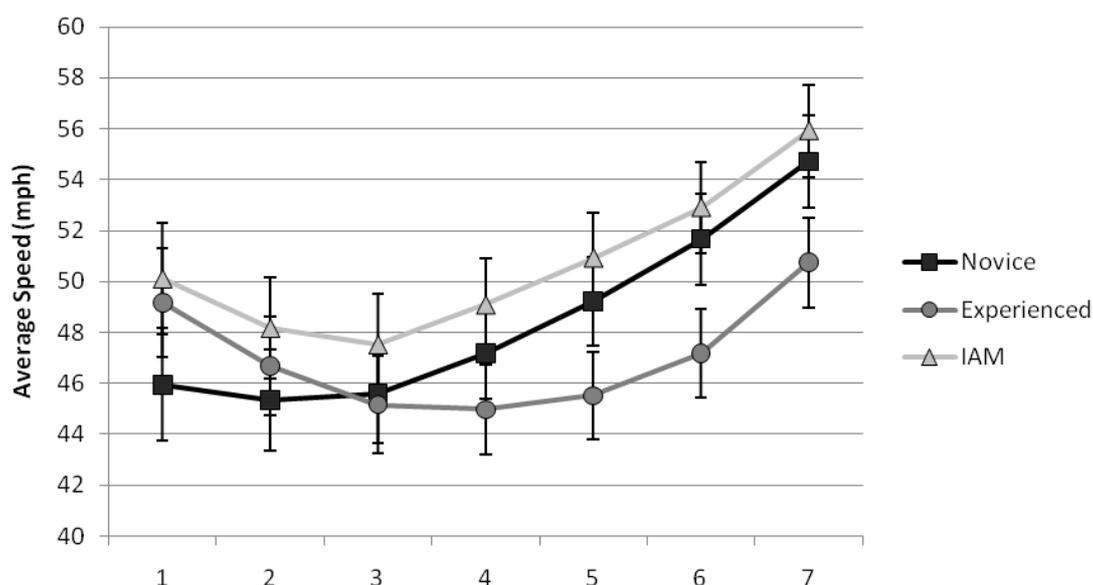
Figure 8.7: Speed comparison on tree-close bend sections (Lap 1)

The general riding pattern, as illustrated in Figure 8.7, was similar across all three rider groups: they decelerated to a point where they began to accelerate out of the bend again. However, the pattern of this deceleration and acceleration differed between the rider groups. On entry to the bend the Experienced and IAM riders were travelling at similar speeds. Both groups decelerated into the bend, but the nadir for the IAM riders occurred approximately 27 degrees into the full bend, whereas the Experienced riders' slowest speed materialized at approximately 45 degrees into the bend. The IAM riders then picked up speed more rapidly than the Experienced riders, resulting in an exit speed that was approximately 5mph faster than the Experienced riders. Novice riders however entered the bend more slowly than the IAM and Experienced riders. Their slowest speed was approximately 9 degrees on average into the full curvature bend. Speed then began to pick up, and once they were half way through the curve, their speed became similar to that of the IAM riders.

In the three other bends on Lap 1 (far trees, near and far Armco barriers) and for all 4 bends on Lap 2, significant effects were observed. Significant main effects for rider group were present, mirroring the same main effects in the rider group x furniture x proximity interactions. IAM riders negotiated the bends the fastest and the Experienced riders were the slowest.

Lateral position within the bends - in the analysis of all four bends on both laps (all of which were left bends) a main effect of bend sub-section was significant showing that all riders changed their lane position through the bend by gradually moving over towards the left of the roadside. The group effects noted in all analyses also mirrored the rider group x furniture x proximity results reported above, with IAM riders placing themselves significantly nearer to the centre-line than the Novice or Experienced riders. However, on the bend with near trees a significant interaction was observed in Lap 1

[F(12,348) = 2.63, p<0.01] and Lap 2 [F(6,348) = 115.348, p<0.001]. As can been seen in Figure 8.8, while IAM riders maintained a more central position than the Novice or Experienced riders through the bends, their position was closer to that of the other groups upon exiting.
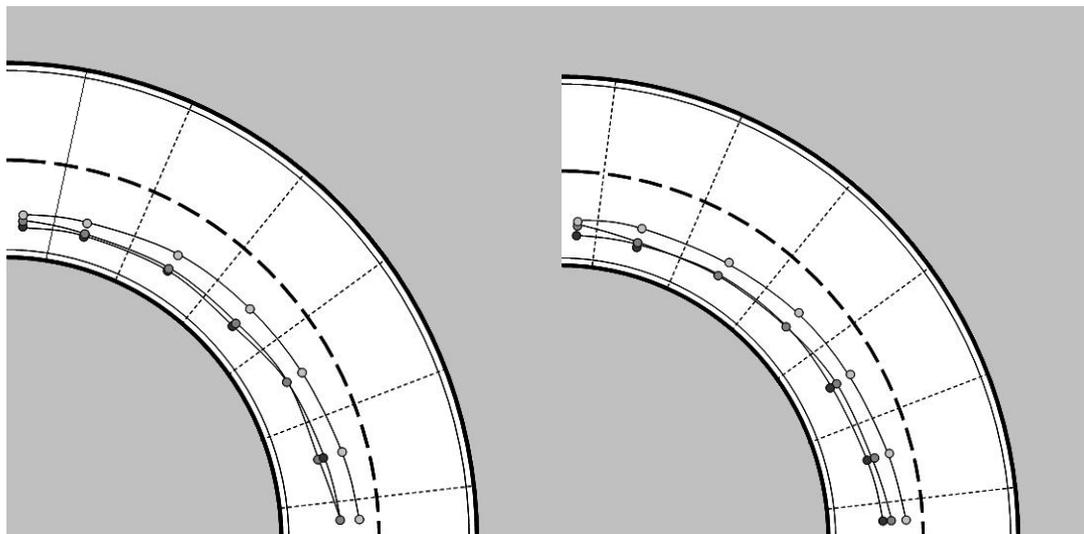
Figure 8.8: Average lateral position of riders for Lap 1 (left) and Lap 2 (right) (the same colour coding is used as in the graphs with Novices as the darkest markers, Experienced riders as the mid-tone markers, and IAM-trained riders and the lightest markers)

Variance of lateral position within the bends – all measures of variance of lateral position for the seven road segments for each of the eight instances of bends were analysed with similar 3x7 ANOVAs. None of the bends revealed an interaction between group and bend segment. There were main effects of the rider groups, but these mirrored the effects noted in the furniture x proximity x group analyses reported earlier. There were also main effects of road segment suggesting that there was greater variance in lateral position during the entrance to (section 1) and exit from (section 7) the bend. While navigating the bend, lateral variance was typically low for all riders.

8.6. Discussion

In this sub-scenario four left-hand bends were developed to explore any differences in riding behaviour for the proximity of different roadside furniture on the outside edge of the road. It was envisaged that the furniture would present different characteristics of optic flow (e.g. the trees were taller and individually spaced, the Armco barrier was low and continuous) and cue salience (e.g. trees are naturally occurring objects, Armco barriers are put in place for a reason) and that these would translate into differences in rider behaviour. IAM riders rode faster around the bends than the other rider groups; Experienced riders were generally the slowest around the bends. This relates to the overall finding of rider speeds in bends mentioned earlier (see Chapter 5) and supports the idea that with advanced training riders can make better progress on their motorcycles.

On the second lap riders tended to negotiate the bends at faster speeds, and a lateral position that was closer to the centre-line (therefore closer to the furniture). This follows the work of De Ridder, et al, (2006) who found that the roadside furniture had a lower impact on behaviour when a curve was negotiated a second time. Looking the at the interaction in Figure 8.4 however it is clear that IAM riders remained at a fairly constant speed across both laps. It was the Novices and Experienced riders that increased their speed on Lap 2. Interestingly however, Novices increased speed for both near and far roadside furniture, whereas the Experienced riders only increased speed on the bends with far furniture. This suggests that the Novices were more

influenced by the familiarity of the bend than the proximity of the furniture. Experienced riders however only allow themselves to increase speed on the safer bends with far furniture. This can be considered rational and safe behaviour by the Experienced riders. IAM riders still made a distinction between near and far furniture but they appeared satisfied with the speed they chose in the Lap 1, and maintained this for Lap 2 they were faster overall than the other two groups). These results show that De Ridder, et al's findings regarding the familiarity of outside bend furniture do not transfer to all motorcyclists. Advance training means that the IAM riders were not tempted to increase speed (although this may be partly due to a ceiling effect – i.e. perhaps they had already chosen the fastest safe speed in Lap 1).

Again in contradiction of De Ridder, et al's results, the interaction between the type of furniture and the proximity suggests that nearby trees produced the greatest decrease in speed. This may have occurred for two reasons:
- the vertical nature of nearby trees is likely to be the one condition that adds the most to the optical flow (Fuller & Santos, 2002). This increased flow of visual stimuli may increase the subjective perception of speed and (as in the case of close proximity trees) encouraged the rider to slow down (Charlton, 2004).
- alternatively, motorcyclists might perceive trees to be more dangerous than a low barrier. Thus speed may have been reduced according to risk homeostasis (Wilde, 1998; 2001).

Regardless of the mechanism, close trees had a significant impact on motorcyclist speed (though not, according to De Ridder, et al, on car drivers). Furthermore, the IAM riders were more sensitive to the presence of trees, reducing their speed to a greater extent than the other two groups when compared to the bends with Armco barriers.

In this study, close proximity furniture affected rider positioning to the left of the lane. Trees also had the greatest impact on lateral position, resulting in the riders positioning themselves further over to the left (away from the centre-line and the furniture). Whilst IAM riders also illustrated this behaviour, they tended to position themselves significantly closer to the centre-line than the other rider groups. This is particularly noticeable in the analysis of bend sub-sections (Figure 8.8), with the IAM riders maintaining a position closer to the centre-line until they were exiting the bend, at which point their road position was similar to the other groups.

Only the Novice and IAM riders reduced their lateral variance when the furniture was further away. Experienced riders maintained a high level of lane variance regardless of the proximity of the furniture and had a greater variation in lateral position than the Novice riders. It would therefore appear that whilst Novice and IAM riders varied their positions less than Experienced riders, they were behaving differently in the bends. IAM riders were faster and closer to the centre-line and maintained a good line throughout the bends, whereas Novices were slower and closer to the inside of the bend. Experienced riders were slowest of all rider groups but had a slightly better position on the bend than the Novice riders. Perhaps due to the slower speed, they had to keep adjusting their line through the curves. Driving simulator research has illustrated that drivers tend to move away laterally from safety barriers on first approach (Van der Horst & de Ridder, 2007) and this would seem to fit with the results of this study. Riders travelled faster and made fewer adjustments to their lateral position when the furniture was further from the road edge. This study also supported Van der Horst and de Ridder's findings by illustrating an effect for trees when they were approximately 2m from the road edge as well as less of an effect when trees were further than 4.5m from the lane edge.

All riders slowed down into bends and then picked up speed on the way out. The results demonstrated general rider advice of 'slow in – fast out'. The different rider groups had different profiles through the bends. IAM riders tended to be faster throughout the bends; Novice riders tended to approach bends slowly and build up their speed; Experienced riders tended approach bends at a similar speed to IAM riders, but

slowed down more before building up their speed. On entry to the bend the Experienced and IAM riders were travelling at similar speeds. Both groups decelerated into the bend with the IAM riders reaching their slowest speed sooner and earlier in the bend than the Experienced riders. The IAM riders then picked up speed more rapidly than the Experienced riders, resulting in a more efficient process through the bend and an exit speed that was approximately 5mph faster than the Experienced riders. Novice riders however entered the bend much more slowly than the IAM and Experienced riders. As a result their slowest speed was almost at the entry of the bend. They then increased their speed and once past the half way point of the curve, their speed became very similar to that of the IAM riders. It appears that Experienced riders entered the bend at a speed that required them to slow down more when compared to the IAM riders. Their greater deceleration in the bend, whilst potentially dangerous in itself, resulted in them exiting the bend at a much slower speed than the IAM riders. Novices however appeared to be more concerned about the bend and decelerate well in advance. While they lost pace on the entry to the curve, this allows them to accelerate sooner, resulting in a faster exit speed. However, their slower entry speed could have left them vulnerable to instability in the bend. The IAM-trained riders appeared to optimise their speed to fall somewhere between the two strategies of the other groups.

9. Left-hand bends

9.1. Introduction

Clarke, et al (2004; 2007) report that a large proportion of motorcycle accidents occur when a motorcyclist loses control on a bend, corner or curve. These accidents are usually regarded as the fault of the motorcyclist, and often do not involve any other traffic.   Such loss of control accidents are more usually associated with riding for pleasure and are also related to inexperience. Riders who have not had a license for long (or who have return to motorcycling after a number of years) as well as riders who hold a provisional license are more likely to be involved in a loss of control accident on a bend. The accidents tend to be a result of the motorcyclist running wide of the curve due to inappropriate speed or poor steering control.

There is also some evidence to suggest that, in general, left-hand bends are more dangerous than right-hand bends (Stewart, 1977; Stewart & Cudworth, 1990). This is thought to be due to a greater difficultly in perceiving curvature when riding on the inside of a bend. In the case of car driving, this problem is difficult to overcome since car drivers are more limited in terms of lateral road position. However, in the case of motorcycling, this problem could be overcome by riding closer to the centre-line of the road.

Given that accidents on bends are linked with inexperience and a difficulty in perceiving curvature, one might expect that experienced riders crash less frequently on bends as a result of better road positioning as well as a more appropriate choice of speed. There are two key influences on how a rider might approach a bend:

- **Progression** - in order to make the fastest progression through a bend, a rider might adopt what is known as the 'racing line', travelling towards the left-hand side of the road as they approach the apex of a left-hand bend (or conversely, travelling towards the centre-line as they approach the apex of a right-hand bend);
- **Safety** – a rider might adopt a position closer to the centre-line in order to gain the best visibility when travelling on a left-hand bend (or conversely, adopt a position closer to the left-hand side to optimize visibility on a right-hand bend).

Since two key aspects of advanced training are safety and progression, it might be expected that IAM riders would only take the racing line after they have obtained a sufficient view through the bend. In contrast, since novices are more likely to be involved in accidents on curves, it might be expected that this group would take a racing line (or what they assume to be a racing line) rather than positioning themselves closer to the centre-line to optimize visibility.

The following experiment was designed to investigate how the rider groups negotiated left-hand bends. Participants were presented with a series of blind bends (bends with embankments and trees on either side to obscure the view through the bend) in order to find out how trained, experienced and novice riders differ in terms of speed choice and lateral position. This approach differed from the bend with barriers sub-scenario reported in Chapter 8 as those bends had complete visibility through the curve. The introduction of blind bends in the current sub-scenario allowed both the racing line or the visual line to be equally plausible options.

In addition to monitoring rider behaviour around the blind bends, one of the bends on Lap 2 contained a hazard (a parked car on the left-hand side of the road). This was not visible on entry to the bend and was designed to be particularly hazardous to riders who took an early racing line without obtaining visibility through the curve. It was predicted that IAM riders would adopt a speed and lane position that is commensurate with the dangers posed by a blind bend (i.e. slower and more towards the centre-line). This

would require less modification to their riding style when the hazard was spotted and provide more time in which to change their speed or position if required.

In contrast, novice riders, in particular, were expected to ride faster and adopt an early racing line, meaning that they would need to take more evasive action upon seeing the hazard. Furthermore, if novices adopted a position closer to the left-hand side of the bend, then they would see the hazard later and have less time in which to respond.

9.2. Method

In this sub-scenario four pairs of opposing bends (four left-hand bends, each immediately followed by a right-hand bend) were designed to mimic riding a series of bends in a rural setting. The speed limit was 60mph. The bends were 700ft long, comprising a 500ft section with a constant curvature of 0.0025 (equivalent to the reciprocal of the radius in feet) preceded by a 100ft entry spiral and followed by a 100ft exit spiral. The left-hand bends sub-scenario was preceded by a standard warning sign for bends ahead. This was positioned 600ft before the first bend.

Trees were positioned either side of the road from 1100ft before the bends to more than 3000ft after the bends. In addition, an embankment on either side of the road was designed to prevent the rider from seeing through the bends (however, it was possible to ascertain the road layout beyond the current bend the rider was in from the treeline beyond the vanishing point of the road).

Since riders were likely to approach the first left-hand bend differently to subsequent bends, this was regarded as a preparatory section and excluded from analyses. For this sub-scenario only behaviour on the second, third and fourth left-hand bends was investigated. The bends on Lap1 provided baseline data. On the second lap, the potential hazard appeared on the third left-hand bend (Figure 9.1).

Figure 9.1: Rider view of vehicle hazard on left-hand bend

If the rider was positioned close to the centre-line as they progressed around the left-hand bend, the car was visible from 289ft away. However, if the rider was positioned further to the left, the car only became visible from 263ft away.

The left-hand bends were analysed in two ways:

- **Responses to the parked car hazard -** the hazard bend (the 3rd left-hand bend on the 2nd lap) was divided into seven sections, each 100ft long. The 1st and 7th sections were the entry spiral and exit spiral respectively, while the middle 5 sections each comprised 14.3 degree sections of the curve itself. Mean speed, lateral position and variance in lateral position were calculated for these seven different sections to explore any differences as riders progressed through the curve and encountered the hazard (which was positioned between the 5th and 6th sections).
- **Modification of behaviour** - rider behaviour was compared to assess the impact of negotiating the hazard on subsequent behaviour. The second and fourth bend of the second lap (the curves immediately before and after the curve with the hazard) were compared. If the appearance of the hazard affected subsequent behaviour, there should have been a difference in speed and position for the fourth curve compared to the second curve. It remained a possibility that behaviour on the fourth curve might simply differ to behaviour on the second curve simply due to an order effect (where, for instance, the rider might achieve the line they wanted more easily by the fourth bend than in the second bend). To account for this, the second and fourth bends on Lap 2 were compared to the same bends on Lap 1. If there was a difference between the second and fourth bend on Lap 2, and the same difference was also found in Lap 1, then this would have nothing to do with encountering the hazard in the third bend of Lap 2. Additionally, any differences between the second curve on Lap 1 and the second curve on Lap 2, would indicate a general familiarity effect. The 2nd and 4th bends were also divided into 7 sections in the same way as the hazard bend in order to explore any effects in specific parts of the bends (e.g. the apex or the spiral). A representation of the bend is illustrated in Figure 9.2.
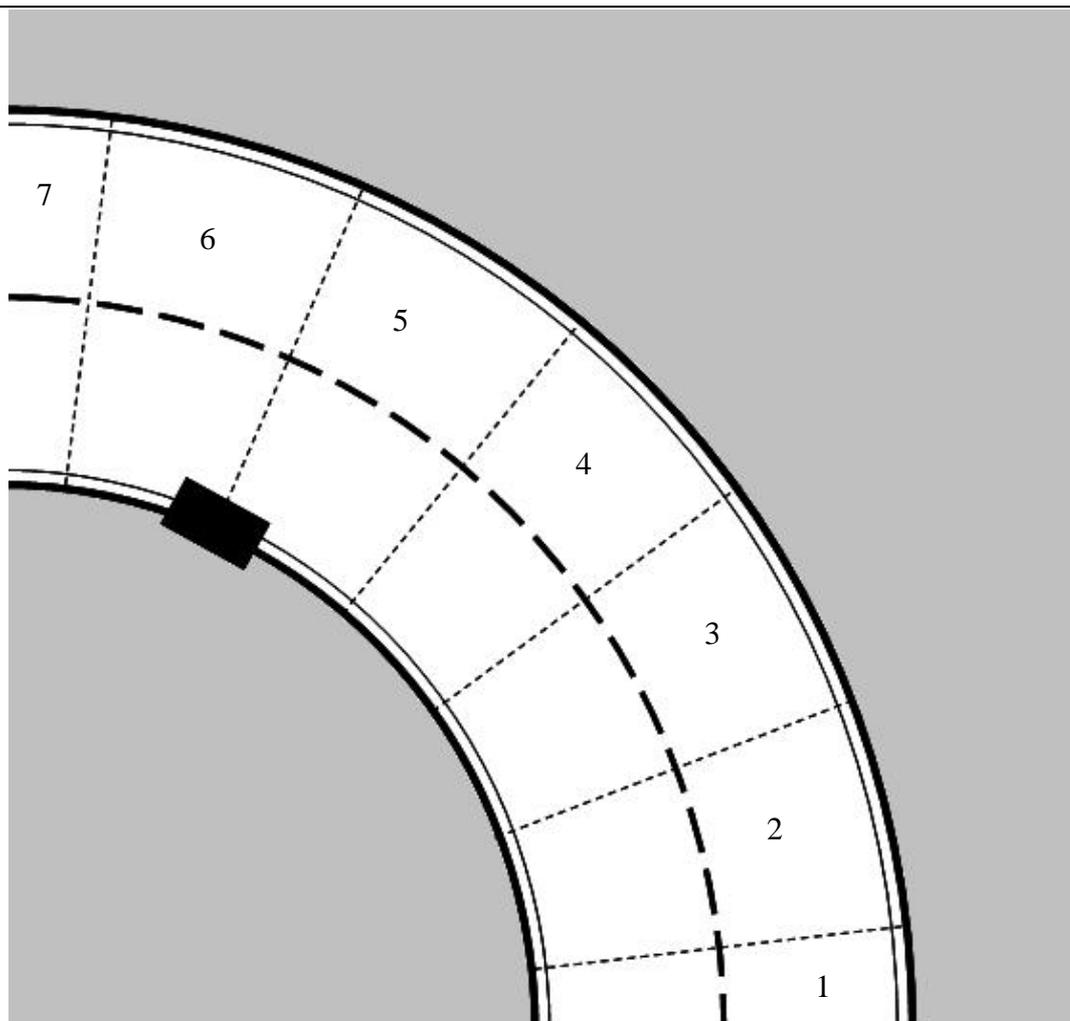
Figure 9.2: Left-hand bend sections

The position of the hazard vehicle is shown as a black rectangle, with the centre of the car between sections 5 and 6. The hazard vehicle is visible from section 3 onwards.

9.3. Results

9.3.1. Analysis of riding behaviour around the hazard bend

> **For analysis, the left-hand hazard bend was divided into 7 sections, each 100ft long.**
>
> **All riders significantly decreased their speed through the bend as they encountered the hazard and then increased speed once past the hazard**
>
> **The IAM riders rode closer to the centre of the road on the left-hand bend than either the Novice or Experienced riders**
>
> **Experienced riders displayed more lateral movement than the IAM riders (although this was not a significant observation)**

Speed, lateral position, and the variance of lateral position data were subjected to a series of 3x7 ANOVAs comparing the measures of each group across the 7 sections of the curve.

Average speed - there was a significant effect of curve section [$F_{(6,348)}$ = 59.603, p<0.001]. Repeated contrasts revealed that riders significantly increased their speed from an average of 48.95mph to 49.84mph between sections 2 and 3 then significantly decreased their speed to an average of 47.17mph on section 4. This corresponds with the hazard becoming visible in section 3. Riders dropped their speed more dramatically to 38.21mph on section 5 then continued at a similar speed before significantly increasing their speed to an average of 41.0mph on section 6. These findings are illustrated in Figure 9.3.
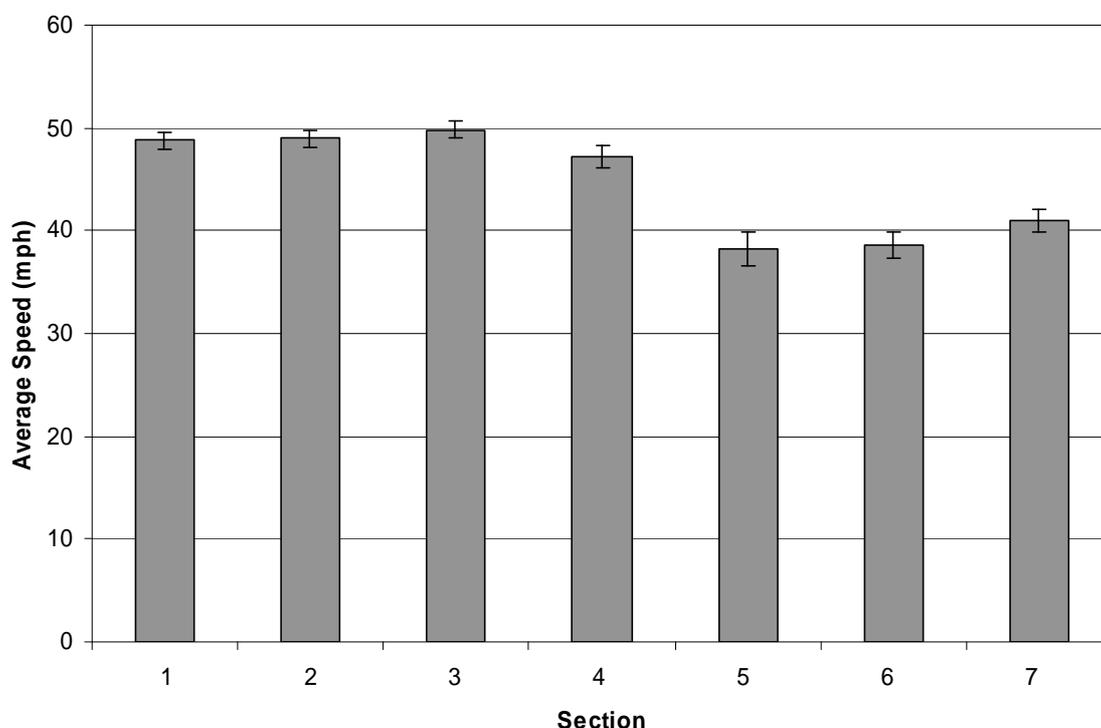
Figure 9.3: Average speed for left-hand bend sections

Lateral Position - there was a main effect for rider group on lateral position [$F_{(2,58)}$ = 8.802, p<0.001]. Scheffe tests revealed that in general, IAM riders rode significantly closer to the centre-line (mean = -3.87ft) than both Experienced (mean = -5.09ft; p<0.05) and Novice riders (mean = -5.60ft; p<0.01), but that Experienced and Novice riders did not differ significantly (p=0.482). A main effect for bend section was also observed [$F_{(6,348)}$ = 86.002, p<0.001] and an interaction between rider group and bend section [$F_{(12,348)}$ = 6.271, p<0.001]. Repeated contrasts revealed that this interaction was significant only between sections 4 and 5 (p<0.05) and between sections 5 and 6 (p<0.01). Through sections 1 to 4, the IAM riders rode significantly closer to the centre-line than both the Novice and Experienced riders (p<0.01). However, when the riders reached section 5, the IAM group still rode significantly closer to the centre-line than the Novice riders (p<0.01), although the difference between IAM and Experienced riders was no longer significant (p=0.178). However, during section 5, the Experienced riders did not significantly differ from the Novice riders either (p=0.1). For sections 6 and 7, the lateral positions of the 3 groups of riders did not significantly differ. All 3 groups of riders did not significantly change lateral position between sections 3 and 4 (minimum p=0.229). The Novice and Experienced riders significantly changed lateral position between all other sections (p<0.01). However, the IAM riders did not significantly change lateral position between sections 5 and 6 (p=0.951). These findings are illustrated in Figure 9.4.
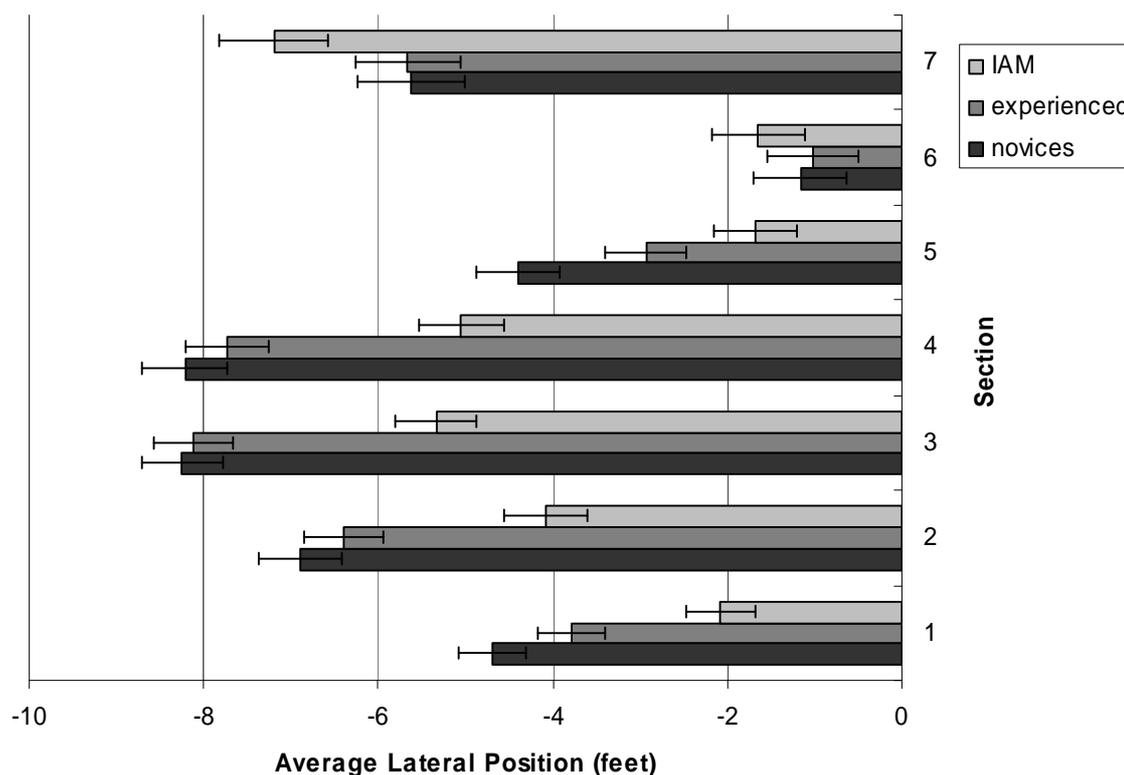
Figure 9.4: Lateral position across the 7 bend sections for the rider groups

While all riders moved closer to the centre-line after seeing the hazard in section 3, the IAM riders were already relatively closer to the centre-line so they had less need to reposition themselves. Thus they moved into the appropriate passing position in section 5 of the bend, whereas the other two groups were still moving toward the centre-line in section 6 (effectively swerving at the last moment to avoid the hazard).

Variance in Lateral Position – a significant main effect was observed for rider group $[F(2,58) = 3.407, p<0.05]$, for curve section $[F(6,348) = 38.719, p<0.001]$ and a significant interaction between rider group and curve section $[F(12,348) = 2.536, p<0.01]$.

The Experienced riders (mean = $1.62ft^2$) displayed more lateral movement than the IAM riders (mean = $1.19ft^2$), an effect that approached statistical significance (p=0.069). However, neither the Experienced riders nor the IAM riders differed significantly from the Novices (mean = $1.24ft^2$; minimum p=0.115). In general, there were significant differences in the amount of lateral movement between each of the 7 sections (p<0.05) apart from between the 6th and 7th sections (p=0.096). Repeated contrasts revealed that the interaction between rider group and section was significant at the beginning of the bend (between sections 1 and 2, p<0.05) and near the hazard (between sections 4 and 5, p<0.05; and between sections 5 and 6, p<0.01). Simple main effects analysis and Scheffe tests revealed that during section 1, the Experienced riders displayed more lateral movement than both Novice (p<0.05) and IAM riders (p<0.01). In section 3, the Experienced group again displayed more lateral movement than the IAM riders and the Novices, although in the latter case this only approached statistical significance (Experienced vs. IAM p<0.05; Experienced vs. Novices p=0.056). During section 5, the IAM riders displayed less lateral movement than the Experienced riders (p<0.05) and demonstrated a near-significant effect over Novice riders (p=0.059). This finding supports the suggestion that the IAM riders had prepared their lane position for passing the hazard sooner than the other two groups. These findings are illustrated in Figure 9.5.
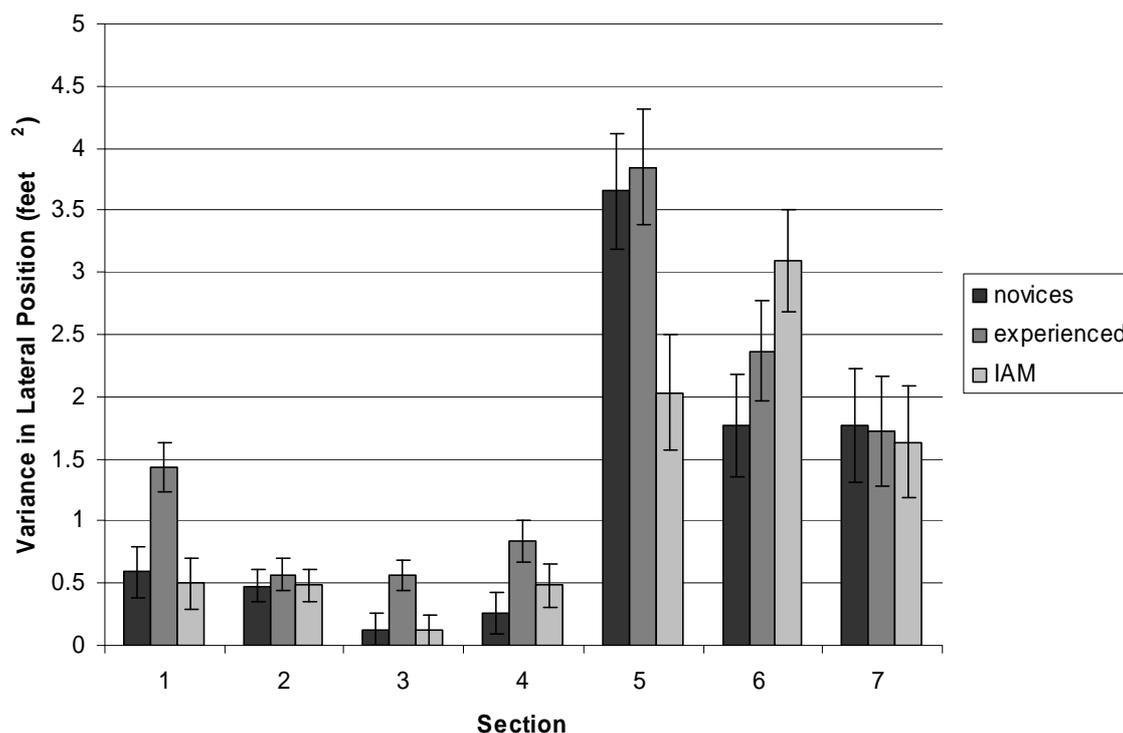
Figure 9.5: Variance in lateral position across the 7 bend sections for the rider groups

9.3.2. Analysis of riding behaviour on pre- and post-hazard bends

> **Familiarity with the bends lead to increased speed, but this was negated by the occurrence of the hazard.**
>
> **Riders increased their speed between bends 2 and 4 on Lap 1. On Lap 2 riders decreased their speed slightly on the 4th bend.**
>
> **IAM riders rode closer to the centre-line of the bend than both Novice and Experienced riders.**
>
> **Riders generally rode closer to the middle of the road on Lap 2 compared to Lap 1.**
>
> **Experienced and Novice riders adopted racing lines early in the bend before they had a line of sight through the bend.**
>
> **In contrast, the IAM riders chose shallower racing lines, and moved to the left at a later point in the curve.**

Speed, lateral position and the variance of lateral position data were subjected to a series of 3x2x2x7 ANOVAs, comparing the three rider groups across Lap 1 and Lap 2, and across the second and fourth bend, for all 7 sections of each curve. It should be noted that the hazard occurred on the third bend of Lap 2, so only the fourth bend of Lap 2 is considered to be post-hazard, while the other three bends act as different control conditions to compare against.

Average speed – a significant main effect was observed for bend [$F(1,58) = 7.633$; $p<0.01$], lap [$F(1,58) = 8.589$, $p<0.01$] and an interaction between bend and lap [$F(1,58) = 15.177$, $p<0.001$].   Simple main effects revealed that on bend 2, riders

were significantly faster during Lap 2 than they were on Lap 1 [$F(1,60) = 26.741$, $p<0.001$]. This represents a familiarity effect, with riders feeling more comfortable with higher speeds having already navigated the bend once before. However, there was no significant difference between Lap 1 and Lap 2 for the 4th bend ($p=0.850$). The familiarity effect was therefore overridden by the appearance of the hazard on the third bend of Lap 2. Furthermore, riders increased their speed between bends 2 and 4 on Lap 1 [$F(1,60) = 20.834$, $p<0.001$], but not on Lap 2 ($p=0.512$), where riders decreased their speed slightly on the 4th bend. Again, this suggests that, on the first Lap, riders became more comfortable with the bends as they went through them, resulting in higher speeds for bend 4 than bend 2, however, this did not translate to Lap 2. After experiencing the hazard in the third bend, riders did not try to increase their speed any further. These findings are illustrated in Figure 9.6.
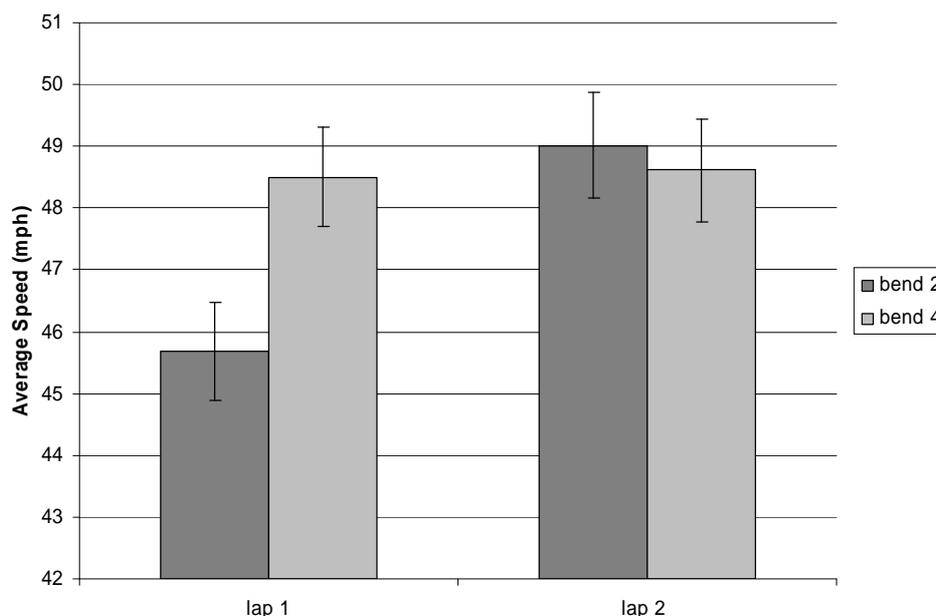
Figure 9.6: Average speeds on the 2nd and 4th bends during Laps 1 & 2

Lateral Position - a significant main effect was observed for rider group [$F(2,58) = 23.981$, $p<0.001$], illustrating that IAM riders (mean = -5.40ft) rode closer to the centre-line than both Novice (mean = -7.33ft; $p<0.001$) and Experienced riders (mean = -7.24ft; $p<0.001$). A significant effect was also observed for lap [$F(1,58) = 5.534$, $p<0.05$], illustrating that riders generally rode closer to the middle of the road on Lap 2 (mean = -6.50ft) when compared to Lap 1 (mean = -6.82ft).

A significant interaction between riding group x lap x bend also approached significance [$F(2,58) = 2.745$, $p=0.073$]. Simple main effects analysis revealed that Novice riders rode the 4th bend closer to the centre of the road on the second lap than on the first lap [$F(1,19) = 8.123$, $p<0.05$]. There were no effects of lap or bend for Experienced riders. However, on Lap 1 the IAM riders rode the fourth bend closer to the centre than the second bend [$F(1,18) = 4.789$, $p<0.05$]. The IAM riders also rode the second bend closer to the centre on Lap 2 than on Lap 1 [$F(1,19) = 9.214$, $p<0.01$]. These findings are illustrated in Figure 9.7.
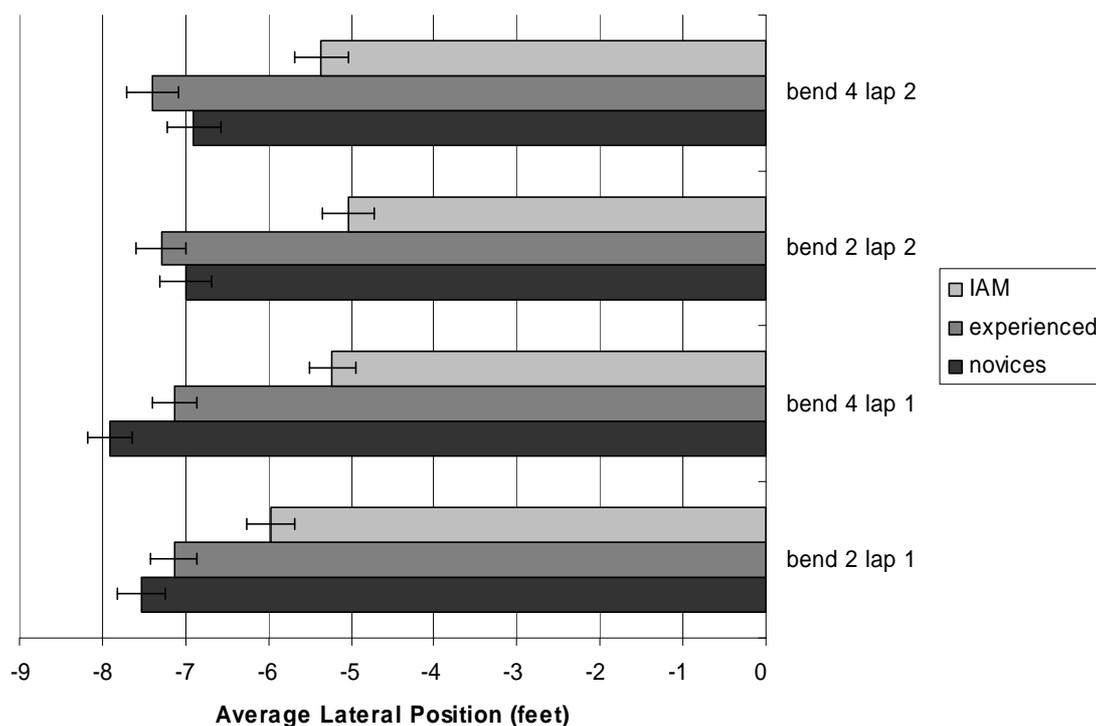
Figure 9.7: Average lateral position for bends 2 and 4, over Laps 1 & 2

There are three interesting points to take from this analysis:
- Novices appeared to change their road position more towards the centre of the bend after seeing the hazard.
- Experienced riders did not change their position at all.
- After the second bend of Lap 1, IAM riders moved closer to the centre-line on all other bends.

The analysis of lateral position also revealed a significant main effect of curve section $[F(6,348) = 146.203, p<0.001]$, an interaction between rider group and curve section $[F(12,348) = 5.024, p<0.001]$ and an interaction between rider group x curve section x bend $[F(12,348) = 1.926, p<0.05]$. As shown in Figure 9.8, on the 2nd bend the Novices moved closer to the edge of the road between sections 1 and 4 (differences between sections 1 and 2, sections 2 and 3, and sections 3 and 4 were all significant with maximum $p<0.05$). On the 4th bend, the Novice riders still moved over to the left at the start of the bend, but only the differences between sections 1 and 2, and between 2 and 3 were significant $(p<0.001)$. The Experienced riders showed a similar pattern, moving over to the left at the start of the bends. However, differences were significant between adjacent sections from 1 to 3 for bend 2 $(p<0.001)$ and from 1 to 4 for bend 4 (maximum $p<0.05$). In contrast, the IAM riders significantly changed their lateral position between all adjacent sections (maximum $p<0.05$), apart from sections 3 to 4 in bend 2 and between sections 3 and 5 in bend 4. IAM riders rode significantly closer to the centre-line of the bend than the Experienced and Novice riders during sections 1 to 5 on bend 2 $(p<0.01)$ and during sections 1 to 6 on bend 4 $(p<0.001$, apart from IAM vs. Experienced in section 1 where $p<0.05$). These findings are illustrated in Figure 9.8.
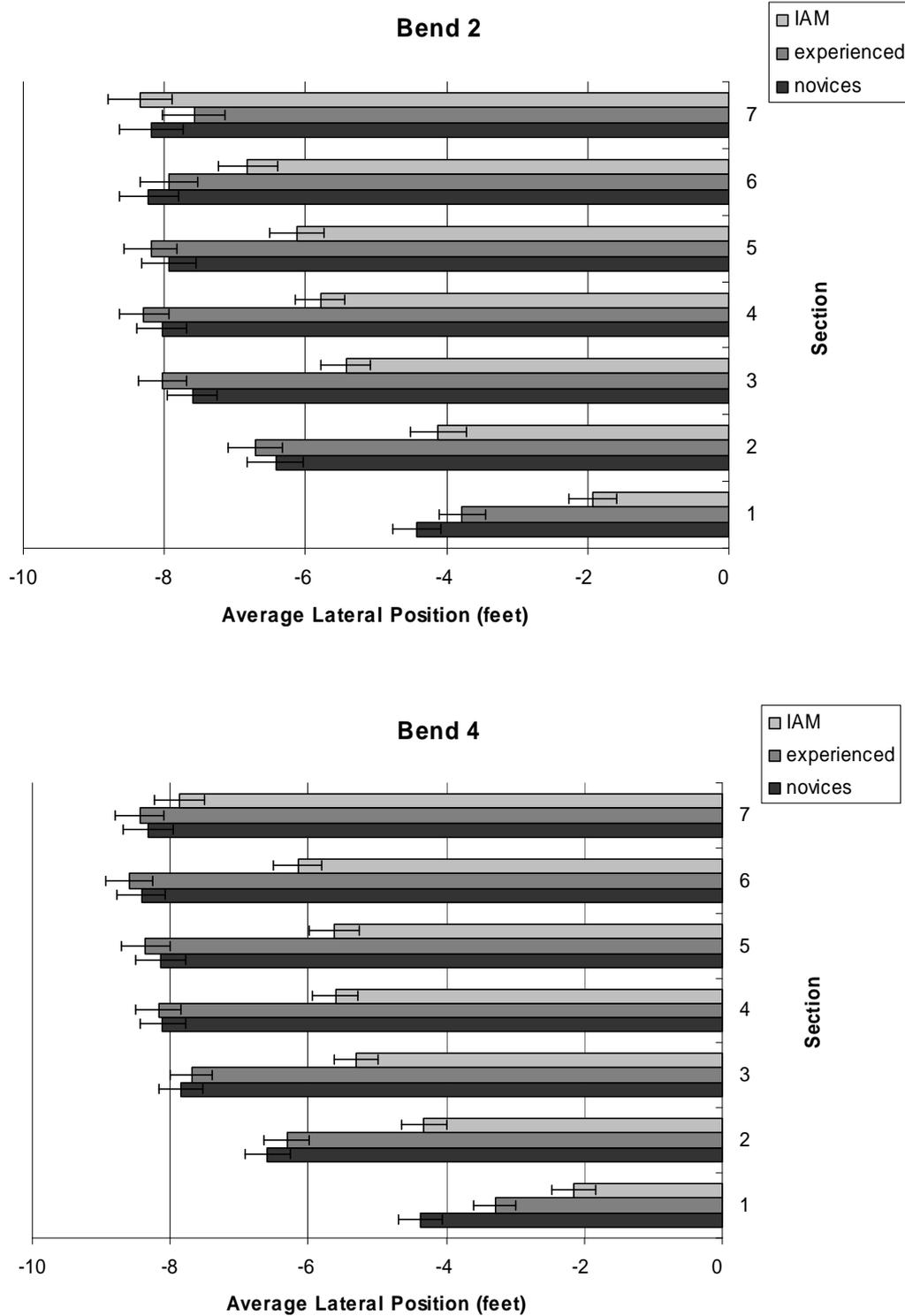
Bend 2

Bend 4

Figure 9.8: Average lateral position of the rider groups over the 7 bend sections for bend 2 (upper) and bend 4 (lower)

If taking a 'racing line' is indicated by a move from the centre-line across to the left-hand side of the road during the curve, then from Figure 9.8 it is apparent that Experienced and Novice riders adopt more of a racing line and engage in it earlier than IAM riders. The rapid shift in positioning suggests they adopted a racing line before they could see around the blind bend. The IAM riders however adopted a less marked racing line, involving a smaller shift to the left spread out over a longer distance and time frame. This was exaggerated even further in Bend 4 and suggests that IAM riders were aware of the need for visibility over and above the desire for the racing line.

Variance in Lateral Position - the analysis revealed a significant main effect of curve section [$F(6,348)$ = 7.825, $p<0.001$].   Repeated contrasts revealed significant decreases in variance in lateral position between sections 1 and 2, and between sections 2 and 3, and a significant increase in variance of lateral position between sections 5 and 6 ($p<0.001$). These findings are illustrated in Figure 9.9.
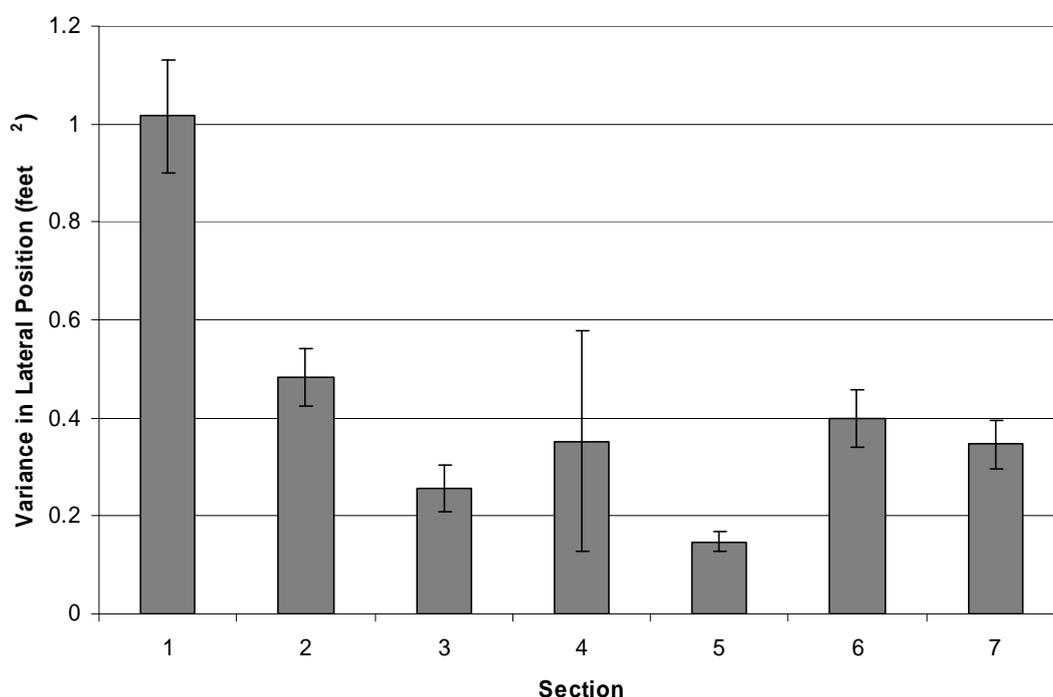
Figure 9.9: Variance in lateral position over the seven bend sections

9.4. Discussion

For analysis, the left-hand hazard bend was divided into seven sections, each 100ft long.   All riders significantly decreased their speed through the bend as they encountered the hazard and then increased speed once past the hazard. Since the hazard became visible while the riders were in section 3 of the bend, their initial reaction was to slow down as soon as they saw the hazard. This pattern of behaviour was the same for all three rider groups.

In a left-hand bend the advanced strategy is to keep towards the centre-line as this provides a better view a round the bend and increases visibility of the motorcyclist to other traffic. The IAM riders exhibited this behaviour and rode closer to the centre of the road than either the Novice or Experienced riders. Using this tactic, they were able to see the hazard earlier and were already laterally further away from the hazard when it appeared. By section 5 the IAM riders had already moved closer to the centre-line and remained in that position (revealed by the reduction in lateral variance). However, the other two rider groups were still changing position in section 6. This suggests that they saw the hazard later and were less prepared for it.   This resulted in late repositioning in the Experienced and Novice groups. For some individuals this would have been akin to swerving at the last moment to avoid the unexpected hazard. These behaviours are represented in Figure 9.10.
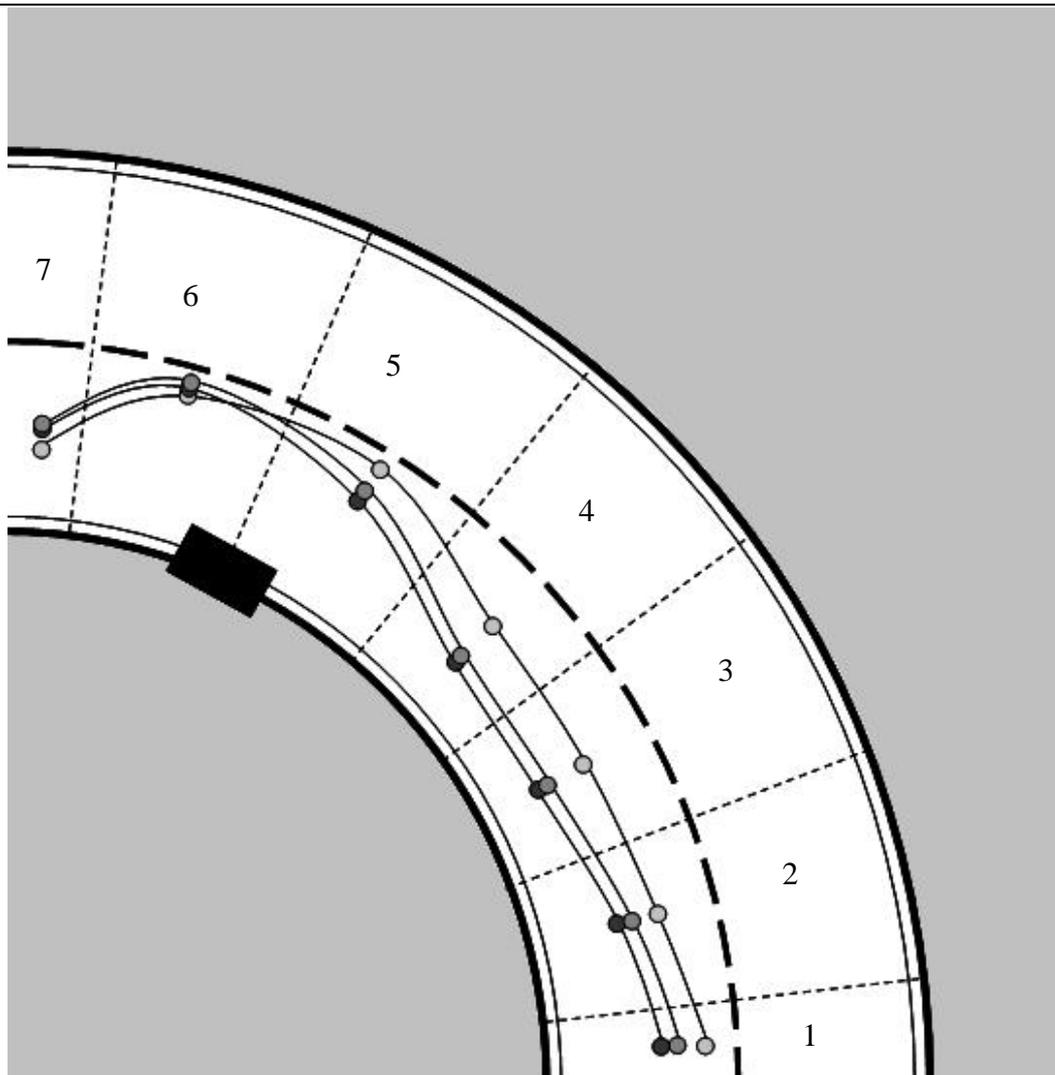
Figure 9.10: Lateral plot for the left-hand bend hazard
(the same colour coding is used as in the graphs with Novices as the darkest markers, Experienced riders as the mid-tone markers, and IAM-trained riders and the lightest markers. The black rectangle represents the parked car hazard)

The IAM riders also recovered their original line slightly quicker than the Novice and Experienced riders so they were in a better position for the upcoming right-hand bend. The Novice and Experienced riders, upon seeing the hazard later and having to correct more for it, appear to have overcorrected by going closer to the centre-line. This means they then had more work to do to regain their original line whilst inadvertently leaving themselves more exposed to oncoming traffic close to the centre-line (by this point the IAM riders would have normally cut in for the upcoming right-hand bend if there had not been the hazard). IAM training would appear to offer benefits in hazard detection and smoother negotiation of hazards on left-hand bends.

In the pre- and post-hazard bends, riders were generally faster on bend 2 in Lap 2 compared with Lap 1. Riders also increased their speed between bends 2 and 4 on Lap 1 but not on Lap 2, where riders decreased their speed slightly on the 4th bend. Both of these effects suggest that practice and familiarity can lead to increased speed on bends however the appearance of a hazard negated the familiarity effect resulting in a more cautious speed for the fourth bend of Lap 2.

IAM riders rode closer to the centre-line of the bend than both Novice and Experienced riders. The Novice and Experienced riders followed a different line to the IAM riders. While all rider groups approximated to a racing line (with a move from the centre-line toward the left road edge), the racing line of the IAM riders was relatively shallow and gradual. Conversely the Novice and Experience riders made greater shifts from the centre-line to the left of the road very early in the bend.

The lateral position of Novice riders appeared to alter after the hazard, with them taking a more central position on bend 4 on the second lap. The Experienced riders did not however appear to readjust their overall lateral position across any of the pre- and post-hazard bends. IAM riders did not need to adjust their lane position on the post-hazard bend as their position was already optimal. They did however alter their overall position closer to the centre-line after the second bend on the first lap. This suggests that initially they were not happy with their positioning and rectified this on subsequent curves (thus they used feedback from how they negotiated the early curves to ensure that they had an appropriate lane position when the unexpected hazard appeared).

Overall the results of this sub-scenario show clear benefits of advanced training. The IAM-riders opted for safety over progression, choosing shallower and less marked racing lines than the other groups. They fine-tuned their position on early bends, placing them in the optimum location for avoiding the subsequent hazard. They did not change their behaviour following the hazard as much as the other groups, but they did not need to. The Novices and the Experience riders adopted more pronounced racing lines prior to having a line of sight through the bend, which is not conducive to safe riding.

10. Right-hand bends

10.1. Introduction

While accidents involving all types of traffic might be more prevalent on left-hand bends, right-hand bends still pose a specific danger for motorcyclists. In an analysis of motorcycle accidents in Scotland (Sexton, Fletcher & Hamilton, 2004), accidents involving going ahead on a right-hand bend made up 9.0% of all motorcycle accidents, only slightly less than accidents involving going ahead on left-hand bends (11.4%). Stewart and Cudworth (1990) suggest that some right-hand bend accidents occur on bends where the accident terminates on a right-hand bend, but is actually initiated on or preceded by a left-hand bend. However, some right-hand bend accidents might occur as a result of a perceptual error in judging the acuteness of the bend.

The following sub-scenario was designed to investigate rider behaviour when negotiating blind right-hand bends. The design was kept as similar as possible to that of the left-hand bends sub-scenario so that comparisons could be drawn between them. Since accidents on curves are generally related to inexperience, this sub-scenario compared the behaviour of three rider groups to find out whether the experienced and trained riders displayed safer rider characteristics, such as slower speed selection and appropriate lane positioning. As in the left-hand bends, a hazard was placed on the 3rd bend (a car moving towards the rider in the opposite lane, but close to the centre-line). As before, the hazard was not visible on entry to the bend and was designed to pose a particular hazard to riders who took an early racing line without visibility through the curve. It was predicted that IAM riders would exercise levels of caution appropriate for blind bends, by adopting slower speeds and riding closer to the left-hand edge of the road in order to obtain greater visibility. As such, these riders would require less modification to their riding style when the hazard was spotted, yet have more time in which to change their speed or position if required.

In contrast, it was expected that novice riders would ride faster and adopt an early racing line (this time riding towards the centre-line of the road), meaning that they would need to take evasive action when the hazard appeared. Furthermore, if novices adopted a position closer to the centre-line of the road, then they would see the hazard later and have less time in which to respond.

10.2. Method

In this sub-scenario four pairs of opposing bends (four right-hand bends, each immediately followed by a left-hand bend) were designed to mimic riding a series of bends in a rural setting. The speed limit was 60mph. The bends were 700ft long, comprising a 500ft section with constant curvature of 0.0025 (equivalent to the reciprocal of the radius in feet) preceded by a 100ft entry spiral and followed by a 100ft exit spiral. The sub-scenario was preceded by a standard warning sign for bends ahead, positioned 600ft before the first bend.

Trees were positioned either side of the road from 1100ft before the bends to more than 3000ft after the bends. In addition, an embankment on either side of the road was designed to prevent the rider from seeing through the bends (however it was possible to ascertain the road layout from the tree-line beyond the vanishing point of the road).

As in the left-hand bends sub-scenario, the first right bend was regarded as a preparatory phase and excluded from analyses. For this sub-scenario only rider behaviour on the three subsequent right-hand bends was investigated. The bends on Lap 1 provided baseline data. On the second lap, the potential hazard appeared on the third right-hand bend (Figure 10.1).

Figure 10.1: Rider view of vehicle hazard on right-hand bend

The car hazard was positioned legally on the road, close to the centre-line, initially at 150ft beyond the apex of the bend (as the motorcycle reached a point 150ft before the apex of the bend). The vehicle travelled at a constant speed of 6.8mph. A slow speed was chosen so that the vehicle did not move too far along the road depending on the relative speed of the motorcyclist. This meant that the vehicle was approximately at the same point on the road for each participant. If the rider was positioned to the left-hand side of the road upon entering the bend, the car became visible when the rider was approximately 300ft from the hazard.

The right bends sub-scenario was analysed in a similar way to the left bends sub-scenario, by dividing the hazard bend into 7 equal sections and by comparing the 2nd and 4th bends on Lap 1 with the same bends on Lap 2. As with the left bends sub-scenario, the second bend was encountered before the hazard, so for this bend any differences between laps would have indicated a practice or familiarity effect. However, on the second lap, the 4th bend was encountered after the hazard, so any differences observed for behaviour on this would have reflected how riders modified their behaviour as a result the encountered hazard. A representation of the bend is illustrated in Figure 10.2.
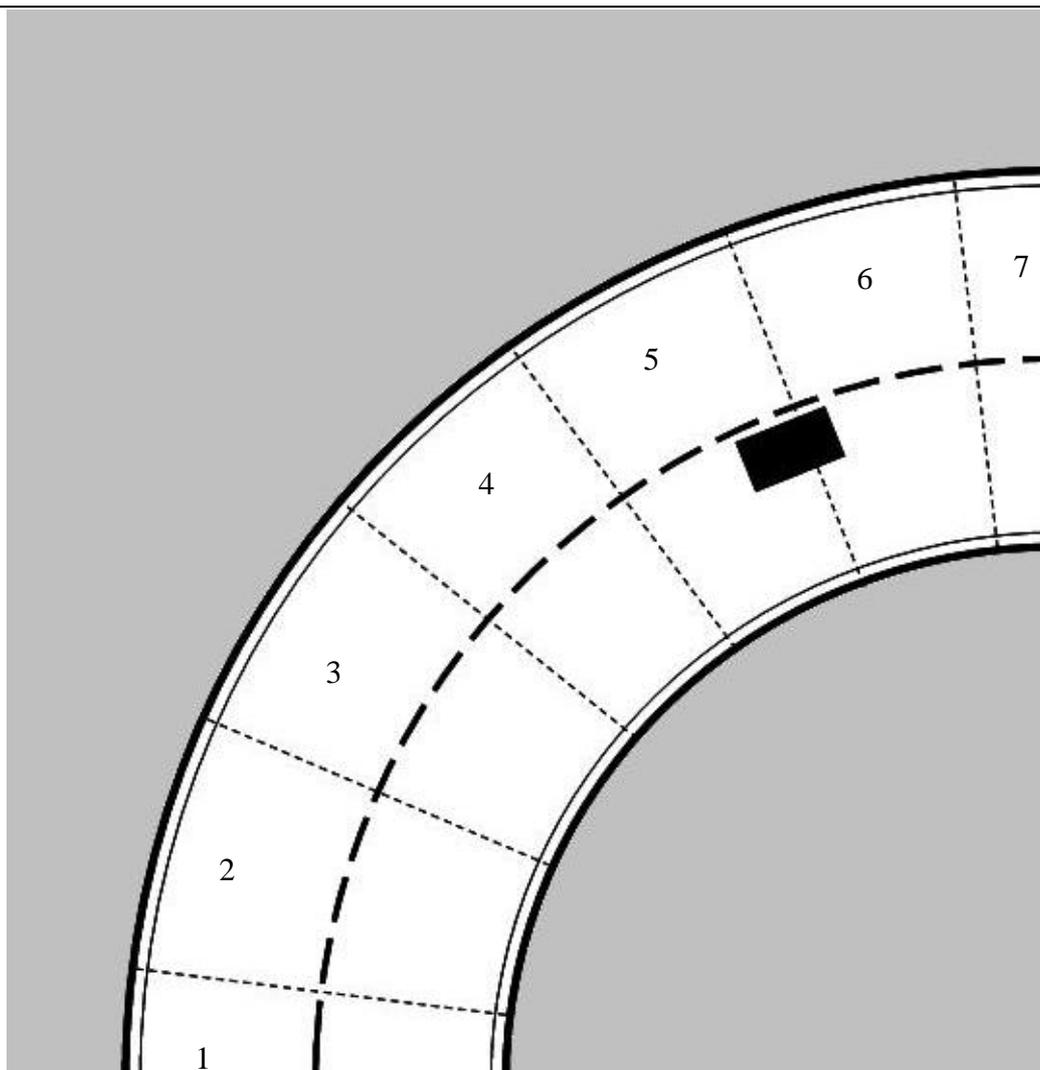
Figure 10.2: Right-hand bend sections
The approximate position of the hazard vehicle is shown as a black rectangle. The hazard vehicle was visible from section 3 onwards.

10.3. Results

10.3.1.   Analysis of riding behaviour around the hazard bend

All rider groups significantly decreased their speed when they saw the hazard and increased their speed once they had passed it.

Experienced riders were significantly closer to the centre-line of the road than the IAM riders.

The Novice and Experienced riders had to significantly change their lateral position in response to the hazard.

Towards the end of the right-hand bend, the IAM riders rode closer to the centre-line than both the Novice and Experienced riders (in preparation for the upcoming left-hand bend).

IAM riders varied their lateral position more than the Novice riders, particularly at the end of the bend.

Speed, lateral position, and the variance of lateral position data were analysed using a series of 3x7 ANOVAs comparing the measures of each rider group across the seven sections of the curve.

Average speed - there was a significant main effect of curve section [$F_{(6,348)}$ = 6.567, $p < 0.001$]. Repeated contrasts revealed that riders significantly decreased their speed between sections 3 and 4 when the hazard appeared ($p < 0.01$), then significantly increased their speed between sections 6 and 7 ($p < 0.05$) after the hazard. There was no effect for rider group and no interaction between rider group and curve section, suggesting that all three rider groups showed a similar pattern of speed through the bend. These findings are illustrated in Figure 10.3.
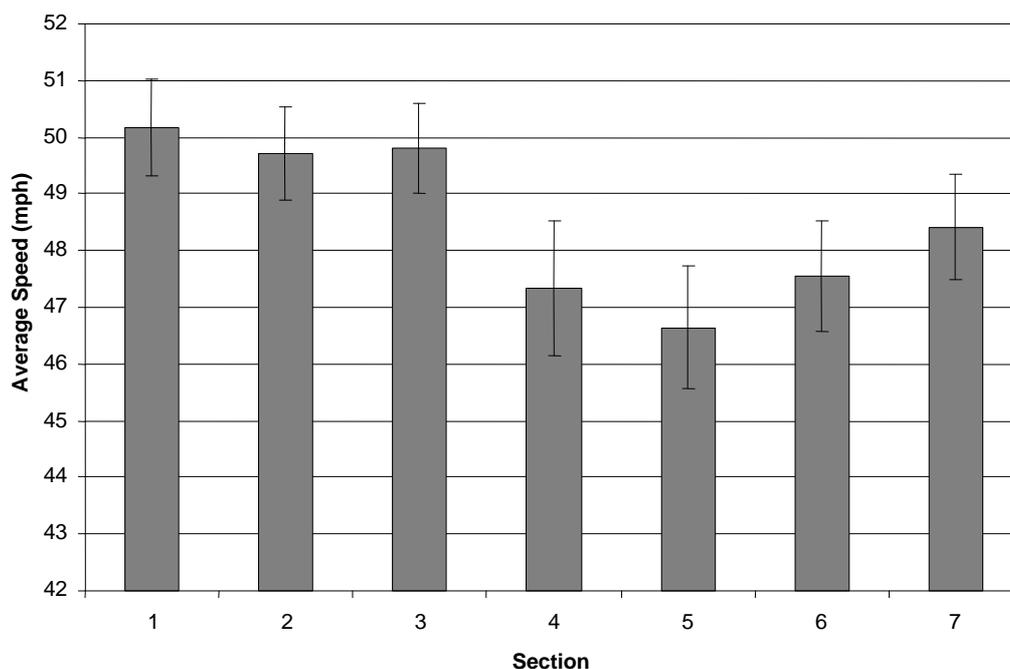
Figure 10.3: Average speed for over sections of the right-hand bend hazard

Lateral Position - a significant main effect was observed for rider group [$F_{(2,58)}$ = 4.140, $p < 0.05$] illustrating that the Experienced riders (mean = -4.25ft) were significantly closer to the centre line than the IAM riders (mean = -5.55ft). The difference between Experienced riders and the Novice riders (mean = -5.41ft) was not significant ($p = 0.075$). A significant effect was also observed for curve section [$F_{(6,348)}$ = 22.487, $p < 0.001$] and an interaction between rider group and curve section [$F_{(12,348)}$ = 3.610, $p < 0.001$]. Repeated contrasts revealed that all three rider groups made significant changes in lateral position over the first three curve sections, moving towards the centre line ($p < 0.01$), but did not change their lateral position between sections 3 and 4 as they approached the apex of the bend. Between sections 4 and 5, Novice and Experienced riders had to make a significant change in lateral position away from the centre line in response to the hazard ($p < 0.001$). Between sections 5 and 6, Novice and IAM riders made a significant change in lateral position, moving back towards the centre line ($p < 0.05$ for Novices; $p < 0.001$ for IAM riders). Then between sections 6 and 7, all three rider groups made significant changes in lateral position back towards the centre line ($p < 0.001$).

Simple main effects analysis also showed that in section 1, the effect of rider group only approached significance ($p = 0.067$), with Experienced riders riding closer to the centre line than IAM riders while Novices were positioned in between. In sections 2, 3 and 4, the difference between IAM and Experienced riders was significant ($p < 0.05$). In section 3 the Experienced riders were also significantly closer to the centre line than the Novice riders ($p < 0.05$). In sections 5 and 6, there were no significant differences in the lateral

positions of the 3 groups. In section 7, the IAM riders rode significantly closer to the centre line than both the Novice riders ($p < 0.01$) and the Experienced riders ($p < 0.05$). Repeated contrasts revealed that an interaction observed for rider group and section was significant only between sections 6 and 7 ($p < 0.05$). These findings are illustrated in Figure 10.4.
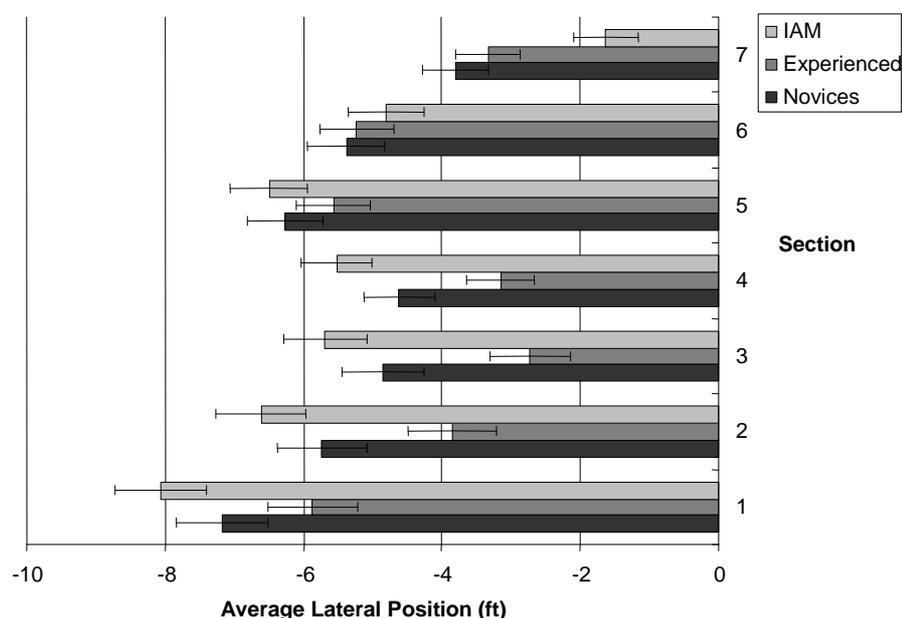
Figure 10.4: Average lateral position for different sections of the right-hand hazard bend

Variance in Lateral Position - a significant main effect was observed for rider group [$F(2,58) = 3.636$, $p < 0.05$] which revealed that IAM riders (mean = $0.79ft^2$) varied their lateral position more than the Novices (mean = $0.43ft^2$). The Experienced riders (mean = $0.71ft^2$), varied their lateral position almost as much as the IAM riders but did not significantly differ from the Novices. There was also a significant interaction between rider group and section [$F(12,348) = 1.895$, $p < 0.05$]. Simple main effects analysis revealed that the effect of section was significant for all three rider groups, so repeated contrasts were performed. Novices increased lateral variance between sections 5 and 6 ($p < 0.05$) and decreased lateral variance between sections 6 and 7 ($p < 0.05$). Both the Experienced riders and the IAM riders significantly decreased lateral variance between sections 1 and 2 ($p < 0.05$ for Experienced; $p < 0.01$ for IAM riders), increased lateral movement between sections 3 and 4 that approached statistical significance ($p = 0.051$ for Experienced; $p = 0.063$ for IAM) and significantly decreased lateral variance between sections 6 and 7 ($p < 0.05$ for both Experienced and IAM). However, the IAM riders also significantly increased lateral variance between sections 5 and 6 ($p < 0.01$). Simple main effects revealed that the only significant differences between rider groups occurred in section 6 [$F(2,58) = 4.658$, $p < 0.05$]. In this section, IAM riders varied lateral position more than the Novice and Experienced riders, but only the difference between IAM and Novice riders was significant ($p < 0.05$). These findings are illustrated in Figure 10.5.
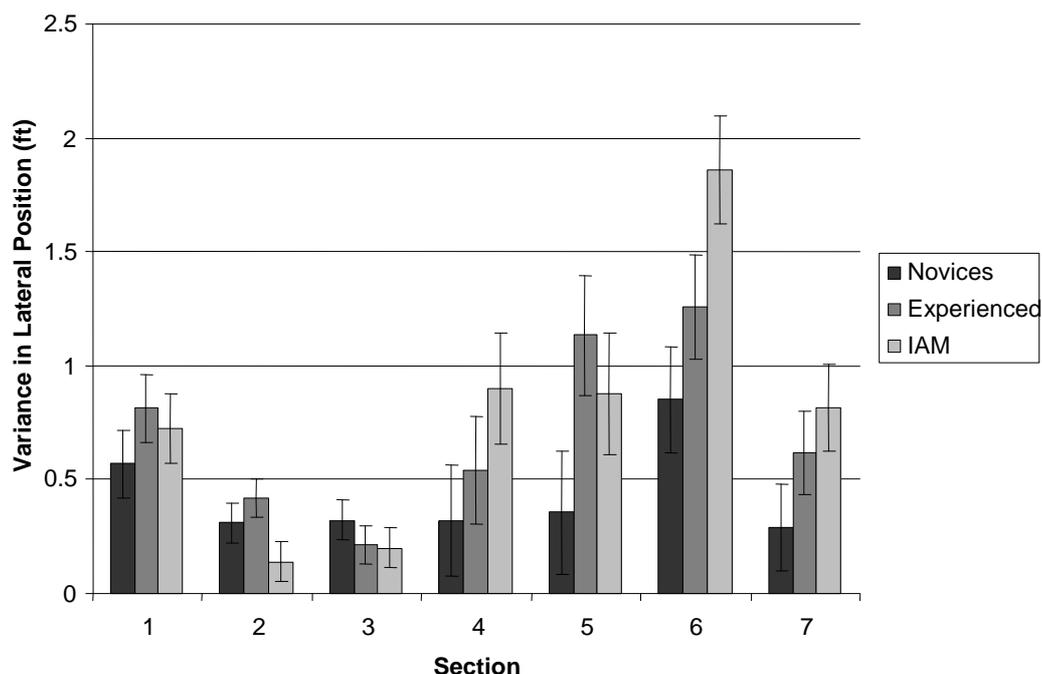
Figure 10.5: Variance in lateral position for rider groups across the sections of the right-hand hazard bend

10.3.2.   Analysis of riding behaviour on pre- and post-hazard bends

> **All rider groups were faster on both bends in Lap 2.**
>
> **Experienced riders rode closer to the centre line than IAM riders and Novice riders. For most of the bend, both the IAM and the Novice riders were further away from the centre line than the Experienced riders.**
>
> **Riders were closer to the centre line in Lap 1 than Lap 2.**
>
> **IAM riders significantly changed lateral position through all adjacent bend sections.**
>
> **At the start of the bend, the IAM riders were significantly further away from the centre line than either the Novice or Experienced riders.**
>
> **Towards the end of the bend, both the IAM and Experienced riders were closer to the centre line than the Novices.**
>
> **After entering the bend, all three rider groups tended to settle into the line they had chosen and became more consistent in their lateral position. However, IAM riders increased lateral movement towards the centre line when exiting the bend. This is consistent with them riding further from the centre line during the bend and therefore preparing for the subsequent left-hand bend.**

Speed, lateral position, and the variance of lateral position data were analysed using a series of 3x2x2x7 ANOVAs comparing the measures for each rider group across the two bends of interest (bend 2 and bend 4), on both laps, and through the seven sections of each curve.

Average speed - there was a significant main effect of lap [$F_{(1,58)}$ = 11.168, p<0.01], which illustrated that riders were faster on Lap 2 (mean = 49.94mph) than Lap 1 (mean = 47.99mph). There was also a significant interaction between bend and lap [$F_{(1,58)}$ = 5.234, p<0.05]. Simple main effects revealed that riders were significantly faster on both bends in Lap 2, although the effect was greater for the 2nd bend [$F_{(1,60)}$ = 14.345, p<0.001] than for the 4th bend [$F_{(1,60)}$ = 4.068, p<0.05]. These findings are illustrated in Figure 10.6.
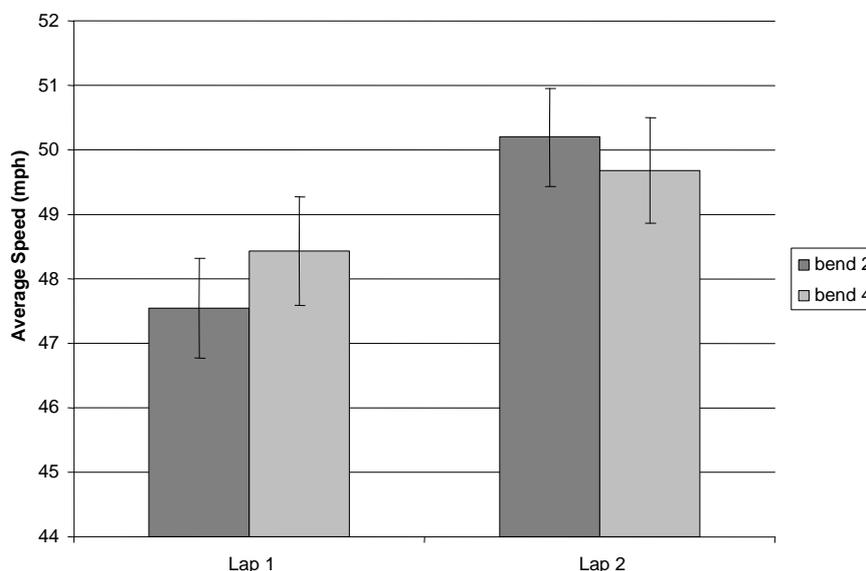
Figure 10.6: Average speed on the 2nd and 4th bends during Laps 1 & 2

Lateral Position - there was a main effect of rider group [$F_{(2,58)}$ = 8.329, p<0.01] which showed that Experienced riders (mean = -3.33ft) rode closer to the centre line that IAM riders (mean = -4.89ft; p<0.01) and Novice riders (mean = -4.64ft; p<0.05). There was a main effect of lap [$F_{(1,58)}$ = 10.704, p<0.01] which revealed that riders were closer to the centre line in Lap 1 (mean = -4.06ft) than Lap 2 (mean = -4.51ft). A main effect of section [$F_{(6,348)}$ = 192.168, p<0.001] showed that riders made a significant change in lateral position between all adjacent sections (p<0.001), always moving towards the centre line. However, there was also an interaction between rider group and curve section [$F_{(12,348)}$ = 7.204, p<0.001]. Repeated contrasts revealed that this interaction occurred between sections 1 and 2 (p<0.05), 5 and 6 (p<0.05), and 6 and 7 (p<0.001). Simple main effects analysis showed that only the IAM riders significantly changed lateral position between all adjacent sections (maximum = p<0.05). The Novice riders significantly changed their lateral position between all adjacent sections from 1 to 6 (maximum = p<0.05), but did not significantly change lateral position between sections 6 and 7. In contrast, the Experienced riders did not significantly change lateral position between sections 4 and 5, but significantly changed lateral position between all other adjacent sections (maximum = p<0.05). In section 1, the IAM riders were significantly further away from the centre line than either the Novice (p<0.01) and Experienced riders (p<0.001). However, in sections 2, 3 and 4 the IAM and the Novice riders were further away from the centre line than the Experienced riders (for Novice vs. Experienced p<0.05; for IAM vs. Experienced max. p<0.01). While the Experienced riders still rode closer to the centre line than the IAM and Novice riders in section 5, only the difference between IAM and Experienced riders was significant (for IAM vs. Experienced p<0.01). In section 7, both the IAM and Experienced riders were closer to the centre line than the Novices (for Novices vs. Experienced p<0.01; for Novices vs. IAM p<0.001). These findings are illustrated in Figure 10.7.
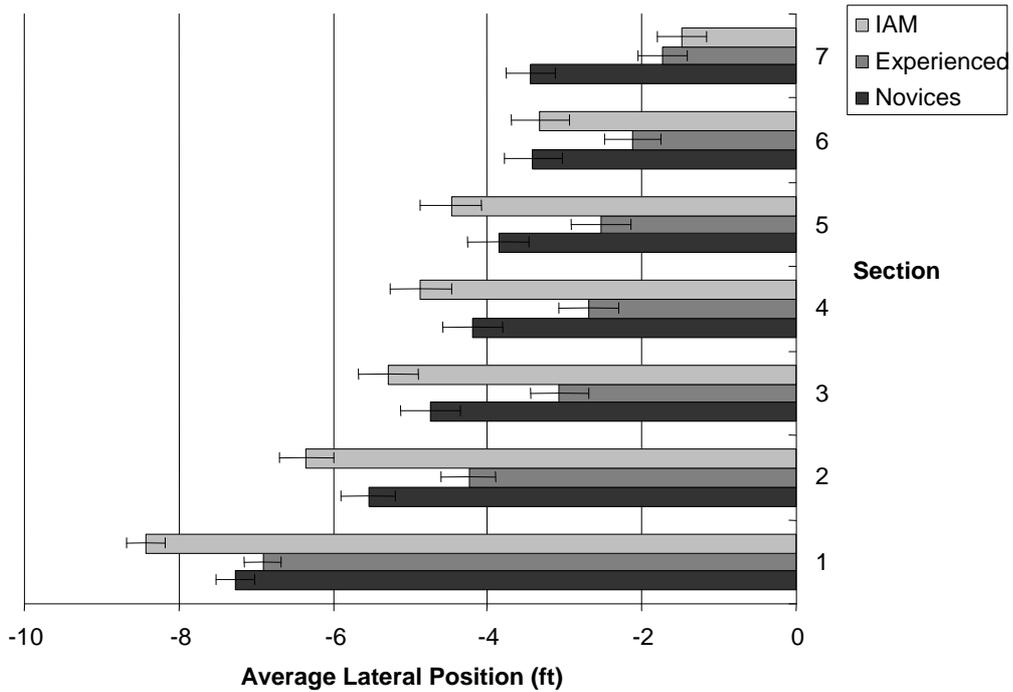
Figure 10.7: Average lateral position for rider groups across the right-hand bends

Variance in Lateral Position - although there were no main effects for rider group or bend on variance in lateral position, there was a significant interaction between rider group and bend [$F_{(2,58)} = 4.378$, $p<0.05$]. Simple main effects analysis revealed that only the Experienced riders were affected by bend [$F_{(1,20)} = 6.838$, $p<0.05$], showing more lateral movement in bend 4 than in bend 2. Furthermore, there was only an effect of rider group for bend 4 [$F_{(2,58)} = 3.878$, $p<0.05$]. Post hoc Scheffe tests revealed that during bend 4, Experienced riders displayed significantly more lateral variation than the Novices. These findings are illustrated in Figure 10.8.
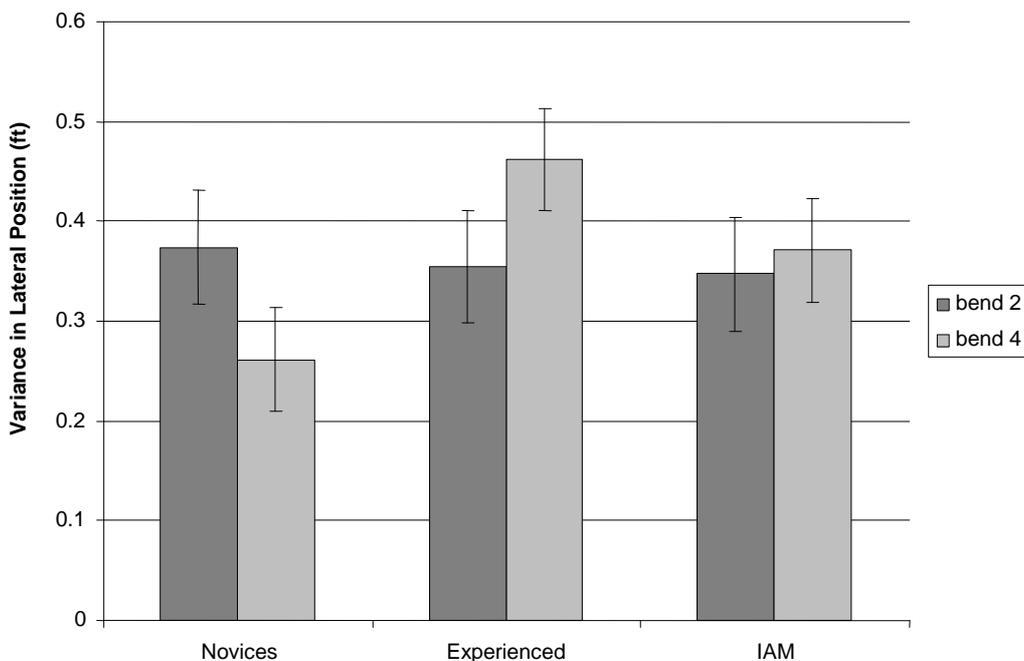
Figure 10.8: Variance in lateral position for rider group in bends 2 & 4

A significant interaction between rider group and curve section was observed [$F(12,348) = 1.829$, $p<0.05$]. Simple main effects analysis revealed that Novices significantly decreased lateral variance between sections 1 and 2 ($p<0.01$). Experienced riders significantly decreased lateral variance between sections 1 and 2 ($p<0.05$), sections 2 and 3 ($p<0.01$), and sections 3 and 4 ($p<0.05$). IAM riders significantly decreased lateral variance between sections 2 and 3 ($p<0.05$), sections 3 and 4 ($p<0.05$), then significantly increased lateral variance between sections 5 and 6 ($p<0.01$). These findings are illustrated in Figure 10.9.
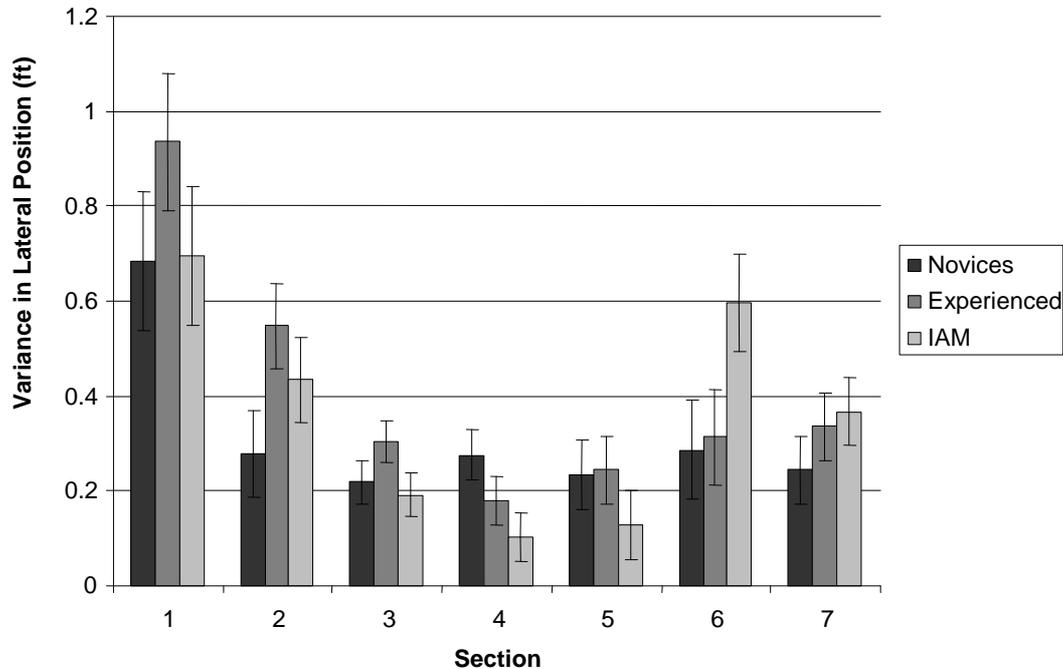
Figure 10.9: Variance in lateral position for rider groups across the right-hand bends sections

10.4. Discussion

All rider groups showed a similar pattern of speed through the bend. They all decreased their speed when they encountered the hazard and increased their speed once past it. In a right-hand bend the advanced training strategy is to keep to the left-hand side of the lane as this provides a better view through the bend and keeps the motorcyclist away from any oncoming traffic. From the results, Experienced riders were significantly closer to the centre-line of the road than the IAM and Novice riders. It would appear that they tended to take more of a racing line through the right-hand bend than the other two rider groups.

In general, riders made significant changes in lateral position over the first three curve sections, generally moving towards the centre-line. There was a clear tendency for all rider groups to take more of a racing line on the right-hand bends. Once they saw the hazard, however, riders made changes in lateral position away from the centre-line. Then from sections 5 to 7, riders made changes in lateral position back towards the centre-line. This is illustrated in Figure 10.10.
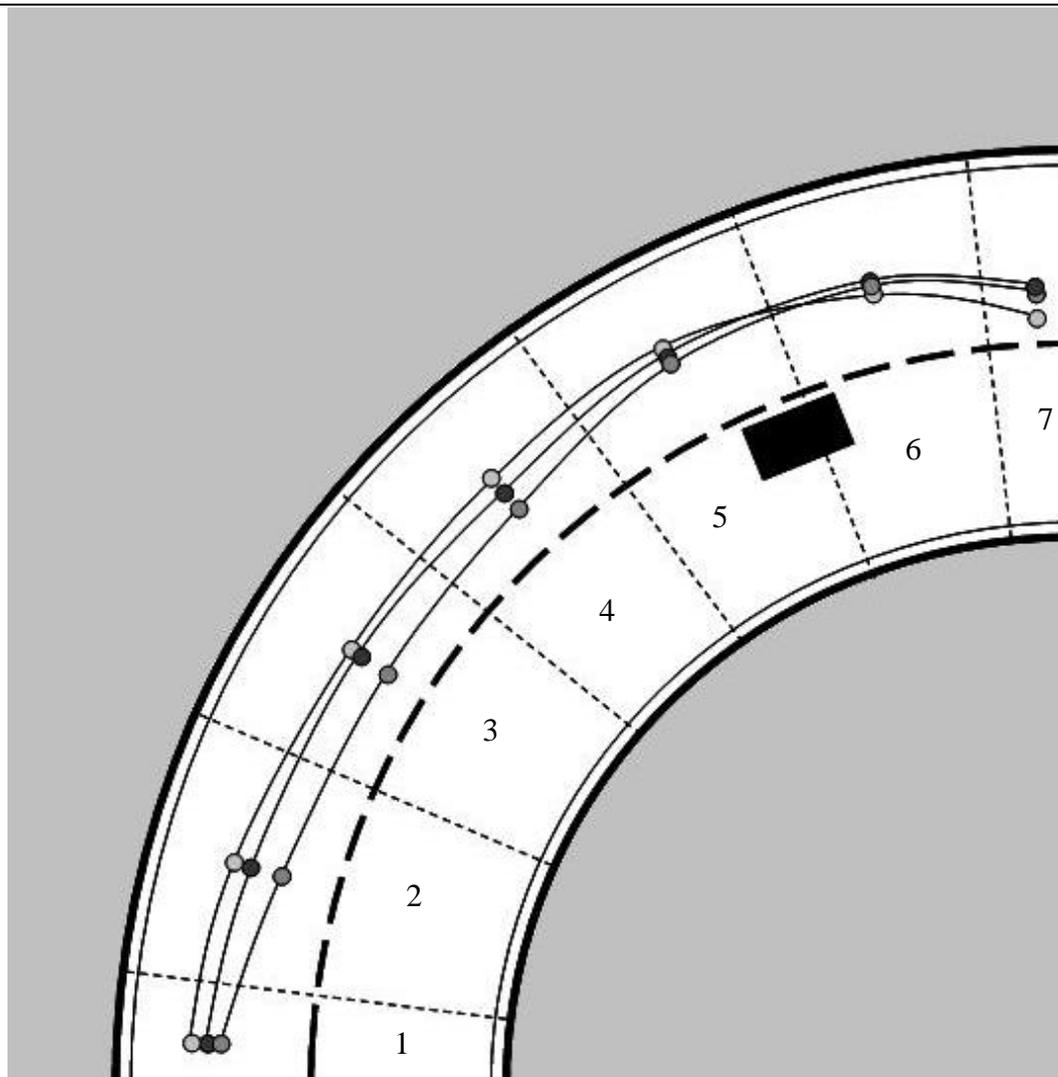
Figure 10.10: Lateral plot for the right-hand bend hazard
(the same colour coding is used as in the graphs with Novices as the darkest markers, Experienced riders as the mid-tone markers, and IAM-trained riders and the lightest markers. The black rectangle represents the oncoming vehicle hazard)

Since the hazard was encountered in section 5, the lateral profiles illustrate that all rider groups moved over to the left to avoid the oncoming vehicle. However, from the analyses, Experienced riders did not make a significant change to their lateral position between sections 5 and 6, while IAM riders did not make a significant change to their lateral position between sections 4 and 5. This suggests that, since IAM riders were already positioned further over to the left, there was no requirement for them to significantly change their lateral position in response to the hazard. However, in section 7, the IAM riders rode significantly closer to the centre line than both the Novice riders and Experienced riders. In the same way as the IAM riders made large lateral changes to their position in the left-hand bends, this could support the idea that these riders were already preparing themselves for the following road characteristics and therefore riding 'through' the bends. It could also indicate that both the Novice and Experienced riders had gone too wide on the bend and could not steer back into the bend as effectively. IAM riders varied their lateral position more than the Novice riders and whilst it was apparent that the Experienced riders varied their lateral position the most in response to the hazard, this was not statistically significant. Rather, the IAM riders made more lateral movement after the hazard as they moved towards the centre line in preparation for next bend.

In relation to the pre- and post-hazard bends, there was a tendency for all riders to take the bends faster on Lap 2, as well as positioning themselves further away from the centre line. This is an interesting result as it suggests both a decrease in caution (travelling faster) and an increase in caution (positioning themselves further from the centre-line). While this may seem initially counter-intuitive, it could be viewed in the light of Wilde's risk homeostasis theory (1998; 2001). This interpretation would suggest that the riders were reducing risk of collision in terms of position to then allow for an increase in speed.

The interaction between bend and lap in regard to speed suggests that, although riders were generally faster in lap 2, the lap effect was smaller for bend 4. Furthermore, there was a slight (but statistically non-significant) reduction in speed between bends 2 and 4 on the 2nd lap. This could suggest that encountering the hazard on bend 3 resulted in the curtailing of speed on the final bend of the 2nd lap. This is the same pattern that was noted for the left-hand bends in Chapter 9.

Interestingly, the IAM riders entered the right-hand bends in approximately the same lateral position as they exited the left-hand bends in the previous sub-scenario (about 8ft to the left of the centre line). While the Experienced and Novice riders were in a similar lateral position to the IAM riders when exiting the left-hand bends in the previous sub-scenario, they were closer to the centre line than the IAM riders in the first section of the right-hand bends in the current sub-scenario. However, between the first two sections, the IAM and the Experienced riders moved towards the centre line more sharply than the Novices, which meant that by section 2 the Experienced riders were still closer to the centre line than the IAM riders, but the Novices were riding in a similar lateral position to the IAM riders. The Experienced riders continued to ride closer to the centre line than the other two groups, but towards the end of the bend, the IAM riders made a lateral movement towards the centre line, adopting a similar position to the Experienced riders in the final section. In contrast, the Novice riders remained over to the left.

All three groups of riders made more lateral movement at the beginning of the bend than in the middle, which is consistent with the riders turning in towards the centre-line as they approached the apex rather than following the curvature of the road. However, this line was sharper for IAM and Experienced riders than it was for Novice riders (Novice riders only reduced lateral variance between the first two sections while IAM and Experienced riders continued to decrease lateral variance up to section 4). Only the IAM riders increased lateral movement at the end of the bend as well as at the beginning, as this was when they moved in towards the centre-line in preparation for the upcoming left-hand bend.

To summarise, all riders moved closer to the centre of the road as they approached the apex of the bend. This line was sharper for IAM and Experienced riders than for Novice riders, but Experienced riders were generally closer to the centre of the road than both the IAM and Novice riders. Therefore, Experienced riders adopted more of a racing line, while IAM and Novice riders adopted a line which offered better visibility. IAM riders made more movement towards the centre line at the end of the bend, adopting a similar position to the Experienced riders only after they have passed the apex of the bend. In general, IAM riders made more use of their lane, changing lateral position between every adjacent section.

11. Rider hazard perception

11.1. Introduction

Hazard perception has been described as a primary high-order skill of predicting the probability of having a collision, or the ability to read the road and anticipate forthcoming events (Horswill & McKenna, 2004; McKenna, Horswill & Alexander, 2006). There are a number of components to good hazard perception skills including the detection of the hazard, appraisal of the threat posed, selection of an appropriate response, and implementation of that response (Grayson, et al, 2003). The majority of the research conducted on hazard perception skills focuses primarily on the first and second of these actions, often using video clips of driving containing various hazardous events to which participants must respond by pressing a button when they perceive a hazard (Quimby & Watts, 1981, Olson & Sivak, 1986; McKenna & Crick, 1991, 1994, 1997; Chapman & Underwood, 1998; McKenna & Horswill, 1999; Crundall, Underwood & Chapman, 2002; Horswill & McKenna, 2004; Sagberg & Bjørnskau, 2006). The benefit of placing hazards within a simulated environment is that it is possible to model specific events with control over extraneous variables. However it is not always possible to control the way in which hazards may be encountered due to the variable nature of each participant's interaction with the simulation. For instance, one rider who is positioned closer to the centre-line may consider a pedestrian less of a hazard that another rider who is closer to the inside edge of the road. Video-based hazard perception testing allows for this level of control, albeit in a less immersive environment. In this research it seemed appropriate to measure hazard perception using both methodologies. Rider responses to the simulator hazards are detailed in Chapters 5, 6, 7, 9 and 10. This chapter will focus upon rider hazard responses using filmed clips taken from a motorcycle.

There have been a limited number of studies measuring hazard perception skills in motorcyclists. Two studies have however reported that motorcyclists respond faster to hazards than car drivers using simple push button responses to filmed clips (Underwood & Chapman, 1998; Horswill & Helman, 2003). In both cases however the clips were all filmed from a moving car, and were primarily intended for a car driving audience. The problem with this approach is apparent in the Horswill and Helman study as they found that motorcyclists were only faster to respond than car drivers if they were told to imagine they were driving a car. If the motorcyclists were asked to view the clips as if they were riding a motorcycle, they were no quicker to respond to hazards than the car drivers. Horswill and Helman suggested that this was because the clips did not represent the sort of hazards that motorcyclists would be looking for when out riding. Nonetheless, these studies suggest that motorcycle experience improved hazard perception skill compared to car drivers when both groups imagined themselves to be driving a car.

One further issue with these studies is that they did not explore the changing nature of hazard perception within a motorcyclist cohort as a function of experience and training. A recent study by Hosking, Liu & Bayly (2010) addressed this, by comparing three groups of participants:
* inexperienced motorcyclists who also had little experience of car driving
* inexperienced motorcyclists who had a considerable amount of car driving experience
* experienced motorcyclists who also have considerable car driving experience.

The riders watched computer-generated hazards while sat on a motorcycle simulator, although there was no interactivity. They merely pressed a button to identify hazards in the same way that one might with a video-based hazard perception test. The results illustrated that car driving experience improved response times to hazards, but the addition of motorcycling experience further increased the speed of responses to the hazards.

The current study builds on previous research by using filmed hazard clips taken from a moving motorcycle, based on hazards that contribute to three of the top four types of motorcycle collisions (Clarke, et al, 2007: t-junctions and other failures to give way; overtaking manoeuvres, and rear shunts). On the basis of the results of Hosking, Liu & Bayly (2010), it was expected that a in relation to response times, novices would be slowest and the IAM-trained riders being the fastest at detecting hazards.

In addition to the measure of response times, several other measures were also collected. It was important to assess what the rider thought the hazard was. Typical hazard perception tests do not collect accuracy data, therefore some button presses might be made at the correct time (e.g. just as a pedestrian is stepping into the road), even though the rider was pressing to register a completely different hazard (e.g. a parked car further ahead). In order to remove erroneous responses, every time the participants pressed the button, the screen went blank and the experimenter asked the participant what they thought the hazard was. Following this question the experimenter also asked why the participant thought the hazard had (or would) occur. Each clip had one or two bonus points attached to it regarding the deep structure of the hazard. For instance, in one clip, a car pulled out in front of the approaching motorcycle from a side road. Immediately prior to this, a car approaching from the opposite direction flashed its headlights to encourage the driver in the side road to pull out. If participants identified this, they receive a bonus point. It was predicted that the Experienced and IAM-trained riders would identify more of these deep-structural elements.

Finally the way that participants framed their responses to the question 'why did the hazard occur' was investigated. Rotter (1966) identified a continuum, known as the 'locus of control' which classifies people according to whether they attribute events to internal factors (e.g. I have a good job because I worked hard) or external factors (e.g. I have a good job because I was in the right place at the right time). Everyone falls somewhere on this continuum, though often people are simply divided into internalisers or externalisers. Research evidence suggests that, in some cases, an internal locus of control relates to a more precautionary approach to events which have potentially negative outcomes (Hoyt, 1973; Phares, 1976). For instance, Hoyt found internalisers to be more likely to wear seat belts, while Arthur, Barrett & Alexander (1991) found a link (albeit a weak one) between an internal locus of control and reduced accidents. Other authors have been less successful in identifying a beneficial relationship between internalisation and reduced accident risk (Guastello & Guastello, 1986).

It has been argued that this disagreement in the literature derives from typical locus of control questions being unrelated to driving. For instance, one item in the Krause and Stryker (1984) scale reads "many of the unhappy things in people's lives are partly due to bad luck. People's misfortunes result from the mistakes they make" which requires a true or false answer. In an effort to capture a measure of locus of control that is more relevant to driving, Montag & Comrey (1987) created two scales that were based on a driving context. They too found that internalisation was positively related to safer driving. However, later research using a multi-dimensional scale of locus of control suggested that internalisers were more likely to engage in risky behaviour (Özkan & Lajunen, 2005).

In the current study an attempt was made to bypass the problems of self-report and image manipulation that questionnaire studies of locus of control may possibly evoke, by recording spontaneous references to internal or external causes for the hazards. Of particular interest was whether the participants would blame the hazard on external causes ('the car driver wasn't looking') or internal causes ('the motorcyclist was too close to the car ahead'). Whilst the latter example was not an internal attribution in the strictest sense, the rider in the video clips (from whose motorcycle the clips are filmed) acted as a proxy for the internal cause. It was predicted that advanced training might induce a more internal response to these hazards than would be observed in the other two groups (Montag & Comrey, 1987).

In order to ensure that any such differences in the attribution of hazards to internal or external causes were due to specific motorcycle experience or training, a shortened version of Rotter's (1966) questionnaire was given to all participants (Krause & Stryker, 1984). The aim of this was to assess whether there were any differences between the groups in general tendencies to provide external or internal attributions to events. It was predicted that if any differences in the attribution of hazards was due specifically to motorcycle training, then there should be no difference between groups in their general score on a locus of control questionnaire.

11.2. Method

All 61 participants contributed data to the analysis of the hazard perception test. The test consisted of 14 randomly-ordered video clips (each lasting less than a minute) presented on a 20 inch iMac computer. The video clips were all filmed from the point of view of a motorcyclist, and depicted a series of staged developing interactions with associated hazards in a real-world road setting. Figure 11.1 illustrates some of the hazards that participants encountered.

Figure 11.1: A selection of scenarios in the hazard perception task

Participants were asked to watch each video sequence, and press the space-bar when they saw a hazard occurring that would require an action on their part (e.g. braking or swerving). When a hazard was detected, the video would pause and the screen would turn black, and the participant was asked two questions:

- what was the hazard?
- why did the hazard occur?

Two experimenters scored the responses for accuracy, occurrence of an early/false response, and any additional information given. Experimenters also attributed causative answers given to the second question based on whether the participant attributed the cause of the hazard primarily to the motorcyclist (internal), or primarily to another driver or traffic conditions (external). Responses to the hazard perception task were also audio recorded to aid in post-hoc coding of responses. A further aspect of the study was a nine item locus of control questionnaire (Krause and Stryker, 1984; after Rotter, 1966). The purpose of this questionnaire was to test underlying tendencies of participants to attribute general causation to factors either internal or external to themselves. Figure 11.2 illustrates the experimental set-up.
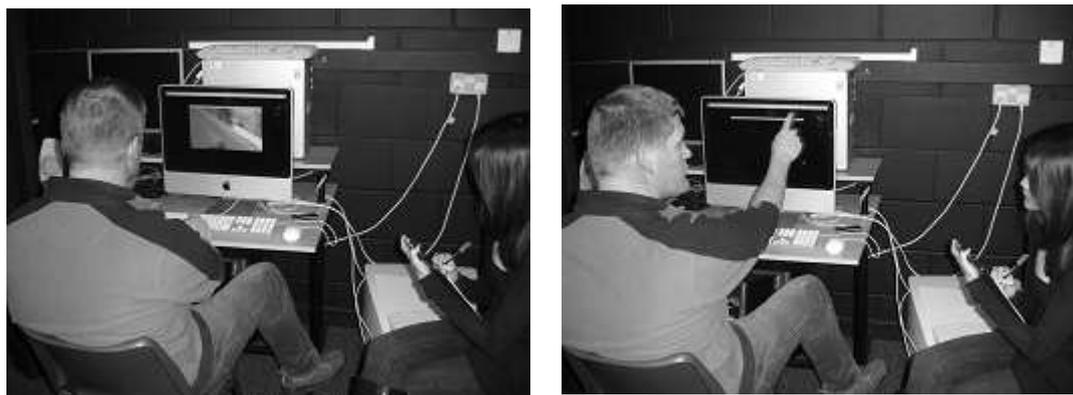
Figure 11.2: A participant performing the hazard perception task

11.3. Results

> **All riders correctly responded to approximately 12 pre-defined hazards out of a possible 14, and no difference was found for the number of responses between the rider groups.**
>
> **IAM riders were quicker to identify the hazards than the Experienced rider group; gave more internal explanations for the hazards than Novice riders and gave fewer externalised explanations than Novice riders.**
>
> **No difference between the groups was observed for 'locus of control' scores reinforcing the idea that advanced training promotes a higher degree of internalization that is specific to motorcycling.**

The first analysis compared the number of button responses made by each group in a 1x3 ANOVA. This was an important initial analysis. If one group tended to make more responses than another then this could have inflated their opportunities for correctly reporting the hazard just by chance. Prior to entering the data into the analysis one IAM-trained rider was removed from the sample. This rider made 63 button presses across 14 clips (an average of 4.5 responses per clip). This was more than three standard deviations away from the mean of the IAM-trained group, and was therefore considered to be a statistical outlier.

The average number of presses made by the remaining 60 participants across all 14 clips was 16.5, 16.3 and 19.2 for Novice, Experienced and IAM-trained riders respectively (averaging, at most, 1.5 presses per clip). No statistical difference was found between the three groups ($p > 0.05$) suggesting that the remaining analyses are unlikely to be confounded by the frequency of responses.

The number of hazards that were responded to (and were correctly identified verbally by the rider immediately following the button press), were then compared in a 1x3 ANOVA. All riders correctly responded to approximately 12 pre-defined hazards out of a total of 14, but no difference was found between the groups ($p > 0.05$). One particular clip appeared to have relatively few responses with only 33.3% of the total sample pressing and accurately identifying the hazard. All other clips had between 71% and 100% of participants responding to, and identifying, the hazard.

The response times to correctly identify hazards were then compared in a 1x3 ANOVA. An effect of rider group was found [$F_{(2,57)} = 3.13$, $p = 0.05$]. Post hoc Tukey HSD tests demonstrated that this effect was due to the IAM-trained riders being faster to respond

to the hazards than the Experienced rider group (p<0.05).   The response times for Novice riders fell in-between these two groups (Table 11.1).

	Novice (n=20)	Experienced (n=21)	IAM-trained (n=19)
Number of presses	16.5	16.3	19.2
Hazards correctly identified (%)	87.9	85.7	82.9
Response times (ms)	924	1164	809
Deep-structure score (%)	30.6	28.1	33.8
Internalised explanation score (%)	20.0	32.1	42.1
Externalised explanation score (%)	82.1	72.1	68.6
Locus of control (score out of 9)	2.3	2.9	2.2

Table 11.1: Hazard perception measures for the three rider groups

A 1x3 ANOVA on the deep structure score revealed no difference between the rider groups. When the same analysis was applied to the number of hazards that received an internalised explanation from the riders, an effect of rider group was found [$F_{(2,57)} = 5.2$, $p<0.01$]. Post hoc tests revealed that the IAM-trained group gave more internal explanations for the hazard than the Novices ($p<0.01$). The Experienced riders ratings fell in-between and were not significantly different (Table 11.1).

A similar 1x3 ANOVA on the number of external explanations given for the hazards also revealed an effect of rider group [$F_{(2,57)} = 3.6$, $p < 0.05$]. Post hoc tests confirmed that the IAM-trained riders gave fewer externalised explanations than Novices ($p<0.05$) with the Experienced riders again falling in-between (Table 11.1).

The tendency for the IAM-trained riders to provide the most internal explanations and the fewest external explanations might have reflected something specific to that group which may have arisen from their greater level of training. Alternatively it might have been that individuals who are generally prone to make more internal attributions (internalisers) may be more likely to undertake further motorcycle training. To tease apart these alternatives, responses to the 'locus of control' questionnaire were analysed. If differences in the rider groups were due to underlying personality differences, the locus of control measure should have followed the same pattern as the internalised and externalised explanation scores. More specifically, the Novice scores would score significantly higher on the locus of control (i.e. more toward the externaliser end of the scale) than the IAM-trained riders. When locus of control scores were compared in a 1x3 ANOVA no effect of rider group was forthcoming ($p>0.05$), reinforcing the notion that advanced training may be intrinsically linked to a internal attribution bias that is specific to motorcycling.

11.4. Discussion

The results have demonstrated that IAM-trained riders were significantly faster to response to hazards in the current test than the Experienced riders. However the Novice riders fell in between the response times of the other two groups. They were slightly faster than the Experienced riders, yet slightly slower than the IAM-trained riders.   These results suggest a more complicated picture that that suggested by Hosking, Liu & Bayly (2010). Their study suggested that increasing experience led to faster response times. The current results however suggest that Experienced riders produced the slowest hazard perception responses.

One possible explanation lies with the requirement to undertake a hazard perception test as part of the driving test. All of the Novice riders who also had a driving license had passed their test after the 2002 introduction of the hazard perception test as a formal requirement of licensing. They also would therefore have undertaken specific hazard perception training. It is also likely that they underwent specific hazard perception training when studying to gain a motorcycle license. Similarly one might also expect IAM-trained riders to become more sensitive to hazards on the road due to their advanced training. However the majority of the Experienced rider group gained

their licenses before 2002 and therefore may have had no previous exposure to a hazard perception test.

While previous studies have always relied upon experienced car drivers to respond faster than novice car drivers in order to validate a particular hazard perception test, the results of this study may suggest that such reliance may be flawed in the future. The reason for introducing formal hazard perception testing into the driving test was to improve the hazard perception abilities of novice drivers. It is possible that novice drivers or riders are actually quite proficient at spotting and responding to hazards in a standard hazard perception task, and the typical pattern of results may be reversed. If this is the case, then it could be argued that older experienced riders may be lacking some of the hazard perception skills that the younger riders have gained from recently undergoing specific hazard perception training. The advanced training received by the IAM riders appears to instill the same level of skill, if not more so. This is an argument for all existing riders, who have never undergone some form of hazard perception training or instruction, to consider upgrading their skills through advanced training.

The other exciting finding is that the novel inclusion of a measure of locus of control in the hazard perception test revealed a clear benefit of experience and training. IAM-trained riders produced more internal attributions of blame ('the motorcyclist shouldn't have been in that position') and fewer external attributions compared to the Novices. In both cases the Experienced riders fell in between. This either suggests that all riders who take IAM advance training are internalisers in every aspect of their lives, or that training and experience increase internal attributions that are specific to motorcycling events. The first possibility is unlikely as the general measure of locus of control revealed no differences between the three rider groups (i.e. no group was particularly more prone to internal or external tendencies). Thus it appears that the IAM-trained riders (and to a lesser extent, the Experienced riders) were more likely to look to their own skills when interpreting potential causes for accidents. This linking of an internal locus to safer riding responses supports previous questionnaire work that has found similar self-reported links (Montag & Comrey, 1987).

The difference between the response time analyses (with Experienced riders fairing the worst) and the analysis of external and internal causes attributed to the hazards (with Novices fairing the worst) suggests that the relatively fast response times of the Novices may reflect a qualitatively different type of skill to that of the IAM-trained riders. In other words the Novice riders may have undergone training to pass a hazard perception test however the IAM-trained riders have undergone a richer training process that has created an onus of responsibility, which is a pre-requisite for safe riding. Whilst it was disappointing that a benefit of advanced training was not present in the analysis of the deep-structure score, it is possible that this particular measure was too underpowered. Alternatively, it might be that deep-structural understanding of hazardous events is something that even the IAM-trained riders cannot extract easily (i.e. communicating what you know of what you know). Regardless of this particular effect however, the overall results suggest that IAM-trained riders have distinct advantages in identifying hazards compared to their experienced counterparts. Even when compared to the Novice riders who perform relatively well, it appears that the knowledge of the IAM-trained riders stems from a qualitatively different understanding of riding.

12. Discussion

12.1. Introduction

This chapter reviews the findings and discusses the potential for simulators within transport research, as well as highlighting key areas for future research activities in the following subsections:

- Meeting the objectives of the research
- Summary of findings
- General observations
- Experience and expertise
- Simulators for transport research
- Future research
- Dissemination

12.2. Meeting the objectives of the research

The aim of this research was to investigate the differences in rider performance according to different levels of training that riders have received, focusing on:

- Novice riders
- Experienced riders (without advanced training)
- IAM riders (who have passed the IAM motorcycle road test)

In order to achieve this, the following objectives were identified:

- Develop an integrated experimental approach
- Build a bespoke riding scenario
- Recruit and conduct the study across the three rider groups
- Analyse and disseminate the findings

In the course of this research a unique integrated experimental design was developed and implemented (this has now been submitted for a journal publication in its own right) and a bespoke riding scenario was built with a number of mini-experiments embedded within it. Given the nature of the simulation software, this scenario (and the various sub-scenario experiments) can be re-used in the future for other motorcycle research as well as transferred to the Human Factors Research Group car simulator to run comparative studies against motorcyclists (for which the data has already been collected) and different car driver groups.

The study was conducted using the required number of participants through local and national recruitment activities. The research was run to capitalize on recruitment through the summer months, however as the specific group criteria were quite strict, it became difficult to find Novice riders even with the support of local rider training schools. It also became difficult to recruit the Advanced riders due to low numbers of newly qualified locally trained riders. A degree of flexibility was required in running sessions out of office hours (e.g. evenings and weekends) to accommodate participants and further recruitment options were used such as targeted rider meetings and a specific national newsletter.

The findings have been thoroughly analysed and already disseminated in a short overview report (Stedmon, et al, 2010) and as an IAM document (IAM, 2010) and since the official launch of the findings at 'Motorcycle Live 2010' the research has received a lot of media interest and is now publicised on internet sites around the world.

12.3. Summary of findings

A summary of the findings is presented below:

Demographics (Chapter 4)

- As expected, the male sample in this study accounted for the majority (88.5%) of participants. However, the Novice group contained the largest proportion of female riders (20%) however, like the Experienced and IAM-trained groups, they appeared to follow the expected demographic trends.
- Novice riders tended to have the least riding experience. IAM and Experienced riders were similar which was encouraging as it meant that the opportunistic samples did not happen, by chance, to have an IAM group that were a lot more experienced than the other riders which could have confounded other data.

General riding, attitudes & workload (Chapter 5)

- In response to the MRBQ, IAM-trained riders reported fewer traffic errors and fewer speed violations than both Novice and Experienced riders.
- In the riding scenario, there is a strong trend which suggested that IAM riders had fewer accidents as a result of the pre-defined hazards.
- Overall, the rider groups rode at similar speeds in the 60mph zones, but IAM riders rode at slower speeds in the 40mph zones, opening the throttle less and braking more strongly.
- IAM riders tended to ride closer to the middle of the road than Experienced riders who, in turn, rode closer to the centre line than Novices.
- IAM riders made more use of the road than Novices (but not Experienced riders). Experienced riders also made more use of road than Novices, but only in 60mph zones. This supports the hypothesis that advanced training improves behaviour over and above experience, but in this research, the improvement was specific to 40mph zones.
- Analysis of the scenario as a whole revealed that IAM riders had the highest speed through curved sections, closely followed by the Novice riders. Experienced riders tended to take all the curves at lower speeds than the other two rider groups.
- An analysis of lane positioning on straights and through curves suggested that IAM riders prepared for bends earlier by changing lane position during the spirals, whereas Novice and Experienced riders tended to alter their position later in the bends.
- No differences were found in the workload measures, indicating that all 3 groups were engaging a similar amount of cognitive and physical effort. This means that, although the IAM riders generally displayed optimum behaviour during the scenario, this was not because they were putting in more effort, or because they found the task easier than the other rider groups.

Side roads (Chapter 6)

- As the riders approached side road hazards, they moved towards the centre of the road in anticipation of a possible hazard, changing lateral position approximately 400 to 300ft before the junction. However, they still made large alterations to their road position (e.g. similar to swerving behaviour) when a car pulled out of the junction. Riders did not anticipate the hazard by reducing speed. Riders did not anticipate the hazard by reducing speed in advance, but they did reduce speed in the last 100ft before the junction in direct response to the hazard.
- The IAM riders approached the side roads at slower speeds regardless of whether or not they could see a potential hazard, whereas Experienced riders only reduced their speed when they could see a potential hazard or if they were not confident that they would be able to see a potential hazard if it was there (i.e. obscured side roads).
- On average Experienced riders were traveling above the speed limit when approaching open side roads and side roads that did not contain a car.
- Whereas the Novice riders did not differ from the IAM riders in terms of speed, the IAM riders rode closer to the centre line than the Novices. The IAM riders also rode closer to the centre line than the Experienced riders but only when

approaching open side roads. When junctions were obscured, Experienced riders displayed a similar level of caution to the IAM riders, riding closer to the centre line. However, the occurrence of the hazard led Novice and Experienced riders to exercise more caution when they could not see a car at subsequent side roads.

Urban riding (Chapter 7)

- In the urban section, only Experienced riders significantly reduced their speed on approach to the parked cars concealing the pedestrian. This was probably because they were on average travelling too fast. The IAM riders approached the cars more slowly and did not need to adjust their speed as dramatically (and then only in the last 50ft). Novices generally did not respond to the hazard with a reduction in speed but attempted to move out of the way.
- Initially, all three groups were positioned similarly with Novices further from the centre-line than the IAM-trained and Experienced riders. On approach to the hazard, all three groups moved towards the centre line, but the IAM riders and Novices made more lateral movement, meaning that by the time they reached the hazard, the IAM riders were much closer to the centre line than the Experienced and Novice riders.
- In the urban section, IAM riders rode closer to centre of the road than the Novices. The behaviour of the Experienced riders depended on whether or not there were parked cars. When there were no parked cars, the Experienced riders adopted a similar lateral position to the IAM riders. However, when there were parked cars, the Experienced riders adopted a similar lateral position to the Novices. All three groups rode closer to the centre of the road in lap 2, after the hazard had occurred.

Bends with barriers (Chapter 8)

- When riding through the bends with Armco barriers, all riders slowed down into the bends then picked up speed on the way out. IAM riders were faster throughout; Novice riders approached the bends slowly and then built up their speed; Experienced riders tended to approach bends at a similar higher speed to the IAM riders, but slowed down more before building up their speed again.
- While the IAM riders were faster than the other two groups on Lap 1, the Novices and Experienced riders speeded up on Lap 2, riding at similar speeds to the IAM riders. However, while Novices speeded up on Lap 2 regardless of whether the bend furniture was near or far, the Experienced riders only increased their speed on bends with furniture that was far from the roadside.
- All riders slowed down on bends when there were trees close to the roadside and rode further from centre-line when there were trees present, or when either type of furniture (i.e. trees or Armco barrier) was close to the road edge.

Left-hand bends (Chapter 9)

- In the left-hand bends scenario, all riders decreased their speed as they encountered the hazard then increased their speed once past the hazard. IAM riders rode closer to the centre line than the Novices or Experienced riders. As a result, the IAM riders got into an appropriate passing position earlier than the other two rider groups.
- In general, familiarity with the left-hand bends led to an increase in speed, but riders ceased to increase speed after the occurrence of the hazard.
- IAM riders rode closer to the centre line than the other two rider groups. Novices changed lateral position after experiencing the hazard, but the Experienced riders did not change their lateral position as result of the hazard.
- IAM riders did not need to change their lateral position as a result of the hazard, as they were already in an optimal position. Experienced and Novice riders adopted racing lines early in the bend before they had a clear line of sight through the bend, but IAM riders adopted shallower racing lines, and moved to the left at a later point in the curve to achieve better visibility.

Right-hand bends (Chapter 10)

- The results of the right-hand bends scenario reflected those of the left-hand bends scenario. Again, riders reduced speed in response to the hazard, then increased speed once past it. The IAM riders chose a line which gave them better

visibility than the Experienced riders (closer to the left-hand side of the road). As a result, the IAM riders did not need to significantly change their lateral position in response to hazard.

- IAM riders also recovered quickly enough to prepare for the upcoming left-hand bend by positioning themselves nearer to centre line than both the Novice and Experienced riders.
- Again, familiarity with the right-hand bends led to an increase in speed, with riders generally riding faster on Lap 2 than on Lap 1. However, riders ceased to increase speed after the occurrence of the hazard. Riders generally rode closer to the centre line on lap 2, so they were more cautious in terms of lateral position on the 2nd lap, despite increasing their speed.

Hazard Perception (Chapter 11)
- On the hazard perception test, there were no differences between rider groups in relation to the number of correct responses, however the IAM riders were quicker to identify the hazards than the Experienced rider group. Also, the IAM riders gave more internal (and fewer external) explanations of why the hazard occurred (i.e. they were more likely to blame the rider than the other road users for the hazardous situation) than the Novice riders despite scoring similarly on a general locus of control measure. This suggests that training promotes a higher degree of internalization that is specific to motorcycling.

12.4. General observations

The aim of this research was to explore issues associated with behaviour, skills and attitudes of the different rider groups. It would seem to be that advanced riders have enhanced skills but perhaps more importantly, a different mindset to our other two rider groups.

IAM training shows clear benefits for urban riding. In 40mph zones IAM riders had better road positions to anticipate a variety of hazards and respond accordingly. IAM riders also performed better in rural situations. Again, this rider group was quicker around the bends, and generally rode in a more defensive position closer to the centre line. IAM riders did not use their brakes as much as the other riders in the 60mph zones and as they were already travelling slower in the 40mph zone they could brake harder.

IAM riders were generally smoother in their riding style making better progress into, around and out of a variety of bends. When furniture was present on the outside of the bend (and in particular, trees close to the roadside) rider behaviour was more cautious with slower speeds and road position surrendered.

When negotiating hazards on either left- or right-hand bends Novice and Experienced riders both appeared to respond late to the hazards and adopt road positions which left them vulnerable to oncoming traffic. Advanced riders were smoother at negotiating the hazards and appeared to be able to ride 'through' the bends by preparing for the next bend earlier than the Novice and Experienced riders. All rider groups tended to take more of a racing line on the right bends than left-hand bends and when hazards were approached on bends there was a clear tendency to reduce speed dramatically. When hazards were encountered on a straight road sections there was more of a tendency to alter road position before reducing speed. This seems to indicate a reservation in riders to initially alter their line on a bend in order to avoid a hazard.

Experienced riders illustrated some behaviours similar to advanced riders (e.g. lateral variance in 60mph zones and entry speeds into bends) but also reverted to behaviours more aligned to Novice riders (e.g. lateral variance in 40mph zones), illustrating that experience alone does not necessarily make people better riders.

It would appear that Novice riders may not have yet fully developed their road awareness and in some instances perhaps adopted behaviours similar to advanced riders without the commensurate skills. Experienced riders appeared to be over

cautious in bends compared to either the Novice or IAM-trained riders, whilst IAM riders showed clear advantages in their riding behaviour across a number of the sub-scenarios. They were generally better able to recognise potential hazards and with a better initial road position they did not have to alter their riding lines drastically.

In general, the results indicated that Advanced riders had a different mind-set to the other groups, especially in relation to aspects of the research such as hazard perception skills and interpretations of liability. In relation to 'locus of control' theory the rider groups were homogenous in their general perspectives but when their interpretations of the hazards were considered, Advanced riders placed a greater emphasis on rider responsibility. This compared well to the rider data from the simulator as Advanced riders took more defensive road positions that allowed better views and opportunities to anticipate and react to hazards. There would appear to be some benefits associated with experience, but a higher level of proficiency gained through advanced training.

12.5. Experience and expertise

A naïve view of experience and expertise is that performance increases in a roughly linear fashion with experience. At some point the individual will begin to receive diminishing returns for their continued increase in experience, and only advanced training will allow further improvements in performance. This suggests that experience is beneficial to an extent, although advanced training may provide enhanced benefits, above and beyond experience.

Some of the reported results follow this pattern. Overall lane variance for instance shows a significant increase from Novice to IAM-trained riders with the Experienced riders falling in the middle. It appears that motorcycle experience does increase a rider's flexibility in lane position, yet advanced training improves this even further.

Other results however do not follow the pattern of linear improvement across the three groups. For instance the first comparisons of self-reported traffic errors and speed violations show that only the IAM-trained riders report significantly lower ratings. Simple motorcycling experience does not diminish the number of errors or speed violations relative to the Novices; instead advanced training is required to change self-reported behaviour. In regard to the traffic errors one could argue that the Experienced riders may actually commit fewer errors than the Novices, but because they have an increased awareness of errors, their reporting rate is higher than it was previously. The IAM riders however are presumably as aware of errors on the road as the Experienced riders even though they reported fewer. This either means that they commit fewer errors or they are predisposed to report fewer errors for some reason. This is an inherent problem with self-reported measures, although the differences observed in the simulator and hazard perception studies support the idea that the lower self reported ratings of traffic errors may reflect greater skill on the road. Similarly with speed violations, it can be argued that the IAM group was trying to create a positive image. Again, their self-reported ratings match their behaviour in the simulator. Whilst it is possible that IAM riders could also ride more slowly in the simulator to reinforce a positive façade, their speeds were not always slower than the other groups. So whilst they have a slower average speed in the 40mph zone (where unexpected hazards might be more likely to occur) they tended to have faster progression through the bends in the 60mph zone. This suggests that the effects of training that are noted in the self-reported ratings are also reflected in the simulator measures and whilst a general reduction in speed is not apparent, there appears to be a tailoring of speed to specific situations.

Research on experienced and advanced car drivers (the latter being IAM trained drivers) has previously shown that the linear function of behavioural improvement often fails to appear (Duncan, et al, 1991). In this research, Novices and IAM-trained drivers often performed similarly on several measures of driving performance, such as frequent mirror checking and early braking, with the experienced drivers performing the worst. Certainly there is a suggestion that some forms of experience can lead to potentially

negative changes in performance (Koustanai, et al, 2008). This pattern is noticeable in the current data. For instance, Experienced riders were the slowest through the bends and performed worst on the hazard perception test. These two very different measures probably illustrate a pattern of group differences for very different reasons. With regard to speed through the bends it is likely that Novices did not fully appreciate the risk presented by approaching a bend at a specific speed. Experienced riders may have been involved in previous instances where they felt that they had taken a bend too fast and this may have resulted in the slower average speeds. The IAM riders however will have been taught specific skills for progression which should allow them to take a bend faster than the Experienced riders. With regard to the hazard perception test however it is likely that the explicit hazard perception training that Novice riders are likely to have encountered in their motorcycle test training, gave them an edge over the Experienced riders. This advantage however appeared to be quite shallow as there was no significant difference between the Novices and the Experienced riders (Novice riders performed at a level between the significant difference between the IAM and Experienced riders). Furthermore, IAM riders complemented their superior hazard perception skills with greater internalisation of the causes of the hazards, suggesting a greater understanding of the events. In this light, one might consider the performance of the Novice riders on the hazard perception test to be a procedural advantage (they understand how the test works and what they should do) rather than perhaps reflecting any superior performance on the road over the Experienced riders.

According to Duncan, et al, (1991) those behaviours that show an improvement in behaviour with experience should have clear feedback. For example in Figure 5.5 it is apparent that the Experienced riders had greater lateral variance than the Novices on 60mph roads (similar to the IAM riders). Yet on 40mph roads, their variance was more akin to the Novices than that of the IAM riders. Following the argument of Duncan, et al, this may have occurred because the Experience riders have encountered feedback on real 60mph roads that has gradually shaped their behaviour to encourage a greater variance of lateral position. On 40mph roads however, variance in lateral position is perhaps more important for visibility and hazard avoidance than progression. Feedback may therefore be shaped through direct experience of hazards (which are infrequent events) and relating them to the position that was adopted in the lane, or through specific training. Thus this particular pattern of lane variance fits with the suggestion of Duncan, et al, (1991) that one of the primary advantages of advanced training is to provide structured feedback that riders or drivers might only come across infrequently in the real world.

12.6. Simulators for transport research

A further aspect of the research was embedded in the use of the novel motorcycle simulator. Within transport research, real world data provides a valuable perspective of human machine interaction within a real context of use. However, this is not always practical, or indeed ethical, especially if investigating user behaviour in situations which could compromise personal or public safety (Stedmon, Young & Hasseldine, 2009). Simulators therefore offer opportunities to investigate how road users perform complex tasks with a higher degree of experimental control (usually in a laboratory setting) but at the potential expense of real world fidelity and ecological validity (Liu, Macchiarella, & Vincenzi, 2009).

Simulators offer a level of abstraction from the real world by providing an artificial environment in which users can experience characteristics of a real system (Stedmon, Young & Hasseldine, 2009). Within transport simulation, design solutions are usually achieved through the integration of underlying hardware (often taken from, or mimicking, an original system) coupled with a computer-generated images for an interactive experience. With any simulator there are limits to the degree of realism that can be achieved and it is important, when developing them, to ensure that they do not become a slavish attempt to recreate a real world system (Stedmon, et al, 2009). A key human factors question is the degree of realism that is required in order that they serve the purpose for which they are intended (training, research, product

development, etc) based on a fundamental understanding of user requirements, user expectations and the intended user experience.

If simulators operate on a spectrum of abstraction from low-end, paper based schematics, through to high-end full replica systems, there are fundamental issues associated with how 'fit for purpose' they might be. With any simulator, participants usually appreciate that they are not operating a real system with the full consequences of that system (e.g. if a pilot crashes in an aircraft simulator, they know they will not be injured). This means that users can make mistakes and learn from the consequences in a safe environment, but it also that simulators therefore suffer from fundamental issues of fidelity and validity. Two dimensions of fidelity are considered to have the greatest impact on the validity of simulator research (Stanton, 1996):

- physical fidelity (the extent to which the simulator *looks* like the real system)
- functional fidelity (the extent to which the simulator *acts* like the real system).

Whilst physical fidelity is important in training simulators, it has been argued that it is less important for research simulators where it can be compromised without affecting the transferability of results assuming that functional fidelity is maintained (Stammers, 1986). Physical fidelity may also support aspects of immersion and a sense of presence in the simulated scenario (i.e. the degree to which someone believes they are in the artificial environment) which may lead to more realistic behaviours (Stanney & Salvendy, 1996).

Fidelity, in itself, is an important factor of simulation design but it also plays an important part in the validity of simulators (Liu, Macchiarella, & Vincenzi, 2009). Motion systems can enhance the face validity of a simulator for participants and passive observers if implemented effectively (e.g. it is what people expect of a transport simulator). However, if the physical motion and cognitive cues are mis-matched, symptoms of general discomfort and simulator sickness can arise which pose significant problems in the design simulators and execution of research.

Fidelity also underpins the ecological validity of simulator research and the transfer of findings to the real world. Ecological validity is the extent to which research generalises from one setting to another and usually the real world is assumed to be the pinnacle of ecological validity. Research has higher ecological validity if it generalises beyond the laboratory to field settings, however a field study, in a naturalistic setting, is not automatically ecologically valid (Coolican, 2005). A study can be high in realism but if it is too specific and constrained, the findings will not generalise to other natural settings and so it has low ecological validity. Simulators can therefore be ecologically valid if they demonstrate findings that can be generalised to other contexts of use.

Within this research and in view of the sensitivity of the data collected from the simulator, there is strong evidence supporting the validity of MotorcycleSim for exploring differences in rider behaviour. This provides a solid basis for the findings reported in this research as well as for future research using for motorcycle simulators in general. The physical fidelity of MotorcycleSim is high with it using a real motorcycle and the functional fidelity is high given the realistic interface of the controls to the software. Currently, there is a limit to the functional fidelity of the counter-steering module and so this study only used positive steering which had been validated in previous research (Stedmon, et al, 2009). With the options to model specific road hazards in realistic scenarios, the ecological validity of the research was also high and therefore provides a strong basis for expecting similar behaviours in real world settings.

12.7. Future research

Having reviewed the findings across the integrated experiment approach, there are some interesting avenues to explore in future research. MotorcycleSim has demonstrated that it is a serious research tool and given its position as the only simulator of its kind running 'STI-SIM Drive' software, it offers a unique opportunity to test riders in controlled experiments. The research has been conducted in a relatively

short period of time without compromising scientific integrity or sensitivity of the measures explored. Indeed, through the careful design of the experimental process, a very efficient procedure was developed which allowed for a complex investigation across a number of complementary measures (e.g. rider attitudes, simulator riding, hazard perception, locus of control).

Given the suggestion that a significant proportion of motorcyclists are either using newly learned skills or relying on old skills that were developed some years ago and which may have subsequently degraded through a period of non-use (Department for Transport, 2005), a useful follow on project would be to look at aspects of experience and expertise development. This could be achieved by shadowing a number of participants through their training and looking at their skill development over time in a longitudinal fashion.

Another area of research that has yet to be explored specifically in a motorcycling context is that of skill fade. Anecdotal evidence suggests that motorcyclists are particularly sensitive to their riding experiences on a daily basis. They will often remark if they are having, or have had, a good day's riding (and this often relates to how well they are riding and not the road conditions). With the demographic data in this study supporting the general observations that motorcycle riding in the UK is largely a leisure activity, some motorcyclists are equally aware that even over the winter, if they do not regularly ride, their skills diminish (and some riders are even sensitive to their skills fading if they do not ride for a few weeks). There could be a proportion of riders who may not be as aware and there is little evidence of how skills fade or which skills fade more than others. Furthermore, with advanced training, there is an assumption that acquired advanced skills are a basis for long-term driving and riding. Again, there is little knowledge about how advanced skills fade over time, what specific skills might be more prone to fading, what that time period might be and when refresher training might be required.

From this research more specifically, the roadside furniture could be explored in more detail. In this study only two types of furniture were used (e.g. the Armco barrier and trees) and a coarse distinction was made between their cue salience (one being a man-made object placed there for a specific reason, the other a naturally occurring object). There are many more variables that could be explored to investigate specific thresholds for behaviour change and how specific furniture characteristics (e.g. low and high walls, fencing structures, buildings, hedges, crops, etc) affect optic flow and subsequent rider behaviour.

Another interesting aspect of this research was rider behaviour on bends, in general, and also when riders experienced hazardous situations on left- and right-hand bends. To extend this research, other variables could be investigated to form a deeper understanding of behaviour on bends (such as oncoming traffic effects and different curve characteristics). In this way it would be possible to extend the lateral plots presented for the hazards in other situations to understand any differences between the rider groups and thresholds for when position is surrendered for safety.

A further option for future research lies in the situation of the MotorcycleSim being housed next to a car simulator running the same software. This means that scenarios are interchangeable and it is therefore possible to compare motorcyclists and car drivers in the same environment. Motorcycles, given their narrower dimensions, are able to exploit lateral deviation on the road more than cars (indeed, optimal use of lateral position is specifically trained for in advanced riding) and how these two transport modes use the road in different ways could be important in understanding how different accidents occur. Although it was primarily built as a research tool, the motorcycle and car simulators offer immense potential to investigate and implement simulator training for both car drivers and motorcyclists. Exploring how such technologies might best support standard training is likely to become more important in the future as training technologies become more affordable.

Furthermore, the compatibility of the car simulator and MotorcycleSim raise the possibility of creating shared virtual environments, within which the behaviour of a rider and a car driver can be investigated at the same time. The level of realism and interaction that this completely novel methodology would provide would be unprecedented and the University of Nottingham is committed to exploring this option and becoming the world's first proponents of cross-modal, shared simulations for road safety research.

This research has also shown that it is possible to profile rider behaviour across three main groups. In many ways this was an exploratory study across a number of measures and further research could look at extending these profiles as well as looking at other rider groups (possibly extending the research to include moped riders, 'born again bikers' and differing levels of experience). Just as car driving research has identified different types of drivers, this research indicates that motorcyclists are not a homogenous road user group and understanding the subtleties of different rider group profiles could prove effective in targeting and communicating road safety initiatives as well as providing focused training.

Motorcycle ergonomics and rider human factors is very much an emerging research domain and this research underlines the importance of understanding different rider abilities and requirements for their future training and safety.

12.8. Dissemination

In addition to this formal report which will be publicly available, a key strategy of the Centre for Motorcycle Ergonomics and Rider Human Factors is to disseminate findings as widely as possible. Within the academic arena this is usually conducted through internationally leading, peer-reviewed journal papers. However, equally important for this kind of research is reaching out and communicating to key stakeholders and policymakers in road safety, motorcycle media, manufacturers and the motorcycle industry, as well as the riders themselves. The following activities have been conducted or are planned:

- Press releases issued through the IAM and UNott
- A poster was presented at the 'STI-SIM Drive' 2010 user group meeting and a journal paper has been submitted for a special issue of Advances in Transport Studies
- Further journal papers are being prepared based on the mini-experiments embedded within the sub-scenarios
- An article is planned for the IAM's 'Advanced Driving' magazine
- A presentation is planned for the 'STI-SIM Drive' 2011 user group meeting

With these activities, the Centre for Motorcycle Ergonomics and Rider Human Factors is committed to publicising the findings as well as formally submitting this research within the academic community.

12.9. Conclusion

The research represents one of the first in-depth and systematic motorcycle simulator studies into rider behaviour. It has demonstrated clear differences between the three rider groups and potential benefits of advanced training above and beyond general rider experience and basic training. Whilst experience seems to help develop rider skills to an extent, advanced training appears to develop deeper levels of awareness, perception and responsibility. It also appears to make riders better urban riders and quicker, smoother and safer riders in rural settings. When taken together the results of this novel integrated experiment approach offer not only a perspective on the behaviour and skills of the rider groups, but also a tantalising insight into the attitudes and mindsets of Novice, Experienced and Advanced riders.

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14. Research team summaries

Dr Alex Stedmon MIEHF CPsychol FRSA (Director of the Centre for Motorcycle Ergonomics and Rider Human Factors, Faculty of Engineering at the University of Nottingham) is a Registered Ergonomist, Chartered Psychologist and Fellow of the Royal Society for the encouragement of Arts, Manufactures and Commerce. He has written over 100 publications reflecting a diverse career over the last 14 years in industry and academia, focusing on two key areas: security and transport. Within transport research his expertise spans most transport sectors (aviation, maritime, rail, automotive & motorcycles). He is a keen motorcyclist (riding a BMW and a Triumph Scrambler) and holds an IAM certificate of advanced training.

Dr David Crundall (Director of the Nottingham Integrated Transport and Environment Simulation facility; Co-Director of the Accident Research Unit) is an applied cognitive psychologist, with a particular interest in the cognitive and visual skill development of drivers and motorcycle riders. He is a member of the Experimental Psychological Society and the International Association of Applied Psychologists, and has published 40 papers in international peer-reviewed journals. He has served on a European Working Group for motorcycle safety, has acted as a research advisor for the International Motorcycle Manufacturers Association, and was the expert spokesperson for a recent Department for Transport motorcycle safety campaign. He has received funding from industry and the Government to undertake work into investigating and improving motorcycle safety.

Dr Elizabeth Crundall (Research Associate in the School of Psychology, University of Nottingham) began her career in research investigating the psychology of music-reading at the University of Nottingham. In particular, she carried out a number of studies into the eye-movement patterns of pianists. As a post-doctoral researcher, Lizzie went on to study visual working memory. After working in industry for a couple of years as a behavioural research consultant, Lizzie joined the Accident Research Unit at the University of Nottingham, investigating the eye-movements of drivers. Recently, she worked on a study that looked at why drivers fail to see motorcyclists at T-junctions.

Rose Saikayasit BEng MSc(Eng) (PhD student within the Human Factors Research Group, Faculty of Engineering at the University of Nottingham). She is a student member of the Institute of Ergonomics and Human Factors. Her main research is focussed on supporting virtual collaboration and the influence of technologies on collaborative design and engineering. She was involved in a project which implemented the Mixed Reality Architecture (MRA) system in a commercial setting for the first time, with the aim to evaluate how the system changes the way in which collaboration takes place in a virtual organisation.

Patrick Ward (Research Associate in the School of Psychology, University of Nottingham) received a BSc (Hons) Psychology degree from the University of Leeds in 1992, and has worked in accident research for the University of Nottingham for the last 12 years. He is co-author of numerous journal papers and final reports for the Department for Transport. He has held a UCCPD qualification in Forensic Road Accident Reconstruction (equivalent to police standard accident investigation qualification) since 2005. He is a member of the Motorcycle Action Group (MAG), and has therefore attended the wettest and windiest motorcycle rallies of recent years. He rides an old Triumph Trident Sprint on his days off.

Dr Editha van Loon (Research Associate in the School of Psychology, University of Nottingham) obtained an MSc in Health Sciences in 1996, followed by a PhD in Sport and Exercise Sciences in 2000. She joined the School of Psychology in October 2001. She was awarded a grant by the ESRC in 2002 for a research project entitled 'Visual strategies used for collision detection in driving'. Since then she has been involved as a researcher and programmer in various driving related projects, most recently an EPSRC funded project developing a simulator-based hazard perception training package, and a Department for Transport funded project on car driver attitudes and visual skills in relation to motorcyclists.

Dr Ainojie Alexander Irune (Dimax Technologies Ltd) is a Human Factors Research Fellow at the Mixed Reality Laboratory (MRL), Human Factors Research Group (HFRG) and Horizon Digital Economy Research at the University of Nottingham. His work involves the investigation of Human Factors and Ergonomic issues within transportation, mobile and ubiquitous computing research. His research primarily focuses on human-centred design and evaluation issues - the impact of information systems on vehicle controllers; the potential for novel user-interfaces in transport, ubiquitous and mobile computing; and the development of methods and measures for evaluating existing and emerging information systems. He is currently a member of the University of Nottingham's Computer Science Research Ethics Committee.

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