

An investigation of the potential causes of motorcycle
accidents at road junctions

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Abstract

Motorcycle visibility is a major road traffic accident concern, and many road traffic collisions (RTCs) involving motorcycles are caused by a “right of way” violation. The aim of this thesis is to investigate drivers’ ability to detect and identify motorcycles when the visual scene at T-junctions is manipulated and the driver is experiencing in-car distractors.

Experiments 1-3 investigated the effects of distracting stimuli on participants’ ability to detect motorcycles (and cars) in static visual scenes depicting T-junctions. The distractions involved speaking, listening or being asked to engage in spatial imagery. Experiments 4 and 5 used the same type of images, but increased the amount of traffic in the static visual scenes of T-junctions, and changed the task demands from detection (of any vehicle) to identification (car or motorcycle). Finally, Experiment 6 examined the role of experience in identifying vehicles by examining the performance of novice and experienced drivers in the types of task developed in Experiments 1-5.

The accuracy and speed with which motorcycles were detected was affected by the distance at which they were depicted, this effect was exacerbated when drivers are being distracted by interactive spatial and verbal tasks (Experiments 1-3), and by the presence on non-target cars at the junction (Experiments 4 and 5). These manipulations had less impact when cars were the targets. Experiment 6 showed that novice drivers were especially inaccurate in detecting motorcycles in the distance. These results may help to improve driver awareness of the conditions under which they are most likely to be prone to cause accidents involving motorcycles. They highlight some of the determinants of whether motorcycles will be identified at T-junctions, which could inform policy.

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Table of Contents

Contents

An investigation of the potential causes of motorcycle accidents at road junctions

Declaration.....	ii
Abstract.....	iii
Acknowledgements.....	iii
Chapter 1	
The Nature and Bases of Motorcycle Road Traffic Collisions.....	1
1.1 Introduction and Scope	Error! Bookmark not defined.
1.2 Overview of the literature	2
1.3 Visual detection of cars and motorcycles	Error! Bookmark not defined.
1.4 Experience and the detection of motorcycles	Error! Bookmark not defined.
1.5 Distraction.....	7
1.6 Secondary tasks: Mobile phones.....	8
1.7 Distraction and driving demands	Error! Bookmark not defined.
1.8 Distraction and driver experience	Error! Bookmark not defined.
1.9 Compensatory behaviours.....	Error! Bookmark not defined.
1.10 Overview, objectives and experiments	19
Chapter 2	
Detecting vehicles at T-junctions: The role of distraction.....	22
2.0 Introduction.....	22
2.1.1 Background	22
2.2 Experiment 1	23
2.2.1 Method	24

Table of Contents

2.2.2 Participants.....	24
2.2.3 Materials	24
2.2.4 Design	27
2.2.5 Procedure	27
2.3 Results.....	29
2.3.1 Accuracy	29
2.3.2 Reaction times.....	30
2.4 Discussion.....	Error! Bookmark not defined.
Chapter 3	
Detecting vehicles at T-junctions: Role of non-target vehicles	33
3.1 Introduction.....	33
3.2 Experiments 2a, 2b and 2c	34
3.3 Method	35
3.3.1 Participants.....	35
3.3.2 Materials and procedure.....	36
3.4 Results.....	Error! Bookmark not defined.
3.4.1 Accuracy	36
3.4.2 Reaction times	
3.5 Discussion	44
Chapter 4	
Detecting and identifying vehicles at T-junctions	
4.1 Introduction.....	46
4.2 Experiment 3.....	47
4.3 Method	47

Table of Contents

4.3.1 Participants.....	47
4.3.2 Materials and Procedure	47
4.4 Results.....	48
4.4.1 Accuracy	48
4.4.2 Reaction Time:.....	50
4.5 Experiment 4.....	50
4.6 Method	51
4.6.1 Participants.....	51
4.6.2. Apparatus, materials and procedure.....	51
4.7 Results.....	53
4.7.1 Accuracy	54
4.7.2 Reaction Time:.....	53
4.8 Discussion.....	54
Chapter 5	
Drivers' expectations in spotting approaching vehicles at junctions.....	56
5.1 Introduction.....	56
5.2 Method	58
5.2.1 Participants.....	58
5.2.2 Materials	59
5.2.3 Design	59
5.2.4 Procedure	60
5.3 Results.....	61
5.3.1 Accuracy:	61
5.3.2 Reaction Time:.....	61

Table of Contents

5.4 Discussion.....	62
Chapter 6	
Experienced versus novice drivers.....	64
6.1 Introduction.....	64
6.2 Experiment 6.....	64
6.3 Method.....	65
6.3.1 Participants.....	65
6.3.2 Materials.....	65
6.3.3 Design.....	66
6.3.4 Procedure.....	66
6.4 Results.....	67
6.4.1 Accuracy:.....	67
6.4.2 Reaction time:.....	70
6.5 Discussion.....	Error! Bookmark not defined.
Chapter 7	
7.0 General Discussion.....	72
7.1 Summary of the results.....	72
7.2 Implications of the results.....	73
7.3 Limitations of this research.....	74
7.4 Future directions.....	75
7.5 Concluding comments and policy implications.....	76
References.....	79

Chapter 1

The Nature and Bases of Motorcycle Road Traffic Collisions

1.1 Introduction and Scope

The motor vehicle is the most common form of transportation, and drivers constitute a large majority of road users (Ball, Owsley, Sloane, Roenker, & Bruni, 1993). Reimer, D'Ambrosio and Coughlin (2007) have noted that, despite the significant technological progress achieved in terms of car safety and advances in driver training programmes (Hedlund, 2007), road traffic collisions (RTCs) remain a major cause of death among people under the age of 40 in developed countries (Plainis et al., 2003). Nonetheless, cars are one of the safer forms of automotive transportation, largely due to the development of crumple zones, crash tests, increased safety standards, and a better quality of seatbelts (Robertson, 1996), which provide drivers with a higher level of protection. Motorcycles, in contrast, cannot incorporate many of these innovations, as the rider is external to the shell of the vehicle, and the vehicle is light enough to fly through the air and/or pose a crush hazard for the rider in high-kinetic energy RTCs. These facts also mean that seat belts will be ineffective, since riders are likely to absorb a great deal of kinetic energy when thrown into any surrounding object. The impracticability of improvements in this area was shown in Honda's failure to implement airbags in even heavy touring bikes (Kuroe et al., 2005). It therefore appears likely that the lethality of collisions to riders is unlikely to decrease over time without behavioural change.

The Department of Transportation (2009) states that while motorcycles account for 4% of all registered vehicles and serve only 1% of all transportation needs, 21% of all traffic fatalities involve motorcyclists. Motorcyclists clearly face a substantially higher risk of injury or death in RTCs. Moreover, although the overall number of RTCs has declined in recent

years, the injury and death toll levels remain high (Eurostat, 2007). Motorcycle RTCs have been linked to several risk factors, including adverse weather (Edwards, 1998), difficult road conditions (Crundall & Underwood, 1998), and a lack of driving experience (Crundall, Underwood, & Chapman, 1999). It has been argued that these and other factors influence the ability of car drivers to spot a potential hazard and respond to the risks effectively (Grayson, Maycock, Groeger, Hammond, & Field, 2003).

Grayson et al. (2003) argue that drivers go through a risk event in every journey, and have suggested that they go through four steps or components in order to prevent a potentially dangerous situation. These steps are hazard detection, threat appraisal, action selection, and implementation. Drivers must thus first be aware of the hazard, evaluate whether the hazard is sufficiently dangerous to merit a response, select an appropriate response to the danger and finally, perform the necessary actions required by the response. Within this framework, failure at any stage of the risk assessment could result in an RTC. The principal concern of the research presented in this thesis was to investigate the causes of RTCs between cars and motorcycles. The next sections consider the four components of this model. At the end of Chapter 1, I will return to this model as a framework for the specific objectives to be addressed by the research reported in this thesis.

1.2 Overview of the literature

As noted in the preceding section, the Department of Transport (DoT) states that motorcyclists are at a higher risk than car drivers of being involved in an RTC for each mile travelled. The DoT (2004) conducted an in-depth study on motorcycle RTCs, evaluating a heterogeneous corpus of police RTC report files, compared this to the RTC database, used photographs, maps and statements of vehicle examiners to build up a qualitative and

quantitative picture of common RTC risk factors, and examined the attitudes of motorcyclists using a questionnaire. This evaluation identified RTC risk factors including a lack of attention, losing control at bends in the road, unwise overtaking by motorcyclists, and a low ratio of motorcycles relative to other road users in the local area (suggestive of the familiarity-based recognition issues discussed later).

The quantitative component of the research identified common risk scenarios for RTCs, finding that 28% of studied incidents involved the car driver pulling out when the motorcycle was very close and implying that the driver did not see the motorcycle. The study attributed the remainder of the RTCs to either a failure to detect the motorcycle or a poor time-of-arrival judgement on the driver's part. The study also found that 38% of the RTCs involved right of way violations, in which the motorcycle was travelling straight ahead on a road while another vehicle was trying to enter that same road in front of the motorcycle. The study notably assigned complete or partial blame for the RTCs to motorbike riders in only 20% of cases. Infringements of the right of way of motorbikes appears to be more heavily linked to other road users, given the remaining 80% of the study corpus. Other investigations of motorcycle RTCs have also revealed similar findings (Clarke, Ward, Bartle, & Truman, 2004). Peek-Asa and Klaus examined descriptions of this type of RTCs, finding that 96% of motorcycle RTCs at junctions occur due to the right of way violation (Peek-Asa & Klaus, 1996)

In-depth on scene examinations of motorcycle RTCs by the Traffic Safety Centre in California found that the majority of these RTCs occurred under no adverse weather conditions and in good quality light, suggesting that the higher spatial frequency and lower salience of motorcycles may be minimised but they do not affect driver behaviours (Hurt, Ouelett, & Thom, 1981). These observations highlight the importance of other factors that

also lead to the failure to detect the presence of motorcycles, such as 'looked but failed to see'-type errors and/or distractions (Crundall, Humphrey, & Clarke, 2008). Rumar (1990) postulated that this reflects a lack of attention by the driver to relevant driving events.

This lack of attention could be a product of a variety of factors (e.g., auditory distraction from passengers or mobile phone conversations) that are likely to be exacerbated by the complex nature of the visual scene. It has also been argued that such distractions might disproportionately influence the processing of unexpected or low-frequency objects such as motorcycles (Hancock, Oron-Gilad & Thom, 2005; Wolfe, Horowitz, Van-Wert & Kenner, 2007); something that will be examined in the next sections.

1.3 Visual detection of cars and motorcycles

The visual system is the primary source of information while driving (Sivak, 1996) and visual attention effectively forms a 'spotlight for navigating the visual scene' (Erikson & Erikson, 1974). Studies have shown that information outside the focus of attention is often neglected. For instance, Galpin, Underwood and Crundall (2009) first presented participants with an image of a road, which was replaced by the brief presentation of a blank blue screen. The participants were then presented with a similar image of a road, except that in the latter image the road markings were removed. Most participants showed great difficulty in identifying the difference between the target image and the original image.

Other studies have also shown that when individuals engage in a particular task, they often neglect surrounding stimuli. This phenomenon is referred to as 'inattention blindness' (see also, Crundall, Shenton & Underwood, 2004). Simons and Chabris (1999) demonstrated that even large and unusual objects such as a gorilla are ignored by experimental participants. It might therefore reasonably be hypothesized that unusual road objects such as motorbikes

might be overlooked due to lack of familiarity.

In one study by Galpin, Underwood and Crundall (2009), participants were asked to play a driving game while their eye movements were recorded. There were two types of games: some participants were instructed to free-drive, while others were told to follow a particular car. Participants taking part in the intentional car-following task produced less horizontal eye movements, had longer fixations, neglected pedestrians, and were more likely to be involved in crashes. The results revealed that taking part in such a task narrows attention, with the poor processing of visual information from the peripheral areas of the visual field leading to increased failure rates in the perception of stimuli in the periphery.

According to Itti and Koch (2000), attention is drawn to the most salient region of the visual field, with salience being determined by an object's low-level features. For example, Hughes (1996) postulated that spatial frequency might determine scene processing, with low-frequency objects extracted first, followed by objects with higher spatial frequencies. In terms of moving objects, such as cars and motorcycles, spatial frequency is represented by the width of the object. In general, cars tend to have a greater width compared to motorcycles; therefore, cars can be viewed as large blocks moving through the visual field with a low spatial frequency. Conversely, motorcycles have relatively high spatial frequencies due to their smaller width. Therefore, drivers would be expected to extract information about cars first before directing their attention to objects with higher spatial frequencies, such as motorcycles. In essence, cars are easier to detect than motorcycles because of the respective spatial frequency of these objects. This is unlikely to be the complete explanation for the relative frequency of RTCs involving cars and motorcycles; because there is evidence that experience and distraction can affect the detection of motorcycles and RTCs in general. One aim of this thesis is to explore the effects of the visual properties of cars and motorcycles on

driver behaviour at T-Junctions (Chapters 2-4).

1.4 Experience and the detection of motorcycles

Crundall et al. (2008a) reviewed the literature in order to identify ways in which the performance of car drivers could be improved and reduce accidents involving cars and motorcycles. Their report proposed a framework for interpreting evidence on car drivers' skills and attitudes towards motorcyclists. They required respondents to fill in 26 general and motorcycle-related items, as well as 24 items of the reduced Driver Behaviour Questionnaire. The results were to the effect that motorcycle experience (especially experience of driving a motorcycle) helps inform drivers about motorcycles and their movement on the road. This knowledge refines their understanding and enhances their ability to deploy strategies and skills aimed at avoiding accidental collisions with motorbike riders. In this way, the negative impact of the low visibility of motorcycles was mitigated in car drivers with motorcycle experience.

Magazzu, Comelli and Marinoni (2006) also evaluated causes of RTC through a study of the Motorcycle Accidents In-Depth Study (MAIDS) database. The MAIDS report is a comprehensive study of accidents involving motorcycles, scooters and mopeds across five European countries. It was carried out with the support of the European Commission and under the auspices of the Association of European Motorcycle Manufacturers. Magazzu, Comelli and Marinoni (2006) assessed RTCs using the Classification and Regression Tree (CART) analysis and the standard unconditional logistic regression method that is widely used for modelling dichotomous outcomes. They showed that drivers with a motorcycle licence are less likely to be responsible for a motorcycle-car RTC whilst driving a car compared to car drivers without a motorcycle licence. Magazzu, Comelli and Marinoni

(2006) identified awareness of motorcycles as a possible reason for this discrepancy, stating that "those drivers who also ride motorcycles have greater exposure to motorcycles and are more aware of the potential dangers at junctions."

The role of expectation in detecting vehicles is also discussed by Brooks and Guppy (1990). They compared groups of drivers who had close acquaintances who were motorcyclists and found that friends and family of motorbike riders were less likely to be involved in RTCs with motorcycles. They also noted that motorcyclist-related drivers performed significantly better than the control group in motorcycle recognition tasks. These researchers claimed that "the greater exposure to motorcycles that these drivers receive may reduce thresholds for spotting them", and, if we accept that recognition may play a role, it is possible that when a driver has a greater expectation of seeing a motorcycle they will be more likely to quickly identify it. Magazzu, Comelli and Marinoni (2006) and Brooks and Guppy (1990) have identified recognition guided by familiarity as crucial, as motorcyclist-related drivers displayed similar detection ability when judging approaching motorcycles and cars, unlike the control group. One component of this thesis was to examine the role of familiarity-based recognition in determining the impact of the relative frequency of motorcycles and cars, and experience with motorcycles, on driver behaviour at T-junctions (Chapters 5 and 6).

1.5 *Distraction*

The National Highway Traffic Safety Administration analysed a baseline database and the 100-Car Study incident database to calculate the population attributable risk percentages for incidents and near-crashes on a per capita basis. The population attributable fraction may be employed to provide an estimate of how much of a disease burden of a

population would be eliminated if the effects of some causal factors were eliminated from the population. The high incidence of RTCs is a problem in the UK. Thus, if the contributing factors discussed above were eliminated, a reduction in adverse effects would be achieved. Lack of attention was linked to 22-24% of the total crashes and near-crashes, with a major subset of those RTCs involving drowsy driving as a major factor. Secondary task interruption was estimated to have caused around 22% of the crashes and near-crashes, with driver inattentiveness contributing to approximately 25 percent of reported traffic RTCs overall. Stutts, Reinfurt, Staplin and Rodgman (2001) also presented a descriptive analysis of five years of National Accident Sampling System (NASS), Crashworthiness Data System (CDS) data, identifying driver distraction as the cause in fact of over half of all inattention crashes.

Regan's (2004) literature review concerning driver distraction found that wireless communication, entertainment systems and map-reading systems had introduced distractions, potentially increasing the risk of a distraction-related accident (see also, Wickens, 2002). These distractions mean that drivers need to allocate attentional resources between driving and non-driving tasks (see also, Young & Regan, 2007). These authors also note that since driving experience may lead to the driving tasks becoming automated, experienced drivers may engage in other tasks with a lesser degree of danger and decreased driving performance. Moreover, drivers also adapt in order to fulfil the demands of the driving environment through various compensatory behaviours that reduce the impact of distraction on driving (see also, Haigney, Taylor & Westerman, 2000). However, under certain conditions, they argued that drivers might fail to allocate sufficient attention to driving, and this could have a detrimental effect on their driving performance. In order to ascertain the role of different kinds of distraction, this thesis also sought to examine whether the nature of the distractor affects driving behaviour particularly in the context of noticing motorcycles at T-junctions

(Chapters 2-4).

1.6 Secondary tasks: Mobile phones

Over the past two decades, people have increased their use of mobile phones both in and out of cars (Allen Consulting Group, 2004). The impacts of hands-free talking on simulated driving have been examined by a study conducted by Strayer et al. (2003). They sought to examine how cell phone conversations affect the driver's recognition memory for objects that they experience while driving. They contrasted single-task conditions (memory performance when participants were driving but not conversing) with dual-task conditions (when participants were driving and conversing on a hands-free cell phone. They used a high-fidelity driving simulator that provided each driver with an immersive driving context. The participants were undergraduates from the University of Utah. They found that an estimated 85% of people had used their mobile phones while they were driving a car (Goodman et al., 1997). However, they acknowledged that there were alternative interpretations of the data collected. Strayer et al. (2003) observed that conversations on mobile phones impaired the ability of drivers to react to vehicles braking in front of them, and that this was in part a result of reduced attention to visual stimuli. Both mobile phones and hands-free kit based calls produce a detrimental effect on driving performance, but many countries only prohibit the use of hand-held mobiles while driving (Goodman et al., 1997; see also Matthews, Legg & Charlton, 2003) even when resultant RTC risk appears similar (Haigney et al., 2000; Redelmeier & Tibshirani, 2003; Strayer et al., 2003).

Briem and Hedman (1995) investigated the effects of using a hands-free phone on driving performance in a simulated driving pursuit-tracking task. The primary task of the experiment was to drive safely. The participants received four secondary tasks while they

drove for 20 minutes. These were a) tuning and listening to the radio in the car, b) a test of working memory, c) difficult telephone talks, and d) a simple conversation about a well-known topic. The driving was divided into two halves. Driving in the first half had to be undertaken on a simulated road surface, and driving in the second half had to be done on a slippery road surface. Performance decrement was present during phone use for both types of driving condition. It is, however, uncertain whether the use of a hands-free phone made a difference on driving performance or the nature of the distractor was more important.

Studies have also investigated how differing levels of cognitive distraction affect driving performance, including the degree to which the complexity or emotionality of a phone conversation can influence driving performance. McKnight and McKnight (1993) explored the differences in drivers' ability to attend to the simulated driving task when engaged in either simple or complex hand-held phone conversations. Five distraction conditions were included: placing a call through dialling on a mobile phone, holding a simple conversation, holding a complex phone conversation, turning the radio on, and no distraction. All three conditions involving mobile phone use impaired driving performance, but that difficult conversations resulted in the greatest number of errors and poorest driving performance. A similar study reported that the response to visual targets (e.g., noticing boards and signs) was significantly slower under more cognitively complex phone conversations compared to simple ones (Al-Tarawneh et al., 2004). Patten et al. (2004) found that during peripheral detection tasks, drivers took longer to react when engaged in complex phone conversations rather than simple ones. Peripheral detection tasks are used to measure workload of driver support systems while driving in different traffic scenarios.

These studies highlight the important impact on driving performance of cognitive distraction. More specifically, they demonstrate that the deterioration in the performance of

the drivers concerned with the usage of phones may be more directly related to the cognitive demands of engaging in a complex distraction while simultaneously performing the driving task than phone use *per se*.

Mobile phone use studies (see also, Nabatilan, et., 2012) have also begun to explore the effects of phone use on visual behaviour (e.g., scanning and eye fixations). For example, in a study by Harbluk, Noy and Eizenman (2002), drivers were tested by driving a city route whilst having a difficult conversation on a phone. Participants received one of three conditions: no secondary task, solving an easy arithmetic addition task and solving a complex arithmetic task. Their subjective assessment of workload, measures of visual scanning, vehicle control, safety and distraction were all assessed. Twenty-one drivers were asked to drive a city route of eight kilometres while carrying out tasks that varied in cognitive complexity. Visual scanning patterns were recorded using eye-tracking equipment and the subjective evaluations of drivers were obtained through questionnaires. Measures of visual scanning revealed that participants made significantly fewer saccadic eye movements under increased cognitive demand, spending more time looking at central areas for hazards when compared to the periphery. Participants also spent less time checking their mirrors and more time searching up and down the road. Hard braking increased during the complex addition task, indicating a longer period before hazard recognition. The increase in complexity of the task increased the workload awareness of the drivers, leading directly to a lower level of performance.

Young and Regan (2007) critically reviewed the literature on in-vehicle driver distraction with emphasis on mobile phone use, and argued that adopting verbal and artificial tasks to reproduce conversations on mobile phones may lead to an overestimation of the damaging effects of mobile phone use. Rakauskas, Gugerty and Ward (2004) explored the

link between the conversational complexity level and distraction of the driver. While driving in a simulated environment, the participants were asked to answer a set of both simple and hard questions (e.g. “What are you doing tomorrow?” and “Do you think the world would be a better place in 100 years?”). The results revealed that although the driving performance was impaired by the engagement in phone conversations, changes in the difficulty of the tasks had no additional effects on performance of the drivers in terms of ratings of subjective workload and the mean speed. One explanation for these findings is that conversations do not require the same degree of cognitive effort as the verbal reasoning and mathematical tasks employed in studies such as Shinar, Tractinsky and Compton (2005). Another possibility is that there was insufficient difference in difficulty level to produce significant effects on the performance of the drivers. Due to this ambiguity in the literature, the present thesis investigated the influence of different forms of distraction on a task that assesses driver performance at T-junctions, in order to understand better the effects of the forms of distraction (Chapters 2-4).

The results described in the previous paragraph do not preclude the possibility that there might be adaptation to phone use, with concomitant reductions in its impact on driver performance. Shinar et al. (2005) investigated whether the frequent occurrence of conversations on a phone would result in a learning effect and reduce the impact on driving performance of the secondary task. As expected, conversations on mobile phones were found to have a negative effect on driving performance. It was noted that phone-using drivers exhibit less mean speed and higher steering inconsistency. The research suggests that previous studies, which have used only a limited number of experimental trials or have used artificial phone tasks, may have thus been overestimating the harmful influences of using a phone on the performance of the drivers. This thesis attempted to examine further the

influence of experience on the impact of distraction and ascertain the extent of the harmful influences of using phones in different traffic scenarios (Chapter 6).

1.7 Distraction and driving demands

Strayer et al. (2003) stated that “changes in the demands of the driving task itself, such as during great traffic density or adverse weather conditions, can affect the distracting effects of engaging in a non-driving task.” For example, on a busy roads drivers must pay more attention to oncoming traffic. This may place a greater cognitive demand on the driver, leading to a reduction of the spare cognitive capacity for the performing secondary tasks, such as conversing on a mobile phone. Several studies have been conducted in order to establish whether there is such an interaction (e.g., Brookhuis, de Vries & de Waard 1991; Horberry, Anderson, Regan, Triggs & Brown, 2003). For example, Strayer and Johnston (2001) explored how the driving environment can have negative influences on the performance-tracking task while using a mobile phone. They hypothesised that under difficult driving conditions, the driver’s ability to divide attention between the driving and non-driving tasks lessened due to the increase in driving difficulty and resultant cognitive load. Participants in the experiment were asked to talk to people using their phones while driving their vehicle. The results of this experiment indicated that participants were twice as unlikely to fail to detect tracking targets when compared to the control group when using a mobile phone during the task. Moreover, this effect was more pronounced in the difficult driving task. The findings of this study suggest that when cognitive demands of the driving tasks are high, the ability of the individual to allocate attention between the driving and non-driving tasks is further diminished. The present study aims to investigate this issue in the context of RTCs involving cars and motorcycles since the latter are overrepresented in RTCs (Chapters

2-4).

As already noted, Strayer et al. (2003) found that response latencies were increased when drivers were talking on a hands-free mobile phone. This increase in reaction time (RT) also became more obvious as the traffic density was greater. The study also showed the influence of weather on the ability of the drivers to make decisions while using mobile phones. They observed that in wet road conditions, there were twice the number of road incidents when the participants were distracted by the mobile phone tasks. The researchers concluded that the task reduced the ability of the participants to process the necessary information to make a safe driving decision.

1.8 Distraction and driver experience

There is a growing body of evidence suggesting that the distracting effects of using phones and other in-vehicle devices can be moderated by driver experience (Lam, 2002; McPhee, Scialfa, Dennis & Caird, 2004). According to RTC data, young novice drivers are among the most likely to be involved in an accident (Deery, 1999; Underwood & Crundall, 2003). These results have been taken to suggest (Regan, Deery & Triggs, 1998) that novice drivers have not yet acquired the driving skills necessary to operate a vehicle while engaging in secondary tasks. Due to this lack of driving skills, they must allocate significant attentional resources exclusively to the driving task and have accordingly restricted attentional resources for devoting to non-driving tasks such as speaking on the phone (see also, Underwood, Crundall & Chapman, 2002). There is also evidence of age-related deterioration in driving performance, with older drivers more susceptible to being affected by distractions (Lam, 2002). In particular, studies on stimulators have shown that compared to younger drivers, traffic signals are more frequently missed by older drivers, and that that they showed a larger

decrease in their speed maintaining skill and lane position when talking on a mobile phone (McKnight & McKnight, 1993; Reed & Green, 1999; Schreiner, Blanco & Hankey, 2004).

In contrast, Strayer and Drews (2004) provided evidence suggesting that age does not affect driving performance when talking on a mobile phone. However, the absence of an effect on driving performance of drivers' age might be attributable to the study comparing older drivers to young novice drivers who, unlike young experienced drivers, are particularly susceptible to distracting effects. In support of this interpretation, Shinar et al. (2005) confirmed that the phone conversations had a greater effect on both the younger and older drivers than middle-aged participants. Given this pattern of results, it would appear that age produces a general reduction of driving performance (e.g., through cognitive decline) that is partially mitigated by the fact that middle-aged drivers have a greater level of experience than younger drivers.

Studies of visual search and attention offer one explanation for the reduction in driving performance often associated with novice drivers. They show that task-related visual search patterns are learned, with adequate learning resulting in a proactive allocation of visual attention (Hayhoe & Ballard, 2005). Furthermore, although the link between attention and performance is not always straightforward, task experience usually results in more efficient visual search patterns (as seen in Brockmole, Hambrick, Windisch & Henderson, 2008; Charness, Reingold, Pomplun & Stampe, 2001; Pashler, Johnston & Ruthruff, 2001).

Ball et al. (1993) assessed numerous characteristics of visualization and information processing in drivers between the ages 55-90 years. The study found that changes in the size of the useful field of view were linked to drivers with a history of crash problems. The useful field of view is the region of the visual field from which information may be obtained without any movement of the eye or head. It is a measure of visual attention. Ball et al. (1993) also

found that adults with a high degree of shrinkage were six times more likely to have been involved in one or more RTCs in the previous five years. To be more specific, the study separated the factors of eye health status, visual sensory function, cognitive skills and chronological age, and found that while significant correlations existed between these factors and crashes, the size of the useful field of view had high sensitivity (89%) and specificity (81%) in predicting which older drivers had a history of crash problems. The useful field of view was measured by instructing participants to perform dual tasks: peripheral tasks and central tasks. The objective was to determine whether the participants could detect the presence of signals, and identify the signals. The findings link proficient visual attention allocation to better driving performance and safety (see also, Trick, Enns, Mills & Vavrik, 2004).

Crundall and Underwood (1998) have argued that the reduced performance often displayed by novice drivers can be the result of inefficient driving strategies. They proposed that through experience drivers allocate their attention more effectively, thereby reducing the cognitive demands of the driving task. The study also claims that experienced drivers often have better visual search patterns that enable them to spot potential hazards more effectively than novice drivers. These patterns were found to allow for greater sampling rates of the visual scene, with a greater number of short fixations. In addition, experienced drivers exhibited greater horizontal scanning of the visual scene. In one study, participants were shown a driving video clip while their visual search patterns were assessed. The results indicated that, compared to experienced drivers, novice drivers have longer fixations while watching the video, which seems to suggest novices take longer to process the visual scene. Moreover, under dangerous driving conditions, these fixations became even longer for novice drivers. These results suggest that when the demands of the driving task increase, novice

drivers are less able to process the visual scene effectively, leading to visual attention being concentrated on a very specific area of the visual scene. Consequently, novice drivers are less able to scan the visual scene for potential hazards and may, therefore, have more risks of being involved in a traffic accident.

Eye-tracking studies have also demonstrated a difference between novice and experienced drivers. Recarte and Nunes (2000) examined how the visual search is influenced by the spatial-imagery task and verbal tasks while driving. The participants were asked to drive 84 kilometres on 2 highways and 2 roads. In addition with this, the participants were also asked to perform 2 spatial-imagery tasks and 2 verbal tasks on each route. They showed that in novice relative to experienced drivers, visual functional-field size was both horizontally and vertically reduced, and more so when spatial-imagery tasks were undertaken. They also demonstrated that participants showed increased fixation time during such tasks, and that glance frequency at mirrors and speedometer decreased during the task. These results were attributed to the fact that specific regions of the visual scene attract attention differently based on the driver's experience.

Underwood et al. (2002) showed that novice drivers have a greater number of fixations on the rear-view mirror, while experienced drivers tend to focus on the nearside mirror. In addition, novice drivers tend to direct their attention more to in-car objects than their experienced counterparts. Crundall et al. (1999) investigated differences in eye movements between experienced, novice and non-drivers. Participants were required to watch a video that contained dangerous events and tasks. First of all, they had to assess how dangerous each clip was. In addition, participants had to respond to lights that randomly appeared on the four corners of the screen. Again, driving experience played a significant role in determining participants' ability to attend to visual targets outside the central field of

vision. In effect, the more efficient search patterns, learned through driving experience, not only allow drivers to detect potential hazards more easily but also reduce the cognitive demands of the driving task. This would again support the hypothesis that more experienced drivers have greater cognitive resources available to them to devote to other tasks such as speaking on mobile phones. Greater driver experience, in other words, is claimed to reduce impairments in driving performance associated with distraction. Taken together, these results suggest that one variable that might affect accidents involving motorcycles is driver experience. The influence of experience on drivers' ability to detect oncoming cars and motorcycles at T-junctions is assessed in Chapter 6.

1.9 *Compensatory behaviours*

Poysti, Rajalin and Summala (2005) have demonstrated that compensatory behaviours can manifest themselves at various levels from the strategic (avoiding secondary tasks completely) to the operational (reducing speed). The drivers could choose to ignore a distracting task at the highest level, thereby moderating their exposure to the risk. For example, older drivers experience a greater impairment in performance than young drivers while talking on a phone. The compensatory performance at the highest level was the result of this task. However, older drivers are thus more likely to avoid using mobile phones when driving (Alm & Nilsson, 1995). Burns, Parks, Burton, Smith and Burch (2002) examined driving performance in a simulator. Their study comprised of four conditions which were: motorway with moderate traffic; car following; curving road; and dual carriageway with traffic lights. The drivers were supposed to answer a standard set of questions and converse with the experimenter over a phone during each condition. A within-subject design was used with the variables: Normal driving, alcohol-affected driving and driving while talking on

phone. They found that drivers had a tendency to decrease their speed when talking on hands-free and hand-held phones, even when a specific set speed had to be maintained. It was concluded from the study that workload is reduced, and the risk level is moderated by the drivers, through decreasing their speed. Similar studies have found that drivers also tend to increase the inter-vehicle distance (Jamson et al., 2004; Strayer & Drews, 2004).

Research has also examined the effects of using other devices on driving performance. One of the main findings from this research is that the drivers decrease their speed when using other devices. For instance, Chiang et al. (2001) showed that car speed is reduced by the drivers when using a route navigation system (see also, Horberry et al., 2003). Another compensatory behaviour such drivers display is to increase their inter-vehicle distance. In a driving simulator study, Jamson et al. (2004) showed that drivers increased the distance between their car and a lead vehicle while processing emails. It is interesting to note that Strayer and Drews (2004) also demonstrated a 12 percent increase in the inter-vehicle distance while using a mobile phone conversation. In both studies, the drivers' compensatory behaviour was often insufficiently adequate to avoid the RTCs.

Finally, research has also shown that drivers could alter the level of attention allocated to the non-driving and driving tasks. Brookhuis et al. (1991) recruited 12 participants who had newly acquired mobile phones. The participants drove a vehicle every day for one hour for three consecutive weeks. They were expected to manage the mobile phone for a short period of time in each of the three traffic conditions. The results indicated that there was a large impact of using the test phone while driving as compared to usual driving. Half of the participants operated the phone manually, and the remainder used a hands-free phone. The group using a hands-free telephone showed better vehicle handling than the group who used a hand-held phone, where handling is measured by the degree and number of steering wheel

movements. Over the course of the 15 test days, a clear improvement was found for some of the measurements. However, this study found that on a busy road using a phone did not affect the attention of the drivers. These results suggest that the level of attention assigned to the secondary task is situation-dependent and changes according to both the driving conditions and the demands of the task.

1.10 Overview, objectives and experiments

Traffic RTCs are a continuing problem despite the advances in car safety equipment. Data from experimental studies of driving suggest that many RTCs are likely to be a result of inattention or distraction. Furthermore, motorcycles are at a particularly high risk of being involved in an RTC. It seems plausible to attribute the increased risk of motorcycle RTCs to their visual characteristics: they are much smaller than cars and are designed to be streamlined, which makes them more difficult to detect. However, there are other potential contributions. Motorcycles account for 1% of all transportation needs (Hancock et al., 2005; Wolfe et al., 2007), which means that they are less likely to be encountered, and it has been argued that this might render them less well processed. This effect might also contribute to the fact that experienced drivers, for whom the absolute familiarity of motorcycles is greater, are less likely to be involved in RTCs involving motorcycles (Hancock et al., 2005; Wolfe et al., 2007). However, experimental evidence concerning the latter possibility is relatively sparse. Alongside this potential influence of familiarity is the fact that experienced and novice car drivers display different search patterns, with novice drivers tended taking longer fixations and making fewer eye movements to peripheral areas than experienced drivers (Anders et al., 2006). It seems plausible to suppose that the different characteristics of bikes and cars (e.g., size) might interact with these different search patterns to make novice drivers

particularly prone to being involved in RTCs involving motorcycles (Ball et al., 1993).

The main aim of this thesis is to understand the causes of motorcycles RTCs through the use of experimental scenarios that allow the characteristics of the relevant stimuli to be readily manipulated. The thesis will focus on the first component of the hazard model (Brockmole et al., 2008), which is hazard detection. Hazard perception is a cognitive ability to detect and recognise dangerous situations and predict how they may develop into situations in which a crash would be very likely. It is related to traffic safety since it is a measurable skill that may be used to detect accident risk among road users. It follows that people skilled at hazard perception are better at detecting cues that predict hazardous situations. However, Brockmole et al. (2008) cautioned against interpreting the correlation between fixation selection and image features as causal.

The key manipulations of the hazard model were motivated by factors known to contribute to car RTCs, but ones that have not been the subject of detailed analysis in the context of RTCs involving motorcycles. Experiment 1 investigated the effects of distracting stimuli on components of virtual driving performance, notably the effect of distractions on the perception of oncoming vehicles when a motorist is making a decision about attempting to pull out of a junction onto another road. Experiments 2a, 2b and 2c examined the effect of visual and oral distractors in this scenario. Experiments 3 and 4 used the same images as in previous experiments except that a highly busy road was chosen in order to assess the generality of the observations from Experiments 1 and 2a-c. In Experiments 1-4 participants were presented with both cars and motorcycles. To investigate the possibility that the effects observed in Experiments 1-4 were a product of intermixing cars and motorcycles, Experiment 5 examined the same issues under conditions in which the relative frequency of cars and motorcycles was manipulated in two groups. Finally, Experiment 6 examined the role of

experience in identifying vehicles by examining the performance of novice and experienced drivers in the types of task developed in Experiments 1-5.

Chapter 2

Detecting vehicles at T-junctions: The role of distraction

2.0 Introduction

2.1.1 Background

As noted in Chapter 1, according to Department of Transport (2004) figures, 96% of all RTCs involved ‘right of way’ violations at junctions: this is when a vehicle travelling straight along a road collides near a T-junction with another vehicle attempting to join that same road. Studies indicate that 28% of RTCs involving a car-motorcycle collision appear to result from the car driver not seeing the approaching motorcycle (Lehtonen, Lappi & Summala, 2011); with the remaining 72% of RTCs attributed to a time-of-arrival calculation error by the driver in estimating the speed of approach of the motorcycle and, as a result, pulling out of the junction at the wrong time. Motorcyclists have been shown to be particularly vulnerable to being involved in a fatal or dangerous RTC, with a ‘killed and serious injury’ (KSI) rate that is approximately twice that for pedal cyclists, and more than fifteen times that for automobile drivers/passengers. Moreover, although motorcyclists comprise 1% of road users in the UK, they account for 13% of all injuries and fatalities. In their examination of the relation between the travelled distance and injuries sustained, Uchida, De Waard and Brookhuis (2011) found that in 2010 a motorcyclist was thirty times more likely to be killed or critically injured in a road traffic accident compared to a car driver involved in a similar incident.

The aim of Experiment 1 was to attempt to model these differences in the incidence of RTCs involving motorcycles and cars and to assess the role of distraction in driving

performance and RTC risk. The procedure was adapted from a previous study on motorcycle detection conducted by Crundall et al. (2008). Experiment 1 investigated the impact of different forms of distraction and examined whether they had different effects on participants' ability to detect motorcycles and cars. The procedure involved briefly presented (250ms) snapshots of motorcycles and cars at various distances from a T-junction at which the driver was positioned in a car. The vehicles could be presented near to the junction, in the mid-distance or far away from the junction. The task and presentation time was intended to mimic a driver's activity at a junction where brief inspection of oncoming traffic from the right might form part of the basis for pulling out. The participants' task was to decide if the image they were presented with contained an approaching vehicle. While viewing the images, they were subjected to distracting stimuli.

2.2 *Experiment 1*

All of the participants were presented with a sequence of images featuring a motorcycle, a car, or neither. The vehicles were presented at three distances (near, mid, far). After each image, the participants' task was to indicate whether it contained an approaching vehicle or not. To study the effect of distraction on their ability to detect approaching vehicles, the participants were divided into four groups: Control, Sound, Image and Verbal. Participants in the control group received no distraction, those in the sound group received presentations of a stream of auditory words, participants in the image group answered questions involving mental visualisation (e.g., "what is bigger, a car or a bus?"), and those in the verbal group received an auditory stream of words and had to indicate, on hearing each word, whether it contained the 'ch' syllable.

2.2.1 Method

2.2.2 Participants

Sixty participants (14 males, 46 females) were recruited, the majority of which were students from Cardiff University. The mean age of the participants was 21.9 years, with mean driving experience of 4.5 years since passing the driving test. All participants stated that they had normal or corrected-to-normal vision. There were two participants, who had better technical skills with regard to driving a motorcycle. The participants were randomly allocated to one of the four groups: Control, Sound, Image and Verbal

2.2.3 Materials

Primary Task

For the primary task, involving the detection of approaching vehicles in the images, the stimuli presented to all participants consisted of a sequence of ten T-junction scenes interspersed with instruction screens. These T-junction scenes were presented for 250 milliseconds each. The scenes were taken from a car driver's viewpoint. The scene images showed an in-car view in which the car driver had just moved towards the T-junction and was looking out to their right for approaching vehicles. Some of the scenes were digitally edited so as to include an approaching vehicle (either a car or a motorcycle) positioned in either the far, mid, or near distance, and travelling towards the T-junction (see Figure 1). Editing the ten scenes in this way produced 60 pictures in total. An additional set of 10 T-junction scenes featuring no approaching vehicle was created, bringing the total number of pictures presented to each group to 70 pictures. These pictures were presented on a standard monitor using E-Prime presentation software. A standard computer keyboard was used to collect the responses of the participants.



Figure 1. Experiment 1: Images containing a motorcycle (top row) and car (bottom row) presented at near, mid and far distances (left to right).

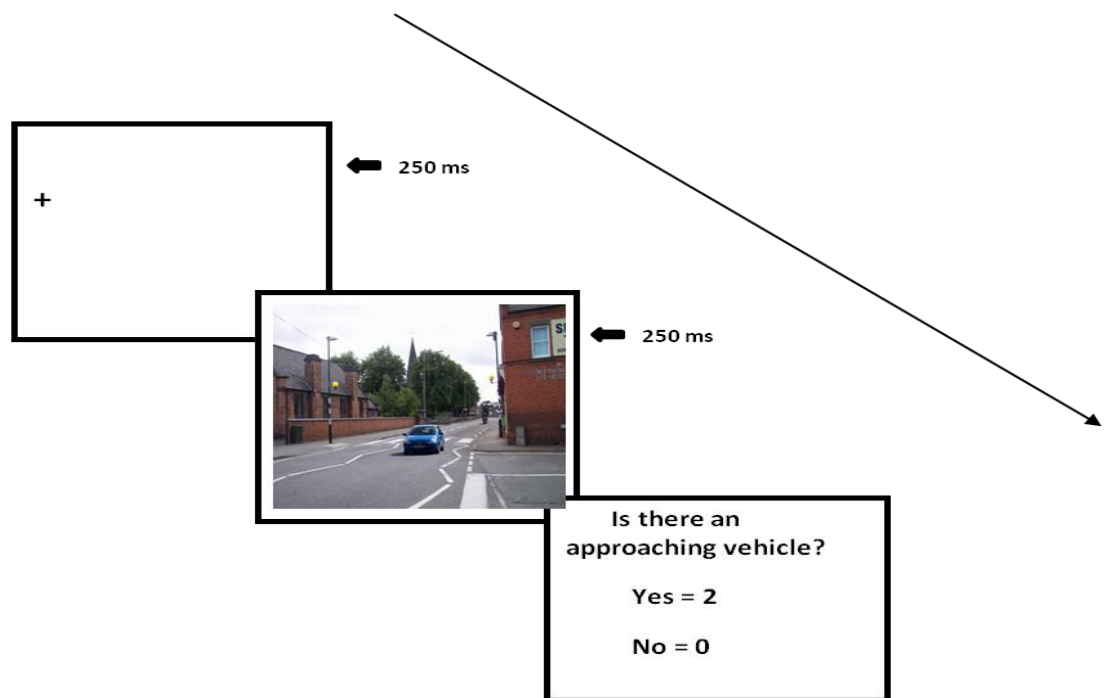


Figure 2. Experiment 1: An example of an image and presentation sequence. The first two screens were each presented for 250 milliseconds.

Secondary tasks

The secondary tasks required the following additional materials:

- **Group Control:** Participants only had to perform the primary task and no further materials were needed.

For Groups Sound, Image and Verbal, the same set of words was used, which included ‘boy’, ‘church’, ‘tower’, ‘bible’. The list was generated using a psychological linguistics website.

- **Group Sound:** An audio recording of a stream of words was presented to the participants while they were performing the primary task. The task was delivered to the participants via the speakers in the laboratory.
- **Group Image:** An audio recording of questions involving mental spatial visualisation was presented to the participants as they performed the primary task. These questions featured comparisons between objects. For instance, “is [name of object] bigger than a bus?” Participants responded verbally, with either a ‘yes’ or ‘no’. All responses were recorded, and both tasks were presented at the same time. The participant responded to the first task on the keyboard and at the same time they answered the questions verbally.
- **Group Verbal:** An audio recording of a stream of words was presented, including words that contain the syllable ‘ch’ (e.g. ‘chair’). While engaging in the primary task, participants had to indicate (by saying ‘yes’ or ‘no’) whether each word contained the ‘ch’ syllable. All of the responses were recorded. The same word stream was used in the sound and imaginary group used in the verbal group, with the task being identical except for the fact that the verbal participants were required to answer verbally. The words were presented via speakers in the lab while non-verbal groups responded to

the computer task via the keyboard.

2.2.4 Design

There were three independent variables, two within-subjects and one between-subjects. The within-subjects variables were the nature of the ‘Vehicle’ (motorcycle or car), and the ‘Distance’ at which the vehicle was presented in the image (‘near’, ‘mid’ or ‘far’). The between-subjects variable was a group (Control, Sound, Image, Verbal). There were two dependent measures: ‘accuracy’ and ‘speed’. The accuracy with which participants detected the approaching vehicles was measured in terms of d' in accordance with signal detection theory (Macmillan & Creelman, 1991); calculated as the standardized difference between the mean rates of hits and false alarms. Reaction times were measured (in ms) from the offset of the image to the response (yes or no). The idea of d' is an exceptionally valuable measure of perceptibility, however infrequently it is hard to take after the connection amongst d' and established "percent missies" measures.

	Response: Different (<i>yes</i>)	Response: Same (<i>no</i>)
Stimuli: YES (<i>different</i>)	HIT	MISS
Stimuli: NO (<i>same</i>)	FALSE ALARM	CORRECT REJECTION

2.2.5 Procedure

Before the start of the experiment, participants were shown a practice run of 10 images, in order to give them an opportunity to familiarise themselves with the experimental format. During these trials, each participant was instructed to fixate a “+” on the screen for

250 ms, and then the image of a T-junction was presented for 250 ms. These timings were adopted from the experimental setup used in Crundall and Underwood (2008; see also, Crundall, Underwood & Chapman, 2010). Participants were then required to identify whether a vehicle was present (or not) by pressing the appropriate keyboard key (see Figure 2) as quickly as possible. The participants were instructed to press '0' to indicate that the shown picture contained no approaching vehicle and to press '2' to indicate that they detected the presence of an approaching vehicle in the picture. While they performed the primary task, participants in three of the groups (Sound, Image and Verbal) received a secondary task. The tasks were presented at the same time. The participants responded on the keyboard for the first task and at the same time they answered the question verbally.

The results were pooled over trials of the same type (e.g., near motorcycles) for the purpose of statistical analysis, and the analysis is presented separately for measures of accuracy and speed.

2.3 Results

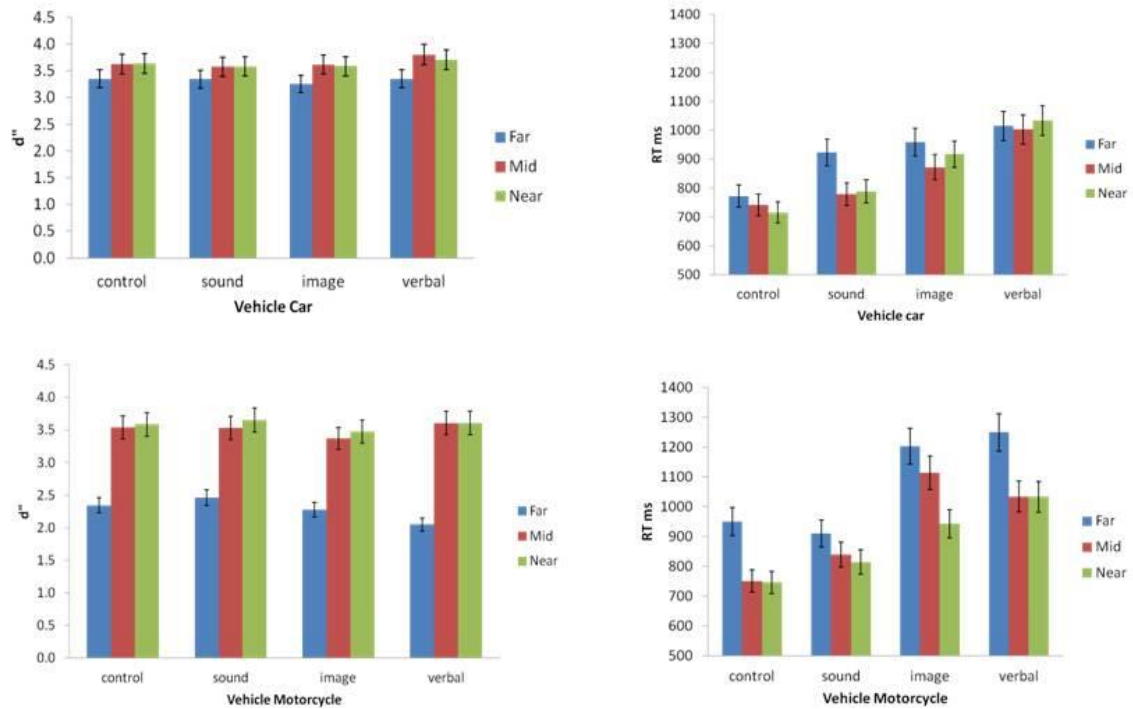


Figure 3. Experiment 1: Mean accuracy (d' ; \pm SEM) in detecting cars (left upper panel) and motorcycles (left lower panel), and reaction times (RT ms; \pm SEM) in detecting cars (right upper panel) and motorcycles (right lower panel).

2.3.1 Accuracy

The mean d' scores (left-hand panels) and mean reaction times (right-hand panels) are shown in Figure 3. Taking both left-hand panels together, there does not appear to be an overall effect of the nature of the distraction (control, sound, image or verbal). However, the scores for cars appear to be more accurate (on average) than those for motorcycles, and participants appear to be much less accurate when the vehicles are depicted in the far distance

than when they are depicted as close to the junction. However, there was also some tendency for the effect of distance appeared to be greater for motorcycles than for cars. Statistical analysis broadly confirmed this description of the pattern of results in Figure 3. The ANOVA included the following factors: group (nature of distraction), vehicle (car or motorcycle), and distance (near, mid or far). This analysis revealed that there was no significant effect of the group ($F(3, 67) = 0.25, p > .85$). However, there was an effect of vehicle ($F(1, 67) = 142.36, p < .001$) and distance ($F(2, 134) = 145.67, p < .001$). There was a significant two-way interaction involving vehicle and distance ($F(2, 134) = 76.33, p > .001$) but no other significant interactions (largest $F(3, 67) = 2.19, p > .09$ for the interaction between vehicle and group). Separate ANOVAs confirmed that there was an effect of distance for cars ($F(2, 140) = 14.93, p < .001$) and motorcycles ($F(2, 140) = 199.59, p < .001$).

2.3.2 Reaction times

The reaction times are shown in the two right-hand panels of Figure 3. Inspection of these panels shows that the nature of the distraction seemed to have a marked effect: The reaction times in the control group were much lower than in the verbal group, with the other groups falling somewhere between these two extremes. This effect of distraction was most marked when the target was a motorcycle. It is also evident that the reaction times for motorcycles were longer than for cars, with this effect being particularly marked when the vehicles were depicted in the distance (i.e., far). A parallel ANOVA to that conducted on the accuracy scores confirmed the accuracy of this description. There was a significant effect of group ($F(3, 67) = 4.23, p < .01$), vehicle ($F(1, 67) = 38.28, p < .001$), and distance ($F(2, 134) = 33.11, p < .001$). There was also an interaction between group and vehicle ($F(3, 67) = 4.85, p < .005$), and between vehicle and distance ($F(2, 134) = 9.63, p < .001$); but there was no interaction between group and distance ($F(6, 134) = 0.88, p > .51$) There was also a three-

way interaction ($F(6, 134) = 2.63, p < .05$). The basis of the three-way interaction was explored by conducting separate ANOVAs on each group.

For group Control, ANOVA revealed an effect of vehicle ($F(1, 17) = 8.14, p < .05$) and distance ($F(2, 34) = 11.83, p < .001$), but no interaction between these factors ($F(2, 34) = 0.25, p > .78$). In contrast, for each of the remaining groups there was an interaction between vehicle and distance. For group Sound, there was no effect of vehicle ($F(1, 17) = 2.63, p > .12$), an effect distance ($F(2, 34) = 8.97, p < .005$), and an interaction between these factors ($F(2, 34) = 3.42, p < .05$). For group Image, there was an effect of vehicle ($F(1, 16) = 15.20, p < .005$), an effect of distance ($F(2, 32) = 6.06, p < .01$), and an interaction between these factors ($F(2, 32) = 4.89, p < .05$). For group Verbal, there was an effect of vehicle ($F(1, 17) = 14.31, p < .005$), distance ($F(2, 34) = 14.09, p < .001$), and an interaction between these factors ($F(2, 34) = 4.54, p < .05$). The results of these analyses are consistent with the idea that the effects of distraction on reaction times are particularly marked when motorcycles are depicted in the distance.

2.4 Discussion

The aim of Experiment 1 was to attempt to model some components of the task that drivers face when exiting a T-junction, and to assess the impact of distraction as a contributor to RTCs in this model. The study investigated the impact of different forms of distraction and examined whether they had differential effects on participants' ability to detect motorcycles and cars. The participants were required to perform a primary and secondary task. For the primary task, involving the detection of approaching vehicles, the stimuli presented to all participants consisted of a sequence of ten T-junction scenes interspersed with instruction

screens. The secondary tasks involved additional aural, visual and verbally based tests designed to tax processes that might be important for execution of the primary task. The principal findings of Experiment 1 were that accuracy was affected by vehicle and distance, but that distraction had no effect, perhaps because of a ceiling effect. In contrast, reaction times were affected by distraction, in addition to distance and vehicle. Importantly, there was an interaction between vehicle, distance and distraction; with particularly slow reaction times to motorcycles presented in the far distance and under the influence of distraction. These findings are related to those of Galpin et al. (2009) and to Strayer et al. (2003). The latter study showed that mobile conversations impaired driver's reactions to vehicles braking in front of them, and McKnight and McKnight (1993) revealed that mobile phone usage resulted in drivers failing to adequately respond to traffic situations (e.g., vehicles slowing down or pedestrians crossing the road). Further, the studies by Al-Tarawneh et al. (2004) and Patten et al. (2004) also found that during peripheral detection tasks, drivers took longer to react when engaged in complex phone conversations rather than simple ones (see also, Harbluk et al., 2002). However, the finding from Experiment 1 that accuracy was not affected by distraction was unexpected, but as mentioned, might have reflected a ceiling effect (the d' scores were very high). In order to assess the accuracy of this suggestion, as well as to increase the generality of the effects observed in Experiment 1, the visual scenes in which the targets were embedded were rendered more complex in Chapter 3 by the addition of nontarget vehicles.

Chapter 3

Detecting vehicles at T-junctions: Role of non-target vehicles

3.1 Introduction

Experiment 1 developed a procedure to study the effect of distractors on target vehicle detection, where the targets were either cars or motorcycles. The experiment demonstrated that cars were more readily detected than motorcycles, an effect that was, in large part, driven by differences when the two types of vehicle were depicted in the distance (and naturally smaller). Experiment 1 also examined the effect of distractors on vehicle detection. The distractors were: listening to a string of words (group sound), answering a question based on visual imagery (group image), and answering a question based on the presence/absence of a phoneme (group verbal). While these distractors had little influence on the accuracy of detection (as measured by d') they had a marked impact on reaction times; with groups verbal and image having significantly longer reaction times than groups control and sound. The absence of an effect of distraction on detection accuracy for either cars or motorcycles is surprising, but it is perhaps most economically explained by either a ceiling effect, or by the observation that participants in Experiment 1 (in groups verbal and image) compensated for the distraction by being more cautious, taking more time to make the decision.

The main aim of Experiments 2a, 2b and 2c was to replicate the results of Experiment 1, and to examine the influence of the presence of non-target vehicles on the detection of (oncoming) target vehicles (again, cars and motorcycles). It has been argued that the presence of non-target vehicles represents an additional source of driver error (see Crandall et al., 2006). Perhaps the effects of distraction on detection accuracy might be more apparent when the critical judgement occurs in a more realistic setting, with a visual scene that

includes nontarget vehicles (in this case cars). In Experiment 2a there were no nontarget vehicles cars, whereas in Experiments 2b and 2c there were one and two cars, respectively.

3.2 *Experiments 2a, 2b and 2c*

The design of Experiment 2 is identical to Experiment 1 with the notable exception that non-target vehicles (cars) were added to the pictures (see Figure 4). Experiment 2 employed a within-subjects design in which the number of non-target vehicles was increased from 0 to 1 and 2. Experiment 2 should allow a replication of the results of Experiment 1 and permit the effects of increasing the number of non-target events to be assessed. However, it is also worth noting that because the design was within-subjects there was the possibility that the additional conditions (where nontarget cars were introduced) could have an impact on the condition in which no nontarget cars were introduced (cf. Experiment 1); at least for those participants who received these additional conditions first.



Figure 4. Experiment 2a-c: Images containing a motorcycle (top row) and car (bottom row) presented at near, mid and far distances (left to right), with 2 nontarget vehicles. The isolated image at the bottom depicts a scene with two nontarget vehicles and no target.

3.3 *Method*

3.3.1 *Participants*

Forty participants (2 males, 38 females) were recruited (who were mostly students at Cardiff University) to take part in this experiment. The mean age of the participants was 25 years, with an average driving experience of 4.2 years since passing their driving test. They all reported normal or corrected-to-normal vision. None of the participants had previous experience of riding a motorcycle. As in Experiment 1, the participants were randomly assigned to one of four groups that received different forms of distraction (control, sound, image or verbal).

3.3.2 *Materials and procedure*

Primary and secondary tasks. The primary task was the same as in Experiment 1, with the exception that the participants also received pictures with nontarget vehicles. The number of nontarget vehicles was 0 (Experiment 2a), 1 (Experiment 2b) or 2 (Experiment 2c). These conditions were presented in a counterbalanced order. As in Experiment 1, there were four groups across which the secondary task varied: Control, Sound, Image and verbal (see Section 2.2.3 for further details). The procedure was the same as Experiment 1 with the exception received three versions of the task, in which the number of nontarget cars was varied (0, 1 or 2).

3.4.1 *Accuracy*

The accuracy scores for cars and motorcycles in Experiment 2a, 2b and 2c are depicted in the upper, middle and lower panels of Figures 5 (cars) and 6 (motorcycles).

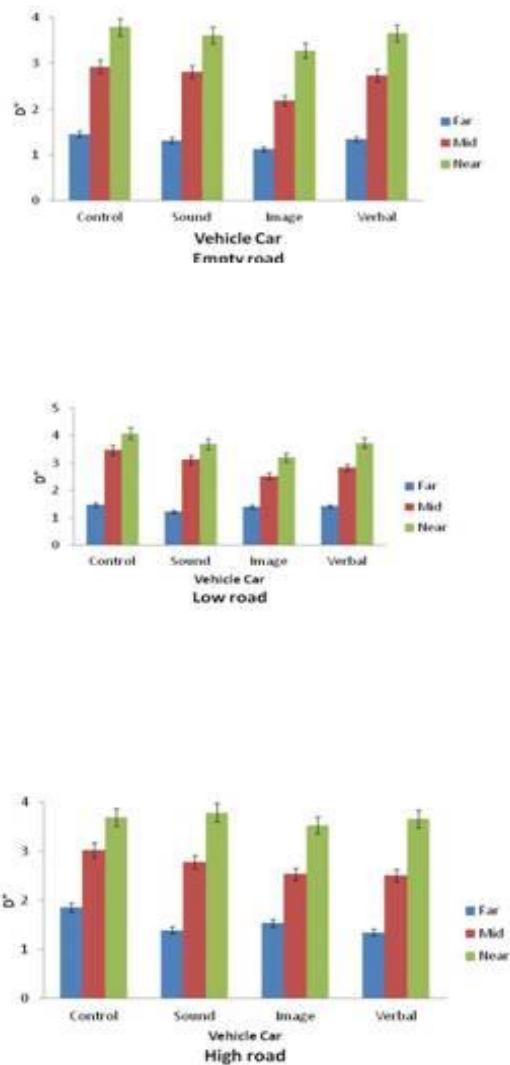


Figure 5. Experiments 2a-c: Mean accuracy (d' ; \pm SEM) for cars in the four groups (Control, Sound, Image and Verbal) with target vehicles presented at 3 distances (Far, Mid and Near). The upper, middle and bottom panels are from the 0, 1 and 2 nontarget conditions, respectively (i.e., Experiments 2a, 2b, and 2c).

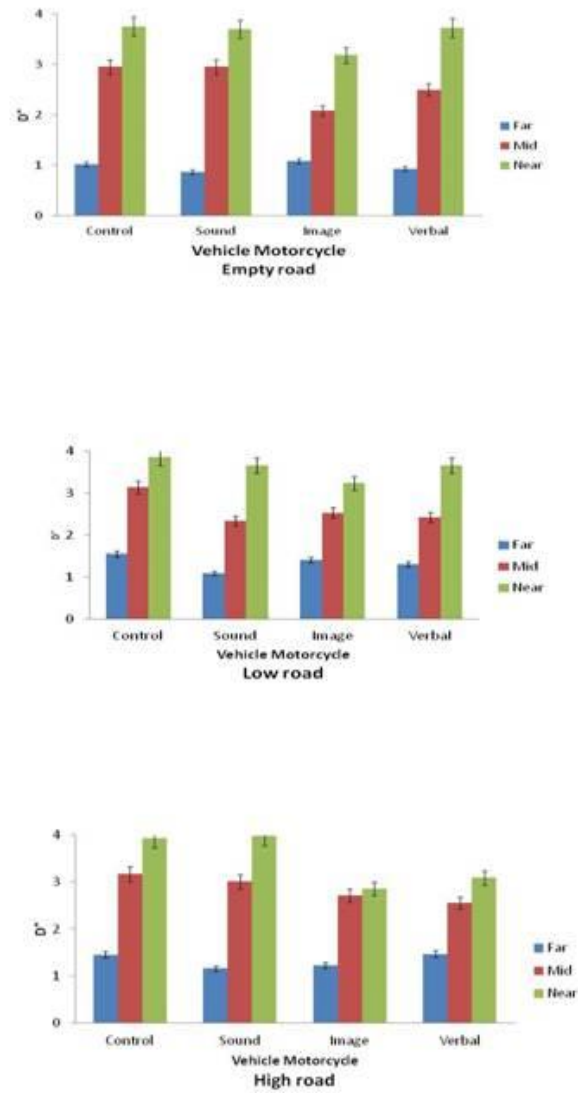


Figure 6. Experiments 2a-c. Mean accuracy (d' ; \pm SEM) for motorcycles in the four groups (Control, Sound, Image and Verbal) with target vehicles presented at 3 distances (Far, Mid and Near). The upper, middle and bottom panels are from the 0, 1 and 2 nontarget conditions, respectively (i.e., Experiments 2a, 2b, and 2c).

Inspection of Figure 5 suggests that accuracy in detecting cars was influenced by whether they were depicted more or less far away from the junction, and this effect did not seem to interact with either the secondary task or with how many nontarget cars were in the scenes (0, 1 or 2; upper, middle and lower panels, respectively). The corresponding scores for motorcycles are shown in Figure 6. This figure depicts a similar pattern to cars with the exception that with two nontargets accuracy declined in groups Image and Verbal when the motorcycle was near to the junction. Statistical analysis confirmed these general impressions.

ANOVA showed that there was no effect of group ($F(3, 40) = 1.12, p > .35$), but there were effects of density ($F(2, 80) = 3.73, p < .05$), vehicle ($F(1, 40) = 12.48, p < .005$), and distance ($F(2, 80) = 295.34, p < .001$). There was also three-way interaction between density, vehicle and distance ($F(4, 160) = 4.53, p < .005$), but no other interactions (largest $F(4, 160) = 1.93, p > .10$ for the interaction between density and distance). To analyse the nature of the three-way interaction, separate ANOVAs for cars and motorcycles were conducted pooled across group. The analysis for cars revealed no effect of density ($F(2, 86) = 2.45, p > .09$), an effect of distance ($F(2, 86) = 230.73, p < .001$), and no significant interaction between these factors ($F(4, 172) = 2.29, p > .06$). The parallel analysis of the results from motorcycles revealed no effect of density ($F(2, 86) = 2.88, p > .06$), an effect of distance ($F(2, 86) = 249.09, p < .001$), and a significant interaction between these factors ($F(4, 172) = 3.76, p < .01$). This interaction is consistent with the impression - gained from inspection the lower panel of Figure 6 - where the increase in density resulted in a low level of accuracy even for motorcycles depicted close to the viewing position.

3.4.2 Reaction times

The mean reaction times for cars and motorcycles are shown in Figure 7 and 8,

respectively. Taking these figures together, the reaction times for cars tended to be faster than for motorcycles, and tended to be slower for vehicles that are depicted in the far distance than those that are depicted closer to the junction; but there was little effect of how many nontarget vehicles were present (0, 1 or 2; upper, middle and lower panels, respectively). There was an effect of secondary task, with reaction times in groups Image and Verbal being longer than in groups Control and Sound. Statistical analysis broadly confirmed this description of the results.

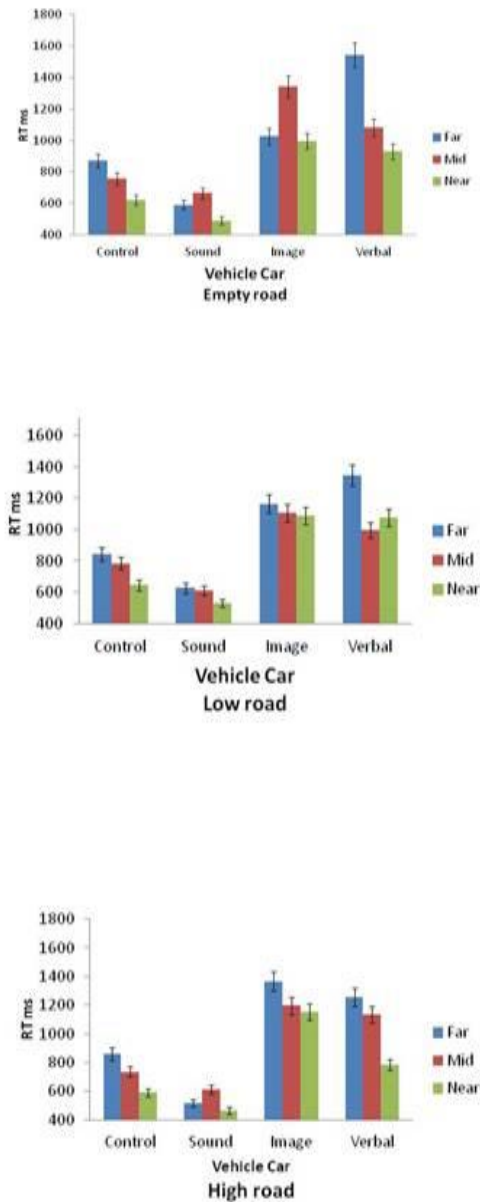


Figure 7. Experiments 2a-c. Mean reaction times (RT ms; \pm SEM) for detecting cars in the four groups (Control, Sound, Image and Verbal) with target vehicles presented at 3 distances (Far, Mid and Near). The upper, middle and bottom panels are from the 0, 1 and 2 nontarget conditions, respectively (i.e., Experiments 2a, 2b, and 2c).

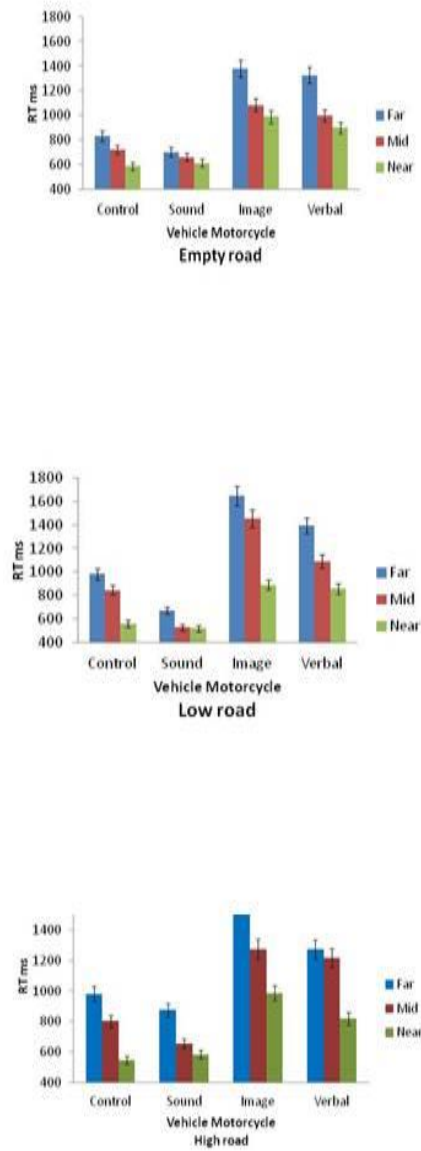


Figure 8. Experiments 2a-c. Mean reaction times (RT ms; \pm SEM) for detecting motorcycles in the four groups (Control, Sound, Image and Verbal) with target vehicles presented at 3 distances (Far, Mid and near). The upper, middle and bottom panels are from the 0, 1 and 2 nontarget conditions, respectively (i.e., Experiments 2a, 2b, and 2c).

ANOVA showed that there was an effect of group ($F(3, 40) = 13.42, p < .001$), no effect of density ($F(2, 80) = 2.04, p > .13$), an effect of vehicle ($F(1, 40) = 4.37, p < .05$), and of distance ($F(2, 80) = 295.34, p < .001$). There was an interaction between group and distance ($F(6, 80) = 2.82, p < .05$) and between vehicle and distance ($F(2, 80) = 5.65, p < .01$). There were three-way interactions between group, vehicle and distance ($F(6, 80) = 2.50, p < .05$) and between density, distance and distance ($F(4, 160) = 2.51, p < .05$). There were no other interactions (largest $F(3, 40) = 2.05, p > .12$, for the interaction between group and vehicle).

To analyse the three-way interaction involving group, separate analyses were conducted for each group. There was an effect of distance in group Control ($F(2, 20) = 14.11, p < .001$), but no other effects or interactions (largest $F(4, 40) = 2.32, p > .07$ for the three-way interaction). In group Sound, there was an effect of distance ($F(2, 20) = 6.59, p < .01$), vehicle ($F(1, 20) = 9.13, p < .05$) and an interaction between these factors ($F(2, 20) = 3.81, p < .05$). There was no effect of density and no other interactions (largest $F(2, 20) = 2.79, p > .08$, for the effect of density). For group Imagine there was an effect of distance ($F(2, 20) = 8.10, p < .005$), and an interaction between distance and vehicle ($F(2, 20) = 4.81, p < .05$). There was no effect of density and no other interactions (largest $F(1, 20) = 3.33, p > .09$, for the effect of vehicle). Finally, the analysis of group Verbal revealed an effect of distance ($F(2, 20) = 6.59, p < .01$), but no other effects or interactions (largest $F(4, 40) = 1.55, p > .20$, for the three-way interaction). These analyses suggest that the effect of vehicle tended to be more evident in the groups given a distractor than in the control group.

Separate analyses conducted on the reaction times for cars and motorcycles (pooled across groups) suggested that any effect of density tended to be larger for motorcycles than

for cars. The analysis of the results for cars revealed an effect of distance ($F(2, 86) = 15.85$, $p < .001$), but no effect of density and no interactions between these factors (both F s < 1). The parallel analysis for motorcycles revealed an effect of density ($F(2, 86) = 2.94$, $p = .058$) and an interaction between density and distance ($F(4, 172) = 2.94$, $p = .059$) that both failed to reach conventional levels of statistical significance. There was an effect of distance ($F(2, 86) = 34.56$, $p < .001$).

3.5 Discussion

Experiments 2a-c attempted to replicate and extend those of Experiment 1 by increasing the number of nontarget vehicles in the visual displays (cf. Strayer et al., 2003). In Experiment 2a there were no nontarget vehicles cars, whereas in Experiments 2b and 2c there were one and two cars, respectively. The same distractors that were employed in Experiment 1 were used. The principal findings of Experiment 2 were that accuracy was affected by vehicle, traffic density, and target vehicle distance; and the interaction between density, vehicle and distance suggests that the detection of motorcycles is particularly affected when they are depicted in the distance with nontarget vehicles near to the junction. As in Experiment 1, the presence and nature of distractors had little effect on the measure of accuracy. However, reaction times were significantly affected by the nature of the distractor, as well as by the other factors (density, vehicle and distance). Taken together, the groups given some form of distraction were slower to react to motorcycles than cars. In particular, the impact of the image and verbal distractors was disproportionately great when compared to the sound distractor. This replicates the results from Experiment 1. This finding is of particular importance given the potential need for drivers to detect rapidly approaching motorcycles.

A number of obvious possible reasons for accidents at T-junctions have been identified that are consistent with the findings in Chapter 3. A study by Langham (1999), which filmed drivers as they approached T-junctions, reported that they spent very little time (with a mean of about 0.3 to 0.4 seconds) looking onto the road they were approaching. This is consistent with the amount of time given to the participants in the current experiments, and might be taken to suggest that drivers are simply careless. However, Wulf et al. (1989) has argued that accidents at T-junctions may be largely explained by ‘cognitive conspicuity’ rather than ‘sensory conspicuity’. Cognitive conspicuity refers to what the driver expected to see (see also, Hole, 2007; Hole & Tyrrell, 1995). In Chapter 4, I examine some implications of this suggestion. Namely, that the presence of nontarget events at the junction might provide an additional basis to enhance the cognitive conspicuity of cars and possibly reduce that of motorcycles.

Chapter 4

Detecting and identifying vehicles at T-junctions

4.1 *Introduction*

Chapter 3 examined the effect of the presence and number of nontarget vehicles (cars) on the detection of oncoming cars and motorcycles at T-junctions. The participants who concurrently experienced either an imagery-based task or a verbal distractor task seemed to find it especially difficult to detect motorcycles when they were depicted relatively near to the T-junction and there were two nontarget vehicles that were also close to the junction (see Experiment 2c). Experiment 3 used an analogous procedure to Experiment 2c. The main differences between Experiment 2c and Experiment 3 was that in Experiment 3 participants did not also receive the procedures from Experiments 2a and 2b (involving no nontarget vehicle or one nontarget vehicle near to the junction). Experiment 3 should allow the effects of interest from Experiment 2c to be replicated. Experiment 4 assessed whether the manipulations of distance of the vehicle from the T-junction and nature of distraction (Control, Sound, Image or Verbal) affected vehicle identification (rather than detection) by changing the task to one of identifying whether the oncoming vehicle was a car or a motorcycle. This change in procedure enabled the experimenter to prime the participants with information that that motorcycles might be present, which was not true in Experiments 1-3.

4.2 Experiment 3

4.3 Method

4.3.1 Participants

Seventy-two participants (6 males, 66 females) were recruited. They were mostly students from Cardiff University and had a mean age of 24.8 years. They had an mean of 4.9 years driving experience since passing the driving test and all reported normal or corrected-to-normal vision. Five of the participants had experience of riding a motorcycle. Participants were randomly assigned to one of the four experimental conditions (i.e., Control, Sound, Image and Verbal).

4.3.2 Materials and Procedure

The primary task, involving the detection of approaching vehicles (cars and motorcycles) at three distances from the T-junction (near, mid and far), was the same as in Experiment 2c. That is, the scenes all contained two nontarget vehicles near to the T-junction. The secondary tasks for the four groups were the same as in previous experiments: Control, Sound, Image and Verbal. The procedure was the same as in Experiment 2.

4.4 Results

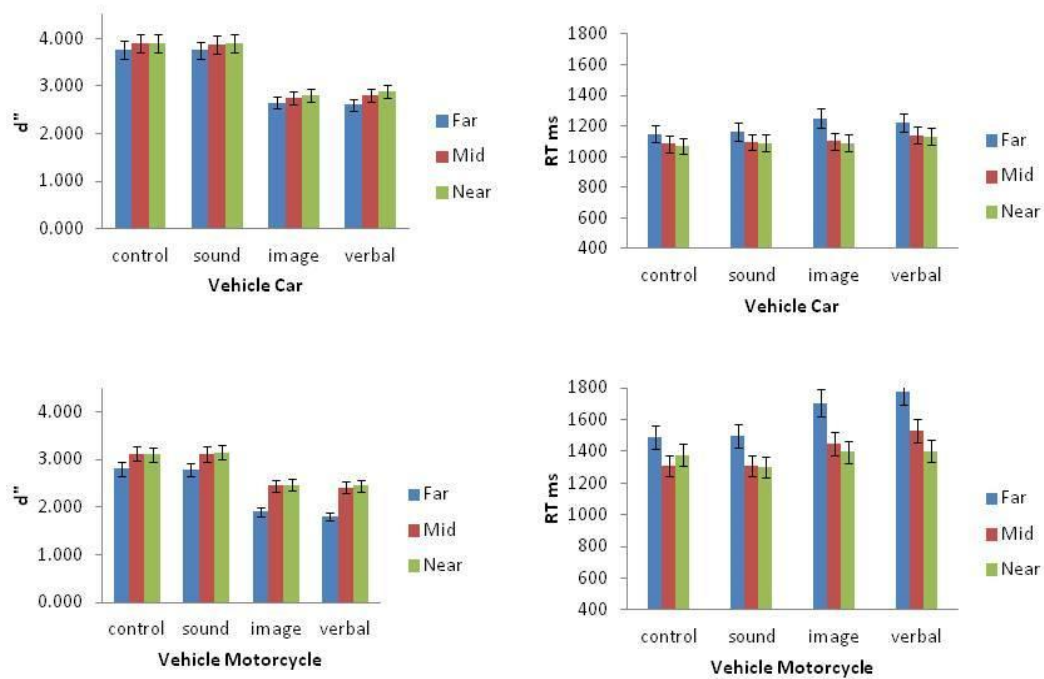


Figure 9. Experiment 3. Mean accuracy (d' ; \pm SEM) in detecting cars (left upper panel) and motorcycles (left lower panel) and reaction times (RT ms; \pm SEM) in detecting cars (right upper panel) and motorcycles (right lower panel).

4.4.1 Accuracy

The mean d' scores (left-hand panels) and mean reaction times (right-hand panels) are shown in Figure 9. Taking both left-hand panels together, there appears to be an effect of

vehicle and the nature of the distraction on accuracy, and participants appear to be less accurate when the vehicles are depicted in the far distance than when they are depicted as close to the junction. However, this effect of distance appeared to be more marked for motorcycles than for cars. Statistical analysis confirmed this description of the pattern of results in Figure 9. ANOVA revealed that there was a significant effect of the group ($F(3, 68) = 9.06, p < .001$), an effect of vehicle ($F(1, 68) = 53.33, p < .001$) and of distance ($F(2, 136) = 407.81, p < .001$). There was an interaction between vehicle and distance, ($F(2, 136) = 148.36, p < .001$) and a three-way interaction ($F(6, 136) = 2.28, p < .05$), but no other interactions (largest $F(3, 68) = 1.61, p > .19$ for the interaction between group and vehicle).

Separate ANOVAs were conducted for each group and revealed similar overall patterns of statistical significance. The analysis for group Control revealed effects of vehicle ($F(1, 17) = 50.05, p < .001$), distance ($F(2, 34) = 82.70, p < .001$), and an interaction between these factors ($F(2, 34) = 45.46, p < .001$). The equivalent analysis for group Sound revealed effects of vehicle ($F(1, 17) = 27.82, p < .001$), distance ($F(2, 34) = 152.52, p < .001$), and an interaction between these factors ($F(2, 34) = 68.76, p < .001$). The analysis for group Image revealed effects of vehicle ($F(1, 17) = 5.67, p < .05$), distance ($F(2, 34) = 104.12, p < .001$), and an interaction between these factors ($F(2, 34) = 24.69, p < .001$). Finally, the analysis for group Verbal revealed effects of vehicle ($F(1, 17) = 4.12, p = .058$), distance ($F(2, 34) = 97.36, p < .001$), and an interaction between these factors ($F(2, 34) = 29.78, p < .001$).

4.4.2 Reaction Time

The reaction times are shown in the two right-hand panels of Figure 9. Inspection of these panels shows that the nature of the distraction seemed to have a marked effect: The reaction times in the group control were much faster than in the group verbal, with the other groups falling somewhere between these two groups. It is also evident that the reaction times for motorcycles were longer than for cars, an effect that was particularly evident when the vehicles were depicted in the distance (i.e., far). ANOVA revealed a significant effect of the group ($F(3, 68) = 5.61, p < .005$), an effect of vehicle ($F(1, 68) = 16.49, p < .001$), and of distance ($F(2, 136) = 8.81, p < .001$). There was no interactions (largest $F(3, 68) = 1.73, p > .16$ for the interaction between group and vehicle). Tukey's HSD showed that group Control differed from groups Image and Verbal ($ps < .05$), but not group Sound. Group Sound also differed from groups Image and Verbal ($ps < .05$), and groups Image and Verbal did not differ.

4.5 Experiment 4

The results of Experiments 1-3 have shown that cars are more easily detected than motorcycles, and that the influences of various manipulations (i.e., distance, density and distraction) are more evident for motorcycles than cars. However, the extent to which at least some of these effects reflects the use of instructions that might implicitly prime participants to expect cars is unknown. Experiment 4 was designed to address this issue by priming the participants that there could be two types of vehicle (cars and motorcycles) present. This was

achieved by having separate response options for car, motorbike, or no target.

4.6 Method

4.6.1 Participants

Forty participants (2 males, 38 females) were recruited. The majority of the participants were from Cardiff University. They had a mean age of 25 years, with an average driving experience of 4.2 years since passing the driving test. They all reported normal or corrected-to-normal vision. None of the participants had experience of riding a motorcycle. The participants were randomly assigned to one of the four groups that had different types of distraction (i.e., Control, Sound, Image and Verbal).

4.6.2 Apparatus, materials and procedure

The apparatus was the same as in Experiment 1. In Experiment 4, however, participants were asked which kind of vehicle was featured in the image. If the image contained an oncoming car the participants were instructed to press the 'C' key, whereas if it was a motorcycle the participants were instructed to press the 'M' key. They were instructed to press the spacebar if there was no vehicle. Other details of the procedure were the same as in Experiment 3 in which the images contained two nontarget vehicles.

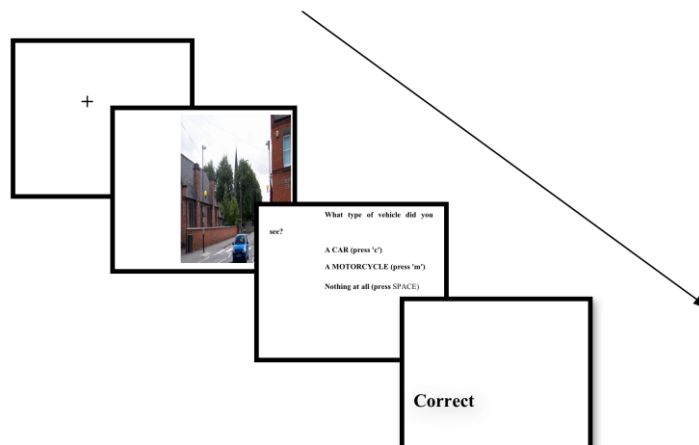


Figure 10. Experiment 4: An example of task stimuli and presentation sequence. The first two screens are presented for 250 milliseconds each.

4.7 Results

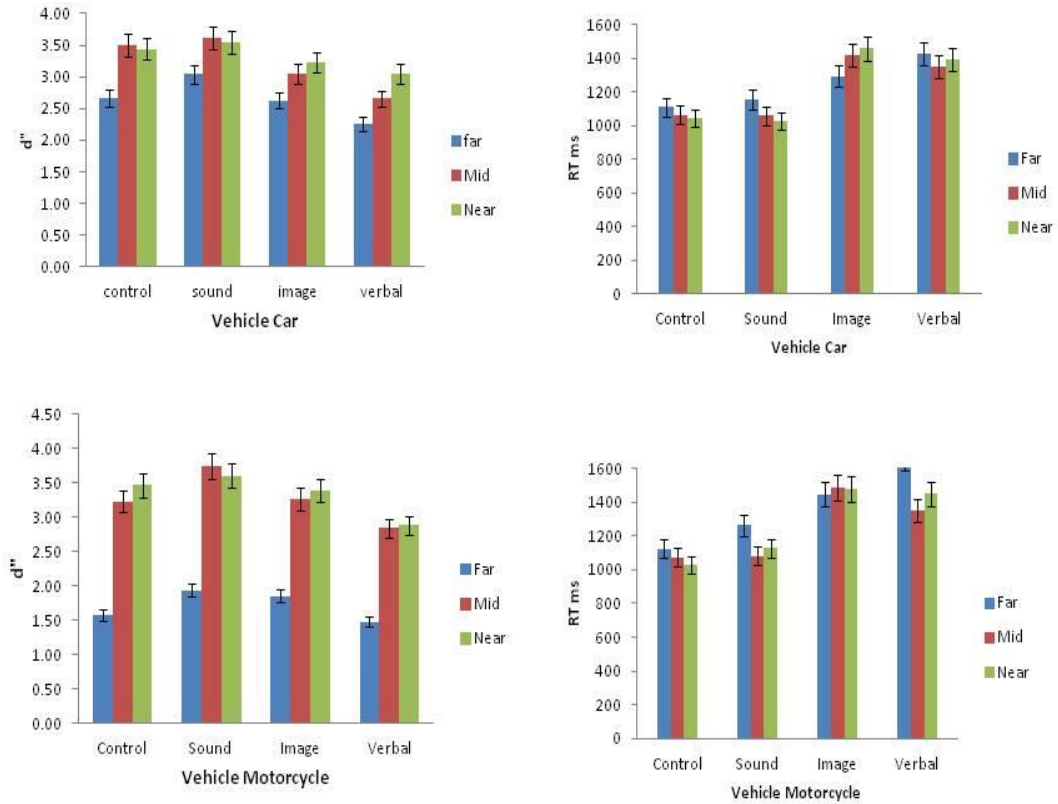


Figure 11: Experiment 4. Mean accuracy (d' ; \pm SEM) for detecting cars (left upper panel) and motorcycles (left lower panel) and reaction times (RT ms; \pm SEM) for detecting cars (right upper panel) and motorcycles (right lower panel).

4.7.1 Accuracy

The mean d' scores (left-hand panels) and mean reaction times (right-hand panels) are shown in Figure 11. Taking both left-hand panels together, there appears to be an overall effect of the nature of the distraction, with groups Control and Sound being more accurate than groups Image and Verbal. Participants were also more accurate with cars than motorcycles, with this difference being particularly marked when the vehicles were depicted in the far distance. Statistical analysis broadly confirmed this description of the pattern of results in Figure 11. ANOVA revealed that there was a significant effect of the group ($F(3, 36) = 3.39, p < .05$). There was an effect of vehicle ($F(1, 36) = 38.47, p < .001$) and of distance ($F(2, 72) = 239.04, p < .001$). There was an interaction between vehicle and distance ($F(2, 72) = 85.25, p < .001$), but none of the other interactions were significant (largest $F(3, 36) = 1.97, p > .13$ for the interaction between group and vehicle). Separate ANOVAs conducted for cars ($F(2, 78) = 43.14, p < .001$) and motorcycles ($F(2, 78) = 328.78, p < .001$) confirmed that there was an effect of distance for both types of vehicle.

4.7.2 Reaction Time

The reaction times are shown in the two right-hand panels of Figure 11, and inspection of these panels reveals that the nature of the distraction had a marked effect: reaction times were shorter in groups Control and Sound than in groups Image and Verbal. It is also evident that the reaction times for cars and motorcycles were similar, but tended to

be longer when the vehicles were depicted in the far distance. ANOVA confirmed that there was a significant effect of the group ($F(3, 36) = 4.44, p < .01$), an effect of vehicle ($F(1, 36) = 6.62, p < .05$), and of distance ($F(2, 72) = 3.58, p < .05$). There was also an interaction between group and distance ($F(6, 72) = 2.60, p < .05$), but no other interactions (largest $F(2, 72) = 1.44, p > .24$ for the interaction between vehicle and distance). Separate ANOVAs revealed that there was an effect of distance in group Sound ($F(2, 18) = 13.03, p > .12$), but not in groups Control ($F(2, 18) = 2.82, p > .12$), Image ($F(2, 18) = 1.37, p > .27$) or Verbal ($F(2, 18) = 2.82, p = .07$).

4.8 Discussion

The results of Experiment 3 replicate those of Experiment 2c in showing that the nature of distraction impacted on accuracy, and that the effect of distraction was particularly marked for motorcycles that were depicted in the distance. Also, reaction times were longer for motorcycles than for cars, a difference that was most pronounced when the vehicles were presented in the distance. In Experiment 4 participants were primed with the information that the targets could be cars or motorcycles. The pattern of results in this experiment were similar to those of Experiment 3 and previous experiments (Experiments 1-2c). However, the effects of distance and vehicle on reaction time were less marked in Experiment 4 than in the previous experiments. While acknowledging that this comparison is across experiments, it seems plausible to suggest that the difference might be based on expectation: having been primed in Experiment 4 that both types of vehicle might be present the participants are less affected by the nature of the vehicle. The issue of whether expectation (and of experience)

affect driver performance are directly investigated in the next two chapters. In Chapter 5 this is achieved by manipulating the relative frequencies of cars and motorcycles, whereas in Chapter 6 it was achieved through assessing more or less experienced drivers.

Chapter 5

Drivers' expectations in spotting approaching vehicles at junctions

5.1 *Introduction*

A number of studies have suggested that motorcycle collision accidents are often the result of reduced visibility factors, such as adverse weather conditions or night-time darkness, since these conditions hamper the car driver's ability to spot an oncoming motorcycle (e.g., Clark, Ward, Truman & Bartle, 2004). The results of Experiments 1-3 are broadly consistent with this view: motorcycles in the distance were generally less accurately identified and latencies were longer than cars in the distance. However, a common instance of right of way incidents is when a car pulls into a main carriageway at a junction at the same moment as a motorcycle is approaching the junction. Under such conditions, even though the car driver inspects the oncoming traffic for any approaching vehicles, he/she fails to spot the motorcycle. Reports from such accidents sometimes include a testimony from the driver where s/he insists that s/he had not seen the motorcycle approach (see Clark et al., 2004). Moreover, a significant proportion of such accidents also occur in the daytime, where such reduced visibility factors do not play a significant role. Indeed, in this type of accident - sometimes referred to as "looked but failed to see" accident - the car driver has already examined the oncoming traffic yet failed to detect the approaching motorcycle.

This raises the issue of expectation as a possible variable in accidents at T-junctions. Crundall et al. (2008) highlight the importance of expectation in detecting the presence of an

approaching vehicle, a subject examined in a number of other studies. For instance, Magazzu, Comelli and Marinoni (2006) have argued that “expectations may also play a role by lowering the threshold for motorcycle detection” explaining that “those drivers who also ride motorcycles have greater exposure to motorcycles and are more aware of the potential dangers at junctions”. They state that “dual drivers” are less likely to cause motorcycle crashes because of this background knowledge and its potential effect on motorcycle detection (Magazzu, Comelli, & Marinoni, 2006). The role of expectation in detecting vehicles is also discussed by Brooks and Guppy (1990), whose findings suggest that drivers with family members and/or close friends who ride motorcycles are less likely to be involved in accidents and show better awareness of motorcycles than people who do not have such contacts.

5.2 *Experiment 5: Manipulating expectation through the stimulus set*

Experiment 5 examines the role of expectation in vehicle detection through manipulating the likelihood that the stimulus set will include motorcycles and cars. In group motorcycle the stimulus set contained 100 motorcycles and 20 cars, and in group car the set contained 100 cars and 20 motorcycles. The participants' task was again to judge whether or not there was a vehicle presented in the picture or not. The question of interest was whether accuracy and reaction times would be affected by the distribution of vehicles in the stimulus set.

5.2 *Method*

5.2.1 *Participants*

Forty four participants (4 males, 40 females, most of whom are students at the Cardiff University) were recruited. They had a mean age of 25.6 years, with an average driving experience of 3 years since passing their driving test. Participants were randomly assigned to one of the two experimental conditions (see below).

5.2.2 *Materials*

The stimuli consisted of sequenced variations of ten T-junction scenes and further instruction screens, which were combined to produce a visual discrimination task. Each scene, again presented for 250 milliseconds, was taken from the viewpoint of a car driver looking to their right at a T-junction. Some scenes were then digitally edited so as to include an approaching vehicle (either a car or a motorcycle) positioned at either the far or near distance, and travelling towards the T-junction (See Figure 12). One hundred and ninety (190) static pictures were presented to the participants, seventy of which contained no vehicle while 120 featured a single vehicle (either a car or motorcycle). The pictures were presented randomly using the E-Prime presentation software. A standard computer keyboard was used to collect the responses of the participants. Participants in group motorcycle were shown 120 pictures; a hundred (100) of which featured an approaching motorcycle while twenty (20) pictures featured an approaching car. Meanwhile, participants in group car were presented with 20 pictures featuring a motorcycle and 100 pictures featuring a car.

5.2.3 Design

There were two within-subjects variables: 'Vehicle Type' (car or motorcycles), 'Distance' (far or near), and one between-subjects variable (group Car or Motorcycle). The same measures of accuracy and reaction time were measured as in previous experiments.

5.2.4 Procedure

Participants first received a practice run of 10 images. During the experimental trials, a fixation screen was presented for 250 ms after which the image of a T-junction image was displayed for 250 ms after which participants were required to identify whether a vehicle was present or not by pressing the appropriate keyboard key as quickly as possible. The participant was expected to press '0' to indicate that the shown picture contained no approaching vehicle, and to press '2' to indicate that they detected the presence of a vehicle in the picture. Instruction slides can be categorised according to the following uses: One hundred and ninety static pictures were presented to the participants, seventy of which featured no approaching vehicles. The pictures were presented in a random sequence using the E-Prime presentation software. A standard computer keyboard was used to collect participant responses. The accuracy of each trial was recorded after each answer, and determined the feedback provided on the next screen.

5.3 Results

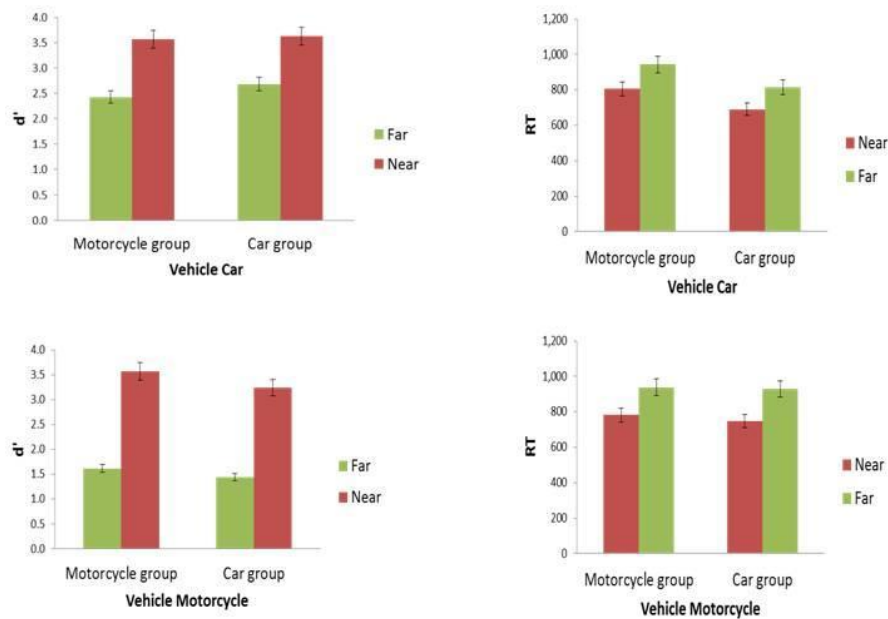


Figure 12. Experiment 5: Mean accuracy (d' ; \pm SEM) in detecting cars (left upper panel) and motorcycles (left lower panel) and reaction times (RT ms; \pm SEM) in detecting cars (right upper panel) and motorcycles (right lower panel).

5.3.1 Accuracy

The mean d' scores (left-hand panels) and mean reaction times (right-hand panels) are shown in Figure 14. Taking both of the left-hand panels together, in both groups Car or Motorcycle, the scores for cars were more accurate (on average) than those for motorcycles,

and participants appear to be much less accurate when the vehicles are depicted in the far distance than when they are depicted as close to the junction. However, this effect of distance appeared to be more marked for motorcycles than for cars. Statistical analysis broadly confirmed this description of the pattern of results. ANOVA with group (Car or Motorcycle), vehicle (car or motorcycle), and distance (near or far), revealed that there was no significant effect of group ($F(1, 37) = 0.05, p > .82$), but that there were effects of vehicle ($F(1, 37) = 38.93, p < .001$) and distance ($F(1, 37) = 125.23, p < .001$). There was an interaction between group and vehicle ($F(1, 37) = 4.43, p < .05$) and an interaction between vehicle and distance ($F(1, 37) = 34.37, p < .001$). There were no other interactions (largest F s < 1). Separate ANOVAs confirmed that in both group Car and Motorcycle accuracy was greater for cars than for motorcycles ($F(1, 18) = 26.04, p < .001$, and $F(1, 19) = 12.30, p < .005$, respectively).

5.3.2 Reaction Time

The reaction times are shown in the two right-hand panels of Figure 12. Inspection of this figure shows that group Motorcycle were slower to respond to cars than group Car, but that these groups did not differ in their reaction times to motorcycles. Also, participants in both groups were slower to respond in the far than the near condition. ANOVA showed that there was no significant effect of the group ($F(1, 37) = 1.70, p > .20$), no effect of vehicle ($F(1, 37) = 2.48, p > .12$), but there was an effect of distance ($F(1, 37) = 33.91, p < .001$). There was also a significant interaction between group and vehicle ($F(1, 37) = 5.26, p < .05$), but no other interactions (F s < 1). Separate ANOVAs were conducted for cars and motorcycles. The

analysis for cars revealed a marginally significant effect of group ($F(1, 37) = 4.08, p = .051$), an effect of distance ($F(1, 37) = 21.05, p < .001$) and no interaction between these factors ($F < 1$). The analysis for motorcycles revealed an effect of distance ($F(1, 37) = 21.55, p < .001$), no effect of group and no interaction between these factors ($F_s < 1$).

5.4 Discussion

Participants were more accurate in detecting cars than motorcycles irrespective of whether the stimulus set was dominated by cars or by motorcycles. This is unlikely to reflect a ceiling effect because accuracy was affected by the distance at which the vehicles were presented. However, as in other experiments within this thesis, there was an effect of the critical between-subjects variable in the reaction times: cars tended to be more rapidly detected in group Car than in group Motorcycle. This effect was not mirrored in the reaction times to motorcycles. These results suggest that the processing of vehicles is influenced by their frequency. The question of why any such effect is only evident in responding to cars and not motorcycles is open. One possible analysis rests on the general idea that the short-term effects of changes in frequency that were experimentally generated are most likely to be evident when mirrored by a consistent long-term difference in frequency. In short, the experimentally induced changes in the frequency of motorcycles might have been too little to overcome the long-term differences in their frequency outside of the laboratory. One implication of this analysis is that increasing the amount of training might affect a change in the processing of motorcycles in groups Motorcycle and Car. However, it might be difficult to arrange that the experimentally induced change in familiarity outweighs those based on

pre-existing differences in familiarity generated by real-world experiences. However, in Experiment 6 the influence of driving experience on the processing of cars and motorcycles was assessed. This difference might be expected to impact on the processing of cars and motorcycles to the extent that it affects the frequency with which different types of vehicle (e.g., motorcycles) have been encountered.

Chapter 6

Experienced versus novice drivers

6.1 *Introduction*

According to road accident data, young novice drivers are among the highest population segments to be involved in an accident (Deery, 1999; Underwood & Crundall, 2003). One obvious contribution to these worrying statistics is that novice drivers have yet to acquire the driving skills necessary to operate a vehicle, and that this fact interacts with distractions of engaging in secondary tasks (Regan et al., 1998). This chapter explores how driving experience affects car and motorcycle detection. The results of Experiments 1-5 were based on (female) drivers who had little experience, and this raised the possibility that the effects observed might have limited generality. For example, Trick et al. (2004) suggested that experienced drivers might spot motorcycles earlier than novice drivers because of their existing knowledge of driving and vehicles. Also, Crundall and Underwood (1998) found that novice drivers require longer fixation to spot hazards on the road. Moreover, Underwood et al. (1999) found that drivers with experience were better able to detect hazards that were not on the road. The aim of Experiment 6 was to assess whether driving experience interacts with the ability to respond effectively to oncoming vehicles (cars and motorcycles).

6.2 *Experiment 6*

In Experiment 6 there were two groups of drivers: novice and experienced. The

procedure was adapted from Experiments 1-5, where participants had to respond to brief snapshots that contained motorcycles or cars that were depicted close to the junction (near) or further up the road (far).

6.3 Methodology

6.3.1 Participants

Twenty-two participants were recruited (mostly students from the University of Cardiff) to take part in this experiment.. The participants in the novice group (3 males, 8 females) had a mean age of 23.4 years, and they had mean of driving experience 2.6 years. The drivers in the experienced group (4 males, 7 females),had a mean age of 35.2 years, and a mean of 10.7 years of driving experience since passing their driving test. They all reported normal or corrected-to-normal vision.

6.3.2 Materials and procedure

The stimuli presented to all participants consisted of a sequence of ten T-junction scenes interspersed with instruction screens. These T-junction scenes - presented for 250 milliseconds each - were taken from the viewpoint of a car driver who had just approached the T-junction and is looking out to his/her right for approaching vehicles. As before, some of the scenes were edited so as to include an approaching vehicle (either a car or a motorcycle) positioned at either the far or near distance, and travelling towards the T-junction. Editing the ten scenes in this way produced 120 pictures in total. An additional set of 60 similar T-junction scenes featuring no approaching vehicle was also created, bringing the total number

of pictures presented to each group to 180 pictures. These pictures were presented randomly using the E-Prime presentation software and a standard computer keyboard was used to collect the responses of the participants.

6.3.3 Design

There were three independent variables: vehicle and distance (that were manipulated within-subjects) and experience, which was between-subjects. As in previous experiments, there were two dependent measures: accuracy and reaction times.

6.3.4 Procedure

Before the experiment, participants were given a practice run of 10 images. During the experimental trials, each participant viewed the fixation screen for 250 ms, followed by the image of a T-junction, also displayed for 250 ms. Participants were then required to identify whether a vehicle was present (or not) by pressing the appropriate keyboard key as quickly as possible: '0' to indicate that the shown picture contained no approaching vehicle, or to press '2' to indicate that they detected the presence of an approaching vehicle in the picture.

6.4 Results

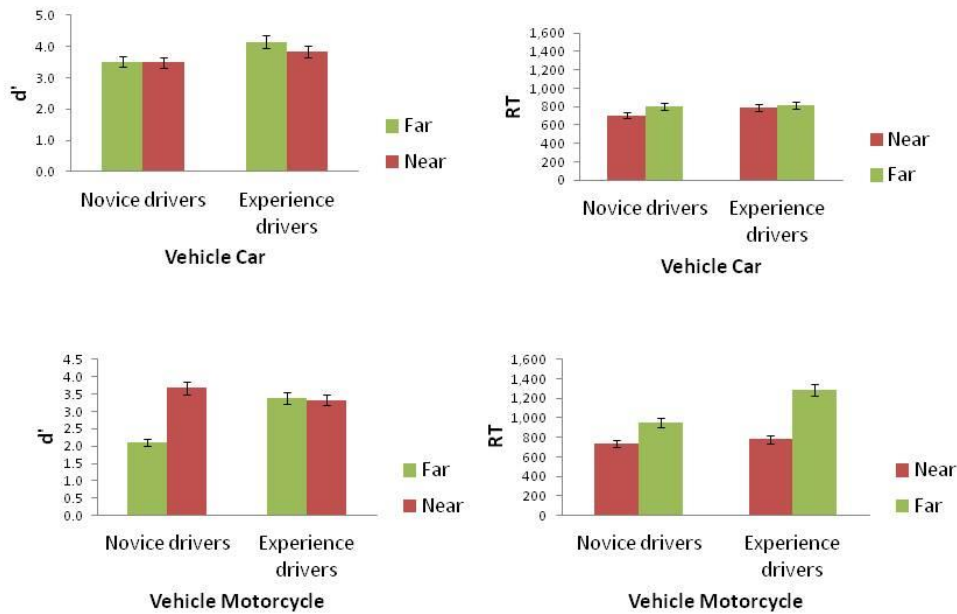


Figure 13. Experiment 6: Mean accuracy (d' ; \pm SEM) in detecting cars (left upper panel) and motorcycles (left lower panel) and reaction times (RT ms; \pm SEM) in detecting cars (right upper panel) and motorcycles (right lower panel).

6.4.1 Accuracy

The mean d' scores are shown in the left-hand panels in Figure 13. Taking both left-hand panels together, there appears to be an overall effect of distance in both novice and experienced drivers. However, the scores for cars appear to be more accurate (on average)

than those for motorcycles, and participants appear to be much less accurate when the vehicles are depicted in the far distance than when they are depicted as close to the junction; and *t*. However, this effect of distance appeared to be more marked for motorcycles than for cars, and especially marked for motorcycles in group Novice. Statistical analysis confirmed the accuracy of this description of the pattern of results depicted in the left-hand panels of Figure 13. ANOVA was conducted with group (novice or experienced), vehicle (car or motorcycle), and distance (near or far) as the factors. This analysis revealed a main effect of group ($F(1, 20) = 24.57, p < .001$), an effect of vehicle ($F(1, 20) = 28.32, p < .001$), and an effect of distance ($F(1, 20) = 5.49, p < .05$). There was no interaction between group and vehicle ($F < 1$), but all of the remaining interactions were significant: group by distance ($F(1, 20) = 15.66, p < .005$), vehicle by distance ($F(1, 20) = 19.35, p < .001$), and the three-way interaction ($F(1, 20) = 9.91, p < .01$). Separate ANOVAs were then conducted for the two groups to explore the nature of the three-way interaction. The analysis of group Experienced revealed an effect of vehicle ($F(1, 10) = 19.27, p < .005$), but no effect of distance and no interaction between vehicle and distance (largest $F(1, 10) = 1.01, p > .33$). The equivalent analysis of group Novice revealed an effect of vehicle ($F(1, 10) = 11.03, p < .01$), distance ($F(1, 10) = 27.62, p < .001$), and an interaction between these factors ($F(1, 10) = 34.17, p < .001$). Further analysis showed that there was an effect of near versus far for motorcycles ($t(10) = 7.80, p < .001$), but not for cars ($t(10) = 0.12, p > .90$)

6.4.2 Reaction time

The reaction times are shown in the two right-hand panels of Figure 17. Inspection of these panels show that the reaction times in the group Novice were much shorter than in the group Experienced. It is also evident that the reaction times for motorcycles were longer than for cars, with this effect being particularly marked when the vehicles were depicted in the distance for group Experienced. A parallel ANOVA to that conducted on the accuracy scores partly confirmed the accuracy of this description. This analysis revealed a main effect of group ($F(1, 20) = 24.06, p < .001$), an effect of vehicle ($F(1, 20) = 36.41, p < .001$), and an effect of distance ($F(1, 20) = 82.40, p < .001$). All of the interactions involving these factors were significant: group by vehicle ($F(1, 20) = 7.12, p < .05$), group by distance ($F(1, 20) = 5.18, p < .05$), vehicle by distance ($F(1, 20) = 40.65, p < .001$), and the three-way interaction ($F(1, 20) = 14.98, p < .005$). Separate ANOVAs were again conducted for the two groups to explore the nature of the three-way interaction. The analysis of group Experienced revealed an effect of vehicle ($F(1, 10) = 31.39, p < .001$), distance ($F(1, 10) = 63.70, p > .001$) and an interaction between vehicle and distance ($F(1, 10) = 37.69, p < .001$). Further analysis revealed that there was no effect of distance for cars ($t(10) = 1.02, p > .32$) but there was an effect of distance for motorcycles ($t(10) = 7.50, p < .001$). The analysis for group Novice revealed an effect of vehicle ($F(1, 10) = 7.13, p < .05$), distance ($F(1, 10) = 23.40, p < .005$), and an interaction between these factors ($F(1, 10) = 5.16, p < .05$). Further analysis showed that there was an effect of distance for cars ($t(10) = 2.62, p < .001$), and motorcycles ($t(10) = 4.86, p < .005$)

6.5 Discussion

The aim of this experiment was to explore the effect of driving experience on the ability of drivers to detect vehicles (cars and motorcycles) that were presented at two distances (near and far). Because experience was defined in terms of number of intervening years post driving test, experience is likely to be correlated with many other factors (most obviously age). Nonetheless, separating the drivers in this way resulted in marked differences. Overall, participants were again more accurate in detecting (i) cars than motorcycles, and (ii) vehicles depicted closer to the junction than further away. However, the detrimental effect of distance was more evident for motorcycles than for cars, and this effect was especially marked for motorcycles in novice drivers. The differences in reaction time were also affected by group, with group Novice responding more quickly than group Experienced. This difference in reaction time, might affect accuracy through a speed-accuracy trade-off. However, it seems unlikely that this difference would have resulted in participants in group Novice being particularly affected by the distance at which motorcycles were depicted. Instead, this difference suggests that the difference in the frequency with which they have encountered motorcycles might be critical. In Experiment 5, cars tended to be more rapidly detected in group Car (for which there were more cars than motorcycles) than in group Motorcycle (for which there were more motorcycles than cars). That is, the frequency with which cars were encountered (during the experiment) affected reaction times. In Experiment 6, group Novice responded more rapidly than group Experienced irrespective of the nature of the vehicle. However, unlike in Experiment 5, novice drivers who we can

assume have encountered fewer motorcyclists than experienced drivers were particularly inaccurate when motorcycles were depicted in the distance. Of course, the experienced drivers were relatively young compared to other studies in which older participants performed poorly (McKnight & McKnight, 1993; Reed & Green, 1999; Lam, 2002; Schreiner, Blanco & Hankey, 2004; Strayer and Drews, 2004). This finding has implications for driver training that will be explored in the General Discussion.

Chapter 7

7.0 General Discussion

The research described in this thesis was intended to shed light on an important issue: why motorcyclists are more likely to be involved in accidents than cars. This was explored using a simple simulated environment that modeled a traffic situation that is associated with accidents involving motorcycles: a car emerging from a T-junction. The participants in the experiments were required to make (speeded) judgments about the presence of oncoming vehicles in static visual scenes. This chapter briefly discusses the results of the experiments and their implications. It also highlights the limitations of the study. Finally, ideas for future research are discussed and some general conclusions are presented.

7.1 *Summary of the results*

Experiment 1 investigated whether or not different forms of distraction affected participants' ability to detect motorcycles and cars at a T-junction. The distractors involved additional aural, visual and verbally based tests designed to tax processes that might be important for identifying whether a briefly presented slide contained a vehicle or not. Experiment 1 showed that accuracy was affected by vehicle and distance, but that distraction had no effect, perhaps because of a ceiling effect. However, reaction times were affected by distraction, in addition to distance and vehicle. Importantly, there was an interaction between vehicle, distance and distraction; with particularly slow reaction times to motorcycles presented in the far distance and under the influence of verbal distraction. Experiments 2a-c

examined the effects of distraction under conditions in which the presence of non-target vehicles (cars) was increased.

Experiments 2a-c replicated and extended the results of Experiment 1 by increasing the number of nontarget vehicles in the visual displays. In Experiment 2a there were no nontarget vehicles cars, whereas in Experiments 2b and 2c there were one and two cars, respectively. In Experiment 2 accuracy was affected by vehicle, traffic density, and target vehicle distance. There was an interaction between density, vehicle and distance, which suggested that the detection of motorcycles is particularly affected when they are depicted in the distance with nontarget vehicles near to the junction. As in Experiment 1, the presence and nature of distractors had little effect on the measure of accuracy. However, reaction times were significantly affected by the nature of the distractor, as well as by the other factors (density, vehicle and distance). Experiment 3 replicated the results of Experiment 2c in showing that the nature of distraction impacted on accuracy, and that the effect of distraction was particularly marked for motorcycles that were depicted in the distance; and reaction times were longer for motorcycles than for cars, a difference that was most pronounced when the vehicles were presented in the distance. In Experiment 4, participants were primed with the information that the targets could be cars or motorcycles.

In Experiment 5, participants were more accurate in detecting cars than motorcycles irrespective of whether the stimulus set was dominated by cars or by motorcycles. There was also an effect of the critical between-subjects variable on the reaction times: cars tended to be more rapidly detected in group Car than in group Motorcycle; but this was not mirrored in the

reaction times to motorcycles. These results suggest that the processing of vehicles is influenced by their frequency. Finally, in Experiment 6 participants were again more accurate in detecting (i) cars than motorcycles, and (ii) vehicles depicted closer to the junction than further away. The detrimental effect of distance was more evident for motorcycles than for cars, and this effect was especially marked for motorcycles in novice drivers. The differences in reaction time were also affected by group: group Novice responding more quickly than group Experienced.

7.2 *Implications of the results*

The results from Experiments 1-6 suggest that many of the factors that have an effect on RTCs generally have a particularly marked impact on driver behaviour involving motorcycles in a T-junction scenario. Thus, visibility and distraction had pronounced effects on features of driver behaviour involving motorcycles (Experiments 1-4). However, there were other factors that seemed to be more specific to motorcycles: their infrequent nature and driver's experience (with them) seemed to interact with components of driver behaviour (Experiments 5 and 6).

These results are particularly interesting in the context of some of the literature discussed in Chapter 1. In Chapter 2, it was shown that the presence of nontarget vehicles influenced both the reaction times and identification rates; effects that were exacerbated by the presence of distractions. These observations are consistent with those of Patten et al. (2004). Where Chapters 1-3 make an original contribution is in the clear demonstration that the motorcycle detection is especially prone to the effects of these variables..

Experiment 5 demonstrated that the short-term effects of changes in vehicle frequency (i.e., over the duration of the experiment) are most apparent when mirrored by a consistent long-term difference in frequency: Participants continued to more easily detect cars than motorcycles even when motorcycles were more frequently presented over the course of the experiment. The finding from Experiment 6 that more experienced drivers have higher levels of detection accuracy (at least under some conditions) is consistent with the suggestion that developing driving skills is a gradual process that continues long after people have passed their driving test (Grayson, Maycock, Groeger, Hammond, and Field (2003). Given the fact that experience is correlated with age is not possible to determine whether experience or age was the critical variable (see also, Hayhoe & Ballard, 2005; McKnight & McKnight, 1993; Reed & Green, 1999; Schreiner, Blanco, & Hankey, 2004). However, one way in which age or experience might affect performance is through their effect on visual search (see Chapter 1).

7.3 *Limitations of this research*

Sampling bias. The participants in these experiments were not representative of the driving population: The majority were female and relatively young (but see Experiment 6). While it may be argued that the results might not be generalized to other populations, the results are of direct relevance to our understanding of the many accidents that occur in this demographic. However, the fact that the experiments did not include a sufficient number of males to assess separately the influence of the manipulations on males and females is

unfortunate, given the number of accidents involving young male drivers. In fact, the research conducted by Massie, Campbell and Williams (1995) suggested that RTCs are associated with being male, young, and having limited driving experience.

Simulations. The use of images of T-junctions presented on computer monitors is potentially problematic in many respects. For example, in the real world, the relevant objects (vehicles) are not stationary, but are moving at high speed. This fact means that the results from Experiments 1-6 are unlikely to fully capture the scale of the problems that confront a driver who is searching for objects that are dynamic and are parts of more complex dynamic scenes. Also, the experimental environments within which Experiments 1-6 were conducted were much more constrained than those that typically face a driver on the road, where the conditions are often changing in unpredictable ways.

7.4 *Future directions*

The advantages of using the constrained scenarios in Experiments 1-6 is that it enables the effects of various manipulations to be explored in a controlled fashion. This means that it remains important to address the limitations identified above as opposed to moving to more realistic driving simulators or to field studies. As discussed above, the subject population had issues regarding demographic representation. Addressing this issue, by using a more representative sample, would allow for more robust conclusions to be drawn regarding the real world applicability of the results.

However, there is also the possibility of using more dynamic images in the form of

video clips or virtual reality in order to increase the engagement of participants and to increase the extent to which the results could be generalized to real driving, while maintaining control of experimental variables. The use of such scenarios could also allow the ready manipulation of other variables that might interact with the ones of interest here. For example, the distractions used could also be varied considerably. Thus, the impact of GPS instructions could be assessed by playing a lane change recording and requiring the subjects to press the area of the screen that contained the correct lane unless a motorbike was also present on the screen. Of course, linking the influence of distractors to hazard detection through the use of eye-tracking would also be valuable and feasible given the ability to monitor eye movements in virtual reality settings.

7.5 *Concluding comments and policy implications*

Clarke et al. (2004) found that 38% of the RTCs involved right of way violations, in which the motorcycle is travelling straight ahead on a road while another vehicle is trying to enter that same road in front of the motorcycle. The further observation that only 20% of these cases involved fault on the part of the rider and that 96% of motorcycle RTCs at junctions occur due to the right of way violation (Peek-Asa & Klaus, 1996) suggests that the research undertaken here has potentially important implications for policy. In particular, the findings that familiarity with hazards (in this case motorcycles) and experience affects performance (Experiments 5 and 6) might have considerable utility. The UK driving test already contains a test where drivers are forced to identify hazards. However, including

specific training related to hazards posed by motorcycles at T-junctions would be a useful addition, as would increased recognition of the potential interactions between distractors and performance at T-junctions.

Chapters 2-5 demonstrated that the impact of distraction on driver recognition and reaction time performance is relatively high for visual and verbal distractions even when this is compared to purely aural distractions. This has important implications for user interface design in vehicles, as visually distracting instruments and displays may distract drivers outside of the more commonly recognised impact of ongoing conversations. It is also notable that this impact on performance is greater when nontarget traffic levels are higher. This implies that the use of GPS systems based on visual displays should be particularly problematic in high traffic areas, with some provision of advice regarding the desirability of the use of purely verbal interface modes being worthwhile. The research conducted here is consistent with research regarding mobile phone use, as the increased complexity of phone use when compared to a hands-free kit affects accident rates in the lab and in the field (Al-Tarawneh et al, 2004).

Finally, and perhaps most importantly, each experiment has shown that the accuracy and speed with which motorcycles are detected are dramatically affected by the distance at which they are depicted. This is exacerbated when drivers are distracted by interactive spatial and verbal tasks. Thus, these results have profound implications for driver training and road safety policy.

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