UNDERSTANDING INTERACTIONS BETWEEN TWO WHEELERS (TW) AND CAR DRIVERS IN A DRIVING SIMULATOR

Final Report to NRMA-ACT Road Safety Trust

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EXECUTIVE SUMMARY

Bicycle and motorcycle (collectively called two-wheelers - TWs) riders comprise about half of the ACT residents hospitalised as a result of land transport injuries. Most of the serious injuries to bicycle riders and, to a lesser extent, motorcycle riders result from collisions with motor vehicles. In the majority of cases, the TWs are not at fault in these crashes. The overall aim of this project was to better understand the road safety risks occurring during interactions between passenger vehicles and TWs from the driver's viewpoint. The research used a mix of questionnaires and driving simulation to examine the effects of previous experience as a TW rider on driver attitudes, self-reported behaviours and simulated driving behaviour, and the perceptual aspects involved in drivers detecting TWs.

Driver attitudes to two-wheelers

While earlier research has identified negative attitudes by drivers to TWs, this study was the first to identify stronger negative attitudes and weaker empathic attitudes to bicycles compared to motorcycles. Motorcycle experience was associated with less negative and stronger empathic attitudes toward motorcycles but drivers who were bicycle riders did not show either less negative or more empathic attitudes to bicycles than other drivers, after controlling for age and gender. Experience as a motorcyclist did not result in less negative attitudes towards bicycles and vice-versa.

Visibility and passing distances

Overall, participants reported significantly greater problems in seeing bicycles compared to motorcycles. Drivers with previous motorcycle or bicycle experience gave lower ratings of problems in seeing motorcycles, but previous experience with TWs did not influence ratings of problems in seeing bicycles (which increased with age). Spatial judgements of the width of TWs were unaffected by previous experience.

While there were no effects of TW experience on judging a safe distance when a motorcycle was overtaking a car, experience affected judgements of the perceived safe distance when a car was overtaking a bicycle. Drivers with bicycle experience selected smaller passing distances, possibly based on experience of previous close passing manoeuvres that were safely negotiated. The findings that drivers with bicycle experience nominated smaller safe distances for a car passing a bicycle and that these judgements did not appear to be reflected in behaviour in the simulator merit further investigation. If they are found to be reliable, then the implication is that self-reports of safe distances to pass a bicycle may not be valid measures to use to measure the effects of campaigns to increase separation distances such as "A metre matters".

There was a trend for safer interactions with approaching motorcycles when the motorcycle conspicuity was higher (headlights on), although this was not statistically significant. There were no significant safety improvements for high conspicuity motorcycles at roundabouts when cars were merging onto the roundabout. The effect of high and low visibility on simulated interactions was difficult to measure, but the results confirm previous findings that headlights appear to be most beneficial when the motorcyclist is approaching the driver, rather than in oblique situations.

Driving behaviours in interactions with two-wheelers

Driving simulator scenarios were developed based on an analysis of the most frequent types of ACT police-reported crashes that involved TWs and cars. The ability to draw firm conclusions from this study is limited by the difficulties experienced in conducting the simulator study and the consequent loss of data.

The measures of driver behaviour in the simulator did not provide any substantial evidence that previous TW experience leads to safer interactions with TWs as a car driver. However, individual differences in driving behaviours were large, making it difficult to identify differences between groups. Drivers with motorcycle experience tended to drive faster, and have smaller separation distances at interactions. Without objective measures of safety for the simulated interactions, it is difficult to determine if this indicates unsafe driving behaviour, or reflects different perceptions of driving based on experience interacting with traffic as a motorcycle rider.

These results of this study suggest that individual differences between drivers influence their safety behaviours in interactions with TWs more than previous TW experience. Participants who scored higher on the Driver Behaviour Questionnaire (DBQ) Violations, DBQ Aggressive violations, and the Sensation seeking measures tended to drive closer to the TWs in the interactions, while also travelling faster at the point where the separation between the driven car the TW was at the minimum.

Given the range of risky scenarios which were identified from ACT crash data, it was difficult to identify measures of safety of the interaction. Time to collision is commonly used but was not applicable in all of the scenarios. Speed at minimum separation has intuitive appeal as a measure of danger, but it needs further investigation. It would be very interesting to present videos derived from the current experiment to a range of TW riders, asking them to rate the degree of risk in the situations. These ratings could then be correlated with the objective measures to determine those which are the best indicators of the degree of perceived risk.

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1 INTRODUCTION

Cycling is associated with numerous benefits and Australian research has calculated that the economic benefits attributed to current levels of cycling participation include savings to the public health systems of $227 million per year, reduced congestion benefits of $63.9 million per year and reduced road trauma costs that currently cost Australia $17 million per year (Bauman et al, 2008). However, cycling particularly on the road is perceived as a risky activity. Over a three year period from 2006 to 2009, approximately 54% of ACT residents seriously injured in crashes on roads were riders of Powered Two Wheelers (PTW) and Push Bikes (PB) (Henley & Harrison, 2012b; 2012a; 2009). This figure increased each year over the three year period, from 49% in 2006-07 to 59% in 2008-09. International research has also shown that cyclists are at greater risk of injury compared with car drivers (Hamilton & Rollin Stott, 2004). Research has also found that individuals usually identify personal safety as the primary reason that prevents them from opting to make journeys by bicycle.

With the ever increase of congestion on our roads, PTWs continue to provide a sustainable solution to mobility in Australia. Their relatively small size, low cost and low consumption enable them to blend efficiently into in the traffic flow while needing less space compared to other vehicles. However riders of PTW are among the most vulnerable road users in Australia. PTW riding is much more likely to result in serious injury than car travel. The fatality rate for Australian motorcyclists per distance travelled is approximately 30 times the rate for car occupants (Johnston, Brooks & Savage, 2008).

A further problem with crash statistics for PTWs and PBs arises due to the under-reporting to Police of crashes involving PTW, and even more so, for PBs. Richardson (2008) showed this to be true for the ACT. While ACT road crash data for 2008 (ACT, 2008) show that TWs comprise a total of 2.9% of vehicles in crashes, Henley and Harrison (2009) report that motorcycle and pedal cycle riders made up 49.5% of ACT residents hospitalized as a result of land transport injuries.

Media reports suggest that the general driving public has a negative perception of TWs. English research found that car drivers with a moderate amount of experience (between 2 and 10 years driving) held the most negative views towards PTWs (Crundall et al, 2008). In addition, drivers often perceive themselves as victims of cyclists, with the opinion that cyclists are placing themselves and other road users at risk (Fincham, 2006). A study of driver positioning during cycling overtaking manoeuvres in England found that lateral distances between cyclists and passing vehicles increased when cyclists rode close to the road edge, didn’t wear a helmet, and the cyclist appeared to be female. The vehicle types with lowest mean overtaking distance were buses, heavy goods vehicles and taxis (Walker, 2007).

However, drivers’ negative perceptions about TWs are generally not supported when crash data is reviewed. Analysis of bicycle-vehicle collisions occurring in the Brisbane local government area found that drivers were responsible in 64.4% of bicycle-vehicle collisions (Schramm et al., 2010). Bicycle crashes are more likely to occur at intersections, with approximately 60% of crashes reported at intersections. Furthermore, in a PTW-car crash, drivers are more often responsible than riders (Wulf et al., 1989). A study in Queensland showed that among the multi-vehicle crashes, the rider was considered most at fault in 37.5% of moped crashes and 36.7% of motorcycle crashes (Haworth et al, 2009).

Most (68.5%) reported PB crashes are angle crashes, with vehicles at fault in 70% of angle crashes (Schramm et al., 2010). This would suggest that it is drivers turning in front of or turning into a cyclist which is causing these crashes. This result may highlight the difficulties drivers have in assessing bicycle speed and/or positioning, a general lack of awareness of cyclists on roadways by drivers, or that conspicuity of cyclists in the road environment is an issue.

The violation of the motorcyclists' right of way by another vehicle driver is the most common cause of crashes (Wulf et al., 1989). In some instances this could be attributed to failure to see the motorcycle. Most of the studies on PB and PTW crashes argue that motorists may have difficulties in detecting the presence of an approaching PB and PTW as a result of PB and PTW's poor conspicuity, inability to determine their speed accurately, or simply motorists looked but did not see approaching TW.

In addition to similar contributory factors being found in PB and PTW crashes, the crash locations and circumstances are also often similar. Table 1 shows Police-reported bicycle and motorcycle/scooter involved in crashes in the ACT by traffic control present at the crash site. It shows that the patterns of crashes of PB and PTW by traffic control are very similar.

Studies of cyclists crashes in Queensland showed that an angle crash (two vehicles approaching from angular directions that collide, typically a result of one vehicle failing to stop or yield) was the most commonly identified type occurring between bicycles and vehicles at 68.5%. This was followed by sideswipes (14.9%) and hitting a parked vehicle (6%). Rear end (4.7%) and head on (1.3%) collisions were the only other crash types to reach greater than 1% (Schramm et al., 2010). Such results are similar to ACT cyclist crash data (Roads ACT, 2009) as shown in Table 2.

A recent study examining bicycle crashes in different cycling environments in the ACT (De Rome, Boufous, Senserrick, Richardson, & Ivers, 2011) found the majority of multi-vehicle crashes (58.8%) occurred in traffic, while 12.5% occurred in bicycle lanes. The remaining multi-vehicle crashes occurred off-road on shared paths (22.5%) and on footpaths (6.2%). Motor vehicles were involved in just over half (52.5%) of the multi-vehicle crashes, while the remaining 47.5% of multi-vehicle crashes involved another bicycle.

When analysing the multi-vehicle crashes involving motor vehicles (n=42), De Rome et al (2011) observed that motor vehicles were predominately adjacent direction (35.7%), same direction (26.2%), and manoeuvring (16.7%) crashes. Intersection crashes involving motor vehicles included failure to give way at stop or give way signs (n=8), left turn overtaking across a bike lane (n=6), turning right across traffic (n=5) and entering roundabouts (n=3).

While the results from De Rome et al's (2011) study are similar to the results of ACT bicycle crashes observed previously (see Table 1 and Table 2), an important difference to note is that the table data is based on police reported crashes while De Rome et al's study was based on hospital emergency department presentations. Another important difference to note is that De Rome and colleagues did not include fatal crashes and some serious injury crashes where the injured PB rider suffered severe trauma and were considered to be medically unfit or otherwise unable to provide informed consent to participate.

Table 1: ACT 2008 Bicycle and Motor Cycle/Scooter involved in crashes by traffic control

Traffic Control	**Bicycle (PB)**	**Motorcycle/Scooter (PTW)**
Uncontrolled	80	135
Control Not operated	0	2
Traffic lights	31	27
Give way sign	56	45
Stop sign	5	11
Police	0	0
School Crossing	0	0
Marked pedestrian Crossing	6	2
Other	1	1
Unknown	3	2
Total	**182**	**225**

Source: Roads ACT, 2009.

Table 2: ACT 2008 PB and PTW involved in crash with other vehicle by accident type

	Accident type									
	Right turn into oncoming vehicle	Right angle collision	Same direction side swipe	Opposite direction side swipe	Head on collision	Rear end collision	Collision with parked vehicle	Collision while one vehicle reversing	Other - Vehicle to Vehicle	**Total**
Bicycle (PB)	16	70	13	1	1	15	2	1	53	**172**
Motorcycle Scooter (PTW)	14	43	20	2	5	59	1	0	17	**161**

Source: Roads ACT, 2009.

The results observed from the Australian crash data, as outlined above, are similar to TW crashes observed overseas. European in-depth studies of PB and PTW crashes (ACEM, 2004; SAVE-U, 2003) have identified that the first contact point in TW-vehicle crashes is commonly the front of the vehicle (see Figure 1 and Figure 2).

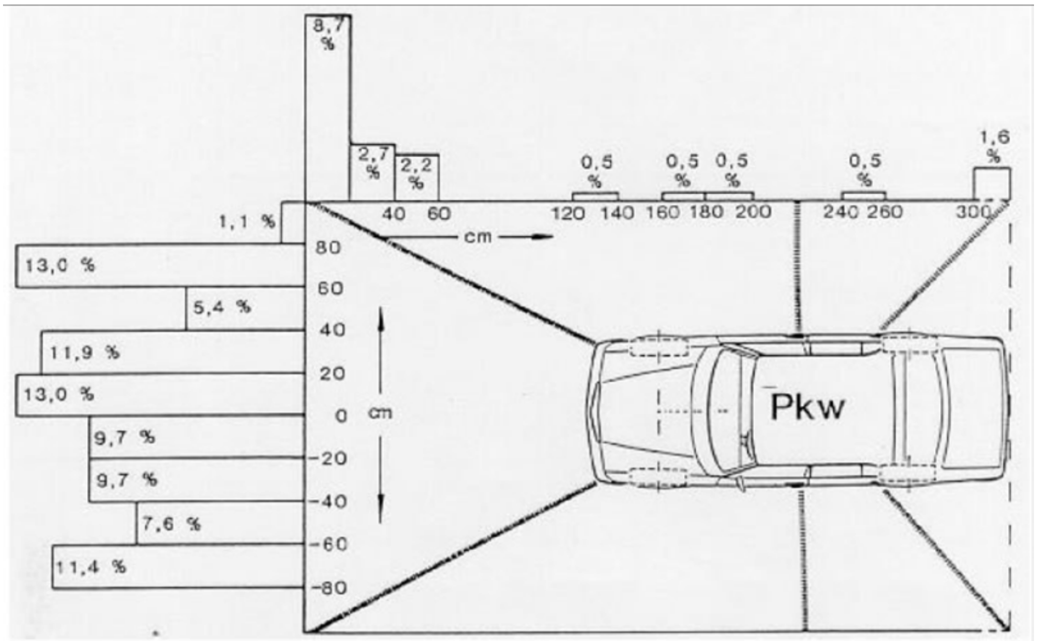

Figure 1: First contact point for vehicle-cyclists crashes (From EU SAVE-U 1A)

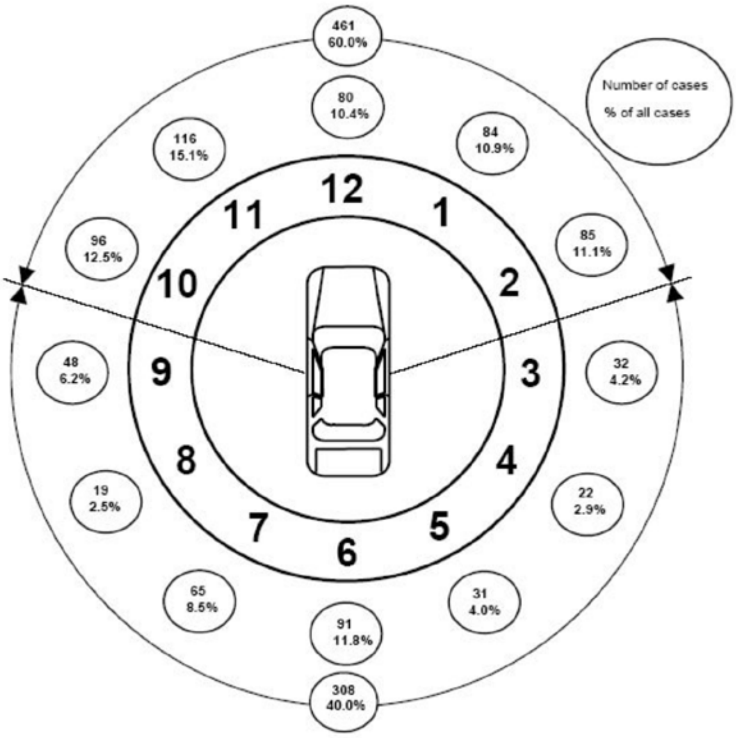

Figure 2: Car's line of sight of PTW with crash rate (MAIDS 2004)

Drawing on this previous research of crashes involving TWs and other vehicles, the present study was designed with the overall aim of better understanding the road safety risks occurring during interactions between passenger vehicles and PTW and cyclists. The present study was designed around the use of the advanced driving simulator at the Centre for Accident Research and Road Safety – Queensland (CARRS-Q). The use of this driving simulator allows researchers to observe, challenge and accurately record the driver's reactions and skills in a controlled, safe environment. The simulator can be used for any form of road safety research which requires an understanding of driver behaviour. However, for many safety-critical situations, such as potential collision scenarios involving motor vehicles and vulnerable TW riders, the simulator makes possible research that would be difficult, costly and unsafe to undertake in a real on-road setting.

This current study assessed the safety aspects of these previously mentioned types of interactions between car drivers and TW riders, and compared the results between drivers with and without experience travelling by PB and PTW vehicles. The use of the advanced driving simulator allowed the interactions between passenger vehicle drivers and TW riders to be manipulated by the researchers and to be examined objectively in a controlled and safe environment.

1.1 PROJECT OBJECTIVES

The overall aim of the project was to better understand the road safety risks occurring during interactions between passenger vehicles and PTW and cyclists from the driver's viewpoint utilising an advanced driving simulator.

Specifically, the objectives of the project were:

1. Develop driving simulator scenarios based on the ACT road network involving interactions between TWs and drivers

2. Determine whether previous experience with TWs affects driver behaviour toward TWs.
    a. Does experience with one mode of TW lead to more positive opinions about that mode?
    b. Does experience with one mode of TW lead to more positive opinions about the other?
    c. Does experience with one mode of TW lead to safer interactions with that mode?
    d. Does experience with one mode of TW lead to safer interactions with the other?
    e. Are the attitudes toward TWs associated with the safety behaviours?

3. Determine whether individual differences between drivers are associated with safety interactions with TWs

4. Determine whether the level of conspicuity of the PTW is associated with the safety of the resulting interaction.
    a. Are car driver behaviours safer when PTW are more conspicuous?
    b. Does PTW experience led to reports of greater ease in seeing PTW?
    c. Does previous TW experience change the effect of the level of conspicuity?
    d. Are the attitudes toward PTWs associated with the safety behaviours?

2 METHOD

2.1 DESIGN

The previous research of crashes involving TWs and other vehicles demonstrated that the appropriate driving scenarios for the driving simulator experiment involve driving manoeuvres in which TW are initially positioned in front or on right angle from the driver. These types of interactions were therefore incorporated into the current study. The locations for the interactions in the current study also included a mix of controlled and uncontrolled intersections. This was undertaken as the previous research into crashes of PB and PTW by traffic control shows that most crashes are occurring at uncontrolled locations, followed by give way signed intersections and traffic light controlled intersections.

A further variable included after drawing on the previous research was the conspicuity of the TW. This was undertaken for both the PB and the PTW. The conspicuity of the PTW was varied by scripting the PTW driving light on or off, while for the PB it was varied by changing the colouring of the rider's clothing.

Participants were divided into one of four categories based on their driving and riding experience. These four categories were operationalised as follows;

1. Car drivers only (CO): Holders of a car licence but not a motorcycle licence, who do not ride a bicycle on the road 1 day a week or more
2. Car drivers who are bicycle riders (BC): Holders of a car licence but not a motorcycle licence, who ride a bicycle on the road 1 day a week or more
3. Car drivers with motorcycle experience (MC): Holders of a car licence and motorcycle licence, who do not ride a bicycle on the road 1 day a week or more
4. Car drivers with motorcycle experience who are bicycle riders (BMC): Holders of a car licence and a motorcycle licence, who ride a bicycle on the road 1 day a week or more.

2.1.1 Driving scenarios

The driving scenario was designed to replicate high crash risk situations in the Australian Capital Territory (ACT). Various environmental, driver and traffic factors that contribute to crashes between TWs and vehicles were identified by reviewing Australian crash databases and peer review papers. This information was integrated with still images of the road, building and surrounding environment in selected ACT locations to create a three dimensional simulated environment of these locations.

The driving scenario included 3 main segments; 2 suburban segments and one city centre segment. Within these segments, six scripted interactions with TWs occurred. Two variations of the scenario were created to investigate the impact of TW conspicuity on driving performance (high conspicuity versus low conspicuity). Conspicuity was alternated between variations (e.g., high conspicuity for the 1st, 3rd and 5th TW interactions in one variation, and high conspicuity for the 2nd and 4th TW in the second variation). In their recent study examining bicycle crashes in the ACT, De Rome et al. (2011) found that 48% of the bicycle riders involved in crashes in traffic and 31% involved in crashes in cycle lanes were wearing high visibility (hi-vis) or bright clothing at the time of the crash.

For the bicycles in the driving scenarios the conspicuity level was varied by either displaying the rider in dark (navy blue and grey) or high visibility (fluorescent yellow) clothing. In the case of the motorcycles in the driving scenarios, the conspicuity level was manipulated by the motorcycle headlight being either on or off.

Aside from these variations, differences across scenarios occurred in relation to other surrounding vehicles only, which varied depending on the individual drivers' speed throughout the simulated drive. Scenario variations were randomly assigned and counterbalanced across participants. In both variations, the scenario;

- Began with a long suburban connector road (Northbourne Ave) of flat terrain with a wide median, mostly straight with several intersections (signalised and unsignalised). Interconnected roads (Macarthur Ave and Barry Dr) upon which the driven car then travelled had shallow curves with a speed limit of 60 km/h and 70 km/h. In two different locations, two unexpected events occurred. One was an approaching bicycle at a signalised intersection (traffic lights) where the driver needed to turn right across the bicycle's path of travel (interaction 1, see Figure 3), and the other was a bicycle that pulled out to overtake a truck obstructing the left lane (interaction 2, Figure 4).

Figure 3: Interaction 1 - driver turns right across the bicycle's path of travel (low conspicuity condition)

Figure 4: Interaction 2 - bicycle pulled out to overtake a truck obstructing the left lane (low conspicuity condition)

- In the urban section, the speed limit was 50 km/h, with a mix of signalised and unsignalised intersections and a mix of 2 and 4 lane roads without dividing medians. This section contained two unexpected events. An approaching motorcycle whose path the driver had to turn right across at an unsignalised intersection (interaction 3, see Figure 5) and a motorcycle that was travelling through a roundabout (standard give way signage at entry to roundabout) which the driver was entering (interaction 4, Figure 6).

Figure 5: Interaction 3 - driver turns right (from Mort St into Alinga St) across the approaching motorcycle's path of travel at an unsignalised intersection (high conspicuity condition)

Figure 6: Interaction 4 - driver entering roundabout (Vernon Circle) on which motorcycle was travelling

- The third section was a suburban connector road (Commonwealth Ave) of flat terrain with a wide median, and primarily straight. One unexpected event occurred in this section. A bicycle was travelling on a roundabout that the driver was required to merge onto (State Circle), and then turn left from. This created the possibility of two interactions with the bicycle (interaction 5, see Figure 7 and interaction 6, see Figure 8).

Figure 7: Interaction 5 - driver entering roundabout on which cyclist was travelling (high conspicuity condition)

Figure 8: Interaction 6 - driver turning left to exit from roundabout with cyclist travelling in the left lane (high conspicuity condition)

2.1.2 Simulator setting and apparatus

The CARRS-Q advanced driving simulator consists of a complete Holden VE Calais vehicle body, with working vehicle controls and instruments, to provide a realistic control cabin and the ability to include up to 5 vehicle occupants (maximum 300kg total weight) during a simulation. The vehicle body is mounted on a Bosch Rexroth E-Motion-1500 Electric Motion System, providing motion with 6 degrees of freedom (surge +716,-602mm, sway +/-603mm, heave +407,-422mm, roll +/-27º, pitch +27,-24º, yaw +/-39º) and capable of supporting a combined load of up to 1500kg.

The driving simulator software is OKTAL's SCANeR™ Studio v1.0 simulation software, which provides simulator control and data acquisition. The simulator is operated by six HP Z800 workstations, each with an XFX GeForce GTX285 1Gb graphics card, running components of the SCANeR™ simulation software in a distributed fashion. The forward images a provided by three Projection Design F22 sx+ 2100 Lumens projectors, projecting onto three flat 4m x 3m screens at 1400x1050 resolution to give a forward field of view of approximately 180° horizontal and 45° vertical. Three 8 inch LCD screens replace the side and central mirrors, each displaying a simulated rear view at an 800x600 resolution. Simulated vehicle and external sounds are provided by using the vehicle's existing stereo speaker system and an additional subwoofer, which also supports Doppler effect.

2.2 PARTICIPANTS

To be eligible to participate, participants were required to have a driver's licence issued within Australia, be aged between 18 and 59 and have no medical conditions that affect their driving. Participants were recruited via the university's classified email list (distributed to both staff and students), two university-based research participation websites, word of mouth, email snowballing via motorcyclist clubs and through local newspaper advertisements. Participants who completed both questionnaires and the simulated driving task were compensated with $50 for their time and travel.

Participants who commenced the driving task were 71 licensed car drivers, 44 (62%) males and 27 (38%) females, aged between 20 and 58 years of age (M = 38.03, SD = 10.25). Due to failure to advance beyond the familiarisation drive, 2 participants were excluded from the final analyses. Following the exclusion of these cases, the final sample comprised 69 participants, 42 (61%) males and 27 (39%) females, aged between 20 and 58 years of age (M = 37.74, SD = 10.21) (see Table 3).

Age differences between the groups approached significance (p = .07), with the participants in the *car only* group being younger (M = 33.58 years of age) than participants in the *motorcycle and car* group (M = 42.39 years of age). Differences were also observed in the number of years since obtaining a car licence, with participants in the *motorcycle and car* group having held their car licence longer (M = 23.44 years) than participants in the *car only* group (M = 14.42 years) However this differences also only approached significance (p = .051).

Analysis of the participants' responses to the questions about the days per week using each of the three modes of transport showed that participants who reported riding a bicycle on the road 1 day a week or more did report driving a car less than participants who did not report riding a bicycle. This tends to support that these participants were active cyclists. This lower level of car use was not evident for those participants in the *motorcycle and car* group. While the majority (78%) of participants in this group reported riding a motorcycle 1 or more days per week, they also reported driving a car at similar levels to the *car only* group.

Gender differences between the groups were observed, with the motorcycling experience groups having a much lower proportion of female participants compared to the *car only* and *bicycle and car* groups.

Table 3: Group means on demographic variables (following the exclusion of 2 cases)

	CO (*n* = 19)	BC (*n* = 15)	MC (*n* = 18)	BMC (*n* = 17)
Gender (*n*)				
Male	7	7	16	12
Female	12	8	2	5
Age (*M*)	33.58 (*SD* = 7.76)	37.07 (*SD* = 11.00)	42.39 (*SD* = 11.08)	38.06 (*SD* = 9.69)
Yrs since obtained car licence (*M*)	14.42 (*SD* = 8.23)	16.73 (*SD* = 10.99)	23.44 (*SD* = 12.32)	20.24 (*SD* = 8.91)
Days/week driving				
Never	-	-	-	-
< 1 day/week	-	-	-	11.8
1 day/week	5.3	13.3	-	-
2-3 days/week	26.3	53.3	16.7	47.1
4-5 days/week	10.5	20.0	22.2	17.6
6-7 days/week	57.9	13.3	61.1	23.5
Days/week bicycling				
Never	20.0	-	40.0	-
< 1 day/week	80.0	-	60.0	-
1 day/week	-	46.7	-	23.5
2-3 days/week	-	20	-	41.2
4-5 days/week	-	20	-	35.3
6-7 days/week	-	13.3	-	-
Yrs since obtained motorcycle licence (*M*)			16.85 (*SD* =14.14)	13.70 (*SD* = 12.40)
Days/week motorcycling				
Never			16.7	17.6
< 1 day/week			5.6	11.8
1 day/week			27.8	5.9
2-3 days/week			16.7	35.3
4-5 days/week			27.8	23.5
6-7 days/week			5.6	5.9

2.3 MEASURES

Subjective and objective assessment methods were employed to evaluate the interactions between TW and car drivers. Subjective measures involved a series of questionnaires to assess driving/riding exposure and to establish a relationship between drivers' attitudes and driving performance. Objective measures involved the collection of a range of data related to the simulator vehicle dynamics and the drivers' eye gaze.

2.3.1 Questionnaire One

The first questionnaire was designed to assess general aspects of driving behaviour, irrespective of participants' experience with two wheelers. The questionnaire was administered to participants prior to their simulated drive and consisted of 3 components: (i) demographics, (ii) general and specific driving behaviour and (iii) an intensity subscale.

Demographic questions: Participants indicated their age, gender, years since they first obtained a drivers licence and how often in the last 12 months they had driven a car (on a weekly basis, e.g., 2-3 days a week).

General and specific driving behaviour: 2 items adapted from Crundall et al. (2008) assessed general driving (e.g., "I do find that driving a car is enjoyable and rewarding", 1 *strongly disagree* to 7 *strongly agree*). A further 28 items from the Driver Behaviour Questionnaire (DBQ; Lawnton et al., 1997; Parker et al., 1995) assessed ordinary violations (8 items), aggressive violations (4 items), errors (8 items) and lapses (8 items). Participants indicated how often in the past year they had made each of the violations, errors or lapses with responses ranging from "never" to "nearly all the time" (e.g., "How often have you underestimated the speed of an oncoming vehicle when overtaking", 0 *never* to 5 *nearly all the time*).

Intensity subscale: The 10-item intensity subscale of the Sensation Seeking Questionnaire (Arnett, 1994) was used to measure sensation seeking. Participants indicated how each item described them; with responses ranging from 4 "describes me very well" to 1 "does not describe me at all". Negatively worded items were reverse coded and all items were subsequently summed.

A copy of this questionnaire is included in Appendix A.

2.3.2 Questionnaire Two

The second questionnaire assessed participants' experience with, and opinions of, two wheeler riders, and included items relating to riding currency, crash and offence history and attitudes towards bicyclists and motorcyclists. Given the nature of the questionnaire, it was administered to participants following their simulated drive to avoid the potential for response priming.

Crash and offence history: Participants indicated how many crashes they had been involved in (and if so, the other type/s of vehicle involved) and whether they had been fined or lost demerit points over the past 3 years. Participants were asked to respond separately to these questions as a car driver, bicycle rider and motorcycle rider, if applicable.

Riding currency: Participants were asked to indicate how often they had ridden a bicycle and motorcycle in the last 12 months (on a weekly basis, e.g., 2-3 days a week) and the years during which they had ridden a two wheeler regularly (from 2006 - 2010).

Attitudes towards bicyclists and motorcyclists: The measure of attitudes towards bicycle riders and motorcycle riders was adapted from Crundall et al. (2008) and comprised four subscales; negative attitudes (5 items), empathetic attitudes (5 items), awareness of perceptual problems (3 items) and spatial understanding (2 items). Negative attitudes, empathetic attitudes and perceptual awareness were assessed by asking participants to rate how much they agreed or disagreed with each statement (e.g., "When a car a motorcyclist collide it is typically the fault of the motorcyclist", 1 *strongly disagree* to 7 *strongly agree*). Responses to the spatial understanding items were in the form of measurements (e.g., metres). Three additional items were included to measure opinions about motorcyclists and bicyclists (e.g., I think that motorcyclists obstruct the road, 1 *strongly disagree* to 7 *strongly agree*). Questions were first asked in relation to motorcycle riders and then repeated in relation to bicycle riders. Negatively worded items were reverse coded and all items were subsequently summed.

Motion sickness questionnaire: As a standard operating procedure a motion sickness questionnaire was administered to participants following their drive. Participants were verbally asked to rate the degree to which they were experiencing 16 undesirable symptoms (e.g., queasy, dizzy) on a scale of 1 to 10, 1 *not at all*, to 10 *severely*. If participants reported high levels of motion sickness, they were asked to remain in the waiting area until the feelings subsided. They were also then contacted 24 hours after participation to confirm that the symptoms had subsided.

Copies of these questionnaires are included in Appendix B.

2.3.3 Driving measures

Driving performance measures collected during the driving task included the following:

- Scenario clock (duration of simulated drive)
- Cartesian distance between the driven car and the scripted vehicles in the scenario
- Speed of the driven car
- Driven car Accelerator Pedal position
- Driven car Brake pedal position
- Driven Car Steering Wheel Position
- Driven car lane of travel
- Driven car Lane Lateral Shift
- Driven Car Lane Width (the width of the lane immediately in front of the vehicle)
- Driven car Road lateral Shift

- Driven Car Road Width (the width of the road (m) immediately in front of the vehicle)
- Driven car Road Curvature curve radius of the road immediately in front of the vehicle)
- Driven Car Tripmeter
- Driven car X Position Vector
- Driven car Y Position Vector
- Driven Car X Acceleration Vector
- Driven Car Y Acceleration Vector
- EyeTracker clock
- Eyetracker object type (e.g. unknown, vehicle, visual object, bounded target)
- Eyetracker object ID
- Eyetracker object distance (m)
- Crash count (number of collisions)
- Angular position Vector of Driven car

These measures were exported directly from the SCANeR™ simulator control and data acquisition software at the end of each participant's testing session.

2.4 PROCEDURE

Ethical clearance was gained from the Queensland University of Technology research ethics committee (approval number 1100000145) prior to commencing the study. Participants attended one simulator session at the location of the CARRS-Q Advanced Driving Simulator. Upon arrival, participants were shown to a waiting area and given a Participant Information Sheet to read and asked to sign a consent form. The participants then completed questionnaire one. Participants then moved to the driving simulator room and were given a brief Health and Safety induction, followed by a driving simulator induction to ensure that they were comfortable with using the simulator vehicle.

Participants were given a familiarisation drive of approximately 1-minute duration where they had the opportunity to become familiar with the braking, acceleration and steering of the vehicle. Approximately 15 minutes were then devoted to calibrating participants' eye gaze in the Eyetracker software prior to their test run. Prior to the commencement of the experimental runs, participants were instructed to follow the signs to the airport and drive as they normally would. Driving sessions ran for approximately 10 minutes, during which time the participant and simulator operator could interact via a microphone (e.g., in cases where the participant missed directional signs or when they opted to cease the session).

Following their simulated drive, participants completed a motion sickness screening and the second questionnaire. Refreshments were provided during this time. Finally, participants were debriefed in terms of the true purpose of the study (as this was not previously made explicit in order to minimise the possibility of priming). To maintain anonymity and confidentiality, a unique code was used to match all participants' questionnaire and simulator data.

2.5 DATA CLEANING

Questionnaire data were entered directly into Statistical Package for the Social Sciences (SPSS). Two participants were excluded entirely from the final data set as they completed only questionnaire 1 and the familiarisation drive. The data from the remaining 69 participants was excluded on a case-by-case basis for the following reasons:

- One participant completed questionnaire one and then four out of the six driving task interactions before aborting the driving task (questionnaire two was not administered), and;
- Three participants completed only four out of the six driving task interactions before aborting the driving task.

In addition, the simulator data results were excluded on a case-by-case basis if no interaction occurred between the participant and the TW in the simulated interactions. To determine cases where this had occurred, the recorded video from the EyeTracker system (centre screen only) for each participant's simulated drive was analysed by a research assistant who was not involved in the data collection phase of the project. These data exclusions occurred for a number of reasons including:

- Participant was in the wrong lane at the interaction location and missed interacting with the simulated TW;
- Participant took a wrong turn and missed a subsequent interaction or interactions, and;
- "swarm" vehicles within the simulation interfered in such a way as to potentially influence the participants behaviour at the point of the interaction.

Simulator data was recorded at a resolution 20Hz and was exported from the SCANeR™ simulator control and data acquisition software in ASCII text files. These data files were imported into Microsoft Excel for data cleaning and calculation purposes. The simulator data from each testing session was separated into segments allowing each interaction to be analysed separately.

2.6 DATA ANALYSIS

Questionnaire data was collated and analysed utilising the Statistical Package for the Social Sciences (SPSS).

The raw data from the simulator data was analysed using Excel. For the calculation of measures from the simulator data, macros were written using Microsoft's Visual Basic for Applications (VBA). The use of macros increased the speed and accuracy of the calculation of variables. After calculation in excel, the computed variables from each interaction for each participant's simulator session were transferred into SPSS for the statistical analysis.

The following measures were calculated from the simulator data:

- TTC_{min}
    - Time to Collision (TTC) is the time required for two vehicles to collide, if they stay at their present speed and on the same path (Federal Highway

Administration, 2003; Laureshyn, Svensson, & Hydén, 2010). TTC is a continuous parameter which may be calculated for any point in time, provided that the road users are on a collision course. TTC is often calculated using the simple assumption that the road users' trajectories will cross at a right angle or are parallel. TTC at a single point in time can be simply defined as;

$$TTC = \frac{d}{v}$$

where *d* is the distance between the two vehicles and *v* is the combined velocity (if both vehicles are heading towards each other on a collision course). The higher a TTC-value, the safer a closing-in situation is. The TTC_{min} is defined as the minimum TTC value between the driven car and the simulated TW during the interaction, calculated at a single point in time (20Hz resolution).

- Separation at TTC_{min}
    - This is defined at the Cartesian distance between the driven car and the simulated TW during the interaction, at the point in time that TTC_{min} occurs. The distance is measured from the midpoint of the driven car to the midpoint of the TW.
- Speed of the driven car at TTC_{min}
    - This is the calculated speed of the driven car in km/h as determined by the SCANeR^{TM} simulator control and data acquisition software, at the point in time that TTC_{min} occurs.
- Minimum separation
    - This is defined at the minimum Cartesian distance between the driven car and the TW during the interaction. The distance is measured from the centrepoint of the driven car to the midpoint of the TW.
- Speed of the driven car at minimum separation
    - This is the calculated speed of the driven car in km/h as determined by the SCANeR^{TM} simulator control and data acquisition software, at the point in time that minimum separation between the driven car and the TW occurs.

3 RESULTS

3.1 DRIVING BEHAVIOUR AND SENSATION SEEKING

The participants' general and specific driving behaviour was examined, along with their propensity for sensation seeking. These results were compared with the participants' previous TW experience (holding a motorcycle licence or riding a bicycle at least once a week). The overall pattern of the results is presented in Table 4.

Table 4: Means, standard deviations and one-way ANOVAs for the general and specific driving behaviour, and sensation seeking measures, by previous TW experience.

Previous TW experience group	CO	BC	MC	BMC	Statistical Significance
General Driving					
I do find that driving a car is enjoyable and rewarding	5.47 (*1.12*)	5.00 (*1.60*)	5.94 (*0.99*)	4.94 (*1.20*)	$F(3,65) = 2.49, p > .05$
I perform all appropriate visual checks when driving, e.g., mirror use, blind spot checks etc	5.89 (*1.33*)	5.67 (*1.05*)	6.39 (*0.70*)	5.82 (*0.95*)	$F(3,65) = 1.55, p > .10$
DBQ Errors	0.62 (*0.30*)	0.66 (*0.42*)	0.51 (*0.45*)	0.71 (*0.45*)	$F(3,64) = .72, p > .10$
DBQ Lapses	0.84 (*0.41*)	1.14 (*0.54*)	0.86 (*0.46*)	0.85 (*0.35*)	$F(3,65) = 1.68, p > .10$
DBQ Violations	0.96 (*0.67*)	0.86 (*0.47*)	1.04 (*0.46*)	0.97 (*0.45*)	$F(3,65) = .33, p > .10$
DBQ Aggressive violations	1.00 (*0.48*)	1.13 (*0.51*)	1.08 (*0.65*)	0.99 (*0.57*)	$F(3,65) = .26, p > .10$
Sensation seeking (intensity subscale)	22.26 (*4.52*)	25.13 (*4.94*)	25.06 (*4.57*)	25.18 (*4.07*)	$F(3,65) = 1.83, p > .10$

The results in Table 4 show that there were no significant differences between the experience groups on any of the general and specific driving behaviour measures or the sensation seeking measure. For the DBQ measures, there was a large amount of within-group variation, as demonstrated by the large standard deviations for these measures.

Given the tendency for age and gender to differ between the driver experience groups, these variables were also included in the analysis. The results of the ANOVAs with age and gender included are presented in Table 5 to Table 11.

Table 5: Multiple regression and overall model ANOVA for the effects of previous experience, age and gender on General driving measure 1 (driving a car is enjoyable and rewarding)

	General driving 1 (driving a car is enjoyable and rewarding)			
	B	Std Error	t	Sig
Age	.026	.015	1.72	$p > .05$
Gender	-.444	.331	-1.34	$p > .10$
Group	-.183	.146	-1.26	$p > .10$
Statistical significance	$F(3, 65) = 1.54$, $p > .10$			

Analysis of the first general driving measure (*I do find that driving a car is enjoyable and rewarding*) showed that neither age or gender, nor previous experience, were significant predictors of the participants' score on this measure.

Table 6: Multiple regression and overall model ANOVA for the effects of previous experience, age and gender on General driving measure 2 (perform all appropriate visual checks when driving)

	General driving 2 (perform all appropriate visual checks when driving)			
	B	Std Error	t	Sig
Age	.042	.012	3.49	$p < .01$
Gender	-.376	.257	-1.47	$p > .10$
Group	-.086	.113	-.76	$p > .10$
Statistical significance	$F(3, 65) = 4.56$, $p < .01$			

The results in Table 6 show that gender and previous experience were not significant predictors of participants' score on the second general driving measure, with age the only significant contributor. Older participants were more likely to report that they perform all appropriate visual checks when driving (e.g., mirror use, blind spot checks etc).

Table 7: Multiple regression and overall model ANOVA for the effects of previous experience, age and gender on DBQ Errors

	DBQ Errors			
	B	Std Error	t	Sig
Age	-.013	.005	-2.68	$p < .01$
Gender	.121	.103	1.18	$p > .10$
Group	.058	.045	1.29	$p > .10$
Statistical significance	$F(3, 64) = 2.74, p > .05$			

Table 8: Multiple regression and overall model ANOVA for the effects of previous experience, age and gender on DBQ Lapses

	DBQ Lapses			
	B	Std Error	t	Sig
Age	-.004	.005	-.69	$p > .10$
Gender	.192	.118	1.62	$p > .10$
Group	.016	.052	.31	$p > .10$
Statistical significance	$F(3, 65) = 1.03, p > .10$			

The results in Table 7 and Table 8 show neither age or gender, nor previous experience were significant predictors of participants' score on the DBQ Errors or DBQ Lapses measures.

Table 9: Multiple regression and overall model ANOVA for the effects of previous experience, age and gender on DBQ Violations

	DBQ Violations			
	B	Std Error	t	Sig
Age	-.015	.006	-2.44	$p < .05$
Gender	-.189	.131	-1.44	$p > .10$
Group	.021	.058	.37	$p > .10$
Statistical significance	$F(3, 65) = 2.98, p < .05$			

The results in Table 9 show that gender and previous experience were not significant predictors of participants' score on the DBQ violations measure, with age the only significant contributor. Younger participants were more likely to report committing driving violations.

Table 10: Multiple regression and overall model ANOVA for the effects of previous experience, age and gender on DBQ Aggressive violations

	DBQ Aggressive violations			
	B	Std Error	t	Sig
Age	-.023	.006	-3.67	$p < .01$
Gender	-.113	.133	-.85	$p > .10$
Group	.022	.059	.37	$p > .10$
Statistical significance	$F(3, 65) = 4.98$, $p < .01$			

As with the DBQ Violations score, the results in Table 10 show that gender and previous experience were not significant predictors of participants' score on the DBQ Aggressive violations measure, with age the only significant contributor. Younger participants were more likely to report committing aggressive driving violations.

Table 11: Multiple regression and overall model ANOVA for the effects of previous experience, age and gender on Sensation seeking (intensity subscale)

	Sensation seeking (intensity subscale)			
	B	Std Error	t	Sig
Age	-.123	.051	-2.43	$p < .05$
Gender	-2.982	1.09	-2.74	$p > .01$
Group	.716	.479	1.49	$p > .10$
Statistical significance	$F(3, 65) = 6.39$, $p < .01$			

The results in Table 11 show that age and gender were significant predictor of participants' score on the Sensation seeking measure. Younger participants had higher sensation seeking scores, as did males overall.

3.2 DRIVER ATTITUDES TOWARD TWO-WHEELERS

3.2.1 Attitudes to motorcycles versus bicycles

The participants' negative and empathic attitudes towards TW riders were examined. Paired samples t-tests (see Table 12) showed stronger ratings of negative attitudes to bicycles than motorcycles and corresponding weaker empathic attitudes towards bicycles. Participant ratings of the awareness of problems in seeing motorcycles and bicycles showed significantly greater ratings for problems in seeing bicycles.

Table 12: Means, standard deviations and paired samples t-tests of ratings of negative attitudes, empathic attitudes and awareness of problems in seeing motorcycles and bicycles.

	Motorcycles		Bicycles		Comparison
	Mean	SD	Mean	SD	
Negative attitudes	3.28	0.91	4.10	0.72	$t(64) = -6.37, p < .001$
Empathic attitudes	4.99	0.84	4.36	0.52	$t(66) = 6.28, p < .001$
Awareness of problems in seeing	4.47	1.18	4.90	1.18	$t(67) = -3.20, p < .01$

3.2.2 The effects of previous experience on driver attitudes

The effects of previous experience (holding a motorcycle licence or riding a bicycle at least once a week) on driver attitudes to motorcyclists and bicyclists were examined. The overall pattern of the results is presented in Figure 9. However, given the tendency for age and gender to differ between the driver experience groups, these variables were also included in the analysis. The results of the ANOVAs are presented in Table 13 to Table 18.

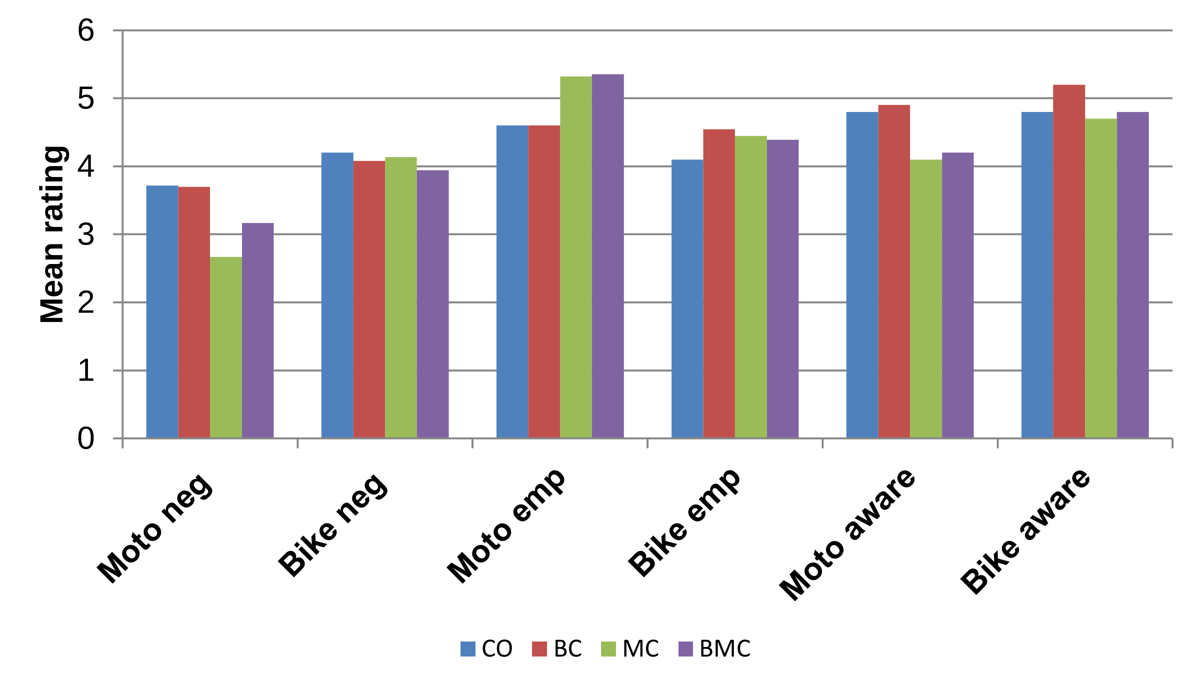

Figure 9: Mean ratings for each of the attitudes towards bicyclists and motorcyclists by driver experience groups

Table 13: Multiple regression and overall model ANOVA for the effects of previous experience and gender on driver negative attitudes to motorcyclists and bicyclists

	Motorcycle negative attitudes				**Bicycle negative attitudes**			
	B	**Std Error**	**t**	**Sig**	**B**	**Std Error**	**t**	**Sig**
Age	-.009	.011	-.81	$p > .10$	.006	.008	.79	$p > .10$
Gender	.007	.232	.03	$p > .10$	-.671	.178	-3.76	$p < .001$
Group	-.249	.101	-2.47	$p < .05$	-.184	.079	-2.33	$p < .05$
Statistical significance	$F(3, 62) = 2.93, p < .05$				$F(3, 63) = 5.11, p < .01$			

The results in Table 13 show that age and gender were not significant predictors of negative attitudes toward motorcycles, and only previous experience was a significant contributor. Participants with previous motorcycling experience reported lower negative attitudes toward motorcycles (see Table 14). Those with motorcycling experience and no regular bicycle riding reported the lowest negative attitudes toward motorcycles, with the females in this group reporting the lowest negative attitudes overall.

Attitudes to bicycles were somewhat more negative compared to motorcycles (see Figure 9), but there were no significant differences between groups. The regression analyses from the participants' negative attitudes toward bicycles (see Table 13) showed that both gender and previous participant's previous experience were significant predictors of negative attitudes toward bicycles. However, analysing the results by previous experience and gender (see Table 14) confirmed that there were no significant differences between the groups. Only female participants with previous motorcycling experience reported lower negative attitudes toward bicycles. Those with cycling, but no motorcycling experience, did not differ markedly from those with no TW experience (car drivers only).

Table 14: Results of Analyses of Variance on mean ratings for negative attitudes by previous experience and gender

	Motorcycle			**Bicycle**		
	M	**F**	**Total**	**M**	**F**	**Total**
CO	4.0	3.5	3.7	4.5	4.1	4.2
BC	3.6	3.8	3.7	4.3	3.9	4.1
MC	2.8	1.8	2.7	4.3	3.2	4.1
BMC	3.1	3.2	3.2	4.3	3.2	3.9
Total	3.2	3.4	3.3	4.3	3.8	4.1
Statistical significance	$F(3, 62) = 6.60, p = .001$			$F(3, 63) = 0.38, p > .10$		

When analysing the empathic attitudes toward motorcycles, it was found that both gender and previous experience were significant predictors of empathic attitudes toward motorcycles (see Table 15). Further analysis by previous experience and gender (see Table 16) found that participants who held a motorcycle licence expressed greater empathic attitudes to motorcycles. Participants who were bicycle riders were not any more empathic towards motorcycles than those who were car drivers only. Males with both motorcycling and bicycling experience reported the most empathic attitudes toward motorcyclists. However females with both motorcycling and bicycling experience were not any more empathic towards motorcycles than those females who were car drivers only.

The regression analyses (see Table 15) showed that neither age or gender, nor previous experience, were significant predictors of empathic attitudes toward bicycles. Further analysis by previous experience and gender (see Table 16) found that there was a trend (p = 0.06) towards bicycle riders being more empathic towards bicycles than those who only drove cars, but no other significant differences were observed.

Table 15: Multiple regression table and overall model ANOVA for the effects of previous experience and gender on driver empathic attitudes to motorcyclists and bicyclists

	Motorcycle empathic attitudes				**Bicycle empathic attitudes**			
	B	**Std Error**	**t**	**Sig**	**B**	**Std Error**	**t**	**Sig**
Age	.000	.009	- .04	$p > .10$	.001	.006	.23	$p > .10$
Gender	- .698	.191	-3.65	$p < .01$	- .144	.136	- 1.06	$p > .10$
Group	.206	.084	2.45	$p < .05$	.059	.060	.99	$p > .10$
Statistical significance	$F(3, 63) = 9.33, p < .001$				$F(3, 64) = 1.12, p > .05$			

Table 16: Results of Analyses of Variance on mean ratings for empathic attitudes, by previous experience and gender

	Motorcycle			**Bicycle**		
	M	**F**	**Total**	**M**	**F**	**Total**
CO	4.8	4.4	4.6	4.1	4.1	4.1
BC	5.0	4.2	4.6	4.7	4.5	4.5
MC	5.3	5.4	5.3	4.5	4.3	4.4
BMC	5.7	4.5	5.4	4.4	4.3	4.4
Total	5.3	4.5	5.0	4.4	4.2	4.4
Statistical significance	$F(3, 63) = 5.06, p < .01$			$F(3, 64) = 2.54, p = .06$		

Analysis of the awareness of problems in seeing motorcycles showed that neither age or gender, nor previous experience, were significant predictors of the participants' ratings of problems in seeing motorcycles (see Table 17).

Table 17: Multiple regression table and overall model ANOVA for the effects of previous experience and gender on driver ratings of problems in seeing motorcycles and bicycles

	Motorcycle awareness				**Bicycle awareness**			
	B	**Std Error**	**t**	**Sig**	**B**	**Std Error**	**t**	**Sig**
Age	- .007	.014	- .52	$p > .10$	- .037	.014	-2.63	$p < .05$
Gender	.136	.310	.44	$p > .10$	.378	.301	1.26	$p > .10$
Group	- .220	.136	-1.61	$p > .10$	.064	.132	.48	$p > .10$
Statistical significance	$F(3, 64) = 1.49, p > .10$				$F(3, 64) = 2.72, p = .052$			

When analysing the awareness of problems in seeing bicycles, it was found that age was a significant predictor of ratings of problems in seeing bicycles (see Table 17). Further analysis by previous experience and gender (see Table 18) showed that there were no significant differences among groups in awareness of problems in seeing bicycles.

Table 18: Results of Analyses of Variance on mean ratings of awareness, by previous experience and gender

	Motorcycle			**Bicycle**		
	M	**F**	**Total**	**M**	**F**	**Total**
CO	4.5	4.9	4.8	5.0	4.8	4.8
BC	5.0	4.8	4.9	5.1	5.3	5.2
MC	4.0	4.3	4.1	4.6	5.5	4.7
BMC	4.3	3.9	4.2	4.6	5.3	4.8
Total	4.4	4.6	4.5	4.8	5.1	4.9
Statistical significance	$F(3, 64) = 2.29, p >.05$			$F(3, 64) = 0.57, p >.10$		

3.2.3 Spatial judgments

Spatial understanding was examined through two items, adapted from Crundall et al. (2008), which were included in Questionnaire 2 (see Appendix B). Examination of the participants' responses to the spatial understanding items showed that previous experience had no effect on judging the width of a bicycle or motorcycle. Further, previous experience had no effect on the participants' judgments of what distance should be left between an overtaking motorcycle and the side of the car being passed in order to remain safe.

The wording of the question to assess safe passing distance for bicycles (see Appendix B) was adapted from Crundall et al. (2008), however the wording was changed to reflect that the car would be passing the bicycle. The wording of this question was as follows:

> *"When a car overtakes a bicycle rider at 60 km/h, what size distance should be left between the side of the car and the bicycle in order to remain safe?"*

The results for this question are shown in Figure 10. A larger proportion of participants with *car only* and *motorcycle and car* experience reported that *2 metres or greater* was a safe passing distance while participants with previous bicycling experience were less likely to nominate this distance. Participants with previous bicycling experience were more likely to nominate *1.0 – 1.5 metres* and *1.5 – 2.0 metres* as a safe passing distance. A greater proportion of participants with *bicycle and car* experience reported that *0.5 – 1.0 metres* was a safe passing distance, compared to the other experience groups (13% vs. 6%).

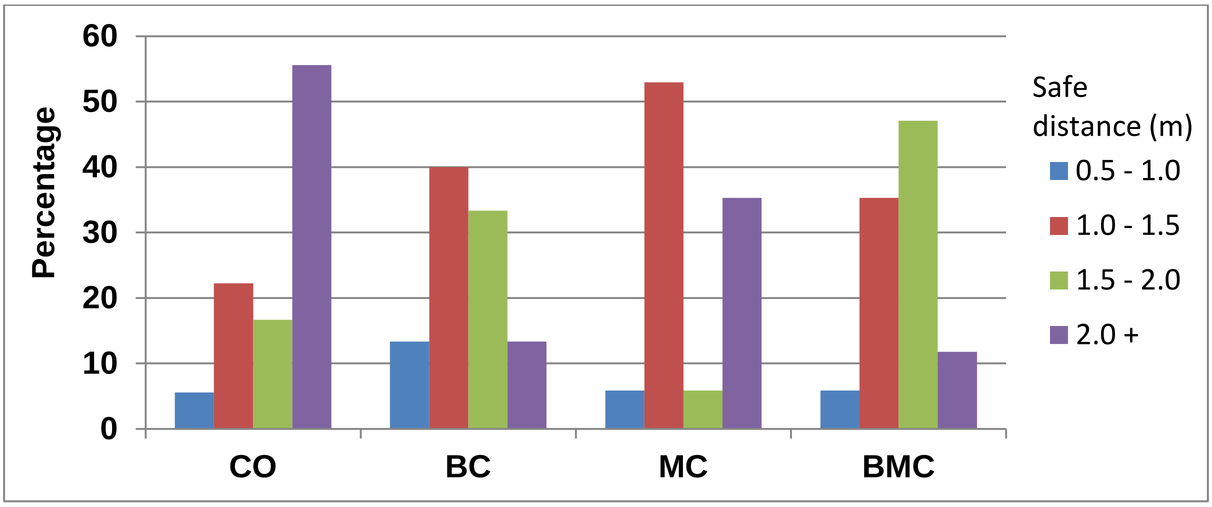

Figure 10: Participants' judgments of what size distance should be left between an overtaking car and the bicycle being passed in order to remain safe

3.3 DRIVER BEHAVIOURS IN INTERACTIONS WITH TWO-WHEELERS

Due to differences in the scenario design for the six scripted interactions (e.g. differing road environments), and due to the advanced driving simulator being fully interactive (the speed and position of the car is completely under the control of the participant), the measures of safety had to be analysed separately for each of the interactions. The measures for safety behaviours (TTC_{min}, separation at TTC_{min}, speed of the driven car at TTC_{min}, minimum separation, speed of the driven car at minimum separation) were calculated for each interaction for each participant. Differences between experience groups on these measures were then analysed for five of the scripted interactions.

For interaction 2, where the bicycle pulled out to overtake a truck obstructing the left lane, few of the participants interacted with the bicycle as expected (overtaking the bicycle rider while the rider was passing the parked truck). Therefore it was generally not possible to measure the safety behaviours for this interaction in the expected manner, and subsequently this interaction was excluded from further analysis.

3.3.1 Effect of drivers' individual differences on driver behaviours

The bivariate relationships between participants' general and specific driving behaviour, propensity for sensation seeking, and their measures for safety behaviours from the driving simulator were explored. No significant correlations were observed for interaction 3 (driver turns right (from Mort St into Alinga St) across the approaching motorcycle's path of travel at an unsignalised intersection). The significant correlations for the remaining four interactions and are presented below in Table 19 to Table 22.

The results for interaction 1 (driver turns right across the bicycle's path of travel) show that there were some significant correlations between the safety behaviours and the participants' scores on the DBQ Errors and DBQ Violations measures (see Table 19). For the DBQ Errors measure there was a weak negative correlation with TTC_{min}, with participants who indicated making more errors on the questionnaire having a lower TTC with the cyclist (less safe) in interaction 1. There were also weak negative correlations between the DQB Violations measure and both TTC_{min} and minimum separation for interaction 1. Participants who indicated making more driving violations on the questionnaire had a lower TTC with, and drove closer to, the cyclist in the interaction.

Table 19: Pearson correlation coefficients between DBQ scales and measures for safety behaviours for Interaction 1

Safety behaviour measure	DBQ Errors (8 items)	DBQ Violations (8 items)
TTC_{min}	-.27*	-.29*
Separation at TTC_{min}	-.24	-.24
Speed of the driven car at TTC_{min}	.17	.19
Minimum separation	-.22	-.27*
Speed of the driven car at minimum separation	.09	.09

Note: only questionnaire measures for which there were significant correlations with the safety behaviours are shown, * = p <.05, ** p = <.01.

The results for interaction 4 (driver entering roundabout on which motorcycle was travelling), show that there were some significant correlations between the safety behaviours and the participants' scores on the DBQ Violations, DBQ Agressive violations and the Sensation seeking measures (see Table 20). For the DBQ violations measure, there were moderate negative correlations with TTC_{min} and separation at TTC_{min}, and moderate positive correlations with the speed of the driven car at TTC_{min} and speed of the driven car at minimum separation. Participants who indicated making more driving violations on the questionnaire not only had a lower TTC with, and drove closer to, the motorcycle in the interaction, they were also driving faster at the point of TTC_{min} and at minimum separation.

For the DBQ Aggressive violations measure, there were weak to moderate negative correlations with TTC_{min} and separation at TTC_{min} , and a weak positive correlation with the speed of the driven car at minimum separation. Similar to the DBQ Violations measure, participants who indicated making more aggressive driving violations had a lower TTC with, and drove closer to, the motorcycle in the interaction, and were also driving faster at the point of minimum separation.

The results for the Sensation seeking measure show that there were moderate positive correlations with the speed of the driven car at TTC_{min} and the speed of the driven car at minimum separation. This indicates that participants who reported greater levels of sensation seeking were driving faster at the point when the physical separation between the driven car and bicycle was at its lowest, and also at the point when the TTC was at its minimum.

Table 20: Pearson correlation coefficients between the DBQ scales, propensity for sensation seeking, and measures for safety behaviours for Interaction 4

Safety behaviour measure	DBQ Violations (8 items)	DBQ Aggressive Violations (4 items)	Sensation seeking (intensity subscale, 10 items)
TTC_{min}	-.38**	-.32**	-.09
Separation at TTC_{min}	-.34**	-.27*	.04
Speed of the driven car at TTC_{min}	.37**	.23	.37**
Minimum separation	.03	.08	-.14
Speed of the driven car at minimum separation	.41**	.26*	.34**

Note: only questionnaire measures for which there were significant correlations with the safety behaviours are shown, * = p <.05, ** p = <.01.

The results for interaction 5 (driver entering roundabout on which cyclist was travelling), also show some significant correlations between the safety behaviours and the participants' scores on the DBQ Violations, DBQ Aggressive violations and the Sensation seeking measures (see Table 21). There was a weak negative correlation between the DBQ Violation measure and the minimum separation and a weak to moderate positive correlation with the speed of the driven car at minimum separation. At the point of minimum separation, participants who reported more diving violations in the questionnaire drove closer to the cyclist and were also driving faster at that point. This was similar for the DBQ Aggressive violations measure, where there was a moderate negative correlation with the minimum separation and a moderate positive correlation with the speed of the driven car at minimum separation. Additionally for the DBQ Aggressive violations measure, there was a weak negative correlation with the separation at TTC_{min}.

For the Sensation seeking measure there was a weak negative correlation with TTC_{min} and a weak to moderate negative correlation with minimum separation. Participants who reported greater levels of sensation seeking had a smaller TTC and drove closer to the cyclist in the interaction.

Table 21: Pearson correlation coefficients between the DBQ scales, propensity for sensation seeking, and measures for safety behaviours for Interaction 5

Safety behaviour measure	DBQ Violations (8 items)	DBQ Aggressive Violations (4 items)	Sensation seeking (intensity subscale, 10 items)
TTC_{min}	-.19	-.18	-.28*
Separation at TTC_{min}	-.10	-.27*	-.18
Speed of the driven car at TTC_{min}	.13	.25	.23
Minimum separation	-.28*	-.40**	.34**
Speed of the driven car at minimum separation	.37**	.42**	.14

Note: only questionnaire measures for which there were significant correlations with the safety behaviours are shown, * = p <.05, ** p = <.01.

The results in Table 22 show that for Interaction 6 (driver turning left to exit from roundabout with cyclist travelling in the left lane), there were moderate significant correlations between the safety behaviours and the participants' scores on the DBQ Violations and DBQ aggressive violations measures. For the DBQ Violations measure, there were negative correlations with TTC_{min}, separation at TTC_{min}, speed of the driven car at TTC_{min} and minimum separation. This indicates that participants with higher scores on the DBQ Violations measure drove closer to the cyclist in the interaction, but were travelling slower at the point of TTC_{min}. For the DBQ Aggressive violations measure, there was a negative correlation with minimum separation and a positive correlation with the speed of the driven car at minimum separation. Therefore participants with higher scores on the DBQ Aggressive violations measure not only drove closer to the cyclist in the interaction, but they were travelling faster at the point of minimum separation.

There were also moderate significant correlations between the TTC_{min} and separation at TTC_{min} and the participants' scores on the first General driving measure (driving a car is enjoyable and rewarding). Participants that scored higher on this General driving measure drove closer to the cyclist in the interaction, but there was no significant correlation with their speed at this point.

Table 22: Pearson correlations between the general and specific driving behaviours, propensity for sensation seeking, and measures for safety behaviours for Interaction 6

Safety behaviour measure	General driving 1 (driving a car is enjoyable and rewarding)	DBQ Violations (8 items)	Sensation seeking (intensity subscale, 10 items)
TTC_{min}	-.34*	-.33*	-.31
Separation at TTC_{min}	-.39*	-.59**	-.29
Speed of the driven car at TTC_{min}	-.25	-.50**	.02
Minimum separation	-.10	-.42**	-.33*
Speed of the driven car at minimum separation	.01	.10	.32*

Note: only questionnaire measures for which there were significant correlations with the safety behaviours are shown, * = p <.05, ** p = <.01.

Overall, the results for the bivariate relationships between participants' specific driving behaviour, propensity for sensation seeking, and their measures for safety behaviours from the driving simulator show some significant weak to moderate correlations, most notably with the DBQ Violations, DBQ Aggressive violations and Sensation seeking measures. This is most notable for the higher speed interactions with TWs (4, 5 and 6) where participants who scored higher on the DBQ Violations and Aggressive violations and the Sensation seeking measures tended to drive closer to the TWs in the interactions, while also travelling faster at the point where the separation between the driven car the TW was at the minimum.

3.3.2 Effect of experience on driver behaviours

The measures for safety behaviours were analysed by experience groups for each of the five scripted interactions interaction for each participant. The ANOVAs showed that there were no significant ($p < .05$) effects of previous experience for any of the five safety measures. The variability in the measures of safety was generally moderate to large. For the majority (70%) of measures of safety across all five interactions analysed, the standard deviation was greater than a quarter of the mean value. While for 23% of the measures of safety, the standard deviation was greater than a half of the mean value. This significant variation in the measures of safety within each group was unexpected, and makes it difficult to detect statistically any differences related to previous experience.

For interaction 1, where the driven car turns right across the bicycle's path of travel, group differences in *speed of the driven car at TTC_{min}* and *speed of the driven car at minimum separation* approached significance, (p = .06). Participants with *motorcycle and car* experience were travelling at faster speeds at *TTC_{min}*, compared to the participants in the other three previous experience groups (see Table 23). These participants were also travelling faster *at minimum separation* compared to the other three previous experience groups, although the difference was not as great as was observed for the *speed of the driven car at*

TTC_{min} measure (see Table 23). However, the difference between the *speed of the driven car at minimum separation* measure between the *motorcycle and car* and *bicycle and car* experience groups was quite large (33.27 km/h vs. 21.93 km/h).

Table 23: Means and standard deviations for the driven car speed measures for interaction 1, by participants' previous experience

	Speed of the driven car at TTC_{min} (km/h)		**Speed of the driven car at minimum separation (km/h)**	
	M	***SD***	***M***	***SD***
CO	26.07	7.74	28.19	8.99
BC	25.73	5.29	21.93	12.13
MC	32.40	8.52	33.27	11.18
BMC	26.73	9.78	27.00	12.97
Total	27.93	8.36	27.97	11.76

Figure 11 below demonstrates the relationship observed between the *speed of the driven car at minimum separation* and the *minimum separation* measures for interaction 1. Firstly it shows that there is significant variation in these measures within each experience group. It also demonstrates another notable difference between the *motorcycle and car* and *bicycle and car* experience groups. While there was a trend for participants in the *bicycle and car* experience group to be travelling at lower speeds the closer they were to the bicycle, this was actually the reverse for the *motorcycle and car* experience group. Participants with *motorcycle and car* experience were not only travelling faster *at minimum separation* compared to participants with *bicycle and car* experience, the closer they were to the bicycle the faster they were travelling.

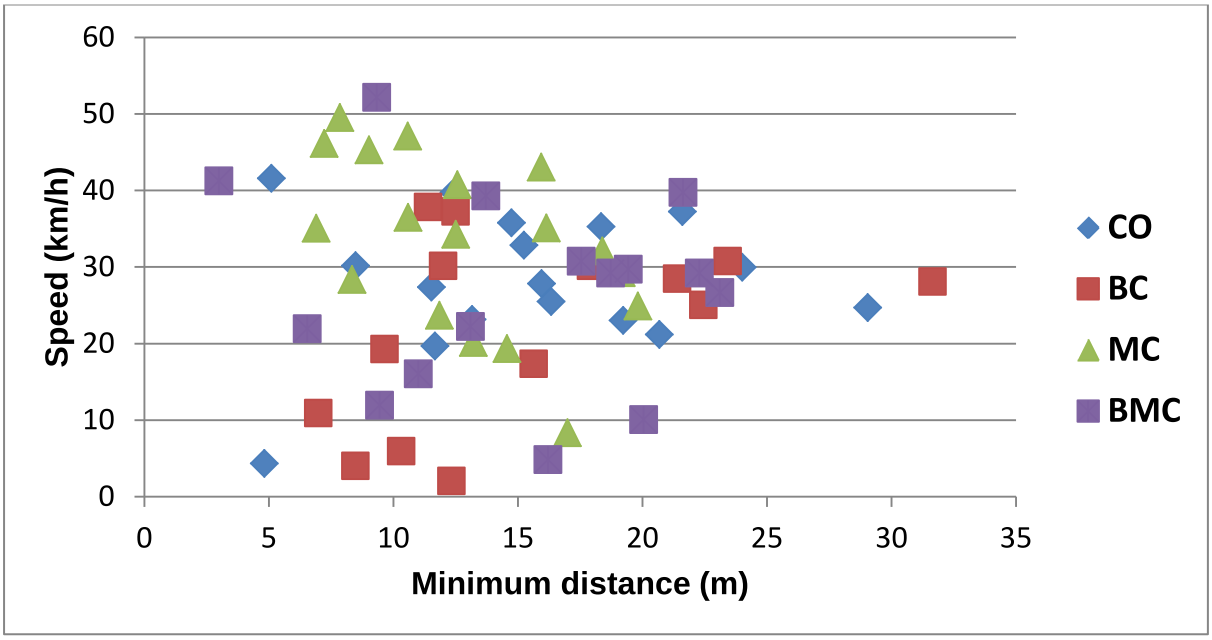

Figure 11: Relationship between the speed of the driven car at minimum separation and the minimum separation distance for interaction 1, by participants' previous experience

3.3.3 Effect of motorcycle conspicuity (headlights) on driver behaviours

The measures of safety behaviours were analysed by the level of conspicuity of the motorcycle in two of the scripted interactions (interaction 3 and 4). The overall pattern of the results for interaction 3 are presented in Figure 12 and Figure 13, and for interaction 4, they are presented in Figure 14 and Figure 15.

The results for the measures of safety for interaction 3 appear to show a small improvement in the participants' safety behaviours for the high conspicuity (headlight on) condition. However, further analysis showed that there was no significant safety improvement for the high conspicuity condition for the interaction with the oncoming motorcyclist.

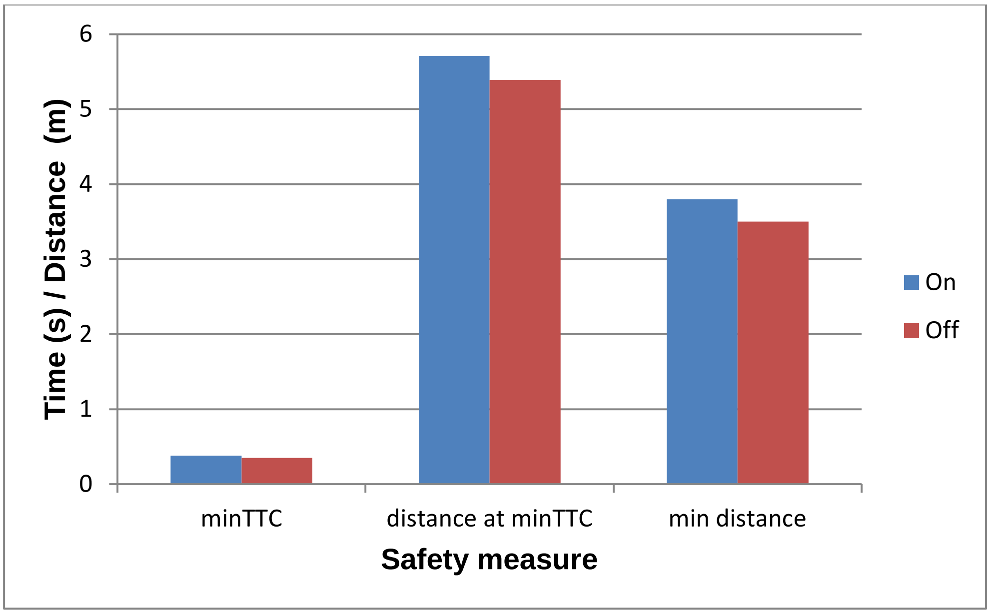

Figure 12: Mean values for measures of safety for interaction 3 (driver turns right across the approaching motorcycle's path), by conspicuity level of the motorcycle

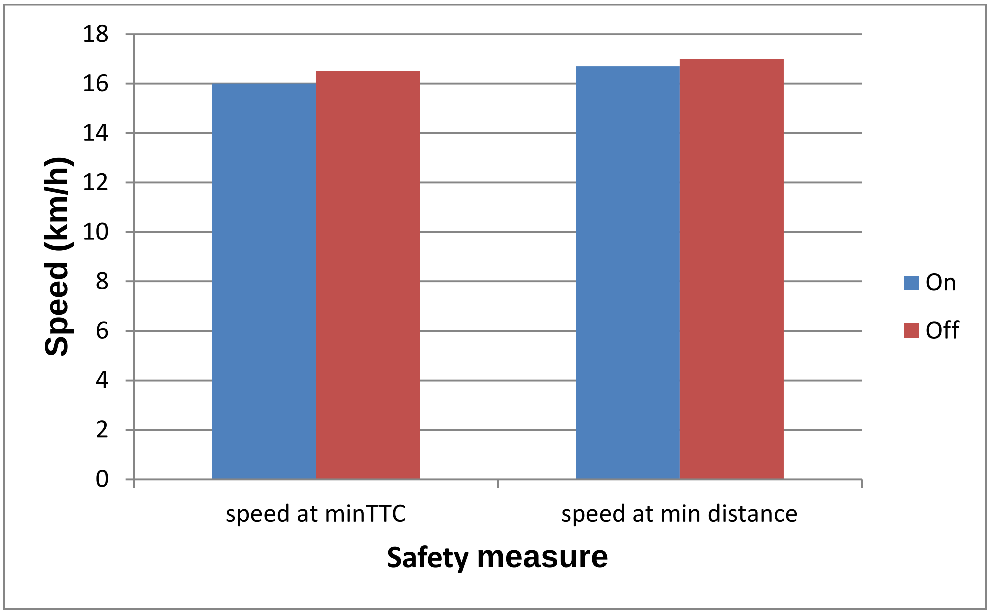

Figure 13: Mean values for the driven car speed measures of safety for interaction 3, by conspicuity level of the motorcycle

Interaction 4, in which a motorcycle that was travelling through a roundabout onto which the driver was entering, was a much more tangential approach than the preceding interaction. This required the participants to turn their head to the right to observe the approaching motorcycle. The results for the measures of safety for interaction 4 show that there was no improvement in the participants' safety behaviours for the high conspicuity (headlight on) condition. For this interaction, the participants actually drove closer, and were travelling faster when the motorcycle headlight was on. Further analysis showed that there was no significant difference in the safety measures between the two conspicuity levels for this interaction involving merging onto a roundabout.

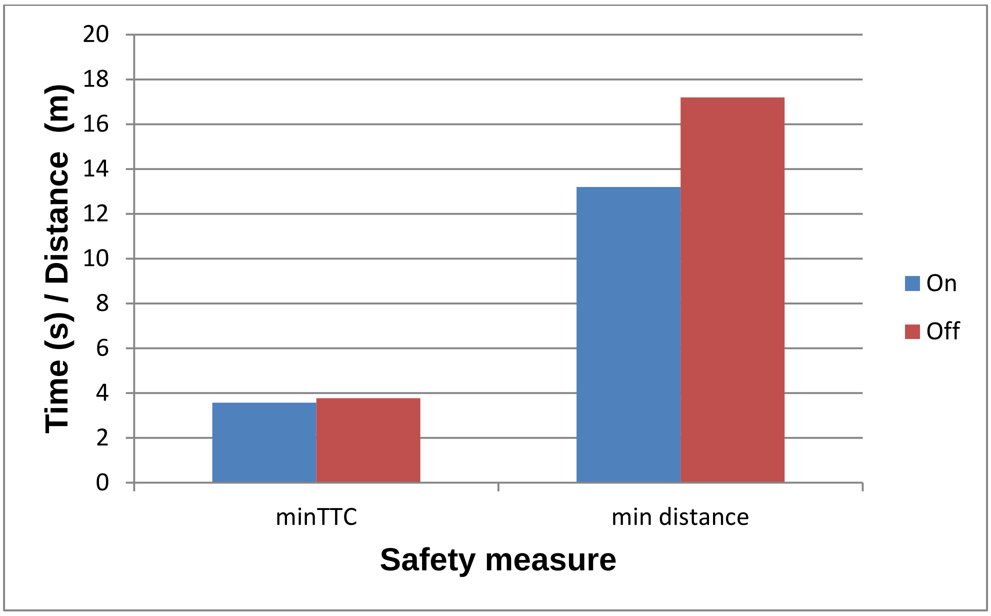

Figure 14: Mean values for measures of safety for interaction 4 (driver entering roundabout on which motorcycle was travelling), by conspicuity level of the motorcycle

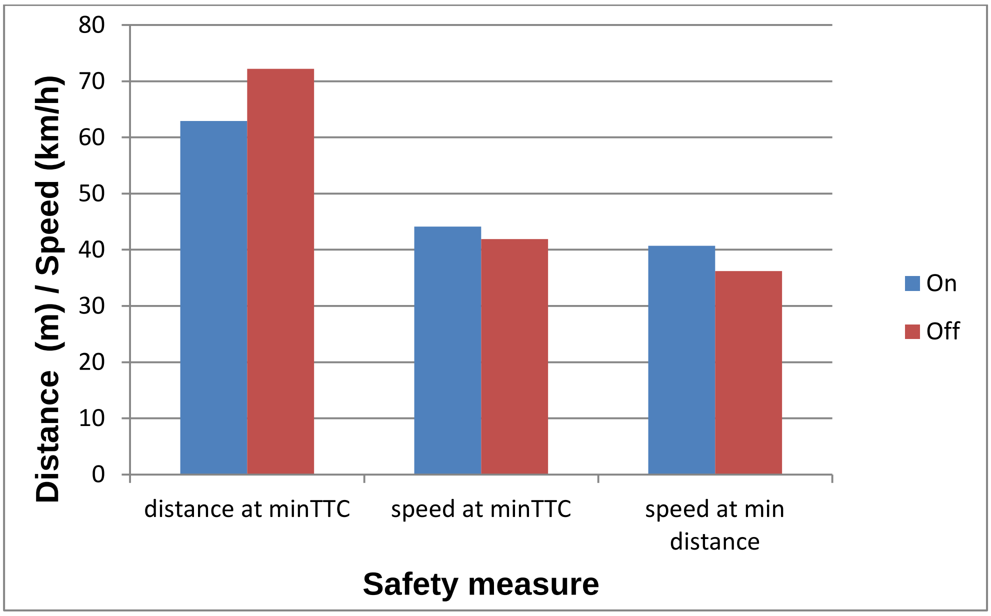

Figure 15: Mean values for measures of safety for interaction 4, by conspicuity level of the motorcycle

Analysing the results for the measures of safety for interactions 3and 4 by previous experience and gender found that there were no significant effects of previous experience, nor were there any significant gender differences.

3.4 RELATIONSHIPS BETWEEN DRIVER ATTITUDES AND BEHAVIOURS

The relationship between reported safe passing distance for bicycles and the actual driving behaviour observed in the driving simulator was compared for interaction 1, where the differences in speed at TTC_{min} and speed at minimum distance approached significance. This relationship is shown in Figure 16.

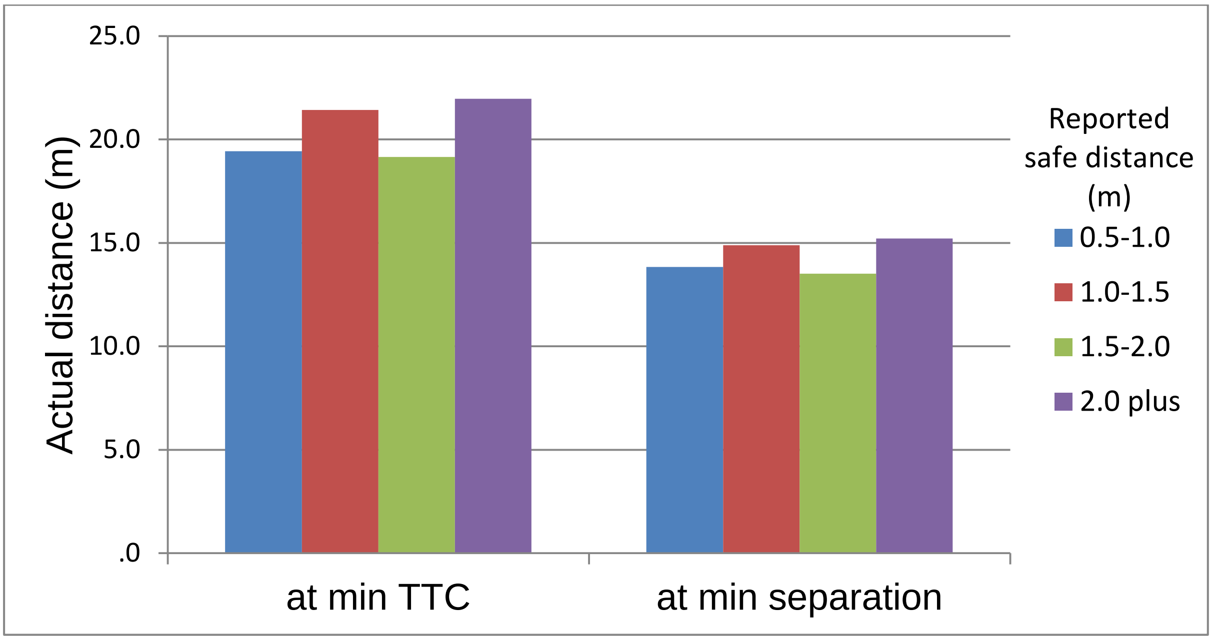

Figure 16: Relationship between participants' reported safe passing distance for bicycles and the actual driving behaviour observed

While those participant who reported the largest safe passing distance for bicycles had on average the greatest actual distance at minimum time to collision and the greatest actual minimum separation (see Figure 16), none of the differences are significant. The actual mean minimum distance between the driven car and the bicycle was much greater than the reported safe passing distance for all four groups (0.5 – 1.0 metres, 1.0 – 1.5 metres, 1.5 – 2.0 metres, 2.0 metres and greater). However, the variation in the mean minimum distance between the driven car and the bicycle was moderate to large for each group (see Table 24).

Table 24: Means and standard deviations for the distance between the driven car and the bicycle, by participants' reported safe passing distance for bicycles

	Distance at TTC_{min} (m)		**Distance at minimum separation (m)**	
Reported safe passing distance for bicycles	***M***	***SD***	***M***	***SD***
0.5 – 1.0 metres	19.43	7.57	13.84	4.90
1.0 – 1.5 metres	21.42	9.33	14.88	6.16
1.5 – 2.0 metres	19.16	9.53	13.51	5.91
2.0 metres & greater	21.96	9.76	15.20	6.30
Total	20.88	9.25	14.57	5.96

4 DISCUSSION

4.1 DEVELOPMENT OF SCENARIOS/SIMULATION

The overall aim of the project was to better understand the road safety risks occurring during interactions between passenger vehicles and PTW and cyclists from the driver's viewpoint utilising an advanced driving simulator. Significant challenges arose in conducting the study in the driving simulator.

The first set of challenges related to attempts to ensure that interactions occurred between the participant as driver and the two-wheelers programmed into the simulation. The advanced driving simulator is fully interactive and therefore the speed and position of the car was completely under the control of the participant. This made it difficult to program the two-wheeler to be in the required position to be interacting with the driven car. For example, there were some instances where the car driver sped up or slowed down when the two-wheeler first appeared and thus managed to execute the required manoeuvre before or after the two-wheeler was in the intersecting path. There were clear limitations on the extent to which the two-wheeler speed (particularly bicycle speed) could be manipulated to attempt to force the interaction, while maintaining the credibility of the scenario. In the second programmed interaction, it was expected that the car driver overtake the bicycle rider while the rider was passing the parked truck. However, many drivers slowed down and travelled behind the rider who was passing the truck. Thus it was not possible to measure lateral passing distance in the expected manner.

The second set of challenges related to portraying the small profile of the bicycle or motorcycle rider on the screen. Using physically accurate visual angles resulted in the riders being hard to see at a distance. In addition, the small visual angle meant that it was extremely difficult for the eyetracking equipment to identify if the participant was looking at the rider. This resulted in the decision not to analyse the small amount of useful data that was obtained from the eyetracking device.

Thirdly, while the research grant specified that the effects of motorcycle headlights on conspicuity were to be assessed, headlights proved to be difficult to simulate. The CARRS-Q advanced driving simulator has three forward projection screens and a headlight can only be represented in terms of projected white light. A simulator which used back projection would be much more effective in portraying motorcycle headlights.

4.2 EFFECTS OF PREVIOUS EXPERIENCE ON DRIVER ATTITUDES

The measure of attitudes towards bicycle riders and motorcycle riders was adapted from a scale measuring driver attitudes towards motorcyclists developed by Crundall et al. (2008). That scale comprised four subscales; negative attitudes (5 items), empathetic attitudes (5 items), awareness of perceptual problems (3 items) and spatial understanding (2 items).

It was surprising that, overall, participants displayed stronger negative attitudes and weaker empathic attitudes to bicycles than motorcycles. To our knowledge, this comparison has not been studied earlier, although negative attitudes by drivers to both bicycle riders and motorcyclists have been reported in the literature (Crundall et al, 2008; Rissel et al, 2002).

The analysis of the effects of previous experience (holding a motorcycle licence or riding a bicycle at least once a week) on driver attitudes to motorcyclists and bicyclists was complicated by the tendency for age and gender to differ between the groups, requiring these variables to be also included in the analyses.

Consistent with the results of Crundall et al. (2008), drivers with motorcycle experience expressed less negative attitudes toward motorcycles. This was not influenced by the age or gender of the driver. However, drivers who were bicycle riders did not show less negative attitudes to bicycles than other drivers after controlling for age and gender. Instead, the attitudes to bicycles appeared to be more negative for male drivers than female drivers.

The results for negative and empathic attitudes were not simply the reverse of each other. Males and drivers with motorcycle experience held stronger empathic attitudes to motorcycles. Strength of empathic attitudes towards bicycles was unaffected by age and gender, with only a trend towards bicycle riders having stronger empathic attitudes towards bicycles. The results do not indicate that experience with one mode of two-wheeler leads to more positive opinions about the other. Experience as a motorcyclist did not result in less negative attitudes towards bicycles and vice-versa.

Drivers with only car experience rate the difficulty of seeing a motorcycle the highest, supporting earlier research that has found drivers with no experience of riding a motorcycle find it more difficult to see motorcycles (Crundall et al, 2008; Clarke et al, 2007). Those participants who had experience as a bicycle rider were found to have lower ratings of difficulty for seeing a motorcycle, while participants who drove a car, rode a bicycle and rode a motorcycle reported the least difficulty in seeing motorcycles. Overall, participants reported significantly greater problems in seeing bicycles compared to motorcycles. Previous experience as two-wheeler rider did not influence perceptions of the visibility of bicycles. However, perceptions of problems with seeing bicycles increased with driver age.

Spatial judgements of the width of bicycles or motorcycles did not differ as a function of TW experience. While there were no effects of TW experience on judging a safe distance between vehicles when a motorcycle was overtaking a car, there were between group differences for the perceived safe distance for a car overtaking a bicycle. The majority of drivers with only experience as a car driver indicated that 2.0m should be provided to cyclists. The majority of drivers with motorcycle experience indicated that 1.0m to 1.5m separation between vehicles was safe. Bicycle riders indicated a distance of 1.0 to 2.0m was safe, however more than 10% indicated that a separation of 0.5m to 1.0m was safe. Due to the nature of the questionnaire we were unable to determine the reasons behind the selection of narrower passing distances by bicycle riders. It may be an indication of the separation distance those cyclists were willing accept as a result of previous close passing manoeuvres that were safely negotiated.

4.3 EFFECTS OF PREVIOUS EXPERIENCE ON DRIVER BEHAVIOURS

The results from this study failed to find evidence that previous experience with one mode of two-wheeler leads to safer interactions with that mode, or the two-wheeler mode, as a car driver. Large individual differences in driving behaviours were observed within groups. While group differences in speed at minimum TTC approached significance at Interaction 1 (car turning across path of bicycle), there was large variability in speed at minimum distance for all groups.

Drivers with previous experience as motorcycle riders tended to drive faster, and have shorter minimum distances at interactions. Without objective measures of safety for the simulated interactions, it is difficult to determine if this indicates unsafe driving behaviours, or reflects different perceptions of driving based on experience interacting with traffic as a motorcycle rider.

The analysis undertaken to determine whether individual differences between drivers are associated with safety interactions with TWs found there were some significant weak to moderate correlations, most notably with the DBQ Violations, DBQ Aggressive violations and Sensation seeking measures. Participants who scored higher on the DBQ Violations, Aggressive violations and the Sensation seeking measures tended to drive closer to the TWs in the interactions, while also travelling faster at the point where the separation between the driven car the TW was at the minimum.

Taken together, these results of this study suggest that individual differences between drivers have a larger influence on their safety behaviours with TWs than previous TW experience.

4.4 EFFECT OF CONSPICUITY ON SAFETY OF INTERACTIONS

There was a trend for safety improvements (larger TTC_{min}, greater distance at TTC_{min}, and slower speeds at TTC_{min}) for approaching motorcycles with running headlights, although these were not statistically significant. This trend is supported by additional research that found that running headlights were associated with a 27% reduction in crash injuries (Wells et al, 2004). There were no significant safety improvements for motorcycles with running headlights at roundabout merges. Having previous motorcycle, and/or bicycle, experience did not influence the safety behaviours of car drivers. Gender was not a factor in the interactions with motorcycles, at both the intersection and roundabout.

4.5 RECOMMENDATIONS FOR FUTURE SIMULATOR STUDIES

The following recommendations for future studies aim to address some of the problems experienced during the current study. Firstly, it is recommended that considerably more time is allocated to piloting and refining the driving scenarios in order to ensure that the scripted interactions will occur as designed. This stage of any future study may require as much effort as the actual experiment itself. However, after the experience gained in this study it in considered of most importance to allow sufficient time to design, pilot, refine and re-test the scenarios to ensure realistic interactions between drivers and the simulated TWs in the experiment.

The second recommendation is related to the challenges experienced in portraying the small profile of the bicycle or motorcycle rider on the screen. The small visual angle meant that it was extremely difficult for the eyetracking equipment to identify if the participant was looking at the rider. It is recommended to wait for eye tracking equipment to mature to a point that it is capable of reliably tracking small objects before incorporating this type of measure into a study. However, other methods of ascertaining whether participants' have seen the TW (such as requiring participant to indicate such) are not considered appropriate, as they may indicate to the participants the true nature of the study which may then influence their interactions with the simulated TWs in the driving scenarios.

4.6 CONCLUSION

The ability to draw firm conclusions from this study is limited by the difficulties experienced in conducting the simulator study and the consequent loss of data. However, a number of useful issues were identified for potential future investigation.

The findings that drivers with bicycle experience nominated smaller safe distances for a car passing a bicycle and that these judgements did not appear to be reflected in behaviour in the simulator merit further investigation. If they are found to be reliable, then the implication is that self-reports of safe distances to pass a bicycle may not be valid measures to use to measure the effects of campaigns to increase separation distances such as “A metre matters”.

Given the range of risky scenarios which were identified from ACT crash data, it was difficult to identify measures of safety of the interaction. Time to collision is commonly used but was not applicable in all of the scenarios. Speed at minimum separation has intuitive appeal as a measure of danger, but it needs further investigation. It would be very interesting to present videos derived from the current experiment to a range of TW riders, asking them to rate the degree of risk in the situations. These ratings could then be correlated with the objective measures to determine those which are the best indicators of the degree of perceived risk.

The effect of high and low visibility on simulated interactions was difficult to measure, but the results confirm previous findings that headlights appear to be most beneficial when the motorcyclist is approaching the driver, rather than in oblique situations.

These results of this study suggest that individual differences between drivers have a larger influence on their safety behaviours with TWs than previous TW experience.

5 REFERENCES

ACEM (2004). MAIDS: In-depth investigations of accidents involving powered two wheelers. Final report 2.0 ACEM

Arnett, J. (1994). Sensation seeking: A new conceptualization and a new scale. *Personality and Individual Differences, 16*(2), 289-296. doi: 10.1016/0191-8869(94)90165-1

Clark, D.D., Ward, P., Bartle, C. & Truman, W. (2007). The role of motorcyclist and driver behaviour in two types of serious accident in the UK. *Accident Analysis and Prevention, 39*, 974-981.

Crundall D, Bibby P., Clarke D., Ward P., & Battle C. (2008) Car drivers' attitudes towards motorcyclists: A survey. *Accident Analysis and Prevention, 40*(2008), 983-993.

De Rome, L., Boufous, S., Senserrick, T., Richardson, D., & Ivers, R. (2011). The pedal study: Factors associated with bicycle crashes and injury severity in the ACT. Sydney: The George Institute for Global Health.

Federal Highway Administration. (2003). *Surrogate Safety Measures From Traffic Simulation Models, Final Report* (FHWA-RD-03-050). McLean, VA: Office of Safety Research and Development.

Fincham, B. (2006a). Bicycle messengers and the road to freedom. *The Sociological Review, 54* (s1): 208-222.

Hamilton, R.J. & Rollin Stott, J.R. (2004). Cycling: the risks. *Trauma, 6* (2), 161-168.

Haworth, N., Greig, K.& Nielson, A. (2009). A comparison of risk taking in moped and motorcycle crashes. In: TRB 88th Annual Meeting, 11-15 January 2009, Washington D.C.

Henley, G. & Harrison, J. E. (2012b). *Serious injury due to land transport, Australia 2008–09* (INJCAT 143). Canberra: Australian Institute of Health and Welfare.

Henley, G. & Harrison, J. E. (2012a). *Serious injury due to land transport, Australia 2007–08* (INJCAT 135). Canberra: Australian Institute of Health and Welfare.

Henley, G. & Harrison, J.E. (2009). *Serious injury due to road traffic accidents Australia 2006-07* (INJCAT 129). Canberra: Australian Institute of Health and Welfare.

Johnston, P., C. Brooks, & H. Savage. Fatal and serious road crashes involving motorcyclists, Road safety research and analysis report. Monograph 20, Department of Infrastructure Transport Regional Development and Local Government, Canberra, 2008.

Kahlmeier S, Racioppi F, Cavill N, Rutter H, Oja P (2010). Health in All Policies in practice: guidance and tools to quantifying the health effects of cycling and walking. *Journal of Physical Activity and Health, 7*(1)

Laureshyn, A., Svensson, A., & Hydén, C. (2010). Evaluation of traffic safety, based on micro-level behavioural data: Theoretical framework and first implementation. *Accident Analysis and Prevention, 42*, 1637-1646. doi: 10.1016/j.aap.2010.03.021

Lawnton, R., Parker, D., Manstead, A. S. R., Stradling, S. G. (1997). The role of affect in predicting social behaviours: The case of road traffic violations. *Journal of Applied Social Psychology, 27*(14), 1259-1276.

Parker, D., Reason, J. T., Manstead, A. S. R., & Stradling, S. G. (1995). Driving errors, driving violations and accident involvement. *Ergonomics, 38*(5), 1036–1048.

Richardson D. (2008) Amalgamation of police and hospital trauma data in the Australian Capital Territory 2001-2003 – NRMA ACT Report Nov 2008.

Rissel, C., Campbell, F., Ashley, B. & Jackson, L. (2002). Driver Road Rule Knowledge and Attitudes towards Cyclists. *Australian Journal of Primary Health, 8*(2), 62-29.

Roads ACT. (2009). 2008 Road traffic crashes in the ACT – Traffic Management and Safety May 2009.

SAVE-U (2003) project Deliverable N. 1A, Vulnerable Road User Scenario Analysis, February 2003.

Schramm, A., Rakotonirainy, A. & Haworth, N. (2010). The role of traffic violations in police-reported bicycle crashes in Queensland. *Journal of the Australasian College of Road Safety, 21(3)*, 61-67.

Walker, I. (2007). Drivers overtaking bicyclists: objective data on the effects of riding position, helmet use, vehicle type and apparent gender. *Accident Analysis and Prevention, 39*(2), 417-425.

Wells, S., Mullin, B., Norton, R., Langley, J., Connor, J., Jackson, R. & Lay-Yee, R. (2004). Motorcycle rider conspicuity and crash related injury: case-control study. *British Medical Journal, 328*, 837-842.

APPENDIX A – QUESTIONNAIRE ONE

Understanding interactions between road users in a driving simulator

The Centre for Accident Research and Road Safety Queensland (CARRS-Q) at the Queensland University of Technology (QUT) is undertaking a project to understand interactions that occur between road users.

This questionnaire is **strictly confidential and anonymous** and you need not answer a question if you consider it too personal. The questionnaire should take roughly 5 minutes to complete. Please take the time to complete this questionnaire and return it as soon as you have finished it.

To ensure your confidentiality and anonymity **please do not put your name on this questionnaire**.

INSTRUCTIONS

For each of the following questions, please select the answer which best reflects your views and/or experiences. Please indicate your answer by circling or ticking the number that corresponds most closely with your opinion.

Centre for Accident Research and Road Safety – Queensland (CARRS-Q)

Queensland University of Technology

130 Victoria Park Road, Kelvin Grove, Queensland 4059 Australia

Email carrsq@qut.edu.au Web www.carrsq.qut.edu.au

CRICOS No. 00213J

Thank you for your assistance ☺

INFORMATION ABOUT YOU

We would like to be able to match this questionnaire with the information we obtain from your simulated driving session. However, we do not want to be able to identify you. **To do this, we would like to collect information from you that will not mean anything to us, but will allow us to match your data. Please complete this information.**	First 3 letters of your Mother's Maiden name: ☐☐☐ Your month of birth: ____________

1. What is your age?	________ YEARS
2. How many years has it been since you first obtained a driver's licence?	________ YEARS
3. Are you (please tick):	☐ Male ☐ Female
4. In the last 12 months, how often on average have you driven a car?	☐ Never – please do not continue with this survey ☐ Less than 1 day a week ☐ 1 day a week ☐ 2-3 days a week ☐ 4-5 days a week ☐ 6-7 days a week

INFORMATION ABOUT YOUR DRIVING AND OTHER BEHAVIOURS

TO WHAT EXTENT DO YOU DISAGREE OR AGREE WITH THE FOLLOWING?	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree
I do find that driving a car is enjoyable and rewarding	1	2	3	4	5	6	7
I perform all appropriate visual checks when driving, e.g., mirror use, blind spot checks etc.	1	2	3	4	5	6	7

For each item below, please indicate which response best applies to you **A = Describes me very well** **B = Describes me somewhat** **C = Does not describe me very well** **D = Does not describe me at all**	**Describes me very well**	**Describes me somewhat**	**Does not describe me very well**	**Does not describe me at all**
When the water is very cold, I prefer not to swim even if it is a hot day	**A**	**B**	**C**	**D**
When I listen to music, I like it loud	**A**	**B**	**C**	**D**
I stay away from movies that are said to be frightening or highly suspenseful	**A**	**B**	**C**	**D**
If I were to go to an amusement park, I would prefer to ride the rollercoaster or other fast rides	**A**	**B**	**C**	**D**
I would never like to gamble with money, even if I could afford it	**A**	**B**	**C**	**D**
I like a movie where there are a lot of explosions and car chases	**A**	**B**	**C**	**D**
In general, I work better when I'm under pressure	**A**	**B**	**C**	**D**
It would be interesting to see a car accident happen	**A**	**B**	**C**	**D**
I like the feeling of standing next to the edge on a high place and looking down	**A**	**B**	**C**	**D**
I can see how it must be exciting to be in a battle during a war	**A**	**B**	**C**	**D**

INFORMATION ABOUT YOUR DRIVING

HOW OFTEN DO YOU DO EACH OF THE FOLLOWING? No one is perfect. Even the best drivers make mistakes, do foolish things, or bend the rules at some time or another. Some of these behaviours are trivial, but some are potentially dangerous. For each item below you are asked to indicate HOW OFTEN, if at all, this kind of thing has happened to you. Base your judgements on what you remember of your driving **<u>over the last year</u>**. Please circle one number, from 0 = '*Never*' to 5 = '*Nearly all the time*') for each item	Never	Hardly ever	Occasionally	Quite often	Frequently	Nearly all the time
Attempt to overtake someone that you hadn't noticed to be signalling a right turn	0	1	2	3	4	5
Get into the wrong lane when approaching a roundabout or a junction	0	1	2	3	4	5
Stay in a lane that you know will be closed ahead until the last minute before forcing your way into another lane	0	1	2	3	4	5
Miss 'Stop' or 'Give Way' signs and narrowly avoid colliding with traffic having right of way	0	1	2	3	4	5
Misread the signs and exit from a roundabout and end up on the wrong road	0	1	2	3	4	5
Fail to notice that pedestrians are crossing when turning into a side street from a main road	0	1	2	3	4	5
Drive especially close to the car in front as a signal to its driver to go faster or get out of the way	0	1	2	3	4	5
Pull out of a junction so far that the driver with right of way has to stop and let you out	0	1	2	3	4	5
Forget where you left your car in the car park	0	1	2	3	4	5
When queuing to turn left onto a main road, you pay such close attention to the mainstream of traffic that you nearly hit the car in front	0	1	2	3	4	5
Sound your horn to indicate your annoyance to another driver	0	1	2	3	4	5
Hit something when reversing that you had not previously seen	0	1	2	3	4	5
Cross a junction knowing that the traffic lights have already turned against you	0	1	2	3	4	5
On turning left nearly hit a cyclist who has come up on your inside	0	1	2	3	4	5
Disregard the speed limit on a motorway	0	1	2	3	4	5
Attempt to drive away from the traffic lights in third gear	0	1	2	3	4	5
Fail to check your rear-view mirror before pulling out, changing lanes, etc.	0	1	2	3	4	5
Become angered by a particular class of road user, and indicate your hostility by whatever means you can	0	1	2	3	4	5
Become impatient with a slow driver in the outer lane and overtake on the inside	0	1	2	3	4	5

Underestimate the speed of an oncoming vehicle when overtaking	0	1	2	3	4	5
Switch on one thing, such as the headlights, when you meant to switch on something else, such as the wipers	0	1	2	3	4	5
Brake too quickly on a slippery road, or steer the wrong way in a skid	0	1	2	3	4	5
When intending to drive to destination A, you 'wake up' to find yourself on the road to destination B, perhaps because the latter is your more usual destination	0	1	2	3	4	5
Drive even though you realise you may be over the legal blood-alcohol limit	0	1	2	3	4	5
Race away from the traffic lights with the intention of beating the driver next to you	0	1	2	3	4	5
Disregard the speed limit on a residential road	0	1	2	3	4	5
Realise that you have no clear recollection of the road along which you have just been travelling	0	1	2	3	4	5
Become angered by another driver and given chase with the intention of giving him/her a piece of your mind	0	1	2	3	4	5

APPENDIX B – QUESTIONNAIRE TWO

Understanding interactions between road users in a driving simulator

The Centre for Accident Research and Road Safety Queensland (CARRS-Q) at the Queensland University of Technology (QUT) is undertaking a project to understand interactions that occur between road users.

This questionnaire is **strictly confidential and anonymous** and you need not answer a question if you consider it too personal. The questionnaire should take roughly 15 minutes to complete. Please take the time to complete this questionnaire and return it as soon as you have finished it.

To ensure your confidentiality and anonymity please **do not put your name on this questionnaire**.

INSTRUCTIONS

For each of the following questions, please select the answer which best reflects your views and/or experiences. Please indicate your answer by circling or ticking the number that corresponds most closely with your opinion.

Centre for Accident Research and Road Safety – Queensland (CARRS-Q)

Queensland University of Technology

130 Victoria Park Road, Kelvin Grove, Queensland 4059 Australia

Email carrsq@qut.edu.au Web www.carrsq.qut.edu.au

CRICOS No. 00213J

Thank you for your assistance ☺

INFORMATION ABOUT YOU

We would like to be able to match this questionnaire with the information we obtain from your simulated driving session. However, we do not want to be able to identify you. **To do this, we would like to collect information from you that will not mean anything to us, but will allow us to match your data. Please complete this information.**	First 3 letters of your Mother's Maiden name: ☐☐☐ Your month of birth: _______________

1. BEFORE ANSWERING THE FOLLOWING QUESTIONS PLEASE READ THESE DEFINITIONS ***'Crashes'*** - any incident involving a motor vehicle that resulted in **damage to a vehicle or other property, or injury**. ***'Offences'*** - any incident for which you were fined **or incurred a loss of demerit points**, **excluding parking offences**.	
As a car driver, during the past **3 years,** how many **crashes** have you been involved in? *(Please tick)*	☐ None ☐ One crash ☐ Two crashes ☐ Three or more crashes
If you **HAVE** been involved in **a crash** during the past **3 years, as a car driver**, did any of these crashes involve........ *(Please tick)*	A motorbike rider? ☐ YES ☐ NO A bicycle rider? ☐ YES ☐ NO Another car driver? ☐ YES ☐ NO I have not been involved in a crash in the last 3 years ☐
As a car driver, during the past **3 years,** on how many occasions have you lost any demerit points or been fined for any traffic **offences? (REMEMBER – this excludes parking offences)** *(Please tick)*	☐ None ☐ One offence ☐ Two offences ☐ Three or more offences

2. Do you hold a current motorcycle licence?

☐ **YES** (please answer the questions below)

☐ **NO** (please go to **question 3** – next page)

<table>
<tr><td colspan="2">How many years has it been since you first obtained your motorcycle licence? (this is <u>not</u> referring to your learners permit) ________________ YEARS</td></tr>
<tr><td colspan="2">In which of these years have you been riding a motorbike on a regular basis (at least once a week)? Please place either a tick or cross in each of the boxes below
☐ 2006 ☐ 2007 ☐ 2008 ☐ 2009 ☐ 2010</td></tr>
<tr><td>In the last 12 months, how often on average have you ridden a motorbike?</td><td>☐ Never
☐ Less than 1 day a week
☐ 1 day a week
☐ 2-3 days a week
☐ 4-5 days a week
☐ 6-7 days a week</td></tr>
<tr><td><u>As a motorbike rider</u>, during the past 3 years, how many crashes have you been involved in? (Please tick)</td><td>☐ None
☐ One crash
☐ Two crashes
☐ Three or more crashes</td></tr>
<tr><td>If you HAVE been involved in a crash during the past 3 years, <u>as a motorbike rider</u>, did any of these crashes involve..... (Please tick)</td><td>A car driver? ☐ YES ☐ NO
A bicycle rider? ☐ YES ☐ NO
Another motorbike rider? ☐ YES ☐ NO
I have not been involved in a crash in the last 3 years ☐</td></tr>
<tr><td><u>As a motorbike rider</u>, during the past 3 years, on how many occasions have you lost any demerit points or been fined for any traffic offences? (REMEMBER – this excludes parking offences) (Please tick)</td><td>☐ None
☐ One offence
☐ Two offences
☐ Three or more offences</td></tr>
</table>

3. Have you ever ridden a bicycle on the road?

☐ **YES** (please answer the questions below)

☐ **NO** (please turn to the questions on the next page)

How many years has it been since you first started riding a bicycle on the road? ________ YEARS	
In which of these years have you been riding a bicycle on a regular basis (at least once a week)? Please place either a tick or cross in each of the boxes below ☐ 2006 ☐ 2007 ☐ 2008 ☐ 2009 ☐ 2010	
In the last **12 months,** how often on average have you ridden **a bicycle?**	☐ Never ☐ Less than 1 day a week ☐ 1 day a week ☐ 2-3 days a week ☐ 4-5 days a week ☐ 6-7 days a week
<u>As a bicycle rider</u>, during the past **3 years**, how many **crashes** have you been involved in? *(Please tick)*	☐ None ☐ One crash ☐ Two crashes ☐ Three or more crashes
If you **HAVE** been involved in **a crash** during the past **3 years, <u>as a bicycle rider</u>**, did any of these crashes involve........*(Please tick)*	A car driver? ☐ YES ☐ NO A motorbike rider? ☐ YES ☐ NO Another bicycle rider? ☐ YES ☐ NO I have not been involved in a crash in the last 3 years ☐

OPINIONS ABOUT MOTORCYCLE RIDERS

TO WHAT EXTENT DO YOU DISAGREE OR AGREE WITH THE FOLLOWING?	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree
When driving in interweaving streams of fast moving traffic with many other drivers often changing lanes, I am constantly aware that **motorcyclists** can be more difficult to spot than under normal driving conditions	1	2	3	4	5	6	7
It is difficult to estimate the speeding of approaching **motorcycles** while waiting to turn at a junction onto a main road	1	2	3	4	5	6	7
When waiting to turn at a junction onto a main road I find that approaching **motorcycles** are as easy to spot as approaching cars	1	2	3	4	5	6	7
When riding **motorcycles**, taking risks is part of the thrill	1	2	3	4	5	6	7
Motorcyclists tend to have headlights on more often than car drivers in the daytime to increase visibility	1	2	3	4	5	6	7
Other motorists should extra take care to look for **motorcyclists**	1	2	3	4	5	6	7
When a car and motorcyclist collide it is typically the fault of the **motorcyclist**	1	2	3	4	5	6	7
Motorcycles are easily hidden from view by parked vehicles and other parts of the road environment, e.g., buildings or overgrown vegetation	1	2	3	4	5	6	7
It is easier to pass the current **motorcycle** test than the current car driving test	1	2	3	4	5	6	7
I have similar personal characteristics to the average **motorcyclist** (regardless of whether you actually ride a motorcycle)	1	2	3	4	5	6	7
Motorcycles are usually easy to spot even against a cluttered background (containing road signs, advertisements, etc.)	1	2	3	4	5	6	7
It costs less to repair the average **motorcycle** after a minor accident, compared with an average car	1	2	3	4	5	6	7
Car drivers are typically more law-abiding than **motorcyclists**	1	2	3	4	5	6	7
I think that **motorcyclists** obstruct the road	1	2	3	4	5	6	7
I think that **motorcyclists** should receive additional training in terms of how to use our roads more safely	1	2	3	4	5	6	7
Most **motorcyclists** do the right thing on the roads	1	2	3	4	5	6	7

When a motorcyclist overtakes a car at 60 km per hour, what size distance should be left between the side of the car and the passing motorcycle in order to remain safe?

☐ Less than 0.5 metres

☐ Between 0.5 metres and 1.0 metre

☐ Between 1.0 metre and 1.5 metres

☐ Between 1.5 metres and 2.0 metres

☐ 2 metres or more

How wide is a motorcycle compared to the width of a car? (e.g., 20% would indicate that a motorcycle was a fifth of the width of a car and 100% would mean it was the same width as the car)

☐ 10%

☐ 20%

☐ 30%

☐ 40%

☐ 50%

☐ 60%

☐ 70%

OPINIONS ABOUT BICYCLE RIDERS

TO WHAT EXTENT DO YOU DISAGREE OR AGREE WITH THE FOLLOWING?	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree
When driving in interweaving streams of fast moving traffic with many other drivers often changing lanes, I am constantly aware that **bicycle riders** can be more difficult to spot than under normal driving conditions	1	2	3	4	5	6	7
It is difficult to estimate the speeding of approaching **bicycle riders** while waiting to turn at a junction onto a main road	1	2	3	4	5	6	7
When waiting to turn at a junction onto a main road I find that approaching **bicycle riders** are as easy to spot as approaching cars	1	2	3	4	5	6	7
When riding **bicycles**, taking risks is part of the thrill	1	2	3	4	5	6	7
Bicycle riders tend to have headlights on more often than car drivers in the daytime to increase visibility	1	2	3	4	5	6	7
Other motorists should extra take care to look for **bicycle riders**	1	2	3	4	5	6	7
When a car and bicycle collide it is typically the fault of the **bicycle rider**	1	2	3	4	5	6	7
Bicycles are easily hidden from view by parked vehicles and other parts of the road environment, e.g., buildings or overgrown vegetation	1	2	3	4	5	6	7
It is easier to take up **bicycle riding** than to pass the current car driving test	1	2	3	4	5	6	7
I have similar personal characteristics to the average **bicycle rider** (regardless of whether you actually ride a bicycle)	1	2	3	4	5	6	7
Bicycles are usually easy to spot even against a cluttered background (containing road signs, advertisements, etc.)	1	2	3	4	5	6	7
It costs less to repair the average **bicycle** after a minor accident, compared with an average car	1	2	3	4	5	6	7
Car drivers are typically more law-abiding than **bicycle riders**	1	2	3	4	5	6	7
I think that **bicycle riders** obstruct the road	1	2	3	4	5	6	7
I think that **bicycle riders** should receive additional training in terms of how to use our roads more safely	1	2	3	4	5	6	7
Most **bicycle riders** do the right thing on the roads	1	2	3	4	5	6	7

When a car overtakes a bicycle rider at 60 km per hour, what size distance should be left between the side of the car and the bicycle in order to remain safe?

☐ Less than 0.5 metres

☐ Between 0.5 metres and 1.0 metre

☐ Between 1.0 metre and 1.5 metres

☐ Between 1.5 metres and 2.0 metres

☐ 2 metres or more

How wide is a bicycle compared to the width of a car? (e.g., 20% would indicate that a bicycle was a fifth of the width of a car and 100% would mean it was the same width as the car)

☐ 10%

☐ 20%

☐ 30%

☐ 40%

☐ 50%

☐ 60%

☐ 70%

APPENDIX C - RESEARCH OUTPUTS

CONFERENCE PRESENTATIONS

Haworth, N., Rakotonirainy, A., Wilson, A., Darvell, M., & Haines, A. Does two-wheeler experience affect behaviours and attitudes to two-wheelers as a car driver? Presentation to Asia-Pacific Cycle Congress, Gold Coast, 11-15 March 2013.

Rakotonirainy, A., Haworth, N., Darvell, M., Wilson, A. & Haines, A. Does driver experience influence motorcycle conspicuity? Presentation to the Human Factors Workshop, A New Look at Motorcycle Conspicuity and Motorcycle Safety Research held at the 92nd Annual Meeting of the Transportation Research Board, Washington D.C., 16 January 2013.

Rakotonirainy, A., Haworth, N., Darvell, M., Wilson, A. & Haines, A. Does experience with one type of two-wheeler affect behaviours and attitudes to other types? Presentation to the International Conference on Traffic and Transport Psychology, Groningen, 28-31 August 2012.

OTHER PRESENTATIONS

The project was also mentioned in various presentations on cycling research at CARRS-Q to:

- French National Transportation Research Institute (IFSTTAR);
- Queensland Health;
- Safer Cycling Round Table, and;
- Directions in Road Safety Forum.