Rural Intersection Active Warning System (RIAWS): A Driving Simulator Study

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Rural Intersection Active Warning System (RIAWS): A Driving Simulator Study

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Abstract

The aim of the study is to evaluate driving speed while navigating through the RIAWS compared to a traditional signed intersection and a control intersection (without signs) using a laboratory-based driving simulator. The driving simulator assessment was completed by 100 drivers aged between 18 and 80 years with a current WA C class licence (passenger vehicle). Each participant completed two researcher-administered questionnaires, a driving simulator assessment and the NASA Task Load Index to measure cognitive load associated with the driving tasks. Overall, the study found that RIAWS "80km/h" sign provided the most effective option for reducing driver speeds on approach to rural intersections.

Keywords

Driving simulator, Rural Intersection Active Warning System (RIAWS), intersection treatment, driving performance

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EXECUTIVE SUMMARY

Background

The Rural Intersection Active Warning System (RIAWS) is an innovative road safety treatment designed to slow the traffic on the major approaches to a high-risk rural intersection when vehicles are turning or crossing into or out of the side roads, thus reducing fatal and serious casualties. RIAWS detects the presence of vehicles approaching from side road(s) and/or right turning vehicles from the main through road, and sends real-time information about such events to the local control system. It then activates electronic signage (variable speed limit or "Slow Down") on the intersection approaches. Traffic waiting at right turn bays and stop lines maintain the electronic sign activation, and the signs turn off when traffic clears.

Previously, the system was trialled by the New Zealand Transport Agency (NZTA) across ten trial sites, and they observed a significant reduction in all crashes and high severity crashes. They found there was sustained speed reduction when potential for collisions existed, and there was evidence of drivers reacting to RIAWS in crashes and mitigating serious harm.

Aims

The aim of the study is to evaluate driving speed while navigating through the RIAWS compared to a traditional signed intersection and a control intersection (without signs) using a laboratory-based driving simulator. A secondary aim is to provide the evidence-base to better inform best design signage regarding the RIAWS.

The hypothesis of the study is that *"the RIAWS displaying a speed limit significantly reduces driver speeds on approach to the intersection, compared to both traditional painted signs and no speed sign conditions."*

Specific objectives were to:

- compare driving simulator performance in terms of instantaneous speed when navigating through RIAWS signed intersections (RIAWS "80km/h", RIAWS "slow down"), traditional painted sign intersections ("80km/h", "slow down") and control intersections with no speed signs.
- Develop recommendations regarding speed signage at rural intersections

Methods

The research was conducted in two phases; with the initial phase consisting of scenario development and subsequently the driving simulator assessment.

Phase 1

Eight driving simulator scenarios containing two RIAWS intersections, two traditional painted sign intersections and two control intersections with no speed-related signage were developed by Dr Simon Wilson, a software engineer, from the Transport Research Laboratory in the United Kingdom, in consultation with Professor Meuleners and Dr Kyle Chow who are road safety experts.

Phase 2

The driving simulator assessment phase of the study was completed by 96 drivers aged between 18 and 80 years with a current WA C class licence (passenger vehicle). Each participant completed two researcher-administered questionnaires, a driving simulator assessment and the NASA Task Load Index to measure cognitive load associated with the driving tasks.

A 2x2 experimental driving simulation study was undertaken to manipulate and compare speed signage (painted traditional signs versus RIAWS) and speed sign content (80km/h versus slow down) at rural intersections in a safe and experimentally controlled environment. The different signed intersections included.

- RIAWS “80km/h” signed intersections
- RIAWS “slow down” signed intersections
- Traditional painted “80km/h” signed intersections
- Traditional painted “slow down” signed intersections
- Control intersection with no speed signage.

Each participant drove one randomly allocated driving scenario which contained a total of four intersections with two randomly selected signed sites and two unsigned control sites. This resulted in a total of eight possible driving scenarios. The four intersections in each scenario were approximately 2343 metres apart from each other.

Descriptive analyses were undertaken to describe the demographic and driving profile of the sample as well as the NASA Task Load Index scores. The outcome of interest was “instantaneous speed”. Mean instantaneous speed was calculated for each of the four signed intersections (RIAWS “80km/h, RIAWS “slow down”, traditional painted “80km/h, traditional painted “slow down”). These means were then each compared to the mean instantaneous speed for the unsigned control intersections to examine differences in speed using independent t-tests.

A two-way analysis of variance (ANOVA) was undertaken to determine if an interaction effect existed between the independent variables and instantaneous speed. The two factors included speed signage (RIAWS versus painted traditional) and speed sign content (80km/h versus slow down). Post-hoc tests using the Sheffe’s test were undertaken when a significant main effect or interaction effect was found in the overall ANOVA. Significant effects were reported at $p<0.05$.

Results

A total of 100 participants completed the study, ranging in age from 18 to 80 years, with a mean age of 49.8 years (SD=18.6). The majority of participants were male (68.0%).

Driving-related characteristics

The majority (65.0%) of participants rated their driving as *good*, and 22.0% as *excellent*. The average number of years of driving experience since obtaining a driver’s license was 31.6 (SD=19.0). Approximately 61% drove on average seven days a week. Twenty-nine percent of participants had undergone additional driver training/ qualifications.

NASA Task Load Index

Overall, there was a mean NASA Task Load Index score of 37.91 (SD=15.31), indicating participants considered the simulator task to require a low cognitive workload. Mental workload put the highest demand on participants as they drove through the driving scenario with a score of 14.44 (SD=7.82) but this demand was considered very low.

Driving simulator speed results

Overall, there were a total of 384 observations for 96 participants. Four participants did not complete the full driving assessment.

The mean instantaneous speed at the unsigned control intersections was 98.6 km/h (SD: 10.8). The mean instantaneous speed at traditional painted sign intersections was 90.9 km/h (SD: 18.8) for "*slow down*" signs and 87.5 km/h (SD: 12.5) for "*80 km/h'* signs. The mean instantaneous speed at the RIAWS electronic sign intersections was 96.2 km/h (SD:13.1) for "*slow down*" signs and 77.9 km/h (SD: 14.8) for "*80 km/hr*" signs.

The results of the t-tests to test the difference in speed for the control intersection (no signs) compared the RIAWS and traditional signed intersections found that the mean instantaneous speed at the RIAWS "80 km/h" signed intersections was significantly lower by 20.6 km/h compared to unsigned control intersections ($p<0.001$). The mean instantaneous speed at the traditional painted "80 km/h" signed intersections was also significantly lower by 11.1 km/h, compared to unsigned control intersections ($p<0.001$). The mean instantaneous speed at the traditional painted "slow down" signed intersections was again significantly lower by 7.7 km/h, compared to unsigned control intersections ($p=0.009$). However, the instantaneous speed at RIAWS "slow down" signed intersections was not significantly lower (-2.4 km/h), than the speed at unsigned control intersections ($p=0.198$).

A two-way ANOVA was undertaken to explore the impact of signage (RIAWS versus painted) and content (80km/h versus slow down) on instantaneous speed. The control sites were not included in this analysis. The results found a significant interaction effect between speed sign content and speed signage ($F(1,3)=11.78$, $p<0.001$). The RIAWS "80km/h" sign resulted in significantly lower instantaneous speeds than all other types of signs including RIAWS "slow down signs ($p<0.001$), traditional painted "80km/h" signs ($p=0.023$) and traditional painted "slow down" signs ($p=0.001$). The RIAWS "slow down" sign resulted in significantly higher instantaneous speed than the traditional painted "80km/h" sign ($p=0.048$) and there was no significant difference for traditional painted "slow down" signs ($p=0.396$). There were no significant differences in speed between traditional painted "80km/h" signs and traditional painted "slow down" signs ($p=0.745$)

Conclusion and recommendations

Overall, the study found that RIAWS “80km/h” sign provided the most effective option for reducing driver speeds on approach to rural intersections. Speed reduction is the main aim of installing the RIAWS at rural intersections so the study results are highly encouraging. Therefore, we recommend that:

1. RIAWS “80km/h” signs and not RIAWS “slow down” signs are considered for implementation at suitable rural intersection sites in WA.
2. Further research is undertaken to determine the most effective placement of the RIAWS “80km/h” signs and how they perform on curved roads.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contribution of Dr Simon Wilson from the Transport Research Laboratory (TRL) in the United Kingdom for his development of the complex driving scenario and his support throughout the data collection process. We would also like to thank Mr John Hess, Miss Siobhan Manners and Mrs Patricia Barrett for their assistance in all aspects of the study including the driving simulator.

1. INTRODUCTION

Intersection crashes were identified as a high risk category of crashes according to the Toward Zero strategy, with 29% of all rural crashes occurring at intersections. Furthermore, crashes involving speed were further identified as high risk crashes, constituting 32% of crashes in rural areas and 34% of crashes in remote areas of WA. The Rural Intersection Active Warning System (RIAWS) is an innovative road safety treatment designed to slow the traffic on the major approaches to a high-risk rural intersection when vehicles are turning or crossing into or out of the side roads, thus reducing fatal and serious casualties. The RIAWS detects the presence of vehicles approaching from side road(s) and/or right turning vehicles from the main through road, and sends real-time information about such events to the local control system. It then activates electronic signage (variable speed limit or "Slow Down") on the intersection approaches. Traffic waiting at right turn bays and stop lines maintain the electronic sign activation, and the signs turn off when traffic clears. This provides a "safe system" by proactively managing crash risk and severity in these higher risk situations (Holst & Russell 2015). The ultimate goal is that RIAWS will reduce fatal and serious casualties at high-risk rural intersections by reducing driving speed, increasing driver awareness and preparing motorists for a possible event, and increasing the gap between vehicles. These goals incorporate three of the four Safe Systems cornerstones: "Safe Road Use", "Safe Roads and Roadsides" and "Safe Speeds".

1.1 Aims and objectives

The aim of the study is to evaluate driver performance while navigating through a RIAWS using a laboratory-based driving simulator. A secondary aim is to provide the evidence base to better inform best design regarding the RIAWS.

The hypothesis of the study is that *"the RIAWS displaying a speed limit significantly reduces driver speeds on approach to the intersection, compared to both traditional painted signs and no speed sign conditions."*

The specific objectives were to:

- compare driving simulator performance in terms of instantaneous speed when navigating through RIAWS signed intersections (RIAWS "80km/h", RIAWS "slow down”), traditional painted sign intersections (“80km/h”, “slow down”) and control intersections with no speed signs.

- Develop recommendations regarding speed signage at rural intersections

2. SIGNIFICANCE

The RIAWS design, to date, has shown extremely promising results at the intersections sites where it has been implemented in New Zealand. A study by Mackie, Scott & Hawley (2015) found the RIAWS is feasible, operates well and is perceived positively by the motoring public. Main Roads WA is interested in implementing the RIAWS in Western Australia (WA) and the opportunity exists to trial the design initially through novel technologies such as a driving simulator. Driving simulators allow empirical investigation of how changes in the road layout may impact on driver performance and behaviour. They represent an approach that is repeatable and easily adaptable, including the ability to quickly alter driving scenarios and expose drivers to hazardous situations in a systematic way, which is difficult to study in a natural driving environment (Engström, Johansson, & Östlund, 2005). They can also distinguish safe from unsafe drivers (Engström et al., 2005) and can be configured specifically to test novel road safety treatments and evaluate driver performance.

It is anticipated that the insights that will be gained from this study will better inform any upcoming real world trial of RIAWS on WA roads, thus minimising the potential risk of such trials.

3. LITERATURE REVIEW

3.1 Rural road conditions and fatalities

In Western Australia, 20% of the population lives in rural and remote towns (Australian Bureau of Statistics, 2016). The state is sprawling, and there are often large distances between these towns. A well-functioning road-transport system is vital to the well-being and prosperity of both residents and visitors to these areas as motor vehicle travel is often the main form of transport between locations.

Crashes in rural and remote locations make up a disproportionate number of fatal crashes each year in WA. Whilst only 20% of the population lives rurally, over 50% of fatal crashes occur on rural roads (Road Safety Commission, 2018b). There are several possible contributors to this increased proportion of fatal crashes in rural and regional locations, including factors related to the behaviour of the driver of the vehicle, the road conditions and the vehicles themselves (Leong, Mahdi, & Chin, 2015). The rural and remote road network covers long distances, and the nature of this extended period of driving can contribute to behavioural factors of fatigue and inattention for drivers.

Intersections crashes are associated with a higher level of severe crash risk than crashes at other types of road infrastructure irrespective of their rural or urban location (Bramwell, Hill, & Thompson, 2014). Intersection crashes also typically involve severe injuries, including head and spinal injuries, often as the result of high speeds and impact to the side of the vehicle (Devlin, Candappa, Corben, & Logan, 2011). In WA, the economic cost of crashes in 2012 alone, was estimated at $2.1 billion, of which 22% were due to fatal crashes and 56% from hospitalisation crashes (Bramwell et al., 2014). The human body has a certain biomechanical tolerance over which serious injury is almost certain. At intersections, it is estimated that this tolerance is reached in crashes where impact speeds exceed 50 km/h (Tingvall & Haworth, 1999). With intersections having been identified as locations where people are at increased risk of crash, intersections present as a pertinent target for innovative designs to minimise crash risk and severity.

3.2 Contributing factors for rural road fatalities

There are several behavioural and situational factors that may contribute to the additional burden of fatal crashes in rural settings. These include higher speeds throughout the road networks, greater presence of fatigue when travelling long distances, increased distance from services, and the design of road infrastructure, namely, intersection design.

3.2.1 Driver behaviour contributing to increased severe crash risk

3.2.1.1 Fatigue and Inattention

Driver fatigue is an established contributory factor for crashes (Armstrong, 2008; Moskowitz H., 2000). Fatigue when driving affects driver alertness and reactivity to unexpected and hazardous situations. This can result in an inability to react sufficiently to avoid a crash. In WA, driver fatigue is estimated to contribute to 6% of all crashes, and up to 30% of all fatal crashes (Australian Transport Council, 2011). In rural and remote areas of Australia, driver fatigue is a particular issue due to the large distances travelled between towns (Centre for Accident Research and Road Safety Queensland, 2005). It has been estimated that the relative risk of a fatal, fatigue-related crash, was 13.5 times higher in rural compared to urban areas (Centre for Accident Research and Road Safety Queensland, 2005). Whilst this estimate is based on data from Queensland, a similar risk is believed to exist in WA, with nearly 20% of drivers reporting having fallen asleep at the wheel at least once (Adams et al., 2017).

As well as the requirement to travel longer distances, road networks rurally can often be monotonous, with little roadside scenery, and straight, features that can result in drivers perceiving the network as ‘easy’ to navigate, which can add to the inattention that may paid by drivers when traversing these roads. Should this attitude be combined with fatigue there is an increased likelihood of a delayed or inappropriate reaction to a hazard, and due to the high speed limits that are present in these areas, a crash resulting in serious injury.

3.2.1.2 Seat Belt Usage

The use of seat belts is an established protective factor in the occurrence of a crash, reducing the risk of death in a crash by 74% (Abbas, Hefny, & Abu-Zidan, 2011; Cummings, 2002). This protective effect is due to the ability of the seat belt to prevent ejection from vehicles, reduce and then spread the impact of the collision, and reduce contact with the vehicle interior, in the event of a crash (Road Safety Commission, 2017). The prevention of the ejection of the occupant from the vehicle in turn prevents additional injuries from impacts with the road, other vehicles and objects, which can be catastrophic for the human body, particularly at high speed (Abbas et al., 2011). The seat belt itself also spreads the impact of the collision across the body, reducing point-specific impact, which can result in greater injury (Abbas et al., 2011).

Despite the clear protective effect of seat belts, their usage rates in WA are lower among vehicle occupants in rural or remote areas when compared to their urban counterparts. This is reflected by the increased proportion of motor vehicle occupants in WA killed or hospitalised due to a crash, not wearing a seat belt, with increased ARIA remoteness index (P. Palamara, 2012). Overall, non-use of seat belts in a serious injury crash in WA, is four times more likely in rural crashes, compared to urban crashes, and is reported in 23% of all rural road fatalities (Road Safety Commission, 2017).

3.2.1.3 Drink Driving

The burden of road crash-related injury associated with drink driving is disproportionately high in rural areas of Australia. In a 2013 report by Palamara and colleagues, using WA crash data, around 13% of drivers involved in a serious injury crash were reported to have tested positive for alcohol (P. Palamara, Kaura, K., Fraser, M.,, 2013). This proportion increased when restricted to regional WA (16.5%) and remote WA only (23.4%) demonstrating the disproportionate presence of alcohol amongst drivers involved in a serious collision in rural and remote areas. Looking at the higher end of the recorded Blood Alcohol Concentration Levels (BACL), overall 51% of drivers/riders who tested positive for alcohol recorded a BACL exceeding 0.100gm%, with this figure increasing to 63.7% for collisions in remote areas.

3.2.2 Rural location contributing to severe crash outcomes

The ultimate outcome of a traumatic health assault, such as a motor vehicle crash, is dependent on how quickly emergency medical aid can be administered to those affected. When the collision is in a rural or remote location, this becomes even more pivotal in the outcome of the crash; depending on the traffic density at the time, it can be an extended period before help is sought and services are notified, which can compound the delays caused by additional distances the services need to cover to reach the sites. In WA this can be overcome to an extent by aerial medical assistance, such as the Royal Flying Doctors service, however such services are costly. Several other restrictors of the emergency care delivered in rural and remote Australia have also been identified in recent years, including difficulties in recruitment and retention, aging volunteer service providers and resourcing (The Council of Ambulance Authorities, 2011).

3.2.3 Road features leading to increased severe crash risk

3.2.3.1 Resourcing

It requires significant resourcing to maintain the rural and remote road network, which covers vastly greater areas than that of the urban road network yet is utilised by only 20% of WA's population (The Australian Rural Roads Group, 2010). Adequate road maintenance in rural areas has been identified as a difficult task due to the difficulty associated with maintaining current knowledge of the vast road network assets and their condition and rate of deterioration (Road Safety Committee, 2002). It has long been asserted that the investment in road maintenance in these areas has been less than is necessary to maintain a high safety standard, yet it is difficult to create a cost-effective case for investment, particularly where there is pressure from a greater population to invest in urban infrastructure. It is in this space that innovative treatments can provide a cost-effective solution by targeting locations, such as rural intersections, that are known to contribute to an increased fatality burden.

3.2.3.2 Speed limits

Speeding is an important contributing factor to the occurrence and severity of crashes. Higher travelling speeds allow drivers less time to respond to hazards and increase the level of energy involved in the event of a crash. (Marchant, 2008).

According to WHO (2009), a 5% increase in average speed is related to a 10% higher risk of crashing and a 20% higher risk of a fatality (World Health Organisation., 2009). According to the ATC (2011), speeding accounts for 34% of fatal and 13% of serious injury crashes in Australia. In WA, speed was considered to be a factor in 24% of all road crash fatalities in 2010, with the proportion being highest in the remote area (29%) versus the regional (26.5%) and metropolitan (19%) areas (Hill, 2012). Earlier studies have shown that 52% of passenger fatalities and 16% of hospitalisation crashes involve speed as a contributing factor (Marchant, 2008). Nearly half of all road fatalities in rural WA between 2012 and 2016 occurred in areas where the speed limit was 110km/h (Road Safety Commission, 2018a).

Periodic surveys of vehicle travel speeds across the Western Australian metropolitan and rural road networks shows that the proportion of speed compliant vehicles varies with geographic location and posted speed zones. Overall, the proportion of vehicles complying with the posted limit (all zones) increased in both locations since 2000 with the greatest percentage increase in the rural area (9.8%) versus the metropolitan area (6.8%) (Radalj, 2012a, 2012b). In 2011, compliance was lowest on 60km/hour roads in the metropolitan area (51.8%) (Radalj, 2012a) and on 90km/hour roads in the rural area (59.9%) (Radalj, 2012b).

Although speed compliance appears greater on Western Australian rural roads versus metropolitan roads, speeding is typically considered more common on rural roads due to low traffic volumes, sparse roadside development and perceived lower likelihood of being detected by police. Tziotis et al. (2006) concluded that speed was a significant factor in crashes on rural and remote Australian and New Zealand roads (Tziotis, 2006). Compared to other OECD countries, Australia has higher speed limits across much of the road system due to its vast regional road network. The majority of regional roads in Australia are single-carriageways with high default speed limits (100 km/hour in most jurisdictions)(Australian Transport Council, 2011). In rural South Australia, fatal and serious injury crashes were found to be over-represented on roads with speed limits of 80 km/hour or higher(Mackenzie, 2008). In addition, the majority of crashes occurred on roads with speed limits of 110 km/hour and these had the largest proportion of high injury severity outcomes (Mackenzie, 2008). A Queensland based study also reported that the proportion of crashes in higher speed zones gradually increased as the ARIA remoteness indicator increased (Steinhardt, 2009).

3.2.3.3 Intersections

There is a clear relationship between serious collisions and intersections; with increased likelihood of crashes causing serious injury or resulting in death consistently reported throughout recent literature (Chow, 2016; Data Analysis Australia, 2006; P. Palamara, Kaura, K., Fraser, M.,, 2013). Although rural intersection crashes have not been thoroughly reported on in Western Australia it has been estimated in some countries that they account for between 20 and 89% of fatal crashes in rural locations (Centre for Transportation Studies, 2018; US. Department of Transportation, 2015).

There are multiple risk factors contributing to the severity of intersection collisions, and the relationship between them is complex. These risk factors include existing infrastructure and surrounding road networks, pedestrian and traffic volumes, traffic demographics including the proportion of trucks, motor vehicles, motorcycles and public transport utilising the road network, as well as other compounding factors including driver behaviour.

There were six potentially modifiable environmental risk factors that are consistently identified in the literature as playing a role in collision risk at intersections; speed, crash angle, whether the intersection was signalised or unsignalised, the intersection type (roundabout, traditional T-intersection or four-legged intersection) and the presence of exclusive right turn or uncontrolled left turn lanes.

In rural settings, intersections tend to be either traditional T-intersection or four-legged intersection designs which have been identified to hold twice the risk of a collision resulting in serious injury or death compared to roundabouts (Chow, 2016). These designs are more prone to collisions at angles that have a higher chance of severe impact, such as side on versus rear end collisions. Coupled with existing high speed throughout the networks this can contribute to a more severe crash outcome.

Signalised intersections have been found to have a lower risk of collisions resulting in serious injury or death (Chow, 2016). However, signalised intersections are uncommon throughout the rural network, due to lower traffic volumes, additional maintenance requirements, and the perceived disruption to the flow of traffic (US. Department of Transportation, 2015). Intersections that may be signalised tend to be innocuous, such as those governed by stop signs, may not be engaging enough to gain the attention of passing motorists who are already prone to fatigue.

3.3 Addressing crashes through Rural intersection Active Warning System

The Rural Intersection Active Warning System (RIAWS) is an innovative road safety treatment which is designed to slow major road through traffic on approaches to an intersection when a potential collision risk exists. The system was implemented by the New Zealand Transport Agency (NZTA) as a trial at a number of rural intersection sites in New Zealand (NZ), with the implementation and performance at each site being monitored (Mackie H & Scott R, 2016; Mackie H, Scott R, & Hawley G, 2015). It has been operational for one to three years depending upon the site. The development, implementation and evaluation of RIAWS is part of a wider programme to address safety at high-risk intersections as part of the NZ government’s Safer Journeys road safety strategy.

The RIAWS is designed to detect the presence of a vehicle approaching from a side road and/or right turning vehicles from the main through road, and sends real-time information about such events to the local control system. It then activates electronic signage (variable speed limit (VSL) or "Slow Down" on the intersection approaches. Traffic waiting at right turn bays and stop lines maintain the electronic sign activation and when traffic clears the sign (VSL or Slow Down) turns off (Holst K. & Russell M., 2015; Mackie H et al., 2015) (Figure 3.1). This provides a "safe system" by proactively managing crash risk and severity in these higher risk situations (Holst K. & Russell M., 2015). The ultimate goal is that RIAWS will reduce fatal and serious casualties at high-risk rural intersections through:

- Slowing motorists on major road intersection approaches and thus reducing crash likelihood by increasing the effective stopping distance and allowing adequate time for driver reaction. This will also reflect a reduction in severity with reduced speeds resulting in reduced energy translated in impact at the time of collision. For example: The RIAWS is designed to instruct motorists of a temporary 70 or 80 km/h speed limit within a permanent 100 km speed limit (or "Slow Down" message) or a 50 km/h limit within a permanent 70 or 80 km/h limit when potential conflict situations exist i.e. the presence of a vehicle waiting on a side road or an opposing right turning vehicle on the main road.
- Increasing driver state awareness through signalisation that engages and alerts drivers who are already prone to fatigue, and traversing a monotonous network; therefore preparing motorists for a possible event. This will effectively reduce reaction time.
- A reduction in speed on approach to these signalised intersections will increase the gap between potentially colliding vehicles, reducing the likelihood of collision.

Figure 3.1 Examples of signage used in the NZ RIAWS trial

The RIAWS design, to date, has shown extremely promising results at the intersections sites where it has been implemented in New Zealand. A study by Mackie, Scott & Hawley (2015) found the RIAWS is feasible, operates well and is perceived positively by the motoring public. Main Roads WA is interested in implementing the RIAWS in WA and the opportunity exists to trial the design initially through novel technologies such as a driving simulator. Driving simulators allow empirical investigation of how changes in the road layout may impact on driver performance and behaviour. They represent an approach that is repeatable and easily adaptable, including the ability to quickly alter driving scenarios and expose drivers to hazardous situations in a systematic way, which is difficult to study in a natural driving environment (Engström et al., 2005). They can also distinguish safe from unsafe drivers and can be configured specifically to test novel road safety treatments and evaluate driver performance (Engström et al., 2005).

3.4 Conclusion

Crashes in rural and remote locations make up a disproportionate number of fatal crashes each year in WA. Whilst only 20% of the population lives rurally, over 50% of fatal crashes occur on rural roads (Road Safety Commission, 2018b). There are several possible contributors to this increased proportion of fatal crashes in rural and regional locations, including factors related to the behaviour of the driver of the vehicle, the road conditions and the vehicles themselves (Leong et al., 2015). Driver behaviours that are known to increase the likelihood of a serious crash, such as fatigue, alcohol use and seat belt usage, are also known to have increased presence and decreased utilisation in rural and remote settings. The very nature of rural and remote locations also poses difficulty for access to emergency services when collisions do occur.

Infrastructure and road network conditions in rural and remote locations also add to the risk of a serious or fatal crash; with higher speed limits generally throughout the network, and the presence of traditional intersection designs that provide increased risk of side on, high impact collisions. RIAWS provides a novel approach to reducing the occurrence of severe and fatal collisions in rural and remote locations through addressing many of these identified risk factors (Holst K. & Russell M., 2015; Mackie H et al., 2015).

This study will be the first study of its kind to provide objective comprehensive evidence on the driving behaviour of WA drivers when driving through the RIAWS. The sample is also large enough to compare the behaviour of different groups of drivers when exposed to the RIAWS, for example young drivers and older drivers.

4. METHODS

The research was conducted in two phases.

Ethical approval was obtained from Curtin University's Human Research Ethics Committee.

4.1 Phase 1: Scenario development

Eight driving simulator scenarios containing two RIAWS intersections, two traditional painted sign intersections and two control intersections with no speed-related signage were developed by Dr Simon Wilson, a software engineer, from the Transport Research Laboratory in the United Kingdom, in consultation with Professor Meuleners and Dr Kyle Chow who are road safety experts.

4.2 Phase 2: driving simulator assessment

4.2.1 Study design

A 2x2 experimental driving simulation study was undertaken to manipulate and compare speed signage (painted traditional versus RIAWS) and speed content (80km/h versus slow down) at rural intersections in a safe and experimentally controlled environment. The different signed intersections included.

- RIAWS "80km/h" signed intersections
- RIAWS "slow down" signed intersections
- Traditional painted "80km/h" signed intersections
- Traditional painted "slow down" signed intersections
- Control intersection with no speed signage.

4.2.2 Sample size and recruitment strategy

The final sample consisted of 100 drivers aged between 18 to 80 years who held a current WA C class (passenger vehicle) licence at the time of the assessment. During the driving simulation three drivers experienced motion sickness and were replaced with another participant. This sample size was sufficient to detect small differences at an alpha of 0.05 with at least 80% power.

Using C-MARC's previously successful recruitment methods, a convenience sample of Perth-based participants were recruited from universities, social media and newspaper advertisements (Appendix A). These included the Curtin Staff Newsletter, the Curtin Student Newsletter, Curtin radio advertisement, Yammer (Curtin's internal Facebook), Facebook and Gumtree advertisements. The first three methods were the most successful, with Yammer being reasonably successful as well.

Inclusion criteri**a** stipulated that each participant had been driving a motor vehicle for at least one year; drove at least three times a week; lived in the Perth metropolitan area, were able to attend a driving simulator assessment at Curtin University and had not moved interstate or from overseas in the past twelve months. Those with a diagnosis of dementia, Parkinson's disease or who were wheelchair-bound; did not speak English, had a history of nausea and/or vomiting; a head injury and/or a history of seasickness were excluded from participating in the study.

4.2.3 Data collection

An information sheet was provided to all participants and informed consent was obtained (Appendix B). Each participant completed two researcher-administered questionnaires (assessing demographic characteristics Appendix C and task workload level Appendix D) as well as a driving simulator assessment at Curtin University. The questionnaire responses were collected by the research assistant using Qualtrics which is an online survey software program used by Curtin University. The complete assessment took approximately one hour.

A small pilot study of five randomly selected participants was undertaken prior to the study commencement. The purpose was to confirm content validity and reliability (test-retest), length and appropriateness of the questionnaire and driving simulator tasks. The questionnaire was reviewed by a panel of road safety, human factors and engineering experts and modifications were made accordingly.

4.2.3.1 Questionnaires

Demographics and driving characteristics: participants' socio-demographic data including age, sex, marital status, education, co-morbid medical conditions, current prescribed medications, and the number of crashes and demerit points/infringement notices incurred over the previous five years were collected (Appendix C).

NASA Task Load Index: The NASA Task Load Index was used to assess the cognitive and physical workload level of the participants at the completion of the driving simulation (Appendix D). Each participant was assessed on six different subscales: mental demands, physical demands, temporal demands, own performance, effort and frustration. The questionnaire was completed using Qualtrics. An overall workload score was calculated by weighting the average scores of the six subscales. The NASA Task Load Index is a reliable tool which has been used widely to assess cognitive demands and physical workload in different contexts (S. G. Hart, 2006; S. G. Hart & Staveland, 1988). The final score ranges from 0 (low) to 100 (high) with higher scores reflecting a higher workload.

4.2.3.2 Driving simulator

The C-MARC simulator represents a fully functioning Kia sedan with working controls and instruments (car and visual system) and is enclosed to remove any outside distractions. It is mounted on a six degree of freedom motion system to recreate driving inertia forces for ultimate realism. When seated in the driving simulator the driver and occupants are immersed in a virtual environment that includes a 360-degree projector wrap-around visual system, allowing for the use of vehicle mirrors. It also features real feeling brake and accelerator systems and includes an audio system that provides realistic traffic sounds as well as instructions and an instructor panel interface for the researchers. Images are displayed in full high definition resolution of 1920 x 1080 pixels per channel and updated at a frame rate of 120 Hz (Figure 4.1).

The OKTAL SCANeRTM studio software package was used to simulate the driving experience. The driving simulator software is used for interactive virtual reality (VR) modelling for construction planning, urban planning, civil engineering and traffic modelling. Combining the program with a driving simulator provides the means to emulate driving situations under a variety of environments. It can create a detailed driving scenario which reproduces a wide range of driving conditions such as, night, rain, snow and bright sunlight.

Figure 4.1: The C-MARC-ARRB simulator

4.2.1 Driving scenario

The simulated driving scenarios consisted of 3D models which represented approximately 1070 kilometres of the generic rural environment in Western Australia (WA). The simulation consisted of midblock sections of road which provided a road environment with speed limits of 110km/h and were posted as such. Each driving scenario consisted of a rural single carriageway road (i.e. no physical separation in the median, only a painted line between the opposing traffic directions). There was no traffic on both directions. As the participant approached each intersection, there was a left-turn pocket which led into a side road on the left. However the participant was instructed to drive straight ahead and not to turn into the side road. As the participant approached the intersection, a vehicle was seen approaching the intersection from the left side of the road, but the vehicle always stopped just before the intersection. The driving scenarios were simulated for day time driving only.

The following types of rural intersection signage were tested in the simulation:

(a) RIAWS "slow down" sign:

An electronic slow down sign (without amber lights) was positioned 300 metres in advance of the intersection (see Figure 4.2), with a side road junction warning sign positioned at 150 metres.

(b) RIAWS "80 km/h" speed limit sign:

An electronic 80km/h sign (without amber lights) was positioned 300 metres in advance of the intersection (see Figure 4.2), with a side road junction warning sign positioned at 150 metres.

(c) Traditional painted "slow down" sign:

A traditional painted slow down sign positioned 300 metres in advance of the intersection, with a side road junction warning sign positioned at 150 meters.

(d) Traditional painted "80 km/h" speed limit sign:

A traditional painted 80 km/h positioned 300 metres in advance of the intersection, with a side road junction warning sign positioned at 150 meters.

(e) Control intersection with no speed signage:

No speed reduction and the side road junction warning sign positioned at 150 meters.

Each participant drove one randomly allocated driving scenario which contained a total of four intersections with two randomly selected signed sites and two unsigned control sites. This resulted in a total of eight possible driving scenarios with the combinations detailed in Table 4.1. The four intersections in each scenario were approximately 2343 metres apart from each other.

Table 4.1: Eight possible driving scenario combinations

Driving Scenarios				
1	No Sign (control)	RIAWS "80km/h"	No Sign (control)	RIAWS "Slow Down"
2	RIAWS "80km/h"	No Sign (control)	Traditional painted "Slow Down"	No Sign (control)
3	No Sign (control)	Traditional painted "Slow Down"	No Sign (control)	Traditional painted "80km/h"
4	Traditional painted "80km/h"	No Sign (control)	RIAWS "80km/h"	No Sign (control)
5	RIAWS Speed Limit	No Sign (control)	Traditional painted "80km/h"	No Sign (control)
6	No Sign (control)	Traditional painted "80km/h"	No Sign (control)	Traditional painted "Slow Down"
7	Traditional painted "Slow Down"	No Sign (control)	RIAWS "Slow Down"	No Sign (control)
8	No Sign (control)	RIAWS "Slow Down"	No Sign (control)	RIAWS "80km/h"

Figure 4.2: Electronic RIAWS 80 km/h speed limit sign and RIAWS slow down sign

4.2.2 Driving procedure

Initially, participants were given the opportunity to drive a practice circuit in the driving simulator to ensure that all participants met a minimum standard proficiency with basic driving tasks (for example: able to use turn signals; side mirrors; accelerator and brake pedal). It also provided them an opportunity to familiarise themselves with the road environment and simulator tasks. The familiarisation route was approximately 1030 metres long and took eight minutesto complete. Each participant was instructed to change lanes and brake several times to become familiar with the way the car handled. This also provided participants with an opportunity to ask any questions before the start of their drive, and allowed them to make any necessary adjustments to the vehicle so that they were comfortable prior to commencing.

Participants were instructed to drive as they normally would. It took approximately 10 15 minutes to complete the drive depending on the speed of the participant. Participants were not told in advance the purpose of the study. Following completion of the driving task, each participant filled out the *NASA Task Load Index* questionnaire (see above) to assess cognitive demands and physical workload at the completion of the driving task(s). Participants were instructed that the NASA Task Load Index tool was to be answered in the context of the workload involved in the driving demands.

4.2.3 Driving speed outcome

The driving speed outcome of interest was “instantaneous speed”. This was the speed measurement captured at the exact location of the speed sign (for signed intersections) and the corresponding location for unsigned control intersections.

4.2.1 Statistical analysis

Descriptive analyses were undertaken to describe the demographic and driving profile of the sample as well as the NASA Task Load Index scores.

The outcome of interest was “instantaneous speed”. Mean instantaneous speed was calculated for each of the four signed intersections (RIAWS “80km/h, RIAWS “slow down”, traditional painted “80km/h, traditional painted “slow down”). These means were then each compared to the mean instantaneous speed for the unsigned control intersections to examine differences in speed using independent t-tests.

A two-way analysis of variance (ANOVA) was undertaken to determine if an interaction effect existed between the independent variables (signage and content) and instantaneous speed. The two factors included signage (RIAWS versus painted) and content (80km/h versus slow down). Post-hoc tests using the Sheffe's test were undertaken when a significant main effect or interaction effect was found in the overall ANOVA. Significant effects were reported at $p<0.05$.

5. RESULTS

5.1 Characteristics of the sample population

5.1.1 Demographic characteristics

A summary of the 100 drivers' demographic information is presented in Table 5.1. The final convenience sample consisted of 100 drivers. The mean age of drivers was 49.8 years (SD=18.6), with a median age of 52.0 years. The drivers ranged in age from 18 to 80 years. The 60+ age group had the highest proportion of participants (38.0%), followed by the 41-59 years age group (27.0%), followed by 25-40 years (20.0%) and 17-24 years (15.0%). The majority of the participants were male (68.0%), married or de-facto (62.0%), had a university degree (55.0%), were currently employed (72.0%) were born in Australia (60.0%) and English was the predominant language spoken at home (94.0%).

5.1.2 Health-related characteristics

The participants' health-related characteristics are summarised in Table 5.2. Of the 100 participants, 49.0% reported that they had been diagnosed with a medical condition. Of these 30% reported having one condition, 12.0% reported two, and 7.0% reported three or more conditions (Table 4). The most frequently self-reported medical conditions were anxiety (8.0%), diabetes (8.0%), heart disease (7.0%) and other (34.0%). Moreover, 45.0% of participants reported that they were currently taking medication with 19% taking one medication, 12% two medications and 14% taking three or more medications.

Table 5.1: Demographic characteristics of the sample population

Variable	Participants/Drivers (n = 100)	
	N	%
Gender		
Female	32	32.0
Male	68	68.0
Age (years)		
17-24	15	15.0
25-40	20	20.0
41-59	27	27.0
≥60	38	38.0
Marital status		
Single	28	28.0
Married/de facto	62	62.0
Separated/divorced/widowed	10	10.0
Highest educational qualification		
Primary or Secondary school	18	18.0
TAFE, apprenticeship	27	27.0
University	55	55.0
Employment status		
Not employed	28	28.0
Employed	72	72.0
Country of birth		
Australia	60	60.0
New Zealand	4	4.0
United Kingdom	14	14.0
China and Hong Kong	2	2.0
South Africa	2	2.0
Zimbabwe	3	3.0
Other	15	15.0
Language spoken at home		
English	94	94.0
Other	6	6.0

Table 5.2: Health-related characteristics of the sample population

Variable	Participants/Drivers (n = 100)	
	N	**%**
Medical condition		
No	51	51.0
Yes	49	49.0
Number of medical conditions reported by driver		
0	51	51.0
1	30	30.0
2	12	12.0
3+	7	7.0
Number of drivers with a self-reported diagnosis of:		
Heart disease	7	7.0
Angina	0	0.0
Stroke	0	0.0
Diabetes	8	8.0
Arthritis	4	4.0
Kidney disease	0	0.0
Hearing impairment	4	4.0
Visual impairment	0	0.0
Sleep apnoea	2	2.0
Depression	5	5.0
Anxiety	8	8.0
Physical impairment	0	0.0
Other medical condition	34	34.0
Currently taking medication(s)		
No	55	55.0
Yes	45	45.0
Number of medications taken		
0	55	55.0
1	19	19.0
2	12	12.0
≥3	14	14.0

5.1.3 Driving-related characteristics

Driving-related characteristics of the sample are presented in Table 5.3. All 100 drivers stated that they '*always*' wore a seat-belt whilst driving with the majority of participants (65.0%) rating their driving as '*good*' and 22.0% as '*excellent*'. The average number of years of driving experience since obtaining a driver's license was 31.6 (SD=19.0) years with a minimum of one and a maximum of 64 years. Fifty one percent of participants wore glasses and/or contact lenses while driving and 73.0% had obtained their driver's license in Australia.

Fourteen percent were involved in a crash in the past year and 22.0% had received at least one traffic infringement in the past year. In terms of driving exposure, 49.0% had driven less than 249 km in the past week while 33.0% had driven between 250 and 499 km in the past week. Sixty one percent drove on average seven days a week. Twenty nine percent of participants had undergone additional driver training/ qualifications.

Table 5.3: Driving-related characteristics of the sample population

Variables	**Participants/Drivers (n = 96)**	
	N	**%**
Glasses/contact lenses worn whilst driving		
No	49	49.0
Yes	51	51.0
Driver's licence obtained in Australia		
No	27	27.0
Yes	73	73.0
Driven motor vehicle in another country for 12+ months		
No	67	67.0
Yes	33	33.0
License(s) held in addition to C/CA license		
No	66	66.0
Yes	34	34.0
Additional driving qualifications/training		
No	71	71.0
Yes	29	29.0
Self-rated quality of driving		
Poor	0	0.0
Fair	0	0.0
Average	13	13.0
Good	65	65.0
Excellent	22	22.0
Self-reported crash involvement in previous 12 months (as the driver)		
No	86	86.0
Yes	14	14.0
Traffic infringement(s) received in previous 12 months		
No	78	78.0
Yes	22	22.0

Number of traffic infringements received in previous 12 months		
0	78	78.0
1	16	16.0
2	4	4.0
3	2	2.0
Years of driving experience since receiving license		
≤9 years	19	19.0
10-19 years	13	13.0
20-29 years	11	11.0
≥30 years	57	57.0
Average number of days driven per week		
2	1	1.0
3	6	6.0
4	12	12.0
5	7	7.0
6	13	13.0
7	61	61.0
Average kilometres driven per week		
≤249 km	49	49.0
250-499 km	33	33.0
500-749 km	11	11.0
≥750 km	7	7.0

5.2 NASA Task Load Index results – cognitive workload

The results of the NASA Task Load Index, completed at the conclusion of the driving simulator assessment are presented in Table 5.4. The overall mean score from the six domains of the NASA Task Load Index was 37.91 (SD=15.31) which demonstrated a low cognitive demand/workload. Mental workload put the highest demand on participants as they drove through the driving scenario with a score of 52.16 (SD=23.16) which was followed by effort (48.97 SD=22.34) but these cognitive demands were considered low.

Table 5.4: Mean NASA-TLX measure of perceived workload demands

Domain	Overall Mean (SD)
Mental	52.16 (23.16)
Physical	27.72 (19.76)
Temporal	27.08 (19.18)
Performance	23.16 (19.70)
Effort	48.97 (22.34)
Frustration	21.00 (20.58)
Total Score	**37.91 (15.31)**

5.3 Driving speed results

Driving simulator data from 96 participants was included in the following analyses which provided a total of 384 observations. This comprised 192 signed intersections (48 RIAWS "80km/h" signs, 48 RIAWS "slow down" signs, 48 traditional painted "80km/h" signs and 48 traditional painted "slow down" signs) and 192 unsigned control intersections. Four participants did not complete the full simulation drive.

5.3.1 Instantaneous speed

Instantaneous speed describes the speed the vehicle was travelling at the position of the speed sign (for intersections signed with RIAWS or the traditional signs) and at the equivalent position for unsigned control sites.

The mean instantaneous speed at the unsigned control intersections was 98.6 km/h (SD: 10.8). The mean instantaneous speed at traditional painted sign intersections was 90.9 km/h (SD: 18.8) for "*slow down*" signs and 87.5 km/h (SD: 12.5) for "*80 km/h'* signs. The mean instantaneous speed at the RIAWS electronic sign intersections was 96.2 km/h (SD:13.1) for "*slow down*" signs and 77.9 km/h (SD: 14.8) for "*80 km/hr*" signs (Table 5.5).

Table 5.5 Instantaneous speed at signed intersections, compared to unsigned control intersections (n=384)

Intersection signage	Sign Content	Mean Speed*	Std. Deviation	Mean difference from control intersection	P-value
RIAWS sign	Slow down	96.2	13.1	-2.4	0.198
	80 km/h	77.9	14.8	-20.6	<0.001
Traditional painted sign	Slow down	90.9	18.8	-7.7	0.009
	80 km/h	87.5	12.5	-11.1	<0.001
Unsigned control intersection	No signs	*98.6*	*10.8*	-	-

**Instantaneous speed*

The results of the t-tests to test the difference in speed for the control intersection (no signs) compared the RIAWS and traditional signed intersections found that the mean instantaneous speed at the RIAWS "80 km/h" signed intersections was significantly lower by 20.6 km/h compared to unsigned control intersections (p<0.001). The mean instantaneous speed at the traditional painted "80 km/h" signed intersections was also significantly lower by 11.1 km/h, compared to unsigned control intersections (p<0.001). The mean instantaneous speed at the traditional painted "slow down" signed intersections was again significantly lower by 7.7 km/h, compared to unsigned control intersections (p=0.009). However, the instantaneous speed at RIAWS "slow down" signed intersections was not significantly lower (-2.4 km/h), than the speed at unsigned control intersections (p=0.198) (Table 5.5).

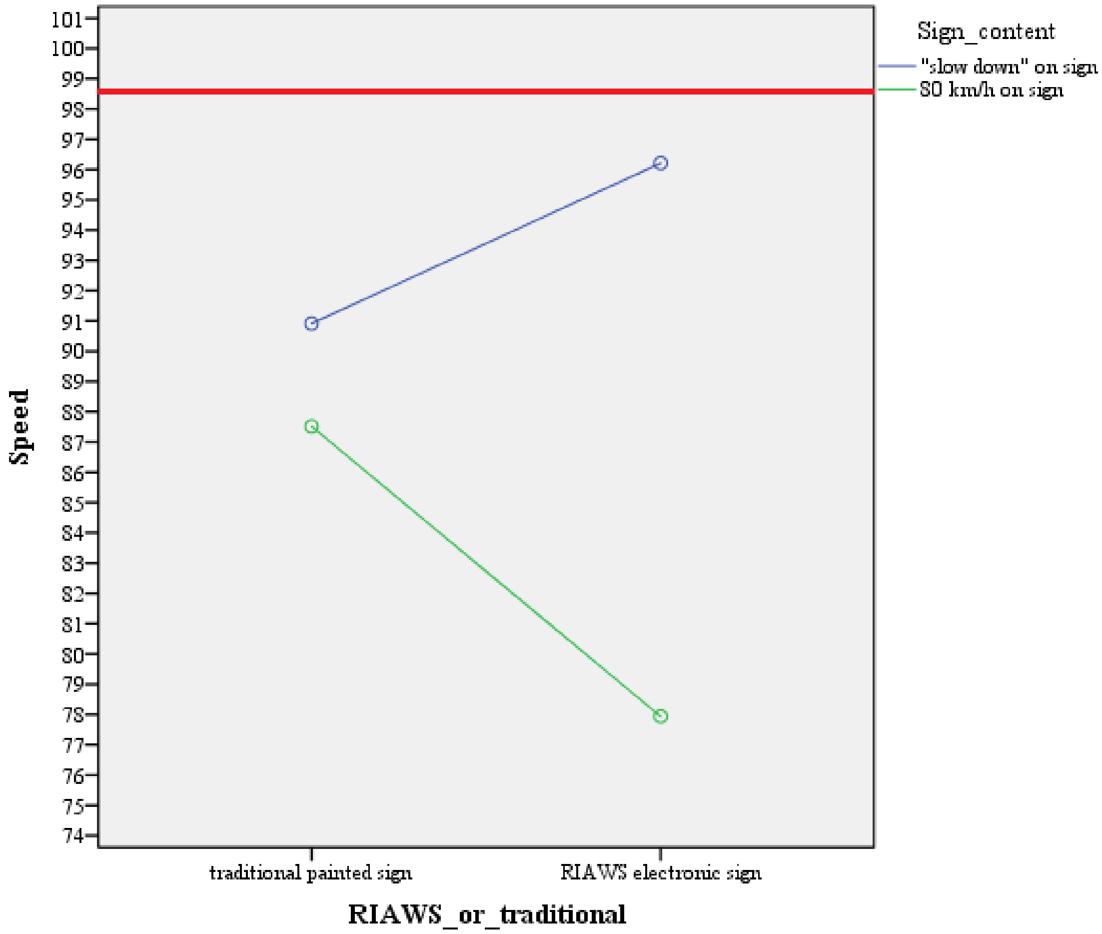
A two-way ANOVA was undertaken to explore the impact of speed signage (RIAWS versus traditional painted) and speed sign content (80km/h versus slow down) on instantaneous speed. The control sites were not included in this analysis. The results found a significant interaction effect between speed sign content and speed signage (F(1,3)=11.78, p<0.001). The RIAWS "80km/h" sign resulted in significantly lower instantaneous speeds than all other types of signs including RIAWS "slow down signs (p<0.001), traditional painted "80km/h" signs (p=0.023) and traditional painted "slow down" signs (p=0.001). The RIAWS "slow down" sign resulted in significantly higher instantaneous speed than the traditional painted "80km/h" sign (p=0.048) and there was no significant difference for traditional painted "slow down" signs (p=0.396). There were no significant differences in speed between traditional painted "80km/h" signs and traditional painted "slow down" signs (p=0.745) (Table 5.6).

Table 5.6 Comparison of instantaneous speed at different signed intersections (n=192)

Intersection signage		MeanDifference	p-value
RIAWS 80 km/h	RIAWS slow down	-18.3	<0.001
	Traditional painted 80 km/h	-9.6	0.023
	Traditional painted slow down	-13.0	0.001
RIAWS slow down	Traditional painted 80 km/h	8.7	0.048
	Traditional painted slow down	5.3	0.396
Traditional painted 80 km/h	Traditional painted slow down	-3.4	0.745

Figure 5.1 presents the mean instantaneous speed by sign type (RIAWS or traditional painted) and sign content (slow down or 80 km/h). The red line represents the mean instantaneous speed at all control sites.

Figure 5.1 Mean instantaneous speed by speed sign type and content



* **Red line** = mean value for unsigned control sites

6. DISCUSSION

Speed is an important contributing factor to the occurrence and severity of crashes with speed contributing to approximately 29% of remote crashes and 27% of regional crashes in WA (Hill, 2012). Higher travelling speeds allow drivers less time to respond to hazards and increase the level of energy involved in the event of a crash (Marchant, 2008). Rural intersections in WA are frequently located on high speed limit roads up to 110km/h and tend to be traditional t-intersection or four-legged designs. These intersection designs have been found to have a higher risk of collisions resulting in serious injury or death compared to roundabouts or signalised intersections (Chow, 2016). This is due to traditional intersections being more prone to collisions at angles that have a higher chance of severe impact and the higher vehicle speeds at these intersections. Roundabouts and signalised intersections are uncommon throughout the rural road network due to lower traffic volumes, maintenance required and perceived disruption to traffic flow (US. Department of Transportation, 2015).

New intersection designs such as RIAWS which were implemented in New Zealand have shown positive road safety outcomes which are consistent with the Safe System approach and may be appropriate for a Western Australia rural road environment. The RIAWS is designed to detect the presence of a vehicle approaching from a side road and/or right turning vehicles from the main through road, and sends real-time information about such events to the local control system. It then activates electronic signage (speed limit or "Slow Down" on the intersection approaches. The RIAWS has the potential to reduce fatal and serious casualties at rural intersections by:

- Slowing motorists on major road intersection approaches and thus reducing crash likelihood (effectively increasing available stopping distance) and severity (less energy on impact)
- Increasing driver state awareness and therefore preparing motorists for a possible event (effectively reducing reaction time)
- Increasing the gaps between potentially colliding vehicles.

The results of this study found that the RIAWS "*80km/h*" sign resulted in significantly lower instantaneous speeds than the other three signs tested with speeds averaging between 10 and 18 km/h slower at the RIAWS "80 km/h signs. Speeds were also over 20 km/h slower at the RIAWS "80km/h" signs compared to the unsigned control sites.

The RIAWS “slow down” sign however did not result in instantaneous speeds that were significantly different to the unsigned control sites and resulted in significantly faster speeds than both the RIAWS “80km/h” sign and the traditional painted “80km/h” sign.

Overall, this suggests that the RIAWS “80km/h” sign is the most effective for lowering speeds on approach to rural intersections with mean instantaneous speed being approximately 78 km/h. This was far more effective than the RIAWS “slow down” sign which had a mean instantaneous speed of 96 km/h.

The results of this driving simulator study provide further evidence for the safety benefits of RIAWS in terms of reduction in speed and this is consistent with the findings of on-road trials in New Zealand. The authors of the New Zealand study found that traffic speeds at the intersections where a RIAWS 70 km/h speed limit sign was activated reduced significantly (Mackie H et al., 2015). While the RIAWS slow down sign also reduced speeds in the New Zealand study, it was much less effective than the RIAWS 70 km/h sign.

The results from the New Zealand study also found that RIAWS had been well accepted by the motoring public with very little adverse feedback about the system (Mackie H et al., 2015). It should be noted that in our study, very low cognitive/ physical workload levels were reported by the drivers via the NASA Taskload index. This suggests that the RIAWS have no negative effects on driving performance.

A strength of the study was the large sample size which had 80% power to detect differences in outcomes at $p<0.05$. However there were several limitations. First, the driving scenario contained straight sections of the road so the impact of RIAWS which are located soon after a curve was not examined in this study. Situational awareness was also not assessed. At high-risk rural intersections, it would be useful to know whether the RIAWS caused participants to be more alert, perhaps in readiness for taking evasive action in the event of an impending collision. However, variable speed limit signs tend to have the effect of catching a motorists’ attention and it might be assumed that the RIAWS has an effect of improving motorist situation awareness (and does not distract them), especially at rural locations with relatively mundane surroundings. Finally the simulated RIAWS images can never offer the resolution of the real world. Notwithstanding these limitations there is enough evidence that the RIAWS provides an effective alternative option for slowing down traffic on approaches to rural intersections when a potential collision risk exists.

7. CONCLUSION AND RECOMMENDATIONS

Overall, the study found that RIAWS “80km/h” sign provided the most effective option for reducing driver speeds on approach to rural intersections. Speed reduction is the main aim of installing the RIAWS at rural intersections so the study results are highly encouraging. Therefore, we recommend that:

1. RIAWS “80km/h” signs and not RIAWS “slow down” signs are considered for implementation at suitable rural intersection sites in WA.
2. Further research is undertaken to determine the most effective placement of the RIAWS “80km/h” signs and how they perform on curved roads.

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APPENDIX A – C-MARC recruitment flyer

Curtin University

Are You Aged 18-80 Years

and Drive a Minimum Of Three Times a Week?

The Curtin-Monash Accident Research Centre (CMARC) is seeking people who drive a minimum of three times a week, to drive their state of the art driving simulator for a road intersection study.

WHO?
You must be 18-80 years of age, have had your licence for at least 12 months, hold a Western Australian C class drivers licence, and be able to participate in a driving simulator assessment.

HOW LONG WILL IT TAKE?
Approximately 60 minutes.

WHY SHOULD I PARTICIPATE?
Intersections are a high risk part of the road network and have higher risk of serious injuries. We hope that the results of this research will benefit the WA community in future by allowing us to develop recommendations to implement Rural Intersection Active Warning System (RIAWS) to improve intersection safety, and reduce serious and fatal injuries.

WHAT DOES IT INVOLVE?
You will be required to complete a series of questionnaires and a driving simulator assessment.

WHERE?
Curtin University,
Technology Park Campus,
Bentley.

WILL I GET PAID?
You will not be paid

MORE INFORMATION
To register to participate visit
goo.gl/cmwC17
or contact Patricia Barrett on
9266 9964 or P.Barrett@curtin.edu.au.

This study has been approved by Curtin University Human Research Ethics Committee (Approval number HRE2018-0032-). If you have any concerns, you may contact the Curtin University Human Research Ethics Committee Secretary on 9266 9223 or hrec@curtin.edu.au.

Make tomorrow better

APPENDIX B – C-MARC participant information statement and consent form

PARTICIPANT INFORMATION STATEMENT

HREC Project Number:	HRE2018-0032
Project Title:	The Rural Intersection Active Warning System (RIAWS): A Driving Simulator Study
Principal Investigator:	Professor Lynn Meuleners Director, Curtin-Monash Accident Research Centre
Version Number:	1
Version Date:	13/11/2017

What is the Project About?

- Crash statistics suggest that intersections are associated with a higher level of crash risk than other parts of the road network.
- The Rural Intersection Active Warning System (RIAWS) is an innovative road safety treatment which is designed to detect the presence of a vehicle approaching and sends real-time information about such events to the local control system. It then activates electronic signage (variable speed limit (VSL) or "Slow Down" on the intersection approaches.
- Our study aims to evaluate the driving performance of 100 WA drivers when they navigate through a RIWAS, using a driving simulator.
- The results of this research will allow us to develop recommendations to implement RIAWS in WA to improve intersection safety, and reduce serious and fatal injuries.

Who is doing the Research?

- The project is being conducted by Professor Lynn Meuleners, Curtin-Monash Accident Research Centre (C-MARC), Curtin University.
- This research project is funded by the Road Safety Commission.
- There will be no costs to you for being involved and you will not be paid for participating in this project.

Why am I being asked to take part and what will I have to do?

- You have been asked to take part because you are aged between 18 and 80 years, live in Perth, have a current WA 'C class' licence (passenger vehicle), have had your licence for one year or more and drive at least three times per week.
- Participation in the study will involve you visiting Curtin University once to complete a driving simulator assessment and questionnaires.
- The study will take place at the Curtin-Monash Accident Research Centre, 7 Parker Place, Technology Park, Bentley, WA.

- You will be asked to drive the C-MARC simulator. It represents an automatic Holden Commodore sedan with working controls and instruments. When driving the simulator, you will be completely enclosed, surrounded by a 360 degree visual system and experience motion from the simulator. First, you will be given the chance to practice driving the simulator. You will then be asked to drive through a simulated driving experience incorporating intersections using the Rural Intersection Active Warning System to activate electronic signs, in the driving simulator. Your performance will be measured and recorded by the simulator software.
- After completing the course, we will ask you to complete a short computer-based questionnaire rating the level of physical and mental effort you experienced while driving.
- During your visit, you will also be asked to complete a face-to-face questionnaire about you (e.g. age, education, country of birth, medical conditions and medications), your driving experience, habits and difficulties and your crash history. It will take approximately one hour to complete the simulator assessment and questionnaires.
- There will be no cost to you for taking part in this research and you will not be paid for taking part.

Are there any benefits' to being in the research project?

- There may be no direct benefit to you from participating in this research.
- We hope that the results of this research will benefit the WA community in future by allowing us to develop recommendations to implement RIAWS in WA to improve intersection safety, and reduce serious and fatal injuries at intersections.

Are there any risks, side-effects, discomforts or inconveniences from being in the research project?

- Some people experience 'simulator sickness', similar to motion sickness while driving the simulator. Symptoms may include headache, sweating, dry mouth, drowsiness, vertigo and/or nausea. These symptoms are temporary. To minimise your risk of 'simulator sickness', the simulator has been calibrated and scenarios carefully designed. However, if you feel any of these symptoms you will be asked to inform the researcher and the assessment will be stopped immediately. You will be offered water and the researcher will remain with you until you are able to leave. Symptoms usually subside within 15 minutes.
- There are no other foreseeable risks from this research project.
- Potential inconveniences to you from being in this research project include time and travel inconveniences.

Who will have access to my information?

- The information collected in this research will be re-identifiable (coded). This means that the stored information will be re-identifiable which means we will remove identifying information on any data or sample and replace it with a code. Only the research team have access to the code to match your name if it is necessary to do so.

Any information we collect will be treated as confidential and used only in this project unless otherwise specified. The following people will have access to the information we collect in this research: the research team and the Curtin University Ethics Committee

- Electronic data will be password-protected and hard copy data will be in locked storage.
- The information we collect in this study will be kept under secure conditions at Curtin University for 7 years after the research has ended and then it will be destroyed.
- You have the right to access, and request correction of, your information in accordance with relevant privacy laws.
- The results of this research may be presented at conferences or published in professional journals. You will not be identified in any results that are published or presented.

Will you tell me the results of the research?

- We will write to you at the end of the research and let you know the results of the research. Results will not be individual but based on all the information we collect and review as part of the research.

Do I have to take part in the research project?

- Taking part in a research project is voluntary. It is your choice to take part or not. You do not have to agree if you do not want to. If you decide to take part and then change your mind, that is okay, you can withdraw from the project. You do not have to give us a reason; just tell us that you want to stop. Please let us know you want to stop so we can make sure you are aware of any thing that needs to be done so you can withdraw safely. If you chose not to take part or start and then stop the study, it will not affect your relationship with the University, staff or colleagues. If you chose to leave the study we will use any information collected unless you tell us not to.

What happens next and who can I contact about the research?

- If you would like further information or to ask questions about the project, please contact:

  Professor Lynn Meuleners

  Ph: (08) 9266 4636

  Email: L.Meuleners@curtin.edu.au

- If you decide to take part in this research we will ask you to sign the consent form. By signing it is telling us that you understand what you have read and what has been discussed. Signing the consent indicates that you agree to be in the research project and have your health information used as described. Please take your time and ask any questions you have before you decide what to do. You will be given a copy of this information and the consent form to keep.

Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC number HRE2018-0032). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au.

CONSENT FORM

HREC Project Number:	HREC number HRE2018-0032
Project Title:	The Rural Intersection Active Warning System (RIAWS): A Driving Simulator Study
Principal Investigator:	Professor Lynn Meuleners Director, Curtin-Monash Accident Research Centre
Version Number:	1
Version Date:	13/11/2017

- I have read the information statement version listed above and I understand its contents.
- I believe I understand the purpose, extent and possible risks of my involvement in this project.
- I voluntarily consent to take part in this research project.
- I have had an opportunity to ask questions and I am satisfied with the answers I have received.
- I understand that this project has been approved by Curtin University Human Research Ethics Committee and will be carried out in line with the National Statement on Ethical Conduct in Human Research (2007) – updated March 2014.
- I understand I will receive a copy of this Information Statement and Consent Form.

Participant Name	
Participant Signature	
Date	

Declaration by researcher: I have supplied an Information Letter and Consent Form to the participant who has signed above, and believe that they understand the purpose, extent and possible risks of their involvement in this project.

Researcher Name	
Researcher Signature	
Date	

APPENDIX C – Study questionnaires

RURAL INTERSECTION ACTIVE WARNING SYSTEM PHONE QUESTIONNAIRE:

Participant Identification Number: ______________________ Date ____________________

If the potential participant answers NO to any of the listed criteria, they are to be excluded from the study

Inclusion Criteria	Tick if No	Comments
18-80 years		
Current WA C class licence for at least 12 months		
Drives minimum 3 times per week		
Live in Perth metro area		
Able to attend driving assessment at Curtin University		
Not moved here from overseas or interstate in last 12 months		

If the potential participant answers YES to any of the following criteria, they are to be excluded from the study

Exclusion Criteria	Tick if Yes	Comments
Dementia		
Parkinson's disease		
Wheelchair bound or requires walking aids		
Epilepsy		
Colour blindness		
History of seasickness		
Stroke/brain injury		
Dizziness/Vestibular Disease		
Taking cold medications		

Curtin University

RAIWS STUDY QUESTIONNAIRE

Start of Block: Demographic details

Q1 Date of survey

____

Q2 Participant Identification Number

____

Q3 Have you driven this driving simulator or a similar one previously?

O Yes (4)

O No (5)

X→ X→

Q4 What is your gender?

O Female (0)

O Male (1)

X→ X→

Q5 What is your marital status?

○ Single (1)

○ De facto (2)

○ Married (3)

○ Separated (4)

○ Divorced (5)

○ Widowed (6)

Q6 What is your highest educational qualification

○ Did not go to school (1)

○ Primary School (2)

○ Secondary School (3)

○ TAFE, Apprenticeship (4)

○ University (5)

Q7 In what country were you born?

- Australia (1)
- New Zealand (2)
- United Kingdom (3)
- Europe (4)
- Vietnam (5)
- China & Hong Kong (6)
- Middle East (7)
- Other (please specify) (8) ____________________
- I don't know (9)

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*

Q8 How old are you?

____

X→ X→

Q9 What language do you speak at home?

- English (1)
- Other (please specify) (2) ____________________

Q10 Are you currently employed?

O Yes (1)

O No (2)

Display This Question:

If Are you currently employed? = Yes

Q11 What is you current occupation?

____

Q12 Do you currently have a diagnosis of any of the following medical conditions?

- ▢ Heart Disease (1)
- ▢ Angina (2)
- ▢ Stroke (3)
- ▢ Diabetes (4)
- ▢ Arthritis (5)
- ▢ Kidney Disease (6)
- ▢ Epilepsy (7)
- ▢ Hearing impairment (8)
- ▢ Visual impairment (9)
- ▢ Sleep apnoea (10)
- ▢ Depression (11)
- ▢ Suffer from anxiety (12)
- ▢ Any physical impairment (13)
- ▢ Any other medical conditions you have been diagnosed with? (14) ____

X→ X→

Q13 Are you currently taking any medications?

O Yes (1)

O No (0)

Skip To: End of Block If Are you currently taking any medications? = No

Q14 If yes, please specify below

	Medication name (including over-the-counter medications eg cough mixture (1)	Type of use (eg daily) (2)	Length of use (e.g. 1 week) (3)
Medication 1. (1)			
Medication 2. (2)			
Medication 3. (3)			
Medication 4. (4)			
Medication 5. (5)			
Medication 6. (6)			
Medication 7. (7)			

Medication 8. (8)			
Medication 9. (9)			
Medication 10. (10)			

End of Block: Demographic details

Start of Block: Driving Habits questionnaire

X→ X→

Q15 Do you wear glasses or contact lenses when you drive?

O Yes (1)

O No (2)

X→ X→

Q16 Did you get you driving license in Australia?

O Yes (1)

O No (2)

Display This Question:

If Did you get you driving license in Australia? = Yes

Q17 In which state of Australia did you get your license?

O Western Australia (1)

O Northern Territory (2)

O Queensland (3)

O New South Wales (4)

O Victoria (5)

O Tasmania (6)

O South Australia (7)

Display This Question:

If Did you get you driving license in Australia? = No

Q18 In which country did you get your driver's license?

____

---

*

Q19 How many years have you been driving since you got your license?

____

Q20 Have you driven a motor vehicle in another country for more than 12 months?

O Yes (1)

O No (2)

Display This Question:

If Have you driven a motor vehicle in another country for more than 12 months? = Yes

Q21 How many years did you drive in another country?

____

Q22 What type(s) of driving license(s) do you hold?

____

Q23 Do you hold any additional driving qualifications/training?

- Yes (1) ____
- No (2)

Q24 Do you wear a seat-belt when you drive?

- Always (1)
- Sometimes (3)
- Never (3)

Q25 How would you rate the quality of your driving?

O Excellent (5)

O Good (4)

O Average (3)

O Fair (2)

O Poor (1)

Q26 In an average week, how many days per week do you usually drive?

____

Q27 In an average week, how many kilometres do you normally drive?

____

Q28 How many crashes have you been involved in over the past year when you were the driver?

____

Q29 How many times in the past year have you received a traffic ticket where you were the driver of the motor vehicle?

____

Q31 In relation to the road design, did you feel that you experienced any difficulty while navigating through any of the intersections? (this question does not include any difficulty you may have had driving the simulator)?

O Yes (1)

O No (2)

Skip To: Q34 If In relation to the road design, did you feel that you experienced any difficulty while navigating... = No

---

Q32 Can you please describe the area where you experienced difficulty and the difficulty that occurred there.

____

____

____

____

____

Q33 What do you feel could have caused these difficulties?

____

____

____

____

____

Q34 Examples of typical “traffic controls” used on WA roads include traffic lights, signs such as “Stop” or “Give way”, and speed signs. While navigating through the scenario did you notice any type(s) of traffic controls that you have not previously encountered on WA roads.

O Yes (1)

O No (2)

Skip To: Q36 If Examples of typical “traffic controls” used on WA roads include traffic lights, signs such as “St... = No

---

Q35 Can you please describe the "new" traffic controls you noticed during the simulator drive, and tell me what you liked or did not like about them.

____

____

____

____

____

Q36 Do you have any other comments about driving the simulator? (include comments about the actual driving of the simulator in this section)

____

____

____

____

____

End of Block: Driving Habits questionnaire

APPENDIX D – NASA Task Load questionnaire

NASA Task Load Index: computer-administered

Please indicate the amount of workload involved for each item on the relevant scale

Mental Demand

How mentally demanding was the task?

Very Low Very High

Physical Demand

How physically demanding was the task?

Very Low Very High

Temporal Demand

How hurried or rushed was the pace of the task?

Very Low Very High

Performance

How successful were you in accomplishing what you were asked to do?

Perfect Failure

Effort

How hard did you have to work to accomplish your level of performance?

Very Low Very High

Frustration

How insecure, discouraged, irritated, stressed, and annoyed were you?

Very Low Very high