The relationship between vehicle performance and novice driver crash involvement

RR 12-001

CURTIN-MONASH ACCIDENT RESEARCH CENTRE
School of Public Health
Curtin University of Technology
Hayman Road
Bentley WA. 6102

with technical supplement by

CENTRE FOR AUTOMOTIVE SAFETY RESEARCH
The University of Adelaide
Frome Road
Adelaide SA 5005

P.Palamara and J. Langford (Main Report)
T.P. Hutchinson and R.W.G. Anderson (Technical Supplement)

May 2012

CURTIN-MONASH ACCIDENT RESEARCH CENTRE
DOCUMENT RETRIEVAL INFORMATION

Report No.	Project No.	Date	Pages	ISBN
RR 12-001	09-002 RSC	May 2012	36+	N/A

Title
The relationship between vehicle performance and novice driver crash involvement

Author(s)
Palamara, P.; Langford, J. (Main Report)
Hutchinson, T.P.; Anderson, R.W.G. (Technical Supplement)

Performing Organisations

Main Report
Curtin-Monash Accident Research Centre
School of Public Health
Curtin University of Technology
Hayman Road
BENTLEY WA. 6102

Tel: (08) 9266-2304
Fax: (08) 9266-2958
www.c-marc.curtin.edu.au

Technical Supplement
Centre for Automotive Safety Research
The University of Adelaide
Frome Road
ADELAIDE SA 5005

Sponsor
Road Safety Council of Western Australia
c/- Office of Road Safety
Department of Transport
10th Floor
40 St. George's Terrace
PERTH WA. 6000

Abstract
The aims of this project were (i) to provide contemporary evidence of the relationship between vehicle performance factors and the risk of serious injury crash involvement among young novice drivers in Western Australia, and (ii) to review the current Australian vehicle restriction programs. Data for analysis were n=11,321 vehicles driven by those aged 17+ years involved in serious injury crashes during the period 2001-2008. High performance vehicles driven by those aged 17-19 years accounted for less than 1% of the serious injury crashes investigated, while 7.6% of serious injury crashes involving drivers aged 17-19 years involved a high performance vehicle. The findings of a number analyses provided some evidence, albeit definitive, to suggest that drivers aged 17-19 years have a higher relative rate of crash involvement when driving a high performance vehicle and that six and eight-cylinder vehicles and high performance four-cylinder vehicles have a higher representation in single vehicle crashes compared with two-vehicle crashes. Comparable vehicle restriction schemes for novice drivers currently operate in four Australian jurisdictions (Victoria, New South Wales, Queensland and South Australia). A review of the schemes noted an absence of published empirical evidence to support their introduction and no evaluations to date to determine their impact on the novice driver problem. All jurisdictions expressed the view that the schemes were somewhat difficult to administer and enforce. On the basis of the above findings and others, a number of recommendations were provided to the Road Safety Council, including the rejection of a vehicle restriction scheme for Western Australian novice drivers.

Keywords
Road safety; vehicle performance; young novice drivers; crash risk

TABLE OF CONTENTS

Technical Supplement
Hutchinson, T.P. & Anderson, R.W.G. (2012)
Vehicle performance and crash risk amongst novice drivers in Western Australia.
Adelaide: Centre for Automotive Safety Research, The University of Adelaide.

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Introduction

Drivers aged 17-25 years in Australia and across all other highly motorised Western countries are substantially over-represented among drivers killed and seriously injured. In 2010, this age group accounted for 26.2% of all driver deaths in Australia while representing only 15.4% of the population. While this age group is nearly twice as likely as all age drivers to be killed, the risk is greater still for those drivers in the initial period of licensure. Graduated Driver Licensing systems have been implemented across countries such as the USA, New Zealand, the United Kingdom and Australia to control the exposure of novices to factors associated with an increased risk of crashing. Unlike their overseas counterparts however, a number of Australian jurisdictions (e.g., Victoria, New South Wales, Queensland, South Australia) have placed restrictions on the vehicles young novices can drive based on the performance of the vehicle.

Western Australia has for some years debated the need to introduce similar restrictions but has not done so to date because of an absence of strong empirical evidence to support a statistically increased risk of crashing among novices who drive high performance vehicles. A review of the limited number of available studies of the relationship between vehicle performance and driver behaviour and driving outcomes, including a much earlier investigation of the issue in Western Australia published in 2005 by Palamara & Gavin, failed to identify strong and valid findings regarding a consistent, quantifiable influence of vehicle performance on driving outcomes. At best, the published research shows a reasonably consistent theme of drivers of high performance vehicles, including young drivers and males, as being more likely to engage in anti social and risk taking behaviour on the road and of having a higher risk of involvement in a crash. The most recent Australasian research by Keall & Newstead (2012) provides the strongest evidence of this, though it also notes that young drivers in high performance vehicles involved in a crash represent a relatively small proportion of crashes among this age group – a finding similarly noted by Palamara & Gavin (2005). None of the previous investigations have however, addressed the relationship between driver characteristics and vehicle selection and the interaction between these in relation to driving outcomes. Thus, it is not entirely clear whether driving outcomes are directly influenced by vehicle performance per se or whether drivers with certain dispositions or personality traits that dispose them to risk taking seek out certain types of vehicles to express their behavioural style. If so, would restricting high sensation seeking drivers to lower

performance vehicles significantly alter their likelihood of engaging in risky behaviours and becoming involved in a crash?

The aim of this study, commissioned by the Road Safety Council of Western Australia in 2009, was to provide more definitive contemporary Western Australian evidence of the relationship between vehicle performance factors, age of driver, and risk of involvement in a serious injury crash to reconsider the need for a restricted vehicles scheme for novice drivers.

The specific objectives of the research were as follows:

Objective One

To investigate the relationship between vehicle performance and serious injury crash involvement among Western Australian drivers (i) aged 17-19 years holding a provisional, restricted 'C' class motor car drivers' licence and (ii) drivers older than 19 years holding a full, unrestricted 'C' class motor car drivers' licence

Objective Two

To compared the finding from Objective 1 with the findings of the previous investigation undertaken by Palamara & Gavin (2005).

Objective Three

To consider the recent experiences of other Australian jurisdictions with respect to vehicle performance restrictions for novice drivers

Objective Four

To provide recommendations to the Road Safety Council of Western Australia regarding the need for vehicle performance restrictions for novice drivers and the form of those restrictions.

Method

The research was undertaken by the Curtin-Monash Accident Research Centre (C-MARC) (Curtin University, Western Australia and Monash University, Victoria) in collaboration with the Centre for Automotive Safety Research (CASR). C-MARC was primarily responsible for the management of the project and Objectives Two and Three, while CASR was primarily responsible for Objective One and the production of the technical supplement. Both institutions contributed to Objective Four.

Data for the investigation of the statistical relationship between vehicle performance and crash risk were selected from all police reported serious injury (death or hospitalisation)

crashes occurring during the period 2001-2008, provided by Main Roads Western Australia. To enable the calculation of the rates of crash involvement for drivers by age and vehicle performance, and to investigate the safety and performance characteristics of the fleet of Western Australian vehicles, a sample of 3,750 registered private passenger vehicles was randomly selected from each year of the period 2001 to 2008 (totalling 30,000 vehicles). Vehicle Identification Numbers (VIN) and driver licensing and vehicle ownership information was obtained from the Department of Transport for each crash involved vehicle and driver and each vehicle in the sample of the vehicle fleet. VINs were subsequently forwarded to RL Polk Australia for the retrieval of manufacturer's information on the performance of the vehicle and its safety features.

After applying the criteria for the inclusion of relevant vehicles and drivers, the final crash dataset consisted of n=11,321 vehicles (post-1990) and actively licensed drivers aged 17+ years (categories into those aged 17-19 years, 20-24 years and 25+ years). The performance of vehicles was based on both the number of cylinders and the power to weight ratio (kilowatt output/kerbside weight x 100kgs) of the vehicle, resulting in the following categories of performance:

- four-cylinder vehicles: PWR ≤59; PWR 60-74; PWR 75-89; PWR ≥90
- six-cylinder vehicles: PWR ≤99; PWR 100-109; PWR ≥110
- eight-cylinder vehicles: PWR ≤109; PWR 110-139; PWR ≥140

Relative rates of crash involvement were calculated for *owner-drivers only* for the various driver/vehicle groups using the average crash rate for those aged 17-19 years in all four-cylinder vehicles. In addition to this analysis, the proportion of high performance vehicles in single and two car crashes was calculated and followed up with univariate and multivariate modelling of the effect of various driver, vehicle, and crash location factors on the ratio of single vehicle crashes to two car crashes. Finally, a set of time series analyses were undertaken on the 2008 sub-set of the sample of the WA vehicle fleet to document the history and introduction of various vehicle safety technologies and vehicle performance characteristics and the relationship between the two.

Summary of Findings

Objective One

The complete findings from the analysis of serious injury crashes 2001-2008 are reported in the attached technical supplement prepared by Hutchinson and Anderson (2012). The main findings were as follows:

- Vehicle performance was categorised using both the number of cylinders of the crashing vehicle and the power to weight ratio of the vehicle. Vehicles considered to be of 'higher performance' were those in the following groups:
    - four-cylinder vehicles with a PWR ≥ 90kw/tonne;
    - six-cylinder vehicles with a PWR ≥ 110kw/tonne; and,
    - all eight-cylinder vehicles
- These high performance vehicles accounted for 7.6% of the n=1,285 vehicles crashed by owner and non owner-drivers aged 17-19 years and less than 1% of the n=11,321 owner and non owner-driver vehicles (all ages) involved in a serious injury crash.
- Calculation of the crash rates for owner drivers only showed that in comparison with the crash rate for those aged 17-19 years in all four-cylinder vehicles, a relative higher rate of crashing for 17-19 year olds was observed for those driving:
    - four-cylinder vehicles with a PWR ≥ 90kw/tonne;
    - six-cylinder vehicles with a PWR ≤ 99kw/tonne and PWR 100-109 kw/tonne; and,
    - all eight-cylinder vehicles
- Overall, the trend was for the relative rate of crashing to decrease with the age of the owner-driver and to increase with the performance of the vehicle.
- The interpretation and confidence of the observed relative crash rates are constrained by the necessary exclusion for methods reasons of some two-thirds of serious injury crashes involving drivers aged 17-19 years.
- Calculation of the relative numbers of high performance vehicles in single and two car crashes where the driver (of any age) was hospitalised or killed showed an increasing proportion of high performance vehicles in single vehicle crashes, ranging from a low of 24% for four-cylinder vehicles with a PWR 60-74 to a high of 57% for eight-cylinder vehicles with a PWR ≥ 140kw/tonne. Overall, the trend was for a higher representation of six and eight-cylinder vehicles and high performance four-cylinder vehicles in single vehicle crashes.

- Multivariate analysis of the ratio of involvement in single and two car crashes showed statistically significant effects for performance of the vehicle, year of car, age of driver, day of week and hour of day, and location of crash based on speed limit and distance in relation to the Perth metropolitan area. Hutchinson & Anderson (2012) advised that caution must be exercised in the interpretation of these individual findings.
- Analysis of the safety features and crash worthiness of vehicles by performance category for a sample of the Western Australian registered fleet, 2008, showed that safety and performance are strongly associated- Electronic Stability Control, side curtain airbags, and a 4 or 5 star ANCAP rating were more common among higher performance vehicles.

Objective Two

The methods employed by Palamara and Gavin (2005) differed somewhat to those employed in this study, particularly in relation to the selection and analysis of crash data; the retrieval of vehicle manufacturers' information to determine the performance characteristics of crashed vehicles, and the classification of the performance of vehicles. Notwithstanding these methodological differences, both studies noted that serious injury crashes involving young novice drivers in high performance vehicles account for a very small proportion of the road crash problem among this age group and more generally. The studies differed however, in relation to the observed statistical relationship between high performance vehicles and the risk of crashing. Palamara and Gavin (2005) found no evidence to support such a relationship, while this study found some evidence and trend of an increased crash risk based on the calculation of relative rates of serious injury crash involvement and the ratio of involvement of high performance vehicles in single vehicle versus two vehicle crashes. Both studies expressed similar concern that restricting young novices from certain high performance vehicles might inadvertently limit their access to vehicles with outstanding or superior technologies to reduce their risk of crash involvement and risk of injury. This study supported the conclusion through an analysis of a sample of Western Australian vehicles registered in 2008, where is was found that higher performance vehicles were also more likely to feature Electronic Stability Control, superior airbag systems, and to have 5-star ANCAP ratings (particularly among four-cylinder vehicles).

Objective Three

Four Australian jurisdictions - Victoria, New South Wales, Queensland, South Australia - currently operate a restricted vehicles scheme for novice drivers that restrict the driving of:

- all eight-cylinder vehicles;
- some normally aspirated high performance six-cylinder vehicles (at times based on a power to weight ratio limit or kilowatt output that varies across jurisdictions), and,
- turbo charged vehicles unless they are 'low powered' or diesel fuelled.

It seemed that the existing Australian vehicle performance restriction schemes were primarily introduced in response to political and community pressure rather than strong existing evidence in support of higher performance vehicles being a significant contributor the crash problem of young novice drivers. Consequently, the operational definitions of a high performance vehicle across the schemes did not necessarily align with a known increased risk of crashing for this driver group. Although there was some consistency across jurisdictions in the broad definition of a 'high performance' vehicle, the definition of a high performance normally aspirated six-cylinder vehicle was found to vary somewhat across the jurisdictions and perhaps for this reason there is strong interest, promoted by vehicle manufacturers, in the development of a national standard based on a simplified power to weight ratio of 130kw/tonne tare weight. The administrative efficiency of this definition is seemingly tied to the redevelopment of and access to the National Exchange of Vehicle and Driver Information System (NEVDIS) to enable the ready retrieval by jurisdictions of the required manufacturer's information on vehicle characteristics (e.g., kilowatt output, tare weight). However, this may not be possible for another two to three years. At present, WA's TRELIS system provides no useful information to assist with the administration and enforcement of a restricted vehicles program since it *does not* contain *all required information* to apply any of the criteria of the existing schemes or the proposed national definition based on a power to weight ratio.

From the discussions with representatives from jurisdictions that operate a restricted vehicle scheme there was reason to conclude:

- the schemes can be difficult to support, defend and promote given the absence of empirical evidence in support of a relationship between vehicle performance and crash risk;

- some schemes have difficulty in informing and advise the motoring public (and police) on permissible and restricted vehicles; for example, lists of vehicles are not readily updated, leaving the onus on the motorist and police to determine if the vehicle is unrestricted or restricted;
- the exemption process can be onerous, resource intensive, and open to abuse, which ultimately undermines the intent and possible effectiveness of the scheme; and,
- that to date, there has been little if any commitment to an evaluation of the effectiveness of the schemes.

Recommendations

Based on the findings of the various project objectives the following recommendations were provided to the Roads Safety Council for consideration.

1. Reject the introduction of a vehicle performance restriction scheme for Western Australian novice drivers.

   This study has failed to provide compelling evidence to support the introduction of a vehicle performance restriction scheme; such a scheme is therefore not recommended at this point in time. Notwithstanding the identified methodological problems for the study, there are a number of reasons to reject the introduction of a vehicle restriction scheme:

   - crashing high performance vehicles driven by novice drivers do not represent a sizable road safety problem;
   - a statistical association between vehicle performance and crash risk for young novice drivers was observed but it was not overwhelming strong or unequivocal;
   - no evaluations of the existing Australian vehicle performance restriction schemes have been undertaken; therefore, it is not known whether such schemes effectively reduce novice driver crashes and injury or whether they are cost-effective;
   - Western Australia does not presently have, nor is likely to have in the near future, ready access to the vehicle performance information required to administer and enforce a vehicle restriction scheme; and that,

- restricting access to some high performance vehicles may inadvertently restrict the access of young novices to vehicles which feature a high level of vehicle safety technology.

2. Progress the introduction of outstanding and empirically supported graduated driver training and licensing initiatives in Western Australia.

Compared with some other Australian and overseas jurisdictions, Western Australia's existing graduated driver training and licensing system could be strengthened by the adoption of other initiatives related to increased driving experience as a learner and reduced exposure to crash risk factors as a provisional driver. In relation to these issues, government should:

- expedite a thorough reexamination, particularly in relation to access and equity issues, of the current requirement for supervised driving during the learner phase to consider an increase in both the number of required hours and the conditions under which those hours are obtained (e.g., daytime versus nighttime; types of roads); and,

- move to introduce other licensing initiatives such as peer passenger restrictions and restrictions on the use of mobile phones during the provisional period. Both initiatives are likely to reduce the occurrence of distracted driving and possible risk taking when driving in the company of peers.

3. Further investigation and development of a broad platform of initiatives to more broadly target the problem of speeding and reckless driving by young novice drivers.

Whilst it is acknowledged that high performance vehicles have an increased ability to accelerate and maintain higher speeds, speeding and other reckless behaviour among young novice drivers is not confined to those driving high performance vehicles. For this reason then, it is recommended that the government of Western Australia investigate and develop initiatives that target the behaviour of the young novice driver, rather than the vehicle per se, in an effort to reduce speeding and other reckless behaviour across this target population. For example, consideration should be given to:

- the introduction of differential speeding penalties for novice drivers that would effectively result in the suspension of a provisional driver in the first 12 months for a single speeding offence (or at the very least a subsequent offence). Such a

system operates in New South Wales and could be applied here as Western Australia similarly suspends provisional drivers in the first 12 months of licensure upon the loss of four demerit points.

- the imposition of vehicle restrictions on provisional drivers who are caught speeding or engaging in reckless or dangerous driving, including BAC offences, while driving a high performance vehicle;

- the introduction of 'offence free' periods as a prerequisite for novice drivers progressing from P1 to P2 stages and from a P2 stage to full licensure; and,

- the development and implementation of a trial education program targeting novice drivers committing any speeding offence, utilising a monitored Intelligent Speed Adaptation (ISA) device fitted to their vehicle.

4. Encourage the purchase of safer vehicles by all young drivers by providing information about safe first car choices and the provision of financial incentives to purchase safer vehicles.

Young novice drivers have a higher risk of crash involvement compared with older and more experienced drivers. For this reason it is important that young drivers have access to vehicles with emerging technologies that will reduce their likelihood of crashing and also provide them with superior protection in the event of a crash. The secondary analysis in this study of a 2008 sample of vehicles registered in Western Australia showed that vehicles with superior safety features such as Electronic Stability Control, side curtain airbags, and even in some cases driver airbags, were far more common in vehicles that might otherwise be classified as high performance from a power to weight ratio point of view, especially among four and six-cylinder vehicles. Indeed, this finding suggests that any possible restriction on the access of novices to higher performance vehicles might, in the shorter term, also inadvertently restrict their access to vehicles with high safety ratings, at least until these technologies filter down over time to be more common among cheaper and lower performance vehicles. In the meantime the government of Western Australia should:

- strongly encourage the purchase of safer vehicles by young novice drivers through an educational campaign on 'safe first car choice', along the lines of campaigns undertaken in New South Wales and Victoria; and,

- consider vehicle registration rebates or discounts to young novice drivers who purchase vehicles meeting the ‘safe first car’ criteria.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the following for their assistance:

- Main Roads Western Australia for the supply of police recorded road crash data.
- The Western Australian Department of Transport (Licensing Services) for the provision of driver and vehicle licensing data.
- The relevant Transport and Licensing authorities in Victoria, New South Wales, Queensland, Tasmania, South Australia and the Northern Territory for information on existing vehicle restriction programs and other graduated licensing initiatives.
- The Office of Road Safety for their assistance with the management of the project.
- Dr Stuart Newstead, Senior Research Fellow, Monash University Accident Research Centre, for his review of the technical supplement.
- Michelle Fraser and Jessica Gorman, Research Associates, Curtin-Monash Accident Research Centre, Curtin University, for the retrieval and review of documentation.

.

1. BACKGROUND

Drivers aged 17-25 years in Australia and across all other highly motorised Western countries are substantially over-represented among drivers killed and seriously injured. In 2010, this age group accounted for 26.2% of all driver deaths in Australia (Bureau of Infrastructure, Transport and Regional Economics, 2011) despite representing only 15.4% of the population (Australian Bureau of Statistics, 2010). Furthermore, drivers aged 17-25 years were nearly twice as likely as all age drivers to be killed: 6.3 deaths per 100,000 population *versus* 3.3 for all age drivers (Bureau of Infrastructure, Transport and Regional Economics, 2011). The over-representation of this driver age group is similarly noted in Western Australia. Western Australian police-recorded crash data linked with death and hospitalisation records for the period 2002-2007 shows that drivers aged 16-25 years accounted for 30% of all fatally injured drivers of light passenger vehicles and 31% of all drivers admitted to hospital, despite representing only 14% of licensed drivers in Western Australia (Oxley et al., 2009).

Over the years a wealth of information has been amassed on the many and varied risk factors for the crash involvement of young and novice drivers (typically those in the provisional licensing period). The most consistent and strongest evidence has related to the risk associated with driver inexperience and age. Research has identified that the combination of inexperience and age associated immaturity increases the risk of crash involvement but that reductions in crash risk over time have higher associations with increasing experience - particularly for the youngest novice drivers - than increases in driver age (i.e., maturation) per se (Forsyth, Maycock & Sexton,1995) Other longitudinal investigations of the crash involvement of novices have clearly demonstrated that their risk of crashing is highest in the initial months of solo driving and decreases rapidly thereafter (McCartt, Shabanova & Leaf, 2003; Palamara, 2005). In Western Australia for example, a five-year follow-up study of the crash rates of the population of drivers first licensed at 17 years of age in 1998 (see Figure 1.1) found that novices were 60% more likely to be involved in a police reported crash in the first six month of licensing compared with the second six months and 2.4 times more likely to crash in the first year compared with the fifth year (Palamara, 2005).

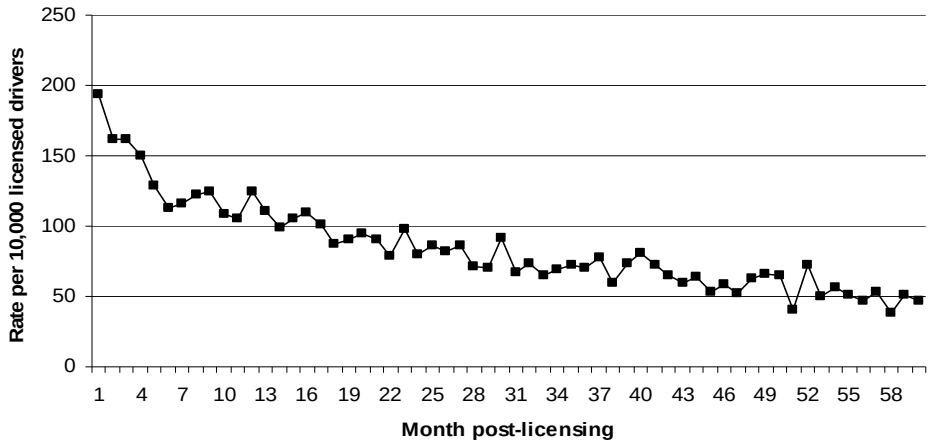

Figure 1.1 Rate of police recorded crash involvement for Western Australian drivers first licensed at 17 years of age in 1998; by month of licensure up to 60 months post licensing (source: Palamara, 2005)

The developmental immaturity of novice drivers serves to exacerbate the risk of crashing because of an associated heightened disposition to engage in on-road risk taking behaviour. For example, young and novice drivers are significantly more likely than older more experienced drivers to self-report a higher frequency of speeding (e.g., Cercarelli, Hendrie, Dyke & Ryan, 1997; Cercarelli, Hendrie, Legge & Ryan, 1997; Cercarelli, Hendrie, Ryan, Legge & Kirov, 1997; Cercarelli, Hendrie, Ryan, Legge & Kirov, 1998; Smart & Vassallo, 2005); to be charged for speeding (e.g., Rosman, 2000; Kloeden, 2008), and to be involved in speed related crashes (McKnight & McKnight, 2000; Harrison, Triggs & Pronk, 1999). While behaviours such as speeding unequivocally increase the risk of crash involvement, it is reasonable to question whether all instances of risk taking by drivers, such as speeding, are deliberate and motivated by personal gain rather than being unintentional and the result of inexperience (Williams, 1998). This issue does not however mitigate the need for appropriate countermeasures to manage risk taking and risky behaviours among those drivers who have the least experience and maturity.

In summary, there is a substantial body of research evidence to confirm that the inexperience and youthfulness of young novice drivers means that they are more likely than older, experienced drivers to engage in risky on-road behaviours - either deliberately or unintentionally - and to be involved in a crash. To counter these

outcomes, Graduated Driver Licensing systems have developed across countries such as North America, New Zealand, the United Kingdom and Australia that aim to control, to varying degrees, the exposure of novices to known, high crash risk factors (e.g., night-time driving; consumption of alcohol; presence of passengers; use of mobile phones) while allowing novices the opportunity to gain experience and safe driving skills under low risk situations. To date there is good evidence of the effectiveness of the format of graduated licensing and its varying components in Nth America (Foss & Evenson, 1999; Shope, Molnar, Elliott, & Waller, 2001; McKnight & Peck, 2002; Vanlaar, Mayhew, Marcoux, Wets, Brijs, & Shope, 2009; McCartt, Teoh, Fields, Braitman & Hellinga, 2010) and New Zealand (Begg & Stephenson, 2003).

Graduated Driver Licensing systems vary somewhat from country to country and even across Australia. Unlike their overseas counterparts, some Australian systems include restrictions on the power or performance of the vehicle novices are permitted to drive. Legislation prohibiting novices from driving vehicles exceeding 125 kilowatts per tonne of kerbside weight was first introduced in the state of Victoria in 1995 (Palamara & Gavin, 2005). In more recent years other versions of a vehicle restriction scheme have been introduced by New South Wales, Queensland, South Australia, and Victoria that include specific reference to the number of engine cylinders and method of aspiration (see Chapter 4 for a summary of these restrictions).

The need to introduce a restricted vehicles scheme for Western Australian novice drivers has been debated since the turn of the century as part of the on-going redevelopment of the state's Graduated Driver Licensing system. To assist the debate a limited investigation of the relationship between vehicle performance and crash risk for WA novice drivers (Palamara & Gavin, 2005; see Chapter 2 for a review) was commissioned. The investigation primarily noted that high performance vehicles (defined as those exceeding a power to weight ratio of 125 kilowatts per tonne of vehicle weight, the Victorian restriction at the time) were only marginally represented in the serious injury crashes of novice drivers. Notwithstanding the many and varied limitations of this investigation the government of the day dismissed the need for a restricted vehicle scheme. However, over the intervening years a number of high profile novice driver crashes have occurred which has led to the

reconsideration of the need to introduce such a scheme as part of the state's Graduated Driver Licensing system.

1.1 Aim and Objectives

This program of research was commissioned by the Road Safety Council of Western Australia to provide more definitive contemporary evidence of the relationship between vehicle performance factors, age of driver, and risk of involvement in a serious injury crash to reconsider the need for a restricted vehicles scheme for novice drivers.

The specific objectives of the program of research were as follows:

Objective One

To investigate the relationship between vehicle performance and serious injury crash involvement among Western Australian drivers (i) aged 17-19 years holding a provisional, restricted 'C' class motor car drivers' licence and (ii) drivers older than 19 years holding a full, unrestricted 'C' class motor car drivers' licence

Objective Two

To compare the finding from Objective 1 with the findings of the previous investigation undertaken by Palamara and Gavin (2005).

Objective Three

To consider the recent experiences of other Australian jurisdictions with respect to vehicle performance restrictions for novice drivers

Objective Four

To provide recommendations to the Road Safety Council of Western Australia regarding the need for vehicle performance restrictions for novice drivers and the form of those restrictions.

1.2 Project Activities

The main project activities to address the aims and objectives were as follows:

Activity One

The identification and review of published scientific literature to describe the existing relationship between vehicle performance factors and driver behaviour and crash involvement.

Activity Two

The analysis of Western Australian motor vehicle crashes 2001-2008 resulting in serious injury (killed or hospitalised) linked with driver licensing, vehicle registration, and vehicle performance data to determine the statistical relationship between vehicle performance and risk of crashing.

Activity Three

A critical comparison of the findings of Activity Two with the findings of other relevant research, particularly the research undertaken by Palamara and Gavin (2005).

Activity Four

The retrieval of on-line information from relevant Transport and Licensing websites across Australia and telephone interviews with key Transport, Licensing and Road Safety stakeholders to describe the development, form, and management of restricted vehicle programs operating in Australia.

Activity Five

Based on the findings of Activities One to Four, the development of a series of recommendations for the Road Safety Council on the need or otherwise of a restricted vehicles program, its form if required, and/or other related initiatives to manage novice driver behaviour and their risk of crash involvement.

1.3 Project Management

The project was undertaken by the Curtin-Monash Accident Research Centre (C-MARC) (Curtin University, Western Australia and Monash University, Victoria) in collaboration with the Centre for Automotive Safety Research (CASR). The former institution was primarily responsible for the management of the project and Activities One, Three and Four. The CASR was primarily responsible for Activity Two and the production of the technical supplement. Both institutions contributed to Activity Five.

1.4 Ethics

The program of research was undertaken with the approval of the Human Research Ethics Committee of the School of Public Health, Faculty of Health Sciences, Curtin University of Technology (approval SPH-38-2011). Approval was also provided by

the Human Research Ethics Committees of The University of Adelaide and Monash University.

2. LITERATURE REVIEW

2.1 Search and retrieval of the scientific literature

The search for literature on the relationship between vehicle performance, driver behaviour, and crash involvement was undertaken using the following databases: Google scholar, ProQuest, Transportation Research Broad databases; Current Contents, Scopus, Factiva and EconLit. 'Key words' were used to identify and retrieve relevant local, national and international publications (books, reports, scientific journal articles, conferences papers). Numerous studies of the relationship between vehicle characteristics and driver behaviour and driving outcomes were identified but most were excluded from the review because they did not explicitly consider the performance of the vehicle per se but focused on issues such as vehicle type and vehicle size and weight. Very few published investigations of the relationship between vehicle performance factors and driver behaviour and driving outcomes were identified. Further still, only a minority of studies considered the relationship among the youngest and most inexperienced novice drivers.

2.2 Vehicle performance and on-road driver behaviours

As vehicle performance influences both the ability to accelerate and to achieve high travel speeds it is not surprising that speeding and speed related behaviours have been the primary focus of on-road behaviours associated with driving a high performance vehicle. Somewhat related are the investigations of the relationship between vehicle performance and driving aggression and road rage.

In the first of a series of investigations undertaken by Horswill and Coster (2002), vehicle performance (based on the summation of the observed vehicles' top speed, acceleration and brake horsepower) was analysed for its influence on the observed speed of drivers in the United Kingdom while controlling for driver age and gender, location of travel and slope of road. An independent linear relationship was found between vehicle performance and observed driver speed, in that drivers of higher performance vehicles were more likely to travel at higher speeds. Driver age was also significantly related to observed speed though the interaction between driver age and vehicle performance was not addressed. Subsequent investigations to determine the causal nature of the relationship led Horswill and Coster (2002) to conclude that the relationship is bi-directional: drivers who take more risk are also likely to choose faster cars, while driving a faster high performance car is also likely to influence one's intention to take risks such as speeding. One possible implication of the

suggested bi-directional nature of the relationship is that drivers who are predisposed to risk taking will most likely choose the most available and affordable car they can to satisfy this motivation, while the risk taking of other drivers may be dependent on their access to a high performance vehicle.

A qualitative examination of the crash reports of 3,000 drivers aged 17-25 years in the United Kingdom (Clarke, Ward & Truman, 2002) provides some evidence to suggest that driving a high performance vehicle is associated with exceeding the speed limit, which in turn was identified as a 'trigger factor' for involvement in a fatal or serious injury crash. Based on their review of crash records the authors concluded that crash involved young drivers of performance vehicles were more likely to have been exceeding the speed limit or driving recklessly compared with a driver not in a performance vehicle. Unfortunately little information was provided to describe the operational definition of a vehicle of 'above average performance other than a reference to vehicles with a 16 valve engine.

Other investigators have considered whether driving a high performance vehicle necessarily increases the risk of driving aggressively (Krahe & Fenske, 2000) and displaying road rage (Smart, Stoduto, Mann & Adlaf, 2004). In the first study of aggressive driving 150 German male drivers aged 20-67 years were surveyed. The performance of the driver's vehicle was defined by horsepower (without reference to weight) and related to the drivers responses on a range of survey instruments measuring driving aggression. Multiple regression analysis showed that the horsepower of the vehicle accounted for just under 4% of the variance in driving aggression scores, while 25% of the variance was explained by a measure of driver masculinity ('macho' personality'). Age of driver accounted for a further 6% of variance in scores. Interestingly, when questioned about their car preferences, drivers who gave highest priority to the speed or sportiness of the car scored highest on a measure of masculinity or 'macho' personality. This later finding perhaps suggests that driver personality is an important element in the choice of vehicle and also driving style.

In the related telephone survey study of 1,600 Canadian drivers aged 18+ years, Smart et al. (2004) reported that drivers of high performance cars (categorised from respondents description of their cars as a 'muscle' or 'sports' car) were significantly more likely than drivers of other cars to report having perpetrated acts of minor road rage (e.g., shouting, cursing, threatening behaviour toward other drivers without

assault or property damage) in the previous 12 months. Performance car drivers were no more likely than drivers of other vehicles to have committed more serious acts of road rage (property damage and assault). While the definition of a performance car in this study is somewhat loose and subjective, the trend is consistent with other studies that suggest drivers of performance vehicles are somewhat more likely to be antisocial and aggressive as displayed by their speeding behaviour.

2.3 Vehicle performance and crash involvement

2.3.1 Australasian research

The first published investigation of the relationship between vehicle performance and crash involvement was undertaken by Drummond and Healy (1986) in the Australian state of Victoria. Using an on-road driving exposure survey methodology linked with crash and vehicle (i.e., brake horsepower) data, the authors found that drivers holding a licence for less than one year and driving a vehicle exceeding 150 brake horsepower (approximately equivalent to 112.5 Kilowatts) had a crash rate (adjusted for exposure) some 20% higher than similarly licensed drivers in vehicles less than 150 brake horsepower. No information was provided on the statistical significance of the difference in the rate. It is also worth noting that the measure of performance in this study, brake horsepower, did not consider the weight of the vehicle which is known to influence vehicle acceleration and speed. Drummond and Healy (1986) concluded that *"...increased vehicle power does not contribute disproportionately to inexperienced driver risk - in absolute terms…"* (page 158).

In a later review of this work, the first author (Drummond, 1994) described the investigation as preliminary rather than conclusive, as it provided only tentative and limited findings because of the small number of vehicles in the 150+ brake horsepower group studied. Drummond (1994) also stated the findings did not provide *"…sufficient justification for the implementation of a novice driver vehicle power restriction…"* (page 54) and that any such restriction would likely yield a crash reduction in the vicinity of only 2%. Contrary to this recommendation Victoria introduced their restricted vehicles scheme in 1995 banning novices from vehicles with a power to weight ratio ≥125kw/tonne.

The second Australian investigation of the relationship between vehicle performance and crash risk was undertaken by Palamara and Gavin (2005). In this Western Australian study, serious injury crashes (resulting in death or hospitalisation)

involving a driver under 20 years of age and licensed for less than two years (equivalent to the provisional licensing period) were identified and the power to weight ratio of the crashing vehicle calculated. Crashes involving an illegal driver Blood Alcohol Concentration Level were excluded from analysis on the presumption that alcohol was likely to be the main cause of the crash. A total of 1,065 crashes met the criteria for inclusion but was later reduced to 662 as a Vehicle Identification Number (VIN) could not be retrieved from the Department of Transport database to assist with the identification of the vehicle's power output (kilowatts) and kerbside weight from the manufacturer's database of vehicle specifications.

Of the 662 relevant crashed vehicles, 65% had a PWR ≥50kw/tonne and <75kw/tonne, while 2.9% (n=19) had a PWR ≥100kw/tonne. Only two vehicles had a PWR exceeding 125kw/t which was the exclusion PWR under Victorian vehicle restriction scheme at the time of the research. The remainder evidenced a power to weight ratio less than 50kw/tonne. An associated case-control investigation based on n=84 crashing drivers matched for age, gender, year of licensure and length of licensure with the vehicle performance information obtained via a survey of n=84 drivers who had not crashed showed that increasing vehicle power to weight ratio was not statistically associated with a significantly increased risk of crashing.

Though the research by Palamara and Gavin (2005) provided some descriptive evidence that young driver serious injury crashes occurring within two year of licensure are not characterised by high vehicle power to weight ratios, the findings from the case-control study are of limited value due to the small number of case-control pairs. The general findings are also limited by a number of other methodological issues. For example, excluding crashes involving illegal BAC levels may have inadvertently excluded drivers of high performance vehicles if on-road risking taking of this sort and the decision to drive a high performance vehicle are inter-correlated via driver characteristics. Secondly, some 38% of novice driver serious injury crashes occurring during the two year study period were excluded because a VIN was not available to retrieve vehicle performance information. Thirdly, the authors made no attempt to categorise the crashes by type (speed related; single vehicle run off road etc) to investigate the possible impact of vehicle performance on crashes that have a higher probability of being speed related. Finally, the vehicle performance information retrieved from the on-line database of

manufacturer information was pertinent to 'base model' vehicles only and therefore may have underestimated the crashed vehicle's power to weight ratio if the vehicle in question was anything other than a base model.

The absence of strong evidence and the limitations on the validity of the findings led Palamara and Gavin (2005) to judiciously recommend that *"Western Australian Provisional drivers should not be subject to a vehicle power to weight ratio restriction"* (page 24) and that *"..the speeding behaviour of the young novice driver be targeted and regulated through changes to the licensing system and penalty structure"* (page 24).

The most recent Australian study of the effect of vehicle performance on the risk of crashing among young drivers was undertaken by Keall and Newstead (2012). The study specifically sought to determine the potential safety benefits of a restricted vehicle program using crash and vehicle registration data from five Australian (New South Wales; Victoria; Queensland; South Australia, and Western Australia) states and New Zealand. In this study vehicles were categorised as 'high performance' in accord with the criteria applied by *any* of the three Australian states (Victoria, New South Wales, Queensland) operating a restricted vehicles program at the time of the study.

In the first instance the authors identified that less than 1% (0.84%) of all vehicles manufactured 1990-2008 and registered to drivers aged 15-24 in New Zealand were classified as high performance. When analysed by market group, this percentage was highest for those in the 4WD large vehicle range (3.77%). The annual rate of crash involvement over the period 2004-2009 per vehicle in New Zealand was calculated for all ages and those aged 15-24 years. The rate of crash involvement for high performance vehicles involving drivers aged 15-24 years (1.08%) was somewhat higher than that for all age drivers (0.28%) of high performance vehicles and slightly higher than that for younger age drivers of non-high performance vehicles (0.85%). The authors concluded that if New Zealand restricted high performance vehicles in accord with those restrictions operating in Australia the estimated injury savings for young drivers could be up to 1.9% and up to 3.9% if the restrictions included other vehicles identified to be involved in crashes where excessive speed was deemed to be a contributing factor.

Analysis of the Australian crash data showed that up to 7.2% of males and 2.1% of females under 25 years involved in a crash across the five Australian jurisdictions studied were driving a high performance vehicle defined by any of the three states where a restriction applies. When restricted to crashes where the driver was killed or hospitalised (KSI), high performance vehicles accounted for 10.6% and 1.5% of KSI respectively among male and female drivers under 25 years of age. Of particular interest was the finding that 3.4% of crashes in Western Australia involving provisional drivers less than 25 years of age were driving a vehicle that would be categorised as high performance under the various existing Australian restrictions.

Based on crashes over the period 2005-2009 in Western Australia *and* South Australia (who did not have vehicle restrictions during the study period) where the proportion of the crash fleet involving drivers under 25 years meeting the restricted vehicles criteria was 4.7%, Keall and Newstead (2012) estimated that drivers in such vehicles were nearly twice as likely to crash compared with those in non-restricted vehicles, and that the potential injury saving was around 2.2% for this driver age group. A near three-fold increase in the estimated injury saving was calculated if the restricted vehicles included those previously identified from the analysis of New Zealand data to be involved in high-speed collisions. These estimates do not however, distinguish between young novice (provisional) and more experienced (non-provisional) young drivers. The other issue of note is that potential estimates are based on the assumptions of perfect compliance with the proposed restrictions, and second, that the move to driving a non-high performance or speed crash related vehicle will effectively change the crash risk of the target drivers (Keall & Newstead, 2012).

The various findings led Keall and Newstead (2012) to conclude that the restricted vehicles in question *"..have a statistically significant higher crash and injury risk than other vehicles for young drivers"* (page 33) and that their restriction as part of a graduated licensing program is rational. However, this conclusion was tempered by the relatively small number of vehicles the current restrictions apply to and the associated modest safety benefits being outweighed by the cost of implementation (Keall & Newstead, 2012).

2.3.2 International research

An early investigation of the association between vehicle performance and crash involvement undertaken by Fontaine (1994) considered crashes occurring in France during the period 1991-1992. The crash risk per kilometres travelled was calculated for categories of crash involved male and female drivers based on age, vehicle power to weight ratio (in vehicle weight ranges), and location of crash. Fontaine (1994) noted that the highest relative risk of crash involvement (all types) was found for the category of drivers who were less than 30 years of age, driving vehicles with a PWR ≥75kw/1,000 kg (within the 800kg to 1,000kg vehicle weight range) in non-urban areas. When single vehicle crashes were specifically considered, a significant effect of PWR on the probability of being killed was identified, but only for the category of *male drivers under 30 years of age*. Based on the derived estimates for the effect of PWR, the probability of a young male driver being killed when driving a vehicle with a PWR of 100kw/1,000kg was 0.11, compared with 0.08 for a vehicle with a PWR of 50kw/1,000kg. Fontaine (1994) concluded that this difference was most likely due to vehicle speed. Overall, the findings suggested that drivers under 30 years of age show a higher risk of crash involvement when driving a high performance car of *medium weight* (ie., sports type cars) in non-urban areas (presumably where permissible speeds and illegal speeds are higher relative to urban areas). The findings also suggested that driving a vehicle with a high PWR is particularly problematic for young males (less than 30 years of age) in the case of single vehicle fatal crashes rather than for all younger age drivers and across all crash types. Unfortunately this study did not specifically address novice drivers.

The aforementioned qualitative investigation of young driver crashes in the United Kingdom (Clarke et al., 2002) reported some evidence to support the increased risk of crashing when driving an above average performance vehicle. In approximately 8% of crashes where the young driver was either fully or partially 'at fault', a vehicle of 'above average' performance' was being driven. Clarke et al. (2002) also noted that a higher proportion of crashes involving above average performance vehicles occurred at night (which perhaps coincides with recreational/leisure driving) and were driven by males. Young drivers who crashed in performance cars were also more likely to have taken the car without the owner's consent. This finding potentially confounds the relationship between exposure to a higher performance vehicle and crash risk, since driver characteristics associated with the

illegal use of the (higher performance) car may be highly correlated with other risk taking behaviours related to crashing. Overall, it is difficult to determine the significance of these findings as the operational definition of the category of 'above average' performance vehicles was not well described, nor was any other information provided to indicate whether 8% is an over-representation for the number of 'above average' performance vehicles registered to young drivers.

2.4 Conclusion

A limited number of studies of vehicle performance and driver behaviour and driving outcomes were available for review. Furthermore, even fewer of these studies focussed on young novice drivers and used acknowledged, standard definitions of vehicle performance such as power to weight ratio. The considerable variability in the research methodologies in relation to the driver groups, independent and dependent variables, and data collection methods makes it difficult to identify strong and valid findings regarding a consistent and quantifiable influence of vehicle performance on driving outcomes. That said, the research shows a reasonably consistent theme of drivers of high performance vehicles, including young drivers and males, as being more likely to engage in anti social and risk taking behaviour on the road and of having a higher risk of involvement in a crash. In relation to the last point, the Australasian research provides the strongest evidence of this though it also notes that young drivers in high performance vehicles involved in a crash represent a relatively small proportion of crashes among this age group.

What is most apparent from the above review is that little attention has focussed on the relationship between driver characteristic and vehicle selection and the interaction between these in relation to driving outcomes. It is not entirely clear whether driving outcomes are directly influenced by vehicle performance per se or whether drivers with certain dispositions or personality traits - such as sensation seeking which has been significantly and consistently associated with on-road risk taking behaviour and crash outcomes (see the review by Palamara et al., 2012) - seek out certain types of vehicles to express their behavioural style. If so, would restricting high sensation seeking drivers to lower performance vehicles significantly alter their likelihood of engaging in risky behaviours and becoming involved in a crash? It is quite likely they would seek to drive the highest performance vehicle they were legally able to and drive it in a manner that maintains their higher crash risk. This issue requires further investigation.

3. ANALYSIS OF WESTERN AUSTRALIAN SERIOUS INJURY CRASH DATA 2001-2008

Police reported serious injury crashes occurring in Western Australia 2001-2008 were analysed to determine the statistical relationship between vehicle performance and risk of serious injury crash involvement. This work was undertaken by the Centre for Automotive Safety Research, The University of Adelaide and reported by Hutchinson & Anderson (2012). The full technical report documenting the methods and findings is presented as a supplement. A general discussion of the findings, particularly in relation to the previous Western Australian research undertaken by Palamara and Gavin (2005) is presented in Chapter 5.

4. REVIEW OF EXISTING VEHICLE PERFORMANCE RESTRICTION SCHEMES

4.1 Retrieval of information

The review was limited to Australia as vehicle performance restriction schemes are not known to operate elsewhere. At present, schemes operate in Victoria, New South Wales, Queensland and South Australia. Accordingly, the Transport and/or Licensing websites of these jurisdictions were accessed and information retrieved on the nature of the schemes. In addition, key Transport and/or Licensing personnel were identified and consulted in each of these jurisdictions (over the period 2010-2012) to obtain further information regarding the circumstances and evidence leading to the introduction of the restriction, the nature of exemptions if any, and current procedures for implementing, monitoring/enforcing, and evaluating the system. Similarly, relevant personnel in Tasmania, the Australian Capital Territory, and the Northern Territory were contacted to enquire why restrictions have not been introduced to date and whether restrictions are likely to be introduced in the future and under what circumstances.

4.2 Overview of existing Australian vehicle restriction schemes

Restriction on the access of Australian novice drivers to 'high performance' vehicles was first introduced in Victoria, 1995. Under the scheme, provisional drivers were prohibited from driving a motor vehicle that exceeded 125 kilowatts per tonne of vehicle kerbside weight or with an engine capacity to weight ratio exceeding 3.5 litres per tonne. New South Wales was the next jurisdiction to introduce vehicle restrictions in 2005, followed by Queensland in 2007 and South Australia in 2010. At present, all four jurisdictions operating a vehicle restriction scheme define a high performance vehicle by the number of cylinders (vehicles with eight or more cylinders are restricted), method of aspiration (turbo/super charged are generally restricted), fuel type (exclusions may be provided to diesels fuel vehicles) and kilowatt output (which varies across the jurisdictions). Victoria abandoned their Power to Weight Ratio criteria in 2007 to be consistent with the broader criteria first introduced by New South Wales. The main elements of each jurisdiction's vehicle restriction scheme are presented in Table 4.1. The information does not represent a definitive description of the existing schemes as some administrative and technical details have been omitted for the sake of brevity (e.g., those related to acceptable and unacceptable engine performance modifications).

Table 4.1 Summary of novice driver vehicle performance restriction schemes operating throughout Australia^

Jurisdiction	Details of Provisional Driver Restricted Vehicles			
	Eight or more Cylinders	**Six-Cylinder**	**Turbo/Supercharged**	**Conditions and Exemptions**
Victoria	All	Certain' nominated' high performance vehicles per published list (not exhaustive but indicative). Criteria are based on whether the vehicle is 'family' type or sports (2 door) vehicle. No defined PWR or KW rating identified.	Diesel fuel vehicles exempted, as are low powered petrol vehicles with a PWR <100 and those with a PWR 100-125 and considered to be a family, non-sports, vehicle.	Restriction applies to Provisional drivers. Exemption to drive a 'high performance' vehicle can be granted if the vehicle is required for genuine employment purposes or would otherwise cause undue hardship.
New South Wales	All, except that 8-cylinder 4WD vehicles may be driven by those in rural/remote areas if no practical alternative is available.	Designated list of restricted vehicles that has not been updated since 2007. Originally vehicles over 200kw power output were restricted but this was found to include some 'appropriate' vehicles. 135 PWR is now the 'cut point' but this has not been publicly stated nor has the public list been updated to reflect this.	Diesel fuel vehicles exempted, as are low powered petrol vehicles with a PWR <125	Restriction applies to Provisional drivers. Exemption to drive a 'high performance' vehicle can be granted if the vehicle is required for genuine employment purposes or the car was owned prior to July 2005.
Queensland	All	Vehicles with an engine output of more than 200kw. This will soon be increased to 210kw to permit certain 'family' type vehicles to be driven.	Diesel fuel vehicles exempted, as are moderate powered petrol vehicles (as per published list).	Restriction applies to drivers on P1 and P2 under 25 years and to those returning from disqualification and younger than 25 years. Exemption to drive a 'high performance' vehicles can be granted if the vehicle is required for work or study purposes or to obtain medical treatment for self or other family member or was owned prior to June 30th 2007.
South Australia	All	Certain' nominated' high performance vehicles per published list (last updated May 2011).*	Diesel fuel vehicles exempted, as are moderate powered petrol vehicles (as per published list).*	Restriction applies to P1 and P2 drivers under 25 years of age, and those under 25 years returning to driving after disqualification. Exemption to drive a 'high performance' vehicle can be granted if the vehicle is required for work purpose or no other vehicle is available for use. Exemption also granted if vehicles was owned prior to September 2010.

^ As at February 2012. *Further technical details were sought from South Australia but were not provided.

Table 4.1 shows that there is consistency across the jurisdictions in regards to the restriction of vehicles with eight or more cylinders but some variation in regard to the restriction on certain six-cylinder vehicles, turbocharged vehicles, and vehicle

power to weight ratio limits. All jurisdictions apply the restriction through the entire provisional driver period and consider applications for exemptions.

Consultation with representatives from the jurisdictions restricting access to high performance vehicles revealed that some jurisdictions are experiencing difficulty maintaining updates of restricted vehicles via published lists, while most find it difficult to manage the overwhelming level of administration required to process applications for exemptions to drive restricted vehicles. In at least one jurisdiction, Victoria, the application to drive a restricted vehicle (a V8 BMW 7 Series) has resulted in court action by the applicant (Robertson *versus* VicRoads). Whilst the presiding Magistrate ruled in favour of VicRoads to uphold the restriction on the use of the vehicle it is understood the applicant is considering pursuing the matter in a higher court with support from vehicle manufacturers Mercedes, BMW and Volkswagen (Robertson, personal communication 2011).

All jurisdictional representatives acknowledged that a combination of community, media and political pressure was largely responsible for the introduction of the initiative. The initiative was not based on reliable scientific evidence of a relationship between vehicle performance and novice driver crash risk or calculations of the safety benefit of restricting the access of young novice drivers to high performance vehicles. Most representatives stated that vehicle restrictions were introduced and 'marketed' as being supportive of their graduated licensing schemes and/or to combat 'hooning' behaviour.

The jurisdictional representatives were not at the time able to provide reliable information on the level of compliance with their restricted vehicle schemes. It was acknowledged however, that 'enforcing' the restriction is problematic since it may be difficult for police to be certain which vehicle is restricted (particularly if lists of restricted vehicles are not regularly updated). This issue was cited as one of the reasons why a standardised measure of 'high performance' based on vehicle power to weight ratio is being proposed for use nationally (see Section 4.3).

To date, Victoria and New South Wales (the longest operating programs) have not per se evaluated the impact of their vehicle restriction programs on novice driver crashes. Queensland is reportedly doing so as part of an on-going comprehensive review of their graduated licensing scheme and South Australia stated it will consider

an evaluation in the future. New South Wales claimed that their recently identified reduction in novice driver crashes and traffic offences had more to do with the overall package of recently introduced graduated licensing initiatives than vehicle restrictions per se. Of the many initiatives recently introduced in NSW, it was reported that the automatic suspension of provisional drivers for three months upon incurring *any speeding offence* had been particularly successful in curbing speeding behaviour (21% reduction in speeding offences from 06/07 to 07/08) and related crashes. In NSW, as in Western Australia, provisional drivers are automatically suspended when they have accrued four demerit points. Unlike Western Australia however, the demerit point penalty for the lowest level speeding offence committed by a provisional driver in New South Wales is four points, which by default will result in the automatic suspension of the driver's licence.

The jurisdictional representatives acknowledged that a vehicle performance restriction is an initiative that does not target the broader population of novice drivers and the most important factors contributing to their over-representation in crashes, which include inexperience, risk taking, and speeding. The representatives agreed that a restriction on high performance vehicles appears to target only minority of 'at risk' drivers, while other noteworthy and effective initiatives of graduated licensing target the broader population of novice drivers at risk and who account for the majority of crashes and traffic offences.

Licensing and/or Transport representatives from the Australian Capital Territory and the Northern Territory advised they were not in the near future considering the introduction of a restricted vehicle scheme. Both jurisdictions advised there was no reason to believe that high performance vehicles were a significant contributor the novice driver crash problem in their jurisdictions or nationally. The Northern Territory also considered that their 'anti-hoon' policies introduced in 2009 would indirectly target the behaviours of those who might risk take in high performance vehicles.

Tasmania advised that vehicle restrictions had been previously considered as part of a review of Novice Driver Reforms, and supported by key stakeholders, but there was however no compelling evidence of an associated road safety benefit. Hence there is currently no intention to introduce the restriction.

4.3 The establishment of a national definition of 'high performance'

Although there is some consistency across jurisdictions in the broad definition of a 'high performance' vehicle, the *Austroads* Registration and Licensing Program Task Force has been approached by the Federal Chamber of Automotive Industries (FCAI) to develop a nationally consistent policy regarding the restriction of high performance vehicles. This request was prompted by criticisms of the existing vehicle restriction schemes by FCAI members in regard to the at-times variable definition of a high performance vehicle and how the restrictions are applied. After a number of workshops on the issue involving representatives from the FCAI and Australian Transport and/or Licensing agencies, an in-principle agreement has been reached for a national definition based on a simplified single Power to Weight Ratio (PWR) measure of 130 kilowatts per tonne of tare weight. Activation of the measure could be as early as 2013/2014, subject to modifications of the national database of drivers and vehicles, known as the National Exchange of Vehicle and Driver Information System (NEVDIS). NEVDIS would be used to provide all jurisdictions with accurate information on vehicles banned under the new national measure. It should be noted however, that agreement on a PWR of 130kw/tonne was reached despite acknowledgement by the Task Force that there is currently no reliable empirical evidence supporting a relationship between vehicle performance and crash risk for young novice drivers.

Jurisdictional representatives from the ACT and the Northern Territory commented that the establishment of a national definition for a high performance vehicle would not necessarily mean they would adopt the initiative.

4.4 Summary and concluding comments

Four Australian jurisdictions currently operate a restricted vehicles scheme for novice drivers that restrict the driving of:

- all eight-cylinder vehicles;
- some normally aspirated high performance six-cylinder vehicles (at times based on a power to weight ratio limit or kilowatt output that varies across jurisdictions); and,
- turbo charged vehicles unless they are 'low powered' or diesel fuelled.

The definition of a high performance normally aspirated six-cylinder vehicle varies somewhat across the jurisdictions and perhaps for this reason there is strong interest,

promoted by vehicle manufacturers, in the development of a national standard based on a simplified power to weight ratio of 130kw/tonne tare weight. The administrative efficiency of this definition is seemingly tied to the redeveloped of and access to the NEVDIS database to enable the ready retrieval by jurisdictions of the required manufacturer's information on vehicle characteristics (e.g., kilowatt output, tare weight). However, this may not be possible for another two to three years. At present, WA's TRELIS system provides no useful information to assist with the administration and enforcement of a restricted vehicles program since it *does not* contain *all required information* to apply any of the criteria of the existing schemes or the proposed national definition based on power to weight ratio.

From the discussions with representatives from jurisdictions that operate a restricted vehicle scheme there is reason to believe:

- the schemes can be difficult to support, defend and promote given the absence of empirical evidence in support of a relationship between vehicle performance and crash risk;
- some schemes have difficulty in informing and advising the motoring public (and police) on permissible and restricted vehicles; for example, lists of vehicles are not readily updated, leaving the onus on the motorist and police to determine if the vehicle is unrestricted or restricted;
- the exemption process can be onerous, resource intensive, and open to abuse, which ultimately undermines the intent and possible effectiveness of the scheme; and,
- that to date, there has been little commitment to an evaluation of the effectiveness of the schemes.

To conclude, it would appear that the existing Australian vehicle performance restriction schemes were primarily introduced in response to political and community pressure rather than strong existing evidence in support of higher performance vehicles being a significant contributor the crash problem of young novice drivers. Consequently, the operational definitions of a high performance vehicle across the schemes do not necessarily align with a known increased risk of crashing for this driver group. From an administrative and enforcement point of view the schemes can be cumbersome and vague and readily circumvented and undermined through the

exemption process. Finally, the interest in a national, standardised definition of a high performance vehicle using power to weight ratio suggests that WA should in any event delay the introduction of a scheme (if the need exists) until the national definition is finalised and the supporting data systems (NEVDIS) are available.

5. DISCUSSION

In this Chapter the findings relating to Objectives One to Three are discussed.

5.1 Objective One

Investigation of the relationship between vehicle performance and the risk of serious injury crash involvement among young novice drivers compared with older age Western Australian drivers

The findings related to this objective, based on the analysis of crash and other data, were presented in the report by Hutchinson and Anderson (2012) (see the Technical Supplement). The report also provided a cogent discussion of the findings which should be read in conjunction with this section.

Bearing in mind the identified limitations of the methodology, there was some persuasive rather than definitive evidence to support the view that young novices in high performance vehicles are more likely to be involved in crashes resulting in a serious injury (i.e., death or hospitalisation). Furthermore, other evidence suggested that higher performance vehicles were more likely to be involved in single vehicle as opposed to two vehicle crashes. This later finding suggests that the combination of driver and high performance vehicle factors are more likely to be causally responsible for such crashes compared with those involved in two vehicle crashes where fault or responsibility may be shared between the two drivers and vehicle combination.

These findings alone do not however, provide the level and strength of evidence to make a compelling case for the introduction of vehicle restrictions or what form they should take. This study, like the previous investigations undertaken by Palamara and Gavin (2005) and Keall and Newstead (2012), was not able to disentangle the effect of vehicle performance on crash risk from the effect of driver characteristics (other than age). For example, it may be that drivers who are more inclined to drive a high performance vehicle are also highly disposed to risky behaviours such as speeding and drink driving. If so, restricting such risky drivers to lower performance vehicles may have little impact on their behaviour and risk of crashing. Alternatively, it may be more productive to implement additional initiatives to broadly decrease speeding among young novice drivers, irrespective of the vehicle they drive.

One of the most significant limitations of this study in determining the increased risk of crashing associated with high performance vehicles was the low number of serious

injury crashes involving young novice drivers. Indeed the low number of fatal and hospitalisation crashes involving young novice drivers in high performance vehicles is a telling observation on the size of the problem. Given the low number of crashes, Hutchinson and Anderson (2012) noted that even the most effective vehicle restriction policy would at best have minimal impact on the overall level of crashes and injury. This point was also made by Drummond (1994) who suggested that restrictions based on vehicle performance might at best lead to a 2% reduction in crashes. When the granting of exemptions and the unknown level of compliance is taken into account there is even more reason to question the likely effectiveness and cost-benefit of a vehicle restriction program to reduce road injury.

5.2 Objective Two

To compare the finding from Objective One with the findings of the previous investigation undertaken by Palamara and Gavin (2005).

5.2.1 Methods issues

Before comparing and contrasting the findings of this study with those of the earlier WA investigation conducted by Palamara and Gavin (2005), it is worth noting the main differences between the studies in the research methods and analytical techniques employed.

Both studies considered serious injury crashes only, though the earlier study was restricted to the investigation of crashes occurring 1999 and 2000 compared with crashes occurring 2001-2008 for this study. While both studies addressed crashes involving provisional drivers aged 17-19 years, *most* crashing drivers in the current study were licensed under a revised Graduated Driver Training and Licensing program (introduced 2002), which may in itself reduce the crash risk of novice drivers relative to drivers investigated in the earlier study. The earlier study also sought to control for the effect of alcohol on the risk of crashing by excluding alcohol related crashes from the analyses, whereas the current study did not do so. The exclusion of such crashes in the earlier study may have inadvertently excluded crashes involving high performance vehicles. Unfortunately this was issue was not verified.

Most importantly, there were marked differences between the studies in the retrieval and validity of vehicle performance data and the classification of vehicles as ‘high performance’. While both studies used the Vehicle Identification Number of the

crashed vehicle to retrieve manufacturer's information to determine the performance of the vehicle, the earlier study could not retrieve information for the exact vehicle using the complete VIN but used an abbreviated VIN to retrieve generic information on the base model/variant of the vehicle. This may have resulted in the invalid retrieval of information for some vehicles if the crashing vehicle was of a higher specification. In contrast, the current study was able to access full manufacturer's details for the specific crashed vehicle as recorded for the vehicle when first registered.

In relation to the classification of vehicle performance, performance in the earlier study was simply and solely based on the vehicle's power to weight ratio with PWR ≥ 125 kw/tonne denoting a 'high performance' vehicle (as per the Victorian scheme at the time of the investigation). In contrast, this study considered vehicle performance in relation to the number of cylinders (4, 6 and 8) and the PWR of the vehicle *within* the various cylinder groups.

The methodological design and statistical techniques used to investigate the relationship between vehicle performance and crash risk also differed across the studies. In the earlier study by Palamara and Gavin (2005) a matched case-control design and conditional logistic regression was employed. 'Cases' were drivers who had crashed while 'Controls" (matched for gender, age and year of licensure) were those who had not crashed. 'Control' drivers were identified from the WA motor vehicle driver licence database and asked to supply information on the car they mostly drove during the year their corresponding 'Case' driver crashed. Unfortunately this design was statistically underpowered as the analysis was restricted to just n=84 matched pairs. Further to this, no information was collected and used to adjust for exposure. In contrast, the current study employed a number of analytical methods to determine the statistical relationship between vehicle performance and crash risk. Firstly, the relative rate of serious injury crash involvement was calculated for owner-drivers (by age) in different vehicle performance categories. The denominator (the measure of 'exposure') for these rates was based on a sample of the registered vehicle fleet, 2001-2008. Second to this, the proportion of crashing vehicles by performance categories in single and two car crashes was calculated to investigate whether drivers of high performance vehicles have a higher representation in single vehicle crashes in which the responsibility for the crash rests solely with the driver rather than (potentially) shared with another

driver in a two-car crash. Multivariate analyses were then undertaken to investigate the confounding effect of other driver, vehicle and crash factors on the relationship between vehicle performance and the ratio of involvement in single and two-car crashes.

Compared with the previous investigation by Palamara and Gavin (2005) - which at the time had limited access to resources and information and was undertaken with a very modest budget - the present study was more considered and expansive and thus provides a more rigorous investigation of the relationship between vehicle performance and crash involvement among young novice drivers.

5.2.2 Findings

Bearing in the mind the aforementioned methodological differences between the studies, there are three main points of comparison of the findings:

- the identified proportion of high performance vehicles crashed by young novice drivers;
- the calculated crash risk for young novices when driving a high performance vehicle; and,
- the crash worthiness of vehicles crashed by young novice drivers.

Both studies showed that crashes involving young novice drivers in high performance vehicles account for a minority of crashes among this group. In the earlier study, approximately 2.9% of crashing vehicles had a PWR ≥ 100kw/t, with just two crashing vehicles (0.3%) equal to or exceeding a PWR of 125kw/tonne, which was at the time the Victorian definition of a high performance vehicle. In the present study 7.6% of crashing vehicles involving a 17-19 year old driver were in the higher performance category (PWR ≥ 90kw/tonne across all cylinder groups). Additional analysis not presented in the technical supplement found only 2% of vehicles had a PWR ≥130kw/tonne, which is the proposed national standard for a high performance vehicle. The greater proportion of high performance vehicles identified in this study compared with the previous may be due to a number of reasons including methodological differences between the studies and variation over time in the access to high performance vehicles by novice drivers.

In relation to the second point, the earlier investigation provided methodologically limited evidence to suggest that young novice drivers do not have a higher risk of crash involvement when driving a higher performance vehicle compared with a non

high performance vehicle. In contrast, the present study provided evidence of a relationship based on relative rates of crash involvement and the ratio of involvement of higher performance vehicles in single car crashes versus two car crashes. That said, the statistical evidence was reported to be more persuasive than definitive. It would seem that the findings of both studies were limited to lesser and greater degrees by methodological issues, particularly in regard to the number of relevant crashes for analysis.

In relation to the crash worthiness of crash involved study vehicles, the earlier study did not attempt to describe or measure this characteristic or indeed any vehicle safety features. Palamara and Gavin (2005) nevertheless noted that restricting novices to vehicles with a lower PWR rating might inadvertently force them into older vehicles with lower crash worthiness ratings as well as lower performance specifications. In contrast, the current study did consider the safety ratings and features of a 2008 sample of the registered fleet in Western Australia in relation to vehicle performance. Hutchinson and Anderson (2012) noted that:

"..higher performance vehicles were more likely to have ESC (Electronic Stability Control), side curtain airbags and even driver airbags. The vehicles were newer and (at least in 4 cylinder categories) were more likely to have a 5-star ANCAP rating" (page 37) [italics added]

Both studies have raised the concern that vehicle restriction programs may inadvertently compromise the access of novices to vehicles with technologies that assist crash avoidance and improve occupant protection in the event of a crash. Whilst safety features and vehicle performance have been shown to be relatively coupled, Hutchinson and Anderson (2012) note that in time such safety features will be more available in vehicles across the various categories of vehicle performance.

5.3 Objective Three

To consider the recent experiences of other Australian jurisdictions with respect to vehicle performance restrictions for novice drivers

Four Australian jurisdictions - Victoria, New South Wales, Queensland and South Australia - currently restrict the access of young novice drivers to high performance vehicles. To the best of our understanding these restrictions (dating back to 1995 in Victoria) were not introduced because of evidence showing an increased risk of crash involvement for novices who drive a high performance vehicle. Rather, it seems the

restrictions were introduced in response to community and political pressure. Some jurisdictions also justified the restrictions as being consistent with the objectives of graduated licensing and other initiatives to combat 'hoon' driving. It is reasonable to assume that biased reporting by the media of young driver crashes and 'hoon behaviour' involving high performance vehicles has played some part in fostering the mistaken perception that such vehicles are a substantial road safety problem and that restrictions are a logical countermeasure to the young driver problem.

In addition to an absence of empirical evidence to support the introduction of these schemes, there appears to have been no attempt to date to evaluate the impact of the vehicle restrictions programs on novice driver crashes and other driving outcomes (e.g., traffic offences and injuries). This is particularly relevant to Victoria where vehicle restrictions based on power to weight ratio were first introduced in 1995. Clearly there is a need to establish the merit of these programs. At best, the investigation undertaken by Keall and Newstead (2012) suggest that the effectiveness of vehicle restriction programs are likely to be undermined by the common place granting of exemptions to drive restricted vehicles. The authors also questioned the cost-effectiveness of the programs given the relatively small number of crashes involving high performance vehicle, the limited potential injury savings and the high administration costs.

In the course of this project other information was gathered to suggest that some members of the community, including vehicle manufacturers, are less supportive of a vehicle restriction scheme if it denies young novice drivers access to vehicles with high crash worthiness and crash avoidance technologies. The case of Robertson *vs* VicRoads exemplifies this. In this case, the young novice driver unsuccessfully sought an exemption to drive a restricted eight-cylinder BMW on the basis that it was the family vehicle and that the vehicle has superior crash worthiness. The conclusion to this case highlights the somewhat contradictory and inconsistent nature of Victoria's restriction scheme. The father of the novice driver has since reported that his son currently drives an *unrestricted* 2006 Lexus GS 450 Hybrid (Robertson, 2012 personal communication). This vehicle has a 3.5 litre six-cylinder hybrid (petrol and electric) engine and is equivalent in performance to a 4.5 litre eight-cylinder engine capable of achieving 0-100km/hour in 6 seconds (http://www.topspeed.com/cars/lexus/2006-lexus-gs-450h-ar1946.html; Hard & Dorman, 2012 personal communication). With a maximum output of 254kilowatts

and a kerbside weight of 1,930kg, the PWR of this vehicle is approximately 132kw/tonne (Hard & Dorman, 2012 personal communication; http://www.carbuddy.com.au/car/values/specification/viewspecs .aspx?gid=49864). This is not a restricted vehicle in Victoria, despite its performance, because it is a normally aspirated six-cylinder engine and Victoria does not specify either a PWR or kilowatt output for restricting certain 'high performance' six-cylinder vehicles. This situation highlights the difficulties that can arise when attempting to restrict vehicles solely on the number of cylinders.

Following on from this point, while the review of the various restriction schemes showed a reasonably high level of consistency across the jurisdictions in regards to which vehicles were restricted, the one area of inconsistency and difference related to high performance six-cylinder engines. For example, the aforementioned Lexus GS 450 Hybrid vehicle is unrestricted in Victoria but would be restricted in Queensland because the power output exceeds Queensland's limit of 200 kilowatts. Inconsistencies such as this underscore the need to standardise the definition of a high performance vehicle, which is what *Austroads* is seeking to do based on a single measure of the ratio of power (kilowatts) to tare weight. To date, a PWR ≥130 has been advocated but not agreed to. Even if this measure was accepted, jurisdictions would require access to the redeveloped NEVDIS database to administer and enforce the restriction. However, the redeveloped database might not be available for some years yet, which makes the implementation of the standardised measure a much longer term reality and certainly not a viable option in the near future for Western Australia.

In summary, the review of the vehicle restriction schemes operating throughout Australia has provided insight of the absence of empirical evidence to support their introduction and an absence of effort to determine the road safety impact of these schemes. For the most part the schemes exclude similar vehicles from use though difference was noted across the jurisdiction in regard to what is a normally aspirated high performance six-cylinder vehicle. It is also apparent that vehicle restriction schemes can be cumbersome to administer and enforce because of the provision of exemptions and lack of clarity on occasion around which vehicles are excluded and exempted. For these reasons it is reasonable to question the value of contemporary vehicle restriction programs.

6. RECOMMENDATIONS

Based on the suite of findings presented the following recommendations are provided to the Roads Safety Council for consideration.

1. Reject the introduction of a vehicle performance restriction scheme for Western Australian novice drivers.

   This study has failed to provide compelling evidence to support the introduction of a vehicle performance restriction scheme; such a scheme is therefore not recommended at this point in time. Notwithstanding the identified methodological problems for the study, there are a number of reasons to reject the introduction of a vehicle restriction scheme:

   - crashing high performance vehicles driven by novice drivers do not represent a sizable road safety problem;
   - a statistical association between vehicle performance and crash risk for young novice drivers was observed but it was not overwhelming strong or unequivocal;
   - no evaluations of the existing Australian vehicle performance restriction schemes have been undertaken; therefore, it is not known whether such schemes effectively reduce novice driver crashes and injury or whether they are cost-effective;
   - Western Australia does not presently have, nor is likely to have in the near future, ready access to the vehicle performance information required to administer and enforce a vehicle restriction scheme; and that,
   - restricting access to some high performance vehicles may inadvertently restrict the access of young novices to vehicles which feature a high level of vehicle safety technology.

2. Progress the introduction of outstanding and empirically supported graduated driver training and licensing initiatives in Western Australia.

   Compared with some other Australian and overseas jurisdictions, Western Australia's existing graduated training and licensing system could be strengthened by the adoption of other initiatives related to increased driving

experience as a learner and reduced exposure to crash risk factors as a provisional driver. In relation to these issues, the government should:

- expedite a thorough reexamination, particularly in relation to access and equity issues, of the current requirement for supervised driving during the learner phase to consider an increase in both the number of required hours and the conditions under which those hours are obtained (e.g., daytime versus nighttime; types of roads); and,

- move to introduce other licensing initiatives such as peer passenger restrictions and restrictions on the use of mobile phones during the provisional period. Both initiatives are likely to reduce the occurrence of distracted driving and possible risk taking when driving in the company of peers.

3. Further investigation and development of a broad platform of initiatives to more broadly target the problem of speeding and reckless driving by young novice drivers.

   Whilst it is acknowledged that high performance vehicles have an increased ability to accelerate and maintain higher speeds, speeding and other reckless behaviour among young novice drivers is not confined to those driving high performance vehicles. For this reason then, it is recommended that the government of Western Australia investigate and develop initiatives that target the behaviour of the young novice driver, rather than the vehicle per se, in an effort to reduce speeding and other reckless behaviour across this target population. For example, consideration should be given to:

   - the introduction of differential speeding penalties for novice drivers that would effectively result in the suspension of a provisional driver in the first 12 months for a single speeding offence (or at the very least a subsequent offence). Such a system operates in New South Wales and could be applied here as Western Australia similarly suspends provisional drivers in the first 12 months of licensure upon the loss of four demerit points.

- the imposition of vehicle restrictions on provisional drivers who are caught speeding or engaging in reckless or dangerous driving, including BAC offences, while driving a high performance vehicle;

- the introduction of 'offence free' periods as a prerequisite for novice drivers progressing from P1 to P2 stages and from a P2 stage to full licensure; and,

- the development and implementation of a trial education program targeting novice drivers committing any speeding offence, utilising a monitored Intelligent Speed Adaptation (ISA) device fitted to their vehicle.

4. Encourage the purchase of safer vehicles by all young drivers by providing information about safe first car choices and the provision of financial incentives to purchase safer vehicles.

   Young novice drivers have a higher risk of crash involvement compared with older and more experienced drivers. For this reason it is important that young drivers have access to vehicles with emerging technologies that will reduce their likelihood of crashing and also provide them with superior protection in the event of a crash. The secondary analysis in this study of a 2008 sample of vehicles registered in Western Australia showed that vehicles with superior safety features such as Electronic Stability Control, side curtain airbags, and even in some cases driver airbags, were far more common in vehicles that might otherwise be classified as high performance from a power to weight ratio point of view, especially among four and six-cylinder vehicles. Indeed, this finding suggests that any possible restriction on the access of novices to higher performance vehicles might, in the shorter term, also inadvertently restrict their access to vehicles with high safety ratings –at least until these technologies filter down over time to be more common among cheaper and lower performance vehicles. In the meantime the state government should:

   - strongly encourage the purchase of safer vehicles by young novice drivers through an educational campaign on 'safe first car choice', along the lines of campaigns undertaken in New South Wales and Victoria; and,

- consider vehicle registration rebates or discounts to young novice drivers who purchase vehicles meeting the ‘safe first car’ criteria.

REFERENCES

Australian Bureau of Statistics. (2010). *Population by age and sex, Australian states and territories*, *June 2010*. Cat. 3201.0

Begg, D. & Stephenson, S. (2003). Graduated driver licensing: The New Zealand experience. *Journal of Safety Research*, *34*, 99-105.

Bureau of Infrasture, Transport and Regional Ecnomics (2011). *Road deaths Australia: 2010 statistical summary*. Canberra, ACT: Commonwealth of Australia.

Cercarelli, R., Hendrie, D., Dyke, P. & Ryan, G. (1997). *Road safety risk factors study: Results from the first survey*. Perth: Road Accident Prevention Research Unit. RR52

Cercarelli, R., Hendrie, D., Legge, M. & Ryan, G. (1997). *Road safety risk factors study: Results from the second survey*. Perth: Road Accident Prevention Research Unit. RR56

Cercarelli, R., Hendrie, D., Ryan, G., Legge, M. & Kirov, C. (1997). *Road safety risk factors study: Results from the third survey*. Perth: Road Accident Prevention Research Unit. RR61

Cercarelli, R., Hendrie, D., Ryan, G., Legge, M. & Kirov, C. (1998). *Road safety risk factors study: Results from the fourth survey.* Perth: Road Accident Prevention Research Unit. RR62.

Clarke, D., Ward., P. & Truman, W. (2002). *In-depth accident causation study of young driver.* UK: Transport Research Laboratory, Report 542.

Drummond, A. (1994). *Young driver research program: A technical and strategic overview of exposure reduction measures as a means of reducing young driver crashes.* ACT: Federal Office of Road Safety CR130.

Drummond, A. & Healy, D. (1986). *The risk of driver crash involvement per distance travelled in metropolitan Melbourne.* Proceedings of ARRB/REAAA Combined Conference, Part 9. Australian Road Research Board, Melbourne.

Foss, R. & Evenson, K. (1999). Effectiveness of graduate driver licensing in reducing motor vehicle crashes. *American Journal of Preventive Medicine*, *16*, 47-56.

Fontaine, H. (1994). High performance cars, age and sex of drivers: Effects on risk and safety. *Proceedings of the 14th International Technical Conference on the Enhanced Safety of Vehicles* Vol. 1. Munich Germany, 23-26th May, 1994.

Forsyth, E., Maycock, G. & Sexton, B. (1995). *Cohort study of learner and novice drivers: Part 3, accidents, offences and driving experience in the first three years of driving*. UK: Transport Research Laboratory 1995 .

Hard, P. & Dorman, G. Lexus of Perth. Personal communication, April, 2012.

Harrison, W.A., Triggs, T.J., Pronk, N.J. (1999). *Speed and young drivers: Developing countermeasures to target excessive speed behaviours amongst young drivers*. (Report No. 159). Clayton, AU: Monash University Accident Research Centre.

Horswill, M. & Coster, M. (2002). The effect of driver characteristics of driver's risk-taking behaviour. *Ergonomic*, *45*, 85-104.

http://www.topspeed.com/cars/lexus/2006-lexus-gs-450h-ar1946.html. 2006 Lexus GS 450H. Accessed 26th April 2012.

http://www.carbuddy.com.au/car/values/specification/viewspecs.aspx?gid=49864). 2006 Lexus GS450 Hybrid GWS191R. Accessed 26th April 2012.

Keall, M. & Newstead, S. (2012). *Potential safety benefits of restricting young drivers from driving high performance vehicles: Analysis of Australian and New Zealand crash and licensing data*. Melbourne: Monash University Accident Research Centre.

Kloeden, C. (2008). The crash and offence experience of newly licensed young drivers in South Australia. New South Wales: Austroads AP-R331/08.
Krahe, B. & Fenske, I. (2002). Predicting aggressive driving behaviour: The role of macho personality, age, and power of car. *Aggressive Behavior*, *28*, 21-29.

McCartt, A.T., Shabanova, V.I., & Leaf, W.A. (2003). Driving experience, crashes, and traffic citations of teenage beginning drivers. *Accident Analysis & Prevention*, **35**, 311-320.

McCartt, A.; Teoh, E.; Fields, M.; Braitman, K. & Hellinga, L. (2010). Graduated licensing laws and fatal crashes of teenage drivers: A national study. *Traffic Injury Prevention*, *11,* 240-248.

McKnight, A.J. & McKnight, A.S. (2000). The Behavioural Contributors to Highway Crashes of Youthful Drivers. *44th Annual Proceedings Association for the Advancement of Automotive Medicine.* Des Plaines, Illinois: Association for the Advancement of Automotive Medicine.

McKnight, A.J., & Peck, R.C. (2002). Graduated driver licensing: What works? *Injury Prevention, 8*(2 Suppl), ii32-ii38.

Oxley , J., Langford , J., Palamara , P., Muir , C., Koppel , S., Bohensky , M., & Williamson , A. (2009). *Non- wearing of Adult Seat Belts in Australia: Where to Next*? New South Wales: Austroads AP-R346/09.

Palamara, P. (2005). *The relationship between vehicle power to weight ratio and young driver crash involvement.* Invited unpublished paper presented to the *Insurance Commission of Western Australia Road Safety Forum,* Perth, November 2005.

Palamara, P. (2012). *Review of young driver risk taking and its association with other risk taking behaviours.* Perth, Western Australia: Curtin-Monash Accident Research Centre. Unpublished report to the Road Safety Council of WA.

Palamara. P. & Gavin, A. (2005). *The relationship between vehicle power to weight ration and young driver crash involvement.* Perth, Western Australia, Injury Research Centre, The University of Western Australia. RR157

Robertson, G. Personal communication, August, 2011.

Robertson, G. Personal communication, April, 2012.

Rosman, D.(2000). *Drink-driving, speeding and road crashes in Western Australian, 1996-1998*. Perth: Road Accident Prevention Research Unit, UWA. RR100

Shope, J.T., Molnar, L.J., Elliott, M.R., & Waller, P.F. (2001). Graduated driver licensing in Michigan: Early impact on motor vehicle crashes among 16-year-old drivers. *Journal of the American Medical Association, 286*, 1593-1598.

Smart, R.; Stoduto, G.; Mann, R. & Adlaf, E. (2004). Road rage experience and behaviour: Vehicle, exposure, and driver factors. *Traffic Injury Prevention*, *5*, 343-348.

Smart, D. & Vassallo, S. (2005). *In the driver's seat: Understanding young adults' driving behaviour.* Melbourne: Australian Institute of Family Studies.

Vanlaar, W.; Mayhew, D.; Marcoux, K.; Wets, G.; Brijs, T. & Shope, J. (2009). An evaluation of graduated driver licensing programs in North America using meta-analytic approach. *Accident Analysis and Prevention*, *41*, 1104-1111.

Wiiliam, A.F. (1998). Risky driving behaviour among adolescents. In, *New perspectives on adolescent risk behaviour*. R. Jessor (Ed.). USA: Cambridge University Press.

Technical Supplement

Hutchinson, T.P. & Anderson, R.W.G. (2012)
Vehicle performance and crash risk amongst novice drivers in Western Australia. Adelaide: Centre for Automotive Safety Research, The University of Adelaide