MONASH University
Accident Research Centre

A centre within the Monash University Injury Research Institute

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Understanding New Zealand novice driver behaviour

Review of Literature and Scope of Naturalistic Driving Study

SUBMITTED BY

Monash Injury Research Institute,
through its Monash University Accident Research Centre
and TARS of the University of Waikato

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EXECUTIVE SUMMARY

Road deaths and serious injuries amongst young novice drivers and passengers remain unacceptably high and represent a serious public health issue. They are among the most vulnerable road users in Australia and New Zealand, as in most developed countries world-wide: the crash rate for novice drivers far exceeds crash and fatality rates of older (middle aged) drivers, being up to ten times higher than for the safest age group (Mayhew, Simpson & Pak, 2003; McCartt, Shabanova & Leaf, 2003; Williams, 1999; Braitman, Kirley, McCartt & Chaudhary, 2008). More importantly, a consistent finding worldwide is the extremely high crash and fatality rate during the first year of driving, most pronounced in the first few months of driving, related to the disproportionately high risk in the time period after licensure. During this critical first year of independent driving it has been estimated that novice drivers are 33 times more likely to be involved in a casualty crash compared with learner drivers (Gregersen, Nyberg & Berg, 2003; Mayhew et al., 2003).

In New Zealand during 2012 alone, young drivers aged 15-24 years were involved in 73 fatal crashes, 439 serious injury crashes and 2,626, minor injury crashes (Ministry of Transport, 2013). The total social cost of the crashes in which 15–24 year-old drivers had the primary responsibility was $755 million, accounting for 24 percent of the social cost associated with all injury crashes. This personal and community cost injury crash is unacceptable and there is an urgent need to identify and implement effective solutions to reduce this toll in line with the New Zealand 2010-2020 road safety strategy, '*Safer Journeys*', that identifies the need to increase the safety of young drivers as an 'area of high concern' (Ministry of Transport, 2010).

Extensive research has focused on identifying crash characteristics and the situations that lead to novice drivers' crashes, especially fatal crashes. Young driver crashes tend to occur under high risk situations and include single-vehicle and run-off-road crashes, high speed, suicides, and drugs and alcohol (Gonzales, Dickinson, DiGuiseppi, & Lowenstein, 2005; Williams, Preusser, & Ferguson, 1998; Whelan et al., 2009). Driving at night and carrying teenage passengers further elevate the risk of both fatal and serious injury crashes (Rice, Peek–Asa, & Kraus, 2003; Chen, Baker, Braver, & Li, 2000; Williams, Ferguson, &Wells, 2005).

Evidence from crash reports and driver surveys also suggests that there are numerous persistent characteristics evident in young novice driver crashes, fatalities and offences in New Zealand and elsewhere, including variables relating to the young driver themselves, broader social influences which include their passengers, the car they drive, and when and how they drive, and their risky driving behaviour in particular (Ministry of Transport, 2010; Begg et al., 2012, 2014; Williams et al., 2005; OECD, 2006; BITRE, 2013; Scott-Parker et al., 2012). Moreover, there are a range of psychosocial factors influencing the behaviour of young novice drivers, including the social influences of parents and peers, and person-related factors such as age-related factors, attitudes and motivations, and sensation seeking.

WHAT ARE THE BIG ISSUES FOR YOUNG DRIVER SAFETY?

Reasons for young driver vulnerability are likely to be complex and multi-faceted, and there is much that remains to be understood in order to eliminate the unacceptable injury and loss of life in this road user group. Adolescence is associated with heightened exploratory behaviour and establishing independence to become young adults. Some of this exploration is healthy, such as exploring new career roles and school or extra curricula programs. Some is not – e.g. binge drinking; risky driving. It is the engagement in less healthy behaviour that can place young people at risk, and contribute to the over-representation of death and serious injury by young drivers on our roads (Senserrick, 2006).

One of the major debates regarding the novice driver problem is the distinction between unintentional and intentional risky driving. A body of research suggests that, for the most part, the problem is a result of

inexperience, younger age, immaturity, etc. Others, in contrast, argue that the main problem is that of intentional risky driving such as deliberate speeding, driving while under the influence of alcohol or drugs, aggressive driving. It is most likely a combination of both and possibly related to stage of licensure: newly licensed drivers are necessarily inexperienced and require a period of time to learn how to drive safely and this group can be considered the 'inexperienced' group. On the other hand, there are the young drivers at a later stage of licensure who are more likely to drive in a more risky fashion.

While much progress has been made to address young driver crash risk, current knowledge about the risks to young drivers is limited, and in-depth research on their propensity for excessive speeding, distraction, aggressive driving and risky manoeuvres is scant. Indeed, current evidence on the risk of this group has been assembled from self-report, simulation studies and analysis of crash data, while **little is known about the real-world driving experience of young drivers.**

- A major gap in our knowledge, then, is: the proportion of young drivers who drive, **how often they drive, and their propensity to engage in a deliberately risky manner** — is their driving punctuated by spontaneous risk taking episodes? **Is there a subgroup of drivers who always drive in a risky manner** that ''pushes the envelope'', and **what are the contributing factors to the propensity to engage in risky driving behaviours**?

The complex interacting factors underpinning young driver risk pose a considerable challenge for the development of effective countermeasures. Notwithstanding these difficulties, there have been numerous initiatives that have been implemented to manage the safety of young drivers, including:

- GDL models
- Parental involvement:
    - Agreements to comply with GDL restrictions
    - Behaviour role model
    - Vehicle purchase and use
    - Awareness and adoption of safe driving practices
- Education and training: appropriate hazard perception training programs and programs that address higher order attentional and motivational attributes
- Promotion of safer driving practices (e.g. eco driving)
- Purchase and use of safety vehicles, including new technologies and insurance schemes
- Enforcement of risky driving (including laws, sanctions, and compliance with GDL restrictions)

Within each of these areas, there are still unanswered questions relating to compliance with GDL restrictions and the effectiveness of the measures, particularly in the NZ context, and how they may be enhanced in order to make further gains in reducing young driver fatal and serious injury crashes in New Zealand. Providing answers to most of these questions and gaps in our knowledge, requires an in-depth understanding of young novice drivers' driving patterns, behaviour and motivations that lead them to engage in risky driving behaviours.

USING INNOVATIVE TECHNOLOGIES TO UNDERSTAND THE BEHAVIOUR OF YOUNG DRIVERS IN NEW ZEALAND

A cornerstone of Australasia's success in road safety has been the development of strategies which are strongly evidence-based. A comprehensive understanding of the risky driving behaviour of young novices is fundamental if targeted and effective countermeasures are to be developed and implemented. It is proposed that an international collaborative partnership for a novice driver Naturalistic Driving Study (NDS) is undertaken – a New Zealand first.

The study will use innovative telematics techniques to track real-world driving of young drivers over the first six months of the critical high-risk period of restricted licensure. This technology has the capacity to provide detailed, objective evidence about everyday real-world driving behaviour and offers unprecedented capacity for advancing understanding of young driver crash risk.

Moreover, the project represents strong partnerships between the AA Research Foundation, the Monash University Accident Research Centre (MUARC), the Transport Traffic and Road Safety Research Group (TARS), Waikato University, the Virginia Tech Transportation Institute (VTTI) and a Steering Group (comprising key stakeholders) in order to support cutting edge research that will inform evidence-based intervention and policy changes.

100 novice drivers' vehicles in the cities of Hamilton and Waikato will be instrumented with a purpose-built Data Acquisition System (miniDAS) (see Figure below). Recruitment of volunteer drivers in a timely manner will be a key to the success of the study and considerable attention has been directed to selection of appropriate incentives. A pilot study will be conducted to examine feasibility of the proposed recruitment approach. The device includes GPS, microphone, inertial measurement sensors (accelerometer, gyroscope, magnetometer), two cameras (forward roadway; driver), and collects/stores a continuous record of vehicle parameters and can be mounted to the windscreen of the vehicle. It will continuously record their driving behaviour (e.g., looking behaviour, speeding, braking, lane keeping), and their interactions with other road users and the road infrastructure.

SIGNFICANCE, OUTCOMES AND BENEFITS

The proposed project represents a significant step forward in providing answers to the gaps in our knowledge as identified above, providing new insights into the driving patterns and behaviours that contribute to the high crash risk of young, novice drivers. Further, NDS techniques offer a revolutionary approach that can provide richer, more detailed and more objective information about the driver, driving behavior and the driving environment. This

real-world data has potential to offer a new level of evidence to directly inform the development of effective initiatives that can make a real difference in novice driver safety.

More importantly, these findings will have **immediate relevance for development of new measures and targeted enhancement of existing measures for the management of young driver safety such as GDL policy, enforcement, road safety education, and driver training programs in New Zealand**, as well as providing access to a rich data source which can be mined in depth and used to inform future countermeasures development. Table 1 provides an overview of the identified research questions, the associated deliverables and the potential recommendations and benefits derived from the findings.

Research Question	Deliverables	Potential Recommendations	Potential Benefit areas
What are the general driving patterns of young drivers (e.g. how far, where, when)	Descriptive data including overall driving distance, total number of trips, number of trips per week, average trip distance and duration, trips/km per day of week/time of day; trips/km by road type, distance from home; rural/urban. Validation of current findings with real-world driving data.		Enhanced driver education Objective exposure data for calculating crash risk
Do young drivers engage in speeding behaviour? If so, when, where, under what conditions?	Proportion of drives/trips when engaged in excessive speeding (over the speed limit – by speed zone; by road type; in rural/urban areas). Comparison with self-reported risk-taking behaviour of NZ young drivers (Begg et al., 2009)	Recommendations regarding enhanced speed management and enforcement strategies for P-Plate drivers Recommendations for the implementation of ITS technologies for P-Plate drivers such as ISA to reduce speeding Recommendations for adoption of eco-driving behaviour	Enhanced enforcement Enhanced driver education and training programs Increased parental involvement
Do young drivers comply with GLS restrictions?	Proportion of drivers/trips with non-compliance with GDL including night driving 10pm-5am with passenger Age-based comparisons of compliance with GDL restrictions Comparisons of effectiveness of NZ GDL with other jurisdictions (pending availability of data including SHRP2, VTTI, UMTRI, Australian NDS)	Recommendations for enhancing GDL policy, such as i) potential for increasing driver licence age from 16 years to 18 years of age, ii) consideration of additional or revised restrictions.	Enhanced GDL policy Enhanced enforcement Increased parental involvement

What are the characteristics of drivers who engage in risky driving behaviour?	Identification of relevant demographic/driving/skills/personal characteristics of driver that predict risky driving behaviour (eg defined by excessive speed; engagement in distracting activities etc.)	Recommendations regarding the specific skills that require improvement amongst younger drivers Recommendations for enhanced driver education and training programs to address specific risky driving behaviours. Recommendations for the promotion of less risky driving and adoption of eco driving behaviour.	Enhanced driver education and training programs Enhanced enforcement
What type of collisions/near collisions/safety-critical events are young drivers involved in?	Objective pre-crash data on driver behaviour, relevant traffic, road and other road user data. Frequency and type of collisions/near collisions and safety critical events	Recommendations to enhance strategies by integrating targets and initiatives to address specific high risk behaviours such as speeding, night driving, vehicle manoeuvre, etc.	Enhanced driver education and training programs Enhanced enforcement

New Zealand has for many years been at the forefront of evidence-based road safety initiatives for young driver safety including the introduction of the world's first GDL. This project offers a further opportunity for innovative research to keep New Zealand in a position of prominence in road safety through an international collaborative research program which has the potential to inform and transform young driver education and training, licensing and enforcement strategies.

The project also represents value for money, given the importance of the research questions, the quality of the research team and the potential to produce outcomes that will directly inform initiatives to reduce death and serious injury of young New Zealand drivers. It is expected that the findings from this study will lead to the development and adoption of effective countermeasures which can significantly reduce the number and costs associated with young driver casualty collisions. For every crash prevented, there could be a cost saving to the NZ community in the order of $2.4million for each fatality, $214,000 for each hospitalized injury and $2,100 for each non-hospitalised injury (figures based on BITRE estimated costs) (BITRE, 2009).

THE RESEARCH TEAM

A research team from MUARC and TARS of the University of Waikato has been assembled for this project. The Team has a long-standing national and international involvement in key areas of road safety including road user behaviour, study design, naturalistic driving studies, and evaluation of effectiveness of initiatives and programs and new technologies on improving road trauma. Team members bring relevant and extensive expertise in road user behaviour, particularly novice drivers and other high risk road user groups, distraction, and evaluation techniques. Team members have published widely in peer-reviewed journals as well as major government and industry reports and have a strong reputation amongst sponsors and funding organizations for delivering research outputs on time, within budget and of a high research quality. Examples of relevant recent published research addressing young driver issues and using NDS methods include: Charlton et al., 2012; Isler et al., 2008a, 2008b, 2011; Scully et al., 2012; Whelan & Oxley, 2007; Johnson et al., 2010a, 2010b, 2013; Oxley, 2005; Starkey et al., 2013 (Please see below for full references). The team consists of Associate Professor Judith Charlton, Dr Jennie Oxley, Associate Professor Robert B. Isler and Associate Professor Nicola Starkey. Full CVs

are available on request. The Team has strong existing research links with leading US researchers at Virginia Tech Transportation Institute (VTTI), Professor Tom Dingus and Dr Sheila Klauer, experts in novice driver NDS methods. The team has liaised with the VTTI researchers on technical matters and the current proposal incorporates provision of equipment and technical expertise for data management by the VTTI group. This international collaboration adds considerable strength to the project and offers potential to draw on US data for comparisons.

STUDY COSTS AND TIMELINES

The proposed novice driver NDS will require considerable partner, stakeholder and researcher input and funding resources to implement. The project will run over twenty-four months with the total cost estimated at NZ$916,465 (GST exclusive; international currency exchange rates at 6.2.2014). Budget items are outlined below by year of expenditure:

	Y1	**Y2**	**Total**
MiniDAS Equipment lease, data cleaning	394,000		394,000
Equipment (laptop, cell phone)	2420		2,420
Participant incentives	37,800		37,800
Personnel: Management, ethics, recruitment, data collection	104,662	52,331	156,993
Pilot test recruitment methods (optional)	15,000		15,000
Analysis and reporting		256,993	256,993
Travel (for installation and recovery of devices/participant testing)	5,197	5,198	10,395
Travel (for Chief Investigator meetings)	6,700	6,700	13,400
Specialist Technical Training (international partner, including travel and personnel costs)	25,500		25,500
Other (consumables/incidentals)	2,000	1,964	3,964
TOTAL	**593,279**	**323,186**	**916,465**

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1 Young driver crash and injury risk

1.1 Statistics

Road deaths and serious injuries amongst young novice drivers and passengers remain unacceptably high and represents a serious public health issue. They are among the most vulnerable road users in Australia and New Zealand, as in most developed countries world-wide, particularly during their first months of driving but also during the first 6-12 months of unsupervised driving (Mayhew, Simpson & Pak, 2003; McCartt, Shabanova & Leaf, 2003; Williams, 1999; Braitman, Kirley, McCartt & Chaudhary, 2008). Worldwide statistics show that the crash rate for novice drivers far exceeds crash and fatality rates of older (middle aged) drivers, being between approximately four times higher than safer age group drivers, and this is particularly so amongst the newest drivers (this group's crash rate is about three times higher than that of older novice drivers). Elvik (2010) has recently suggested that the injury rate of novice drivers is up to ten times higher than for the safest age group and that these rates might even be increasing.

Young drivers are overrepresented in crash and traffic fatality statistics. In member countries of the Organisation for Economic Co-operation and Development (OECD, 2006) between 18 and 30 percent of killed drivers are between 15 and 24 years old, although the same age group constitutes only between 9 and 13 percent of the population in their countries. As an example, the overall number of road deaths in Australia has decreased marginally (an overall reduction of -2.3%) between 2003 and 2012, with overall reductions of 3.1 percent amongst drivers and 4.2 percent amongst passengers. Moreover, there has been a larger overall decline in the number of young drivers aged 17 to 25 years involved in fatal outcome crashes, from 206 driver deaths in 2003 to 141 driver deaths in 2012, a net reduction of 5.1 percent (Figure 1). However, 23 percent of drivers killed were aged between 18 and 25 years, despite this age group representing only around 14 percent of Australian licence holders. Further, young adults are at high risk of dying as passengers, with young passengers representing two out of every seven passengers killed in Australia in 2007 (BITRE, 2013).

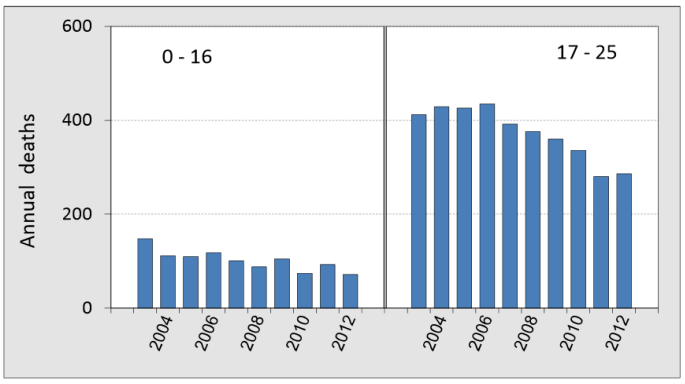


Figure 1: Annual number of road deaths for younger road users, 2003 – 2012 (Source, BITRE, 2012).

In New Zealand, young drivers are also over-represented in crash and fatal statistics. In 2012, young drivers aged 15–24 were involved in 73 fatal traffic crashes, 549 serious injury crashes and 2,626 minor injury crashes. Of these crashes, the 15-24 year old drivers had the primary responsibility in 55 of the fatal crashes, 436 of the serious injury crashes and 2,044 of the minor injury crashes. These crashes resulted in 68 deaths, 567 serious injuries and 2,830 minor injuries. The total social cost of the crashes in which 15–24 year-old drivers had the primary responsibility was $755 million, accounting for 24 percent of the social cost associated with all injury crashes (Ministry of Transport, 2013). This personal and community cost injury crash is unacceptable and there is an urgent need to identify and implement effective solutions to reduce this toll in line with NZTA 's 2010-2020

road safety strategy, '*Safer Journeys*' that identifies the need to increase the safety of young drivers as an 'area of high concern' (Ministry of Transport, 2010).

More importantly, a consistent finding worldwide is the extremely high crash and fatality rate during the first year of driving, most pronounced in the first few months of driving, related to the disproportionately high risk in the time period after licensure. During this critical first year of independent driving it has been estimated that novice drivers are 33 times more likely to be involved in a casualty crash compared with learner drivers (Gregersen, Nyberg & Berg, 2003; Sagberg, 2000; Mayhew et al., 2003). Indeed, Figure 2 outlines the high proportion of Victorian drivers in their first years of driving compared with learner and fully licensed drivers, and the rapid decline in casualty crashes involving probationary drivers as years of licensure increase. The sharp decline in crash rates after 6 months of driving with a probationary licence suggests that even limited driving experience has substantial beneficial effects in risk reduction. These changes in crash rates over time, could be attributable either to experience (increase in skill) or to maturation (declining influence of lifestyle factors such as sensation seeking) or to a combination of these two factors (e.g., Tronsmoen, 2011).

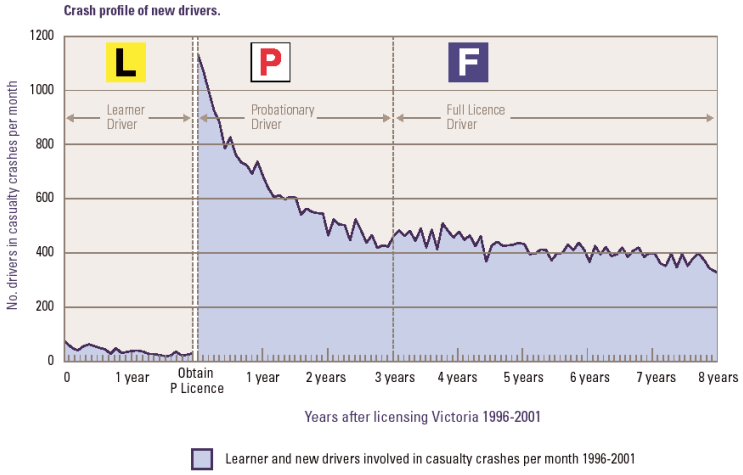


Figure 2: Casualty crashes per month by driving experience (Source: VicRoads, 2005)

In support of this, McCartt et al.'s (2003) self-reported survey of teenagers every 6 months from their freshman to senior high school years (N=911) on crash involvement and citations showed that, based on survival analysis, the risk of a first crash during the first month of licensure (0.053) was substantially higher than during any of the next 11 months (mean risk per month: 0.025). The likelihood of a first citation during the first month of licensure (0.023) also was higher than during any of the subsequent 11 months (mean risk per month: 0.012). Similarly, when viewed as a function of cumulative miles driven, the risk of a first crash or citation was highest during the first 500 miles driven after licensure. Fewer parental restrictions (e.g. no nighttime curfew) and a lower grade point average (GPA) were associated with a higher crash risk. Male gender, a lower GPA and living in a rural area were also associated with a higher citation rate.

1.2 Crash characteristics

Extensive research has focused on identifying crash characteristics and the situations that lead to novice drivers' crashes, especially fatal crashes. Young driver crashes tend to occur under high risk-situations and include single-vehicle and run-off-road crashes, high speed, suicides, and drugs and alcohol. Driving at night and carrying teenage passengers elevate the risk of both injury crashes (Rice, Peek–Asa, & Kraus, 2003) and fatal crashes (Chen, Baker, Braver, & Li, 2000; Williams, Ferguson, & Wells, 2005; Ulmer, Williams, & Preusser, 1997), especially among 16-year-old drivers. Travelling faster than posted speed limits or driving too fast for conditions also contribute to fatal crashes involving 16-year-old drivers (Gonzales, Dickinson, DiGuiseppi, &

Lowenstein, 2005; Williams, Preusser, & Ferguson, 1998; Williams, Preusser, Ulmer, & Weinstein, 1995). Furthermore, compared with crashes involving older drivers, 16-year-old drivers are more likely to be involved in single-vehicle fatal crashes (Gonzales et al., 2005; Williams et al., 1995; Ulmer et al., 1997; Whelan et al., 2009), and fatal crashes of 16–19-year-old drivers occur more frequently on wet or slippery roads (Marmor & Marmor, 2006; Braitman et al., 2008).

In their analysis of young drivers aged 18 to 25 years killed on Victorian roads in 2012, the Transport Accident Commission (www.tac.vic.gov.au) identified the following characteristics (categories not mutually exclusive):

- 76% were males
- 68% were killed on country roads
- 71% were killed in single vehicle crashes
- 59% were involved in crashes that occurred during high alcohol times
- 50% of crashes occurred between the hours of 8pm and 6am
- 56% of deaths occurred on 100km/h signposted roads
- 53% died between 8pm Friday and 8pm Sunday

In South Australia, Wundersitz (2012) analysed the non-fatal crashes of 256 young drivers aged 16 to 24 years who were involved in a crash on South Australian roads. The at-scene in-depth study found that young and less experienced drivers were more likely to be involved in single-vehicle crashes and crashes that occurred in rural areas, on undivided roads and on roads with higher speed limits than slightly older and more experienced young drivers. They were also much more likely to have peer passengers in the vehicle when they crashed.

In their study of non-fatal crashes, Braitman and her colleagues (2008) examined police reported non-fatal crashes (n=893) involving 16 year old drivers in the US State of Connecticut. In addition to studying police report narratives, they conducted telephone interviews with n=260 of the crash-involved drivers to identify behavioural factors contributing to crashes. Of the 260 crash-involved teenage drivers interviewed, 69 percent were involved in multiple-vehicle crashes. Interestingly, around two-thirds of crashes occurred within five miles of the teen's home. Drivers were at-fault in 68 percent of the multiple-vehicle crashes and 95 percent of single-vehicle crashes. Seventy-six percent of the interviewed drivers were deemed to be at-fault status.

The most common primary contributing factors identified for at-fault crashes were search and detection (looking, distraction, inattention etc.) (35%) followed by speeding (28%), evaluation (following distance, judgement of speed or right of way) (17%), and lost control/slid (8%). The remaining factors, including driver impairment alcohol, fatigue) each represented 5% or less of the crashes. Talking on mobile phones contributed to only 1 percent of at-fault drivers' crashes. Interestingly, the state law banning drivers younger than 18 from talking on cell phones became effective during the study period and cell-phone related crashes did not differ pre- vs. post-introduction of this law. Male drivers were significantly more likely than female drivers to speed or lose control of their vehicles or slide, while female drivers were significantly more likely to fail to detect another vehicle or traffic control compared with male drivers. The authors noted that some of the contributory factors observed in this study differed from *fatal* crash factors involving teenage drivers reported by Gonzales et al. (2005) and Williams et al. (2005), including greater likelihood of day time crashes, less likelihood of alcohol impairment. Other factors including speeding and driving too fast for conditions were found to be similar to those reported in fatal crash studies involving 16-year-old drivers (Gonzales et al., 2005; Williams et al., 1995; Williams et al., 2005).

2 What are the issues for young driver safety?

There are numerous persistent characteristics evident in young novice driver crashes, fatalities and offences, including variables relating to the young driver themselves, broader social influences which include their passengers, the car they drive, and when and how they drive, and their risky driving behaviour in particular. Moreover, there are a range of psychosocial factors influencing the behaviour of young novice drivers, including the social influences of parents and peers, and person-related factors such as age-related factors, attitudes and motivations, and sensation seeking.

Adolescence marks a period of time when rapid and extreme physical, cognitive, and psychosocial changes are occurring and the high crash risk of young novice drivers reflects the effects of both youth and inexperience.

2.1 Age

Youth factors include maturity, lifestyle, peer group, socialization, over-estimation of ability and under-estimation of risk. The effects of inexperience are evidenced by the fact that crash rates drop dramatically with increased driving mileage (see Figure 2 above), and the fact that even drivers delaying licensure to older ages show a similar increased crash risk during the first 12 months of unsupervised driving to younger drivers. The elevated risk associated with young drivers is largely attributed to i) lack of experience, ii) age factors, including immature brain functioning and under-developed cognitive-perceptual skills, iii) lack of insight, iv) low level of actual knowledge and skill, especially hazard perception skill; and iv) propensity for risk-taking and sensation seeking, including intentional risk-taking (although intentional risk-taking is not considered to be a contributing factor in the majority of cases) (Steinberg, 2008; Williams, Tefft & Grabowski, 2012; Simons-Morton et al., 2011; Chen et al., 2009). Gregersen and Berg (1994) added that these factors may also be influenced by motivational and attitudinal factors governed by individual, cultural and situational factors outside the traffic situation.

The evidence regarding the contribution of the key factors to crash and injury risk are discussed below.

Given the lack of evidence that training and pre-licence practice is protective (see discussion below), Simons-Morton (2011) contends that the only pre-licence factor that is known to influence crash rates during the first year of licensure is age. He found that drivers who are first licensed in their twenties have a similar pattern of crash rates as those who are licensed at age 18, high at first and declining rapidly. However, the initial rate is higher for the younger drivers and declines somewhat more slowly. He suggests therefore, that younger age at licensure is a risk factor and older age at licensure is protective.

There are a number of age-related factors, including maturation (brain and social), gender, and a range of other factors including parenting and other socialization factors. These are discussed below.

2.2 Maturation: brain development

Adolescence involves continued cognitive maturation. Compared with younger children, thinking becomes more abstract and less concrete, allowing adolescents to consider multiple aspects of their actions and decisions at one time, assess potential consequences of a decision, consider outcomes associated with behavioural choices, and plan for the future. These cognitive changes are coupled with psychosocial development, including susceptibility to peer pressure and increased need for autonomy. These newfound cognitive and psychosocial capacities have several implications for teen driving and safety, including (1) skill development and expertise, (2) regulatory competency (e.g., susceptibility to distraction, emotional control, and (3) self-regulation in the context of perceived risk (Keating & Halpern-Felsher, 2008; Luna, Garver, Urban et al., 2004).

There is also evidence showing that the areas of the adolescent brain that are important for safe driving, such as those that deal with multi-tasking, impulse control and the ability to envision consequences of action, are not fully

developed, with implications for safe driving. Young drivers are thought to lack the perceptual and cognitive skills necessary to safely interact with the driving environment, and experience difficulty translating these skills into safe driving, mainly due to under-developed perceptual and cognitive skills necessary to safely interact with the driving environment (Gregersen, 1996). Translation of skills into safe driving requires complex strategies, expertise, and concentration, with errors in execution often resulting in serious injuries, even fatal outcomes.

Although teens are generally successful at acquiring lower order driving skills, adolescents are not cognitively mature enough to fully execute safe driving skills.

2.3 Maturation: social development

There is also emerging evidence suggesting a link between age-related behaviour and continued maturation, and therefore between behavioural immaturity and crash risk. Neurological evidence suggests that anatomical and physiological characteristics of regions of the brain governing impulse control, prioritization, and strategy (the dorsal lateral prefrontal cortex) are still "under construction" during teen years and do not develop fully until the age of approximately 25 years (Giedd, 2004; Gogtay, Giedd, Lusk et al., 2004; Isler et al., 2009; Lewis-Evans, 2010; Keating & Halpern-Felsher, 2008; Dahl, 2008).

This area of the brain has been linked to the inhibiting of impulses, poor judgement, the ability to weigh the consequences of decisions, and elevated emotionality; hence substantial time is required before mature judgement clearly impacts driving safety (Gogtay et al., 2004). In addition, over confidence is considered a potential factor in crash involvement: young drivers tend to relatively under-estimate the risk of crash involvement and over-estimate their own driving skills (Gregersen, 1996). The result is that particular risks arise from regulatory challenges that occur in complex and distracting contexts.

Dahl (2008) argues that pubertal brain changes appear to influence a wide range of emotional processes and motivational tendencies in ways that interact with cognitive control systems, as well as in ways that may provide insights into aspects of risk taking, sensation seeking, and some types of reckless decisions in adolescence relevant to driving. The findings of his examination of brain immaturity and risk behaviour suggest that adolescents engage in relatively fewer prefrontal cognitive control and regulatory processes compared with adults when making decisions permitting a relatively greater influence from affective systems. This results in adolescents being more prone to risk-taking in certain situations, including when in social and peer contexts that activate strong feelings. Moreover, Dahl (2008) suggested that adolescents do not simply take more risks, they appear to be more vulnerable to a wide range of emotional influences, depending on the specific context. Taken together, Dahl argues that "… these studies highlight the unique contributions of a developmental neurobehavioral perspective and, in particular, the need to understand the complex interplay between cognitive and affective systems in the maturation of self-control" (p. S281).

2.4 Sleepiness and fatigue

Fatigue is a major contributor to road crashes around the world and much research has been conducted to understand the issues of fatigue and impact on collision involvement. While fatigue affects everyone differently, some common consequences of fatigue include:

- Reduced alertness – less capacity to respond to the demands of tasks;
- Reduced concentration – more difficulty with decision-making and reasoning;
- Impaired memory – shorter attention spans;
- Poorer task performance – reduced ability to respond with sufficient speed and accuracy;

- Irritability and depressed mood;
- Drowsiness;
- Increased likelihood of "microsleeps" - brief 4-5 second sleep periods that a person usually does not know are happening;
- Lower resistance to the effects of alcohol and drugs; and,
- Higher risk of illness.

Sleepiness (or fatigue) is largely dependent on circadian rhythms and the circadian cycle is a potentially valuable indicator of when fatigue is likely to occur. The human body responds to its internal clock in different ways from morning to night:

- The presence of bright light in the morning tells the brain it is time to become active
- Mental and physical alertness rises and remains at a high level throughout the morning hours
- A modest decline in alertness will normally be experienced during the early afternoon (sometimes called the "post-lunch dip")
- Alertness rises again in late afternoon, often peaking for the day in the evening hours

Regardless of what a person is doing, fatigue will occur during the low points in the cycle, i.e. early afternoon and during the night. If a person is already fatigued at the start of the day, the circadian cycle will still remain, but that individual will be less alert during the day and drowsier at night.

While everyone has circadian rhythms, the length of the cycle, and the size and timing of the peaks and troughs in the cycle vary from one person to another. There is also evidence that an individual's cycle may vary slightly from one season to another, with the consequence that periods of drowsiness may be more frequent during the winter months. More importantly, there is increasing evidence that circadian rhythms of adolescents are different to adults (Bartlett, Biggs & Armstrong, 2013).

There is growing evidence of a link between lack of sleep, and the dips in the circadian cycle and injury risk on the road, in the workplace, and elsewhere. With regard to sleep habits, sleepiness and circadian rhythms of youth and adolescents, there is also growing evidence that many youth obtain insufficient sleep – particularly on school nights (Groeger, 2006).

Three sets of normal developmental changes in adolescence contribute to increased vulnerability to sleep problems: i) night-time sleep becomes lighter (less deep stage-4 sleep) and more prone to external disruptions; ii) daytime sleepiness increases during puberty, probably reflecting an increased need for sleep during this period of rapid physical growth, cognitive development, and emotional changes; and iii) biological changes in the circadian system at puberty shift sleep timing preferences in the direction of delayed-sleep phase, that is, a developmental shift in the tendency to prefer later bedtimes and later rising times.

Moreover, concern is growing about the consequences of sleep deprivation among teenagers. These consequences – including sleepiness and negative effects on attention, reaction time, judgment, and emotion regulation – have relevance to driving safety.

Sleep changes influence alcohol tolerance and creates and/or exacerbate emotional difficulties, including clinical problems with aggression, anger, and impulse control (Dahl, 2008). Thus, sleep deprivation in adolescents may

contribute to driving risks in at least four ways: i) lapses in attention/falling asleep while driving leading to crashes; ii) impaired judgment and decision making leading to impulsive and risky behaviour; iii) a negative synergy of alcohol and sleep deprivation; and iv) increased reactive aggression that could increase risk of impulsive or reckless actions in response to anger.

Another critical impingement on attention regulation is sleep deprivation, which is widespread among adolescents. Given current school and other schedules, adolescents are typically required to awake anywhere between 1 and 3 hours before their natural sleep cycle is complete, resulting in their being extremely sleepy in the morning hours as well as throughout the day. A recent large study of sleep habits amongst youth in the US found that 45 percent of adolescents report insufficient sleep on school nights, and 28 percent complain they often feel 'irritable and cranky' as a result of getting too little sleep (ref).

This sleep deprivation has been implicated as a nontrivial contributor to teen crashes. GDL's night-time driving restrictions may deal indirectly with some portion of this excess risk, but they do not resolve all adolescent sleep issues, including those concerning driving in the early morning, when adolescents are often equally sleepy (Keating & Halpern-Felshner, 2008).

There is considerable evidence that a majority of adolescents do not get enough sleep for optimal functioning during the day. It is also clear that driving while drowsy is a serious traffic safety problem, especially among young drivers. Moving the school start time 1 hour later for all of the adolescents in large county school district resulted in meaningful increases in sleep time, an increase in the percentage of students who got an adequate amount of sleep, and a decrease in catch-up sleep on weekends. It was also associated with a significant drop in vehicle collision rates for high school-aged drivers in that county, whereas crash rates increased in the rest of the state during the same time period (Danner & Phillips, 2008).

Young drivers have better performances than older drivers after a short trip (2–4 h), but they suffer much more from performance decrement than older drivers after 8 hours of driving, showing a high vulnerability to fatigue (Philip et al., 2004). Because RT is an important component of adaptative responses in real world activities (i.e., while driving) one could speculate that sleep-related collisions do not simply affect young drivers because of a higher exposure of this age group to sleep restriction, but also because of a higher sensitivity to sleep loss or an overestimation of performance (Philip et al., 2004).

2.5 Propensity to engage in 'risky behaviour': Is it 'the young driver problem', or the 'problem young driver'?

One of the major debates in young driver research is whether the primary causal crash factor (and therefore primary target for intervention) is underdeveloped skills due to inexperience – 'the young driver problem', or intentional risk taking associated with adolescence – 'the problem young driver'. While both have been clearly established as contributors, the debate continues.

The research addressing inexperience, lack of hazard perception skills, etc., has an underlying assumption that the primary explanation for why adolescents take risks, including those related to driving, is that teens cannot adequately assess risk, they exaggerate the amount of control they have over their driving abilities and driving outcomes, and they perceive themselves as invulnerable to harm. However, it may be the case that some novice drivers intentionally or deliberately take risks.

As examples, McKnight and McKnight (2003) evaluated behavioural factors contributing to crashes involving drivers aged 16-19 years olds. For younger, less experienced drivers (16.5-17.5 years), a significantly greater proportion of crashes were attributed to lack of visual search prior to left turns, not watching the car ahead, driving too fast for conditions, and failure to adjust to wet roads. However, a significantly smaller proportion of crashes involving the younger driver group involved following too closely and alcohol impairment. Males were

significantly over-represented in speed, fatigue and alcohol-related crashes, while females were significantly over-represented in crashes involving inadequate search before left turns (i.e. across traffic, equivalent to right turn in Australia and NZ) and before crossing intersections. However, overall, age and gender differences were relatively few and small in magnitude, indicating that behavioural factors explaining crashes can be broadly generalized across the young driver population at large. A limitation was that driving experience per se, was not measured and therefore could not be separately disentangled from the effects of driver age. Nevertheless, McKnight and McKnight (2003) concluded that the ''overwhelming majority'' of crashes were due to failure to ''employ routine safe operating practices'' and failure to recognize the inherent risk rather than ''thrill seeking'' or deliberate risk taking. In contrast, a very small minority of crashes involved deliberate risk-taking, such as excessive speeds and reckless driving. In contrast, Clarke, Ward and Truman (2005) concluded that a large proportion of crashes resulted from intentional risk taking rather than any particular failure of skill.

Senserrick (2006) noted a number of methodological differences between the two studies – age range and experience level of drivers studied; subjective interpretation of crash report data. However, Senserrick also urges researchers to move beyond this debate and suggests that both inexperience *and* risk-taking (intentional and unintentional) are important variables to consider. Similarly, Shope (2006) noted that "underlying these is a multitude of contributing and moderating factors, which are not all amenable to change".

Others too, make these distinctions. Rothengatter (1997) argued that performance as well as motivational and attitudinal factors may be important for safe driving. Also, according to Peräaho et al. (2003), it is important to distinguish between 'what the driver can do' (performance factors), and 'what the driver is willing to do' (motivational and attitudinal factors). Likewise, Parker et al. (1995) and Åberg and Rimmö (1998) distinguished between errors and violation in driver behaviour (Peräaho et al., 2003). Performance is linked to driving skills and the ability to avoid errors and accidents in urgent situations. On the other hand, violations relate primarily to how the driver decides to use his or her skills (Tronsmoen, 2011).

Simons-Morton (2011) makes a further distinction, suggesting that: "There are two important stages in adolescent development of safe driving competence. The first stage, the novice driver stage, is defined by highly elevated crash rates at licensure that decline rapidly during the first year or so of licensure. The novice young driver problem is largely a matter of inexperience and the lengthy period of time required to learn how to drive safely. The second stage, the young driver stage, is defined by higher-than-average crash rates for young drivers relative to older, experienced adults. This part of the young driver problem is due greatly to the propensity of younger drivers to drive in a more risky fashion than older, more experienced drivers."

More recently, Wundersitz (2012) examined contributing factors to 256 crashes involving young drivers in South Australia and noted the following:

- Consistent with previous research, three quarters of young drivers in the sample committed at least one error resulting in a crash, suggesting young driver over-involvement in errors leading to crashes.
- Overall, the most frequent errors resulting in young driver crashes were decision making errors followed by vehicle operation errors and errors relating to perception.
- Less experienced drivers made significantly more vehicle operation errors, particularly failing to adequately control the vehicle while more experienced young drivers made more perception errors relating to visibility and observation.
- A higher prevalence of speeding and fatigue was reported in this study, compared with other similar studies investigating young driver crashes.

- Young drivers who exhibited risk-taking behaviour were more likely to be male, drive a high performance vehicle, drive at excessive speed and undertake dangerous overtaking manoeuvres, have peer passengers in the vehicle and be more seriously injured in the crash than young drivers who made simple errors. Crashes involving risk-taking behaviour were also more likely to occur at night and on weekends,

- Moreover, she noted that despite a perception that many young driver crashes are due to risk-taking behaviour, this study found that the majority (70%) of young driver behaviour leading to crashes was not primarily caused by risk-taking behaviour but due to young drivers making errors in which they failed to use routine safe operating practices.

These findings highlight that both intentional and unintentional risk factors are at play. Moreover, Wundersitz (2012) noted that these findings support existing research that suggests vehicle control skills increase rapidly with experience while perceptual and decision making skills take more time to develop.

Scott-Parker, Hyde, Watson and King (2012) developed the Behaviour of Young Novice Drivers Scale (BYNDS), in an attempt to disentangle which behaviours might be considered intentional and unintentional risky driving behaviours (see Figure 3). Utilising the BYNDS, Scott-Parker et al. (2012) found that, during the first six months of independent driving, self-reported crashes were associated with fixed violations, risky driving exposure, and misjudgement; self-reported offences were moderately associated with risky driving exposure and transient violations; and road-rule compliance intentions were highly associated with transient violations.

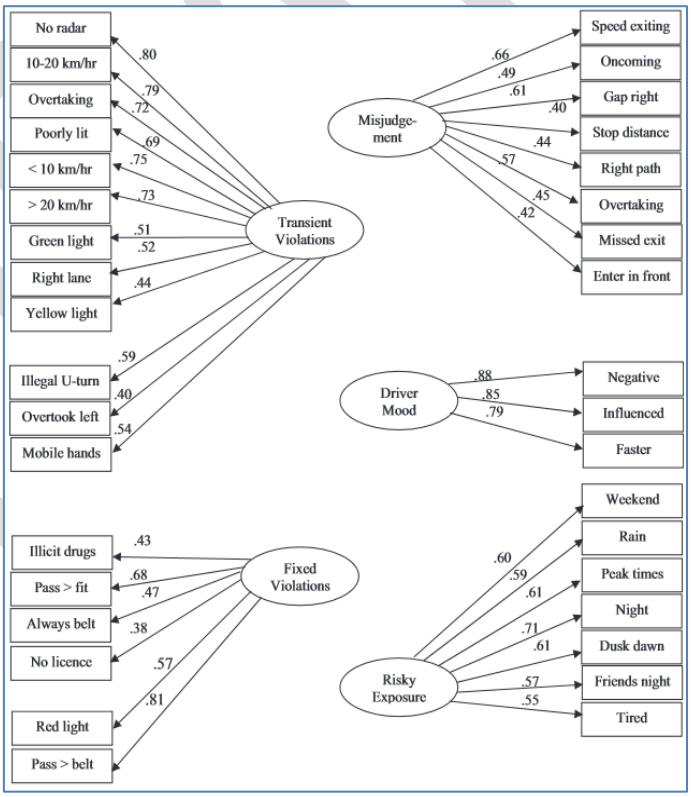


Figure 3: The revised Behaviour of Young Novice Drivers Scale (BYNDS) model (Source: Scott-Parker et al., 2012).

2.6 Unintentional 'risky driving': Inexperience

Inexperience is thought by many to be the main contributing factor to crash and injury risk amongst young novice drivers. The acquisition of any complex set of skills requires a significant amount of time (Keating & Halpern-Felsher, 2008). Driving is a complex task and much of the literature on young drivers points to acquisition of experience (and therefore lack of experience) as a major contributory factor to their crash risk. A range of higher-order cognitive-perceptual skills are important for safe driving, including information processing, hazard perception, situational awareness, attentional control, time-sharing and self-calibration. However, the literature also suggests that age, immaturity and driving experience are generally closely linked – and one of the methodological challenges of research on novice drivers is to be able to disentangle the relative contributions of age, immaturity and experience.

The young novice driver is faced with many new situations and tasks which all require mental resources. In particular, the perceptual situation is new and imposes special demands on visual search skills and interpretation of what is happening in a dynamic traffic environment. It is well established that novice drivers need to engage more mental capacity to handle all the situations that occur during driving and that the novice driver cannot handle these new situations as well as experienced drivers.

Learning basic vehicle management requires only a few hours of instruction and practice, but judgement consistent with safe driving is thought to develop only with substantial driving experience. Lack of driving skill may be less important than poor judgement, which develops more slowly than motor skills with extensive driving experience and critical brain maturation. Indeed, one of the issues extensively addressed in the literature is the ability to perceive hazards. Good hazard perception skill can only be acquired through experience and many studies have demonstrated that novice drivers are less likely than experienced drivers to anticipate hazards, especially ones that are difficult to detect (Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock., 2002; Pradham et al., 2005; Wang et al., 2010).

A recent review was undertaken of eleven (1990 or newer) studies that tried to separate the crash effects of age and experience, represented by length of licensure. The weight of evidence is that age and experience have important, independent effects on crash risk, even after differences in driving mileage are accounted for. The studies consistently found that teenage drivers had dramatically higher crash rates than older drivers, particularly drivers older than 25, after controlling for length of licensure. Studies that distinguished 16-year-olds found that crash rates for novice 16-year-olds were higher than rates for novice 17-year-olds, but crash rates for novice 17-year-olds were not consistently higher than rates for novice 18- to 19-year-olds. With regard to experience, the weight of evidence suggests a steep learning curve among drivers of all ages, particularly teenagers, and strong benefits from longer licensure. Of the studies that attempted to quantify the relative importance of age and experience factors, most found a more powerful effect from length of licensure (McCartt, et al., 2009).

The most widely researched skill in relation to driving experience is hazard perception (Elander, West & French, 1993). Hazard perception is the ability to perceive and identify specific hazards in the driving environment (McKenna & Crick, 1991), and involves scanning of the traffic environment, evaluating other drivers' location, predicting objects and other drivers' behaviour and acting on that information (Ferguson, 2003). Several studies have shown differences in visual search strategies between young novice drivers and experienced drivers. In particular, strategies of young novice drivers are less flexible, they concentrate on a smaller visual area, fixations are of longer duration, they are slower at detecting hazards, and are poor at detecting distant hazards compared to experienced drivers (Mourant & Rockwell, 1972; Falkmer & Gregersen, 2001; Chapman & Underwood, 1998). A recent Australian study supplemented these findings and additionally showed that young novice drivers tended to focus their attention on near hazards, in particular those in adjoining lanes, suggesting that they were

significantly poorer than experienced drivers at detecting hazards in the driver's lane (Whelan, Groeger, Senserrick & Triggs, 2002).

It is widely accepted that hazard perception, i.e. situation awareness to hazardous situations is a skill that is highly correlated with traffic crashes (Horswill & McKenna, 2004). Studies also show that experienced drivers perceive potential risk situations better and more quickly than novice drivers (Quimby & Watts, 1981; Finn & Bragg, 1986; McKenna & Crick, 1991; Drummond, 1994; Renge, 1998). Drivers who can detect hazards faster are less involved in traffic crashes than those who detect hazards slower (e.g., Hull & Christie, 1992, cited in McKenna & Crick, 1991; Peltz & Krupat, 1974; Wallis & Horswill, 2007). Likewise, young inexperienced drivers, who demonstrate poor hazard perception skills relative to experienced drivers, are much more likely to be involved in a crash (e.g., Pollatsek, Narayanaan, Pradhan, & Fisher, 2006, cited in Borowsky, Oron-Gilad & Parmet, 2009).

One of the ways to examine detection/perception of hazards is to examine eye glance/scanning behaviours. Attention to the road is essential to safe driving, but the development of appropriate eye glance scanning behaviors may require substantial driving experience. Novice teen drivers may focus almost exclusively on the road ahead rather than scanning the mirrors, and when performing secondary tasks, they may spend more time with eyes on the task than on the road. Olsen et al. (2009) examine the extent to which the scanning of novice teens improves with experience. Driving performance under a set of conditions involving in-vehicle tasks was compared between 18 novice teen (within 4 weeks of licensure and again 6 months later) and 18 experienced adult drivers. The results suggested that, for some tasks, rearview and left mirror-window (LM-W) glances improved from initial testing to the 6-month follow-up and that some differences between teens and adults at initial testing were no longer significant at the 6-month follow-up, suggesting significant learning effects. The frequency of rearview and LM-W glances during secondary tasks improved among teens at the 6-month follow-up, but teens still had significantly fewer glances to mirrors than did adults when engaged in a secondary task (Olsen et al., 2009)

Both early and recent research found that when the road situation is complex, novice drivers tend to stare at the road directly ahead of them as compared to experienced drivers (Lee et al., 2008). Mourant and Rockwell (1972 also reported that new drivers, compared to experienced drivers, spend less time scanning the mirrors. Underwood and colleagues indicated that novice drivers look around the vehicle less frequently than experienced drivers, both to search for potential hazards and to maintain a general awareness of the locations of the neighboring vehicles. Research using driving simulators has also shown similar results in terms of driver behaviors and eye glance scanning. For example, Greenberg and colleagues (2003) reported that there were significant performance differences between teens and adults for hand-held cell phone tasks in a driving simulator (Lee et al., 2008).

In their examination of detection of road hazards by novice and adult drivers, Lee et al. (2008) found significant differences between teen drivers and more experienced adult drivers using a combined hazard detection analysis. The findings also showed that the adult drivers observed hazards and demonstrated overt recognition of hazards more frequently than the teen drivers, and that a large portion of teen drivers failed to disengage from peripheral task engagement in the presence of hazards.

A discussion on the research addressing 'intentional risky' driving follows.

2.7 'Intentional risky' driving behaviour

As indicated above, there are various definitions and underlying causes of risky driving behaviour which the young novice driver may perform with or without being aware of the increased risks, however, the analyses of crash and violation/offence statistics clearly show heightened risk due to engaging in particular risky behaviours

including speeding, following too closely, unsafe accelerations, rapid lane change, drink/drug driving, aggressive driving, etc. (Sarkar & Andreas, 2004). Moreover, there is much research attesting to the fact that a high proportion of young novice driver crashes arise from voluntary risky driver behaviour (Catchpole, Macdonald, & Bowland, 1994; Ivers et al., 2009). In addition, others suggest that higher risk acceptance increases the risk of serious injury from a car crash by eight times (Turner & McClure, 2004), and that generally, teenagers' perceptions of their own skills and those of drivers around them contribute to their risky behaviour. There is also evidence that young drivers, and particularly young male drivers, are highly likely to over-estimate their skills (Gregersen & Bjurulf, 1996). Moreover, the research suggests that drivers (of all ages) who participate in one type of risky driving behaviour are more likely to engage in other types of risky driving behaviour (Beirness & Simpson, 1988; Bingham & Shope, 2004; Caspi et al., 1997; Williams, 1998), leading to the suggestion that high-risk driving behaviour is part of a broader underlying problem behaviour syndrome (see Jessor & Jessor, 1977; Jessor, 1987).

To illustrate, driver error, such as distraction and speeding, was the most common contributor to young novice driver crashes in the United States between July 2005 and December 2007, and the young novice driver was at fault in 80 percent of these crashes (Curry, Hafetz, Kallan, Winston, & Durbin, 2011). In addition, a review of fatal crash statistics shows that, among teenage drivers, speeding, alcohol impairment, and low seatbelt use all play a dominant role in causing crashes and a higher level of fatalities. Statistics from 2004 Fatality Analysis Reporting System (FARS) data shows that speeding is cited in 44% of fatalities of the 16 to 19-year-old drivers, which is higher than any other age group. In 2004, 22% of the 16 to 19-year-old drivers killed had a Blood Alcohol Concentration (BAC) of 0.08 grams per deciliter (g/dL) or higher (NHTSA, 2004). Although seatbelt use is not a contributing factor in the cause of a fatal crash, low seatbelt use rates clearly contribute to the high level of fatalities associated with teen crashes. McCartt and Northrup (2004) showed that from 1995-2000 nationwide seatbelt use was lowest among teenagers (16 to 19 years old) with only 36% among fatally injured teen drivers, and 23% among fatally injured passengers.

Patil, Shope, Raghunathan and Bingham (2006) examined the literature describing risky driving and summarise the behaviours as driving competitively (e.g., enjoyment of out-manoeuvering other drivers), risk-taking driving (e.g., taking driving risks for the thrill of it), high-risk driving (e.g., speeding, improper turning or passing), driving aggression (e.g., tailgating to punish other drivers, honking angrily, making rude gestures), and noted that the attitudes and personality characteristics that promote these behaviours are seen by the American public as serious threats to safety.

Patil et al (2006) also noted that there is good evidence that personality characteristics such as aggressiveness, hostility, sensation seeking, normlessness, disinhibition, susceptibility to boredom, impaired risk perception, and perceived invulnerability, are associated with higher rates of risky driving behaviours and negative driving outcomes (Burns & Wilde, 1995; Furnham & Saipe, 1993; Greene et al., 2000; Iversen & Rundmo, 2002; Jonah, 1997; McMillen et al., 1991; van Beurden et al., 2005; Vavrik, 1997; Wells-Parker et al.,2002). Furthermore, risky driving behaviour has been closely linked to risky behaviour associated with non-driving lifestyles and behaviours. Lifestyles reflecting high rates of risky behaviours, thrill- or risk/sensation-seeking, poor impulse control, and aggression in non-driving contexts predict high-risk driving and related negative driving outcomes (Alparslan et al., 1999; Bierness & Simpson, 1988; Jonah, 1997; Yu & Williford, 1993).

Jacobsohn et al. (2012) argue that, as children enter adolescence, rates of delinquent activity (high-speed driving, for example) increase 10-fold and remain high across the following decade. In addition to seeking thrills, adolescents are trying to find ways to establish that they are no longer children. With conventional means of appearing to be adults unavailable for many teens (e.g., marriage, adult jobs), risky behaviours are one means of establishing that one is no longer a child. Equally important, the striving to establish one's autonomy vis-à-vis

parents and to turn increasingly to peers is a fundamental feature of adolescence across many mammalian species.

A number of studies have examined the adoption of risky driving behaviour of young drivers in New Zealand. A component of the larger Christchurch Health and Development Study which included parental interviews, child interviews, psychometric testing, teacher report, and examination of medical, Police and other records, focused on young driver participants at age 21 years and reflected their driving experiences for the previous three years (18-21 years) (Fergusson et al., 2003). The findings of this study showed that more than 90 percent of drivers engaged in some form of risky driving behaviour, the most common risk-taking behaviours being exceeding the speed limit by at least 20 km/h and driving within four hours of drinking alcohol. A smaller proportion of the sample reported very high-risk behaviours, including street racing (11 %) and running red lights (8.3%). Those were most likely to be involved in risky driving were male, alcohol and cannabis abusers, those involved in criminal offending, and with high levels of affiliation with deviant peers. A strong association was found between extent of risky driving behaviour and crash risk. Those who reported seven or more risky driving behaviours had rates of motor vehicle crashes that were 6.9 times (95% CI: 4.1-11.4) times higher than those who reported no risky driving. After adjusting for driving exposure (and other driver characteristics), the RR of high frequency risky behaviour drivers remained at 4.3 times (3.3 times) higher than those who reported no risky driving

In another New Zealand study, Blows, Ameratunga, Ivers et al. (2005) examined the relationship between risky driving habits, prior traffic convictions and crash injury using cross-sectional data amongst 21,893 individuals in NZ, including 8,029 16–24 year olds. The authors note that "risky driving behaviours, such as drink driving, speeding and non-use of seatbelts, are considered responsible for a significant proportion fatal crashes". Other risky driving behaviours such as racing other vehicles for thrills, close following and illegal passing, have also been associated with increased risk in a number of cohort, case control and cross-sectional studies (Evans & Wasielewski, 1982, 1983; Preusser et al., 1991; Centres for Disease Control and Prevention, 1994; Rajalin, 1994; Harrison, 1997; Begg et al., 1999; Bell et al., 2000; Fergusson et al., 2003; Lam, 2003, all cited in Blows et al., 2005). They also noted that several studies have also suggested that people who report 'habitual' risky driving and have a history of convictions are also at increased risk (Peck, 1993; Centres for Disease Control and Prevention, 1994; Rajalin, 1994; Bell et al., 2000; Fergusson et al., 2003; all cited in Blows et al., 2005). Blows and colleagues found that those who reported frequently racing a motor vehicle for excitement or driving at 20 km/h or more over the speed limit, and those who had received traffic convictions in the previous year, were between two and four times more likely to have been injured while driving over the same time period. Driving at 20 km/h or more above the speed limits was a stronger risk factor for younger (<25 years) than older drivers. Unlicensed driving was a risk factor for older but not younger drivers.

A large-scale longitudinal Victorian-based study, part of the Australian Temperament Project (ATP), has also provided important evidence on risk factors for high risk driving behaviour (Vassallo et al., 2007). The ATP is a longitudinal study following the psychosocial development of a large cohort of children born in the State of Victoria, Australia, between Sept 1982 and Jan 1983. Participants in the current study were 1,135 young adults (56% female) who completed survey questions, about their current driving behaviour and learner driver experiences during the most recent data collection wave, at age 19–20 years. Data collected from parent and teacher surveys in earlier phases of study were also included. Survey questions included items related to licensing: type of licence held and age licence was obtained; questions relating to experiences as a learner driver: number of professional driving lessons, frequency of driving practice and degree of stress and conflict experienced when practising driving; and items relating to driving experiences since licensure: driving exposure (e.g. weekly hours driving/riding); crash experiences (e.g. no. crashes when driving, whether alone/with passengers, property damage or injury/death); and enforcement experiences (e.g. no. speeding offences).

Engagement in risky driving behaviour was assessed by eight items which required participants to recall the number of occasions during their past 10 driving trips in which they had: (1) driven up to 10 km/h above the limit, (2) driven between 10 and 25 km/h over the limit; (3) driven more than 25 km/h over the limit; (4) not worn a seatbelt (or helmet) at all; (5) not worn a seatbelt (helmet) for part of the trip; (6) driven when very tired; (7) driven when affected by alcohol and (8) driven when affected by an illegal drug.

With regard to 'risky driving behaviour', 31 percent had been detected speeding, over 80% reported speeding by up to 10 km/h at least once during their past 10 trips, and approximately two-thirds reported that they had driven when very tired on at least one of these occasions. More males than females reported that during their past 10 trips they had exceeded the speed limit, driven without a seatbelt and/or driven when affected by alcohol.

More importantly, a few participants (7%) exhibited a consistent pattern of highly unsafe driving. Vassallo et al. (2007) reported that a variety of concurrent and past factors differentiated this group. The most consistent and powerful group differences emerged in the domains of temperament style (low task persistence/orientation), behaviour problems (higher aggression and antisocial behaviour), social skills (lower cooperation, responsibility and empathy), school (lower school adjustment) and peer relationships (more frequent affiliation with antisocial peers). The authors concluded that this was a high risk sub group of YD who have "high aggression or hostility, attentional problems, alcohol and drug use, a sensation seeking personality style, attitudes favourable to norm-defying behaviours, low parental supervision, limited parental control of driving, and involvement with peers who misuse drugs and alcohol".

Møller and Gregersen (2008) examined the relation between risk-taking behaviour while driving, the psychosocial function of driving, leisure time activities, car oriented peer group interaction and educational attainment, drawing on Problem Behaviour Theory (PBT), which distinguishes between behaviour that is approved of by the general society and problem behaviour that is condemned. A total of 2,417 drivers aged 18–25 years, who were randomly selected from the Danish Driving Licence Register, participated in the study. Behaviours used to measure deliberate risk-taking behaviour capture issues such as driving at high speed, driving with extra motives and disregarding safety margins. The psychosocial function of driving was measured based on nine questions covering different psychosocial functions such as status, freedom, adventure etc. Additionally, questions also addressed the degree of emotional involvement in driving.

The findings showed a positive significant effect on risk-taking behaviour based on the score on the psychosocial function of driving (most significant were 'status' and 'blowing off steam') and a similar effect for driving related interaction with friends. Low structure/high impulsivity leisure time activities (e.g. PC-games, body building, partying with friends) were also related to increased risk-taking behaviour. The authors concluded that results of this study show that the driving behaviour of the young driver is influenced by motives related to the general life situation of the young driver. This implies that the young driver not only needs skills for handling the car, reading the traffic etc. in order to drive safely the young driver also needs skills to handle the influences from motives stemming from his/her general life situation. The results of this study confirm the need of a differentiated approach based on knowledge of different subgroups of young drivers.

In a later study, Møller (2009) explored the psychosocial function of driving as well as the process through which a relationship between lifestyle and driving behaviour is established and identified four psychosocial functions of driving and the organisation of youth life thought to be important for the adoption of risk-taking behaviour. A lifestyle with few planned activities, few hobbies and meeting with friends as the centre of activities seems to facilitate the use of the car in a way that leads to risk-taking behaviour. The results also suggest that the driving behaviour of the young driver is influenced by other motives than driving safely and that subjective norms regarding driving within the peer group influence the manner and extent to which these motives are expressed in driving behaviour.

Similarly, Bingham, Shope & Raghunathan (2006) used PBT as a framework to examine individual characteristics that predict high-risk driving behaviour amongst a group of young adults (average age 24.4 years) with a current Michigan drivers licence using a telephone survey. Psychosocial information was collected and included: i) perceived environment: parental monitoring & permissiveness; ii) personality system: parent-orientedness, school grades; tolerance of deviance; iii) adolescent problem behaviour: smoking, marijuana use, alcohol misuse. Driving information and traffic offence history was also collected. The offense measures were based on ticketed moving violations recorded in the driver records during two intervals. The first interval was from the participant's licensure through age 19, and the second was from age 20 to approximately age 24. The findings showed that, generally, greater exposure was related to more offences. For men, while adjusting for exposure, lower marks in school and greater substance use predicted more minor offenses in the first interval. In the second interval, more minor offenses were predicted by lower marks in school, more substance use, lower parent orientation, and lower parental permissiveness. For women, more minor offenses in the first interval were predicted by poorer marks in school, greater tolerance of deviance, and more substance use, and more second interval offenses were predicted by lower marks in school.

Age also appears to correlate (negatively) with aggressive driving. Relative to older drivers, younger drivers have higher violation rates (Groeger and Brown, 1989), underestimate the risks of various violations (Dejoy, 1992), have a lower level of motivation to comply with traffic laws (Yagil,1998), and are over-involved in running red lights (Retting & Williams, 1996, cited in Shinar & Compton, 2004). Shinar and Compton (2004) also found that aggressive driving is gender- and age-related, and the presence of passengers was associated with lower rates of aggressive driving. Men and younger drivers are more aggressive than women and older drivers, and the associations are strongest in the least frequent and most extreme aggressive driving behaviours: cutting across multiple lanes and passing on the shoulders. Thus, gender differences are greater for riskier and more aggressive behaviours than for less risky and less aggressive behaviours. These results are consistent with the notion that women can be as aggressive as men as long as the aggressive behaviours are relatively mild (Hyde, 1984; Shinar, 1998).

Several studies have confirmed that there is a strong association between safety attitudes generally and risk behaviour in traffic (Lajunen & Summala, 1999; Parker et al., 1995). Iversen and Rundmo (2004) found that attitudes towards traffic safety were associated with involvement in risk behaviour, especially attitudes about rule violations and speeding, as well as other forms of reckless driving. They also found that younger respondents had a greater tendency to endorse attitudes less conducive to traffic safety than older respondents did. Ulleberg and Rundmo (2002) found that the attitude dimensions explained 50 percent of the variance in self-reported risk-taking behaviour. In addition, their study showed that self-reported risk behaviour was a significant predictor of accidents.

2.7.1 Speeding

Speeding contributes to an overwhelming percentage of all fatal crash types among teenagers. Although speeding is not a unique problem associated only with teenagers, the magnitude of its involvement for teenagers is unique. It is well established that speeding convictions and crashes involving speeding are more common among young drivers, particularly males (Janke, Masten, McKenzie,Gebers, & Kelsey, 2003; Williams, Preusser, Ulmer, & Weinstein, 1995; Williams et al., 2006). It is also well-established that the combination of excessive speed, alcohol and passengers is an important and crucial cause of crash involvement and severity of injury, particularly for single vehicle run-off-road crashes and especially among young men (Brorsson, Rydgren & Ifver, 1993; Begg, Langley & Williams, 1999; McKnight & McKnight, 2000; Evans, 1991; Twisk, 1994).

Data from Minnesota shows that in 2002, speeding was the primary causal factor in 30% of all teen (16-19 year old) driver fatal crashes. Figure 4 is based on statistics gathered from FARS for the year 2004, and shows the

percentage of driver fatalities in passenger vehicles in which driving too fast for conditions, or in excess of the posted maximum was cited as a driver related causal factor by police officers.

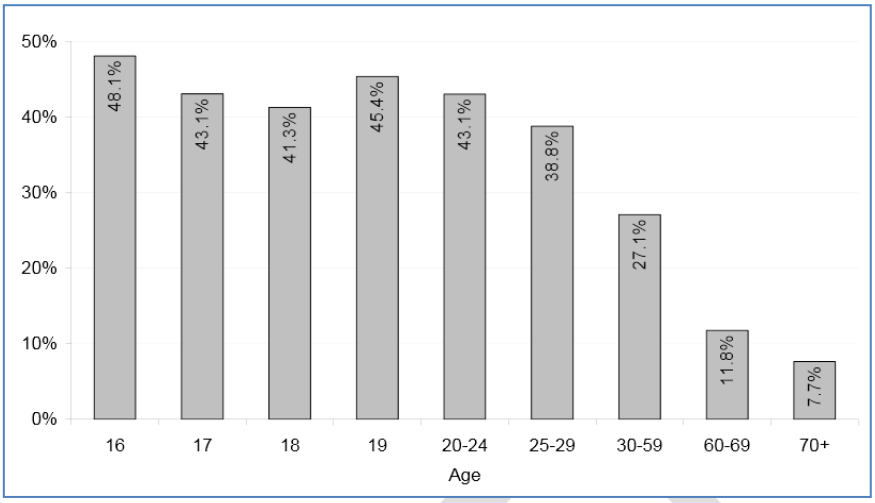


Figure 4: Proportion of drivers fatally injured in passenger vehicles that were driving too fast for conditions or in excess of posted maximum by age (Source: FARS 2004).

Scott-Parker and her colleagues (2012) examined the relationships between previous behaviour, attitudes, psychosocial characteristics and speeding amongst young Australian drivers. Based on survey responses of 378 novice drivers, significant predictors of speeding in early probationary licence holders included gender, car ownership, reward sensitivity, depression, personal attitudes, and Learner speeding.

McKay, Coben and Larkin (2003) evaluated the effect of parental beliefs and driving behaviours on teen driving behaviours and crash risk. The goal was to create a model including both teen and parent behaviours and beliefs that would predict increased crash risk for the teen. Using survey methods, McKay et al evaluated responses of 739 parent and teen pairs, and found a weak association between teens' and parents' beliefs and the driving behaviours of teens. The authors noted that while the parent had some influence on the teen's beliefs and behaviour, this finding suggests that other effects were also present, and may outweigh the parent's influence. The study also found that while there were no strong predictors of teen crashes, a teen's perceptions of personal crash risk and self-reported driving infringements were found to be associated with their risk of crashing.

In New Zealand, too, an analysis of crash data between 2007 to 2011 (Ministry of Transport NZ, 2012) showed that young drivers aged 15 to 24 years were 2.5 times more likely than older drivers (25 years and older) to have had speed (driving too fast for conditions) as a major contributing factor (see Figure 5)

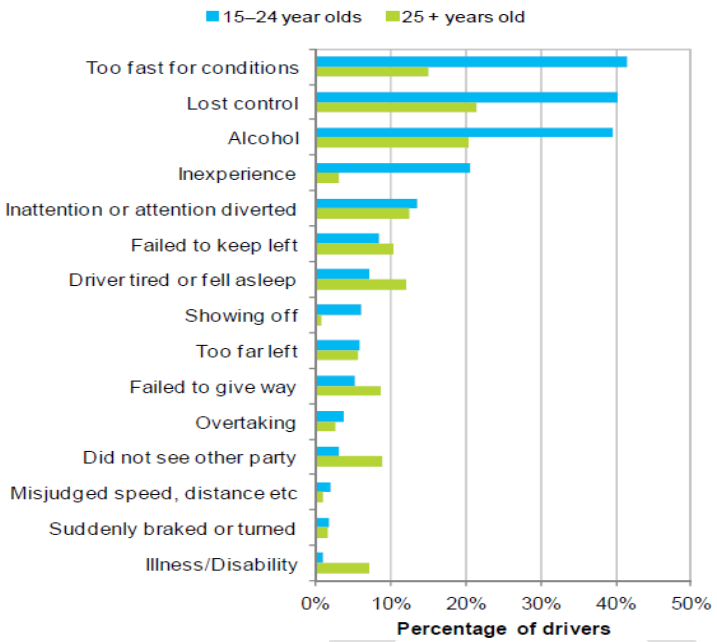


Figure 5: Driver contribution to fatal crashes 2007-2011 by age group
(Source: New Zealand Ministry of Transport, 2012).

Clearly, younger drivers up to about age 25 years, in comparison with older drivers, are more likely to be involved in a fatal crash due to exceeding the speed limit or driving faster for the conditions.

2.7.2 Night driving

Increased crash risk at night is common worldwide. Australian and international data show that young novice drivers are over-represented in crashes during all hours of the day but especially during evening and night hours (ATSB, 2002; Gregersen & Nyberg, 2002; Maycock, 2002; Williams, 1996). It is estimated that the young novice drivers are three times more likely to crash at night than older drivers (Williams, 2000). More recently, Rice et al. (2003), confirmed the likelihood of causing an injury crash increases with advancing night-time hours for 16-17 year olds, with 10pm to midnight representing the highest risk. Further, novice drivers have more severe crashes, a higher injury rate, and higher fatality rate during night-time driving when compared to more experienced drivers (Akerstedt & Kecklund, 2001; Doherty, Andrey & MacGregor, 1998; Massie et al., 1997; Rice et al., 2003; Williams & Karpf, 1983).

This over-representation is believed to be due to a number of factors in addition to darkness (Corfitsen, 1994), fatigue (Connor et al., 2002; Philip et al., 2001), and inexperience (Williams, 2003), including impoverished visual information and increased likelihood of alcohol involvement and speeding, and the fact that young drivers spend proportionally more of their time driving during these hours compared with other (older) drivers and usually in recreational circumstances and with their same-aged friends as passengers (Preusser et al., 1993; Clarke et al., 2002; Crettenden, Yeo & Drummond, 1994; Ferguson, 2003; Keall et al., 2004; Williams, 2003; Williams & Ferguson, 2002). During recreational driving, even drivers who generally try to follow the road rules can be more easily distracted or encouraged to take risks.

In New Zealand, too, it is reported that young drivers tend to be disproportionately represented in fatal crashes at night. For example, between 2009 and 2011, over 50 percent of fatal crashes occurring on Friday and Saturday nights involved a young driver, whereas only 26 percent of daytime crashes involved a young driver (Ministry of Transport NZ, 2012).

2.7.3 Alcohol use

Alcohol impairs driving performance, with reports showing that up to 40 percent of fatal crashes worldwide are alcohol-related (e.g., Evans, 2004; Turner et al., 2011). There is also strong evidence that younger drivers constitute a higher percentage of alcohol-related crashes than any other age group. Drivers under 20 years have a five-fold higher average risk of being involved in an alcohol-related crash compared with drivers over age 30 years (e.g., Keall et al., 2004). Due to this over-representation, considerable research has examined possible causes as well as preventative measures. Much of these efforts hinge on the assumption that younger drivers are typically at a greater risk because they are less experienced, both in terms of driving and alcohol use (Evans, 2004).

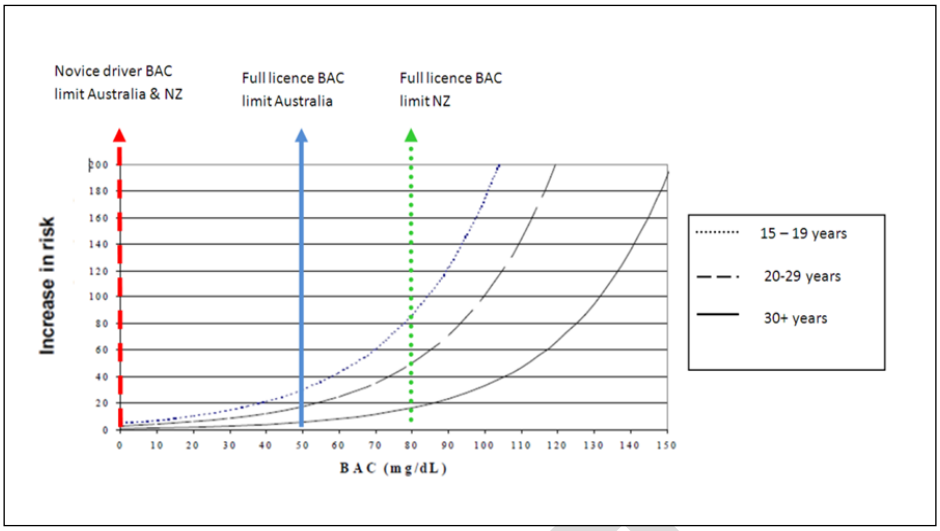
NHTSA (2008) also reported that drivers aged 16 - 24 years account for 23 percent of all alcohol-involved fatal crashes who had a blood alcohol concentration (BAC) of 0.08 g/dl or higher in 2007. Moreover, they noted that safety restraints were used by only 34 percent of fatally injured alcohol-impaired drivers, a decline of 6 percent compared with 2006 data. In 3 widely cited studies, Hingson et al (2001; 2002; 2005, cited in Turner et al., 2011) have extrapolated from national traffic accident reports and college enrolment as a proportion of census data to estimate alcohol-related traffic deaths among college students nationally: rates ranged from 14.1 to 15.2 deaths per 100,000.

In their examination of alcohol-involved crashes among teen drivers in the state of Michigan, US, Bingham and colleagues (2009) identified a number of factors that increased the likelihood that a teen driver will have an alcohol-related crash. They found that, while teens are less likely to be involved in alcohol-related crashes than in other types of crashes, when they did drink and drive teens were more likely than adults to experience an alcohol-related crash, and that the presence of peer passengers and speeding contributed most to an increased likelihood that an alcohol-related crash would result in a casualty. Moreover, they noted that teens experienced a two times greater risk of crashing than adults. When alcohol is coupled with other conditions, the risk of being involved in an alcohol-related crash was as much as 18 times greater for male teen drivers and 11 times greater for female teen drivers compared with adults.

The proportion of alcohol-related fatal crashes in New Zealand decreased from 36% to 29% from 1985 to 2005, but this decline was not evident among adolescents. Of the fatal crashes involving adolescents in 1980 and 2000, 31% and 33%, respectively, were attributed to drink driving. Furthermore, while the risk of fatal crash involvement increases with increasing blood alcohol levels in drivers of every age group, this risk is highest among adolescents. In New Zealand, the risk of fatal injury for drivers aged 15–19 years is more than five times than that for drivers older than 30 years at all blood alcohol levels (Tin Tin, Woodward & Ameratunga, 2008)

Data from Victoria suggests that approximately 36% of all fatal alcohol-related crashes involve drivers aged 18-25 years, even though they only represent around 13% of licence holders. The majority of these drivers are in the 21-25 years age bracket (ATC, 2011). Young drivers are at greater crash risk than fully licensed, experienced drivers with the same BAC level (Keall et al., 2004; Zador et al., 2000).

BAC risk curves have been modified to examine age effects on crash risk by BAC level (e.g., Preusser, 2002; Keall et al., 2004). Figure 6 shows Keall et al.'s (2004) estimates of the relative risk of being involved in a fatal crash by age group, identifying the legal BAC limits in Australia and New Zealand for novice and full licence drivers. It provides an informative graphical representation of the crash risk reductions associated with the introduction of zero BAC limits for novice drivers compared to their previous 0.05% BAC limit (0.08% in NZ). As outlined below, Keall et al., (2004) modified Compton et al.'s (2002) BAC risk curve to examine age effects on crash risk by BAC level.



Note: BAC level is measured in mg/dL, e.g., 50 represents 0.05%

Figure 6: Relative risk of fatal crash per age group by BAC level
(Source: based on data from Keall et al., 2004).

Figure 6 also shows that drivers aged 15-19 years are 15 times more likely to be involved in a fatal crash even with what is considered a low BAC of 0.03% compared to a sober driver. Variations in GLS legislation (including the length of provisional licensing periods) between jurisdictions has a direct effect on BAC crash risk for novice drivers. For example, in Victoria, due to the four-year probationary licence requirements a driver cannot become fully licensed until they are aged 22 years or older, following this their legally permissible BAC limit increases to 0.05%. According to Keall and his colleagues, for drivers aged between 20 and 29 years, the risk of fatal crash involvement is 20 times that a sober driver in the same age group . In contrast, in New Zealand, attainment of a full licence (and therefore a legal BAC level of 0.08%) could occur for drivers as young as 20 years of age (during the time that this study was undertaken), resulting in an increased crash risk approximately 50 times that of a sober peer (Ministry of Transport NZ, 2010). It should be noted recent changes have been made to the BAC legislation in New Zealand where, from 2014 the BAC legal limit will be lowered to 0.05 for those over 20 years of age, and all drivers detected with a BAC level of between 0.05 and 0.08 will receive a fine and lose demerit points.

Keall et al., (2004) conducted a case-control study exploring the relationship between driver age and number of passengers with varying BAC levels in New Zealand, from 1995 to 2000. Data obtained from roadside RBT sites provided an exposure measure which was matched according to day of the week, time, and location demographics with driver fatality BAC data obtained from coroners' reports. Their model estimated statistically significant higher crash risks for young drivers across all BAC levels commencing at the 0.02% BAC level. At a low BAC level of 0.02%, young driver (under 20 years) crash risk was at least five times that of drivers aged 30 years or over with the same BAC level. This risk was also three times higher for the 20-29 year old drivers.

Considerable laboratory research indicates that moderate doses of alcohol impair a broad range of skilled activities related to driving performance in young adults (Holloway, 1995; Stapleton et al., 1986; Moskowitz & Robinson, 1987). Alcohol slows simple and complex reaction time (Holloway, 1995), decreases hand steadiness (Laberg & Loberg, 1989), reduces inhibitory control (Fillmore, 2003), and impairs pursuit rotor tracking (Harrison & Fillmore, 2005).

The effects of alcohol on risk-taking behaviour whilst driving have also been documented (Stein & Allen, 1986; 1987). Leung, Godley and Starmer (2003) conducted simulator experiments on both novice drivers (aged between 18 and 21 years) and more experienced mature drivers (aged between 25 and 35 years) to explore the

effects of low levels of alcohol on performance, particularly in relation to hazard perception, distance and time judgement, and risk perception. The 32 participants were tested in both a sober condition and then following 'modest' alcohol intake (mean BAC 0.064% for mature drivers & 0.059% for young drivers). In reference to tests conducted in the post alcohol intake phase, their findings showed that even 'modest' amounts of alcohol impaired a driver's ability to divide attention on tasks such as: detecting an oncoming vehicle on a curved road, estimating the time taken for a vehicle to pass, and overtaking another vehicle. Alcohol use was also associated with accepting higher levels of risk, as evidenced by accepting shorter gaps when turning right in front of oncoming vehicles in a gap acceptance task. Moreover, male drivers were found to take greater risks than during an overtaking task while when sober; their associated risk was further intensified after alcohol consumption when they decreased the speed at which they were overtaking and thus increased the time taken to safely pass the vehicle. Interestingly, Leung et al's., (2003) research did not find any significant effect of 'modest' amounts of alcohol on decision-making.

Research indicates that drinking is associated with risk-taking and sensation-seeking behaviour among adolescents (Tsai et al., 2010). Alcohol has disinhibiting effects that may increase the likelihood of unsafe activities, including risky driving behaviours. In particular, driving under the influence is frequently coupled to other behaviours that can increase serious crash injury risk (for example, lack of safety restraint use, speeding, etc).

Previous research has identified several factors associated with adolescent drink driving including particular patterns and locations of drinking, other risky road behaviours including nonuse of seatbelts, and riding with drinking drivers, and the use of other substances including tobacco and drugs (see Tin Tin et al., 2008) Conversely, supportive relationships with parents, schools and communities have been shown to reduce the risk of drink driving. Consistent with theories proposed by Bronfenbrenner and Vygotsky, these findings indicate that ecological and sociocultural factors can serve as important even if context-specific mediating factors on adolescent risk taking.

An analysis of a subset of survey respondents aged 15 years and older from the New Zealand Youth Survey showed that 17.3 percent of participants reported drink driving in the previous month. Drink driving was significantly associated with frequent (at least weekly) alcohol use, binge drinking and usually drinking away from home, that is in cars, outdoors, at bars or nightclubs, at parties, at school and at work. Students' perception that parents and schools care about them, parental monitoring, and high academic achievement was associated with a reduced risk of drink driving while having friends who drink alcohol increased this risk. These associations were similar among boys and girls.

Last, is the issue of gender differences. Predominantly, male drivers have been the targeted group as they have been traditionally regarded as those who participate in more risky driving and road rage (Deery, 1999), display 'macho personality' and more aggressive driving behaviours (Krahé & Fenske, 2002), drive at greater speeds and drive in a drunken state (Laapotti & Keskinen, 2004; Shope, Waller, Lang, 1996; Shope, Waller, Raghunathan, et al., 2001a). In comparison, female drivers have typically been regarded as 'safe' drivers and less likely to engage in risky driving behaviours. However, there appears to be an increasing gender equalization between young female and male adolescent drivers emerging, particularly with regard to drinking and driving, and associated behaviours.

Studies have investigated the influence of culture, social pressures and competition between the genders on the increase in aggressive behaviour seen among young women. As women continue to be encouraged to take on more traditional male roles within cultures and society, young women may also feel compelled to match their young male counterparts in risk-taking behaviours and aggression (Bingham et al., 2006; Tsai et al., 2010). Tsai et al (2010) examined alcohol and restraint use by gender amongst young drivers and found that alcohol-

involved fatal crash rates in young female drivers aged 19 to 24 years have increased. While male drivers continue to surpass women in the number of alcohol-involved fatal crashes, young womens' use of alcohol and subsequent involvement in a fatal crash increased among female drivers aged 19 to 20 years and 20 to 24 years over the period 1995 to 2007.

In addition, other research indicates that women are drinking and driving more often and that the proportion of female drivers involved in fatal crashes is increasing. U.S. Fatal Accident Reporting System data (Fell, 1987) suggest that although overall alcohol involvement rates in fatal crashes have been declining for the past four years, the rates for females aged 21-24 year olds have not, and their alcohol involvement rate in late-night single vehicle crashes, a surrogate measure of alcohol-related crashes, is almost as high as that of male drivers. Popkin (1991) examined the involvement of North Carolina (NC) female drivers who are less than 35 years of age for the period of 1976 through 1985 and reports on trends in driver licensing, arrests for drinking and driving, single-vehicle night-time and alcohol-related crashes, and measured blood alcohol levels in fatalities. It identifies an emerging driving-while-impaired problem for younger women, particularly those 21 to 24 years of age.

2.7.4 Distraction

Driver distraction is dependent on many interrelated extrinsic and intrinsic factors. Extrinsic factors may include the demands of driving and non-driving tasks, the circumstances that distract drivers, the length of time they are distracted, the specific con figuration of physical circumstances, the density of the traffic, etc. The intrinsic variables may include driving experience, age, how prone the individual is to risk, the personality of the driver, etc. (for a review, see Regan et al. 2008).

For teen driving, regulatory competence is the ability of adolescents to deploy acquired driving expertise in real world situations, even when there are major distractions. These distractions can be external (e.g., a group of rowdy friends in the car), self-generated (e.g., talking on a cell phone or eating while driving), or fully internal (e.g., ruminating on a social event that occurred previously). Managing to stay on the task of safe driving while employing one's best expertise is a significant challenge for all drivers, and particularly for adolescents, whose regulatory competence is still developing.

There are several reasons for concern, particularly about teenagers and distracted driving. Young drivers are among the strongest users of cell phones, and they tend to be early adopters and aggressive users of new technology (Lee, 2007). In addition, driver age appears to be an important factor moderating drivers' engagement in distracting activities, that is, young drivers are more willing to engage in distracting tasks while driving (Young & Lenné, 2010). Moreover, distractions likely entail greater risk for novices than more experienced drivers. Driving is less automated for novices; consequently, they must devote more of their attentional capacity to the multiple tasks involved in driving (Lansdown, 2002). With less attentional capacity to spare, they may be more susceptible to a distraction - related crash (Lee, 2007). For drivers of any age, distractions can increase overall cognitive load, which can impair the driver's ability to detect changes in the driving environment (Lamble et al., 2002). With novices, however, the threshold for 'impairment' may be lower since driving requires more cognitive resources (even in the absence of distractions). Finally, research suggests many key areas of the brain are still developing during adolescence, including areas involved in regulatory competence, forming judgments and decision making (Keating, 2007), all of which have important implications for driving. For these reasons, teenage drivers may have greater difficulty than experienced adult drivers in effectively managing potentially distracting behaviors and situations while driving.

Young and Lenné (2010) conducted a survey of 287 Victorian drivers to quantify the extent to which drivers reportedly engage in a range of potentially distracting activities; the factors that influence their willingness to engage; and the strategies they use, if any, to manage distraction. Almost 60 percent of drivers use a mobile phone while driving and over one third use the phone in hand-held mode. A high proportion of drivers use audio

entertainment systems, but relatively few use in-vehicle visual displays such as DVD players. Driver engagement in non-technology-based activities, such as eating, drinking, smoking and reading is also prevalent. Young drivers (18–25 yrs) were significantly more likely to report engaging in certain distracting activities, such as using a mobile phone, CD player and eating and drinking, than their middle-age (26–54 yrs) and older (55+ yrs) counterparts. Most drivers (84%) believe that their driving is less safe when engaged in distracting tasks and take steps to avoid distraction.

Peer passengers

There is a strong relationship between the presence of passengers and driving behaviour and crash involvement. Numerous studies demonstrate that the presence of peer passengers increases the likelihood of a crash (Chen et al., 2000; Lam, Norton, Woodward, Connor & Ameratunga, 2003), and the risk increases incrementally with each additional same-aged passenger to around four times the risk with two or more teenage peers compared with driving alone (Chen et al., 2000; NHTSA, 2012). Similar results have been found in New South Wales, Australia, where the risk of a fatal or serious injury crash increased incrementally from carriage of 1-2 passengers and from 2-3 or more passengers for all novice drivers under age 25 years irrespective of licence type (Lam et al., , 2003). Chen et al. (2006) also examined vehicle crash surveillance data in 15 US States and demonstrate that, due to the presence of young teen passengers, more single-vehicle crashes, and the greater likelihood of restraint non-use, teen drivers and passengers had a greater injury risk in teen night-time crashes than teen daytime crashes.

Further, research clearly shows that a greater proportion of passenger injuries among teenagers occur when they are travelling in a car driven by a teenager (e.g., Aldridge, Himmler, Aultman-Hall & Stamatiadis, 1999; Williams, 2000; Chen et al., 2000; Doherty et al., 1998). Williams (2000) found that passengers who were peers of the driver placed themselves at an increasingly elevated crash risk with every additional passenger.

There are several reasons why the presence of peer passengers might increase crash and injury risk. Passengers can provide additional distractions to the driver, increasing their cognitive load and reducing their ability to attention share with important driving tasks. Peer passengers, especially for young novice drivers, can sometimes encourage drivers to engage in more intentional risky and anti-social driving such as driving faster and driving with shorter following distances, (McKenna & Crick, 1991; Regan & Mitsopoulos, 2001; Young, Regan & Hammer, 2003). Attitudes of others can contribute to the likelihood of engaging in risk behaviour. Teenagers who socialise with others who display risky behaviours are more likely to engage in that type of behaviour (Sarkar & Andreas, 2004). Young drivers are intensely social, highly susceptible to peer pressure and easily distracted.

In a naturalistic study of 52 teenage drivers using in-vehicle cameras, Goodwin, Foss and O'Brien (2012) found risky driving behaviors were indeed more common in the presence of passengers. For example, drivers carrying multiple teenage peers were three times as likely as those with no passengers to engage in one or more potentially risky behaviors such as speeding, following too closely, or goofing/showing off with the vehicle. However, passengers encouraged the driver to take risks in only 1 percent of the video clips when passengers were present. This suggests the mere presence of peers may have been the more important influence on risky driving behaviors than passengers actively encouraging the driver to take risks (Goodwin et al., 2012). However, it is also plausible that "riskier" drivers are more likely to carry multiple peers.

Somewhat different findings were obtained in another recent study also involving instrumented vehicles. Simons-Morton et al. (2011) equipped the vehicles of 42 newly licensed teenage drivers with recording systems that monitored driving performance and vehicle occupants. Teens engaged in less risky driving – defined as g-force events high enough to make the passengers uncomfortable – when carrying teenage passengers. However, having friends who tend to be risky (i.e., who smoke, drink alcohol, use marijuana, do not use seat belts, etc.)

was associated with rougher driving as well as crash /near crash incidents. The authors conjectured that injunctive norms – the perceived expectations of others – may play a key role in teenage driving risk (Simons-Morton et al., 2011).

Most recently, Goodwin, Foss, Harrel & O'Brien (2012) examined distracted driver behaviors and potentially distracting conditions among young, beginning drivers. The findings showed that the presence of teenage peers – especially multiple peers – sometimes resulted in horseplay and loud conversation in the vehicle. Both horseplay and loud conversation were particularly common after 9 p.m. on weekends, a time when much of teen driving may be "recreational." By contrast, carrying parents – and to a lesser degree siblings – was associated with a substantially lower likelihood of horseplay and loud conversation. Potentially distracting conditions in the vehicle such as horseplay went hand-in-hand with serious incidents and high g-forces. However, causality cannot be inferred. Carrying multiple passengers may have caused these incidents, but it is also possible that riskier drivers are simply more likely to carry multiple, rowdy passengers. Finally, electronic device use and other distracted driver behaviors were strongly associated with looking away from the roadway, although electronic device use was only weakly related to serious incidents.

Mobile phone use

It is now well established that mobile phone use while driving compromises both driving performance and driving safety, in both real and stimulated driving environments. Depending on the type of engagement, mobile phone use while driving has been found to be associated with poor speed maintenance (Charlton, 2009; Haigneyet al., 2000), failure to maintain an appropriate headway position (Charlton, 2009; Rosenbloom, 2006), increased mental workload (Alm and Nilsson, 1995; Kircher et al., 2004; Matthews et al., 2003; McKnight and McKnight, 1993), and the failure to detect relevant traffic signals (Strayer and Johnston, 2001). A number of studies have also found that engaging in a mobile phone conversation while driving (either hands-free or while holding the phone) can increase driver's braking response time to hazards (Consiglio et al., 2003), to common traffic signals (Hancock et al., 2003; McKnight & McKnight, 1993; Strayer and Johnston, 2001) and to lead vehicles decelerating (Alm & Nilsson,1995; Strayeretal.,2003). Epidemiological research has shown that conversing on a cell phone while driving is associated with an increased risk of being involved in a vehicle crash of between four and nine times (McEvoy et al., 2005; Redelmeier & Tibshirani, 1997; Violanti, 1998; Violanti & Marshall, 1996; Hallett et al., 2011. In its 100-Car Naturalistic Driving Study, the US Department of Transportation National Highway Traffic Safety Administration found use of a wireless device while driving to be the single highest cause of driver inattention contributing to crashes, near crashes, and incidents (Neale, Dingus, Klauer, Sudweeks & Goodman, 2005).

Additionally, practice has not been shown to reduce the distractive effects of cell phone use while driving (Cooper & Strayer, 2008), implying that even drivers who use their mobile phone frequently are still at the same level of risk as those who do not use their mobile phone frequently (although see Shinar et al., 2005, for contrary data).

Despite the known risks of mobile phone use and the potential effect this behaviour can have on young driver crash involvement, very little research has been undertaken addressing this issue. McCartt et al (2006) undertook a review of the literature addressing drivers' use of cell phones to identify trends in drivers' phone use andto determine the state of knowledge about the safety consequences of such use and also noted that few studies included participants younger than 18 or explicitly examined the effects of phone use among teenagers.

Greenberg et al. (2003) reported that, when compared with adult drivers (ages 25–66 years), teenager drivers (ages 16–18 years) detected far fewer events in front of vehicles when dialling hand-held phones and had more lane deviations during hand-held voicemail tasks. Shinar et al. (2005) observed similar performances on driving measures (e.g., speed, lane keeping) for younger drivers (ages 18–22 years) and intermediate drivers (ages 30–

33 years), and both groups performed better than older drivers (ages 60–71 years). In another study, Ranney et al. (2005) found that younger drivers (ages 18–25 years) were faster than older drivers (ages 50–60 years) at dialing and answering hand-held and hands-free phones. However, these studies did not address the issue of distraction, nor crash risk.

Vivoda et al. (2008) examined mobile phone use while driving at night. They found that rates of night-time mobile phone use were similar to results found in previous daytime studies, being approximately 6 percent. They also found that use was highest for females and for younger drivers. In fact, the highest rate observed during the study (of 11.9%) was for 16 to 29 year old females. They argued that the high level of mobile phone use found within the young age group, coupled with the increased crash risk associated with mobile phone use, night-time driving, and for young drivers in general, suggests that this issue may become an important transportation-related concern.

A large recent study in New Zealand (Hallett et al., 2011) investigated the prevalence of mobile phone conversing while driving and examined driver's beliefs regarding the risks associated with conversing on a mobile phone while driving and drivers' views on legislation that would restrict cell phone use while driving. High prevalence rates of engaging in cell phone conversations while driving were observed. Over 60 percent of participants in this survey reported conversing on their mobile phone while driving in the past week. The survey also revealed that most drivers were not fully aware of the risk associated with talking on a mobile phone while driving. This is reflected by results revealing that the sampled population regard this behaviour as 'moderately safe' (38.2%) to 'moderately unsafe' (31.5%), with a small percentage of participants perceiving this behaviour as 'extremely unsafe' (5%). Finally, the majority of participants supported a ban on hand-held mobile phone use, such as hand-held conversing and text messaging, providing hands-free devices are still allowed. Further, over 60 percent of drivers in this survey reported talking on their mobile phone while driving (either hand-held or hands-free), for at least an average of 3min per week. Other self-reported prevalence surveys have found that anywhere between 56 and 81 percent of respondents converse on their mobile phone while driving before legislation was introduced.

Most importantly, for this discussion, the results of this survey also reveal that drivers aged 16–20 years and those in the 51 plus category converse on their cell phone considerably less than the other four age groups. The finding that older drivers spend less time conversing on their mobile phone while driving is consistent with other research (Sullman & Baas, 2004). The finding, however, that the youngest respondents spend the least amount of time conversing was not expected. Hallett et al (2011) suggested a plausible reason could relate to the relatively high cost of mobile phone calling rates in New Zealand.

Of interest, a more recent observational study of mobile phone use among Wellington drivers found that, out of 8,335 cars systematically observed at traffic lights and 9,520 cars in moving traffic (each at three different Wellington locations), the use of mobile phones was a low 1.87%. More importantly, this study showed that younger drivers (<25 years) were almost three times more likely to use their mobile phones while driving compared to older drivers, especially in moving traffic. In addition, overall, it was much more common for drivers to use their phones in a "non-ear position" (77.8%) than next to their ear, this behaviour was also significantly higher among younger drivers compared with older drivers (Starkey, Wilson, Charlton et al., 2013).

With regard to texting while driving, it appears that young drivers do engage in this behaviour (Bryant et al., 2006), the incorporate technology-mediated communication to a greater extent than older adults (Bryant et al., 2006), and that texting while driving results in an even greater decrease in driving performance compared with mobile phone conversations while driving. Drews et al. (2009) reported that, in a simulator, texting drivers showed a decrease in control and responded more slowly to the braking lights of other cars compared to mobile conversing drivers and controls. In several other driving simulation studies, texters took their eyes off the road

and made unnecessary lane changes more frequently than did mobile conversers (Crisler et al.,2008; Libby and Chaparro, 2009; Hosking et al., 2009; cited in Harrison, 2011).

Harrison (2011) surveyed a sample of college students on texting behaviour and attitudes and analyses revealed that almost all (91%) participants reported having used text messaging while driving, with many reporting doing so with passengers, including children riding in their vehicles. Further, a substantial number of participants reported driving dangerously above the speed limit and drifting into other traffic lanes while texting, and many reported "sexting" and arguing via text messages while driving. Interestingly, these young drivers also agreed that texting while driving is dangerous and should be illegal.

Moreover, novice drivers appear to be especially susceptible to distraction as a result of texting. A simulation showed the amount of time young texters spend not looking at the road while driving was about 400 percent greater than older controls (Hosking et al., 2009).

3 Current management strategies and initiatives addressing young driver crash risk within a Safe System framework and their effectiveness

Over the last three or four decades, there have been many initiatives suggested and implemented internationally and in Australasia to address the over-representation of young novice drivers in casualty crashes. Traditional measures predominantly have relied upon education and have had limited success in regulating the risky driving behaviour of the young novice driver. More recently, the implementation and subsequent reform of Graduated Driver Licensing (GDL) systems has been a popular approach and appears to have been effective in addressing the young driver problem. In addition, Police enforcement of safe driving practices, improved road design and operation (particularly measures aimed to reduce speeding and barrier systems to reduce injuries in single-vehicle run-off-road crashes), and improvements in vehicle safety (advanced crash avoidance and occupant protection) as well as parental involvement, promotion of eco-driving, and the use of telematics (in conjunction with insurance incentives) all show promise to varying degrees. This section discusses the research addressing the effectiveness of each approach in addressing young driver crash risk.

3.1 Driver training and education

Driver training and educational approaches have traditionally been one of the most important means to improve driving skill, particularly in developing specific skills to handle and manoeuvre vehicles and enhancing knowledge and attitudes relating to safe driving behaviour, and it has been taken for granted that skill training is an effective way to improve safety (Gregersen 1996). Although being basically sensible, the idea of teaching manoeuvring skills has, however, been challenged. New ideas about the nature of driving suggest that motives, anticipation, self-confidence and other factors might be even more important in safe driving than the skills themselves.

Repeated reviews of the effectiveness of traditional vehicle-handling and control training programs show few benefits for either Learner or Provisional drivers in terms of crash and injury reductions. In fact, in some cases, training can be counterproductive resulting in inflated confidence in their ability to cope with driving in hazardous situations and risk-taking without sufficient improvement of actual skills, such that traffic violations and crash involvement increase. As a consequence of training or driving experience, drivers' confidence in their skills increases more rapidly than their actual skills (Gregersen 1996; Renge 1995). Studies examining the association between skid courses and self-assessment support this hypothesis (Gregersen, 1996; Keskinen, Hatakka, Katila, & Laapotti, 1992; Tronsmoen, 2008). An experiment conducted by Gregersen showed that 'skill'-trained drivers tend to evaluate their skills as better than 'insight'-trained drivers, after just half an hour's practise. Positive feedback (easy tasks and repetition), together with the rewarding nature of learning, can increase self-confidence

even though the actual skills to manage in real situations have not developed to the same degree (Gregersen 1996).

More promising results have been found for training of higher-order skills, namely, attitudinal-motivational and cognitive-perceptual skills (e.g., Washington et al., 2011).

For Learner drivers, basic vehicle-handling skills training is important and effective in learning to operate a vehicle in traffic, in passing practical driving tests, and in preventing crashes during the Learner period. Training of car control skills does not, however, protect Learners from crash involvement once they have graduated to a licence that allows unsupervised driving. In contrast, insight-based training as part of the licensing system shows substantial crash reductions post-licensing (Gregersen, 1996; Nyberg & Engström, 1999; Senserrick & Swinburne, 2001). It is clear that there are many perceptual and cognitive skills, acquired through experience, and amenable to training, which are necessary for safe driving. Evaluations of CD-ROM packages to train hazard perception and other higher-order cognitive-perceptual skills have shown positive results; namely that Learners can be better trained in such skills, which are known to play a large role in young driver crashes, without inflating confidence in driving ability (Regan, Triggs & Godley, 2000; Fisher, Laurie, Glaser, Connerney, Pollatsek, Duffy & Brock, 2002). As an example, the VicRoads-developed Hazard Perception Test (HPT) was introduced in 1996 for Provisional licensure, in addition to the on-road practical test requirement. While an evaluation of the HPT found that novices with very low scores had higher crash involvement than novices with average and high scores (Congdon, 1999), it is noteworthy that it only examined a small sub-set of these skills. Lenné, Regan, Triggs and Haworth (2004) argued that the HPT should be upgrades to ensure that it assesses the full range of perceptual and cognitive skills required to drive safely, not just those relating to hazard perception.

For Provisional drivers, the insight-training approach has been shows to be more effective in reducing crash involvement and has been shown to target misconceptions of driver ability and susceptibility to risk. Hazard perception research has also found that novices can be trained to perceive hazards more quickly using video, small group discussion and in-car feedback methods.

Groeger and Banks (2007) argue that what is learned during driver training must be transferred successfully to a broader range of circumstances than can possibly be anticipated during formal training. The purposes for which learners drive while under instruction or practising with parents are not those that will later motivate them. Furthermore, the times of day and weather conditions when driving occurs, the extent and sources of distraction, relationships with others in the vehicle, etc. will overlap very little with the circumstances that pertained before licensing. Because of this, it should be understood not only how driving skill is acquired, but also how effectively acquired skills can be used under post-licensing driving conditions. According to almost all theorists in the area, transfer, if it occurs at all, will depend on the degree of overlap between learning and transfer contexts.

The licensing age in Sweden was altered in order to permit more practice before full licensing (see Sagberg and Gregersen 2005) and at least two longitudinal studies of drivers' skill acquisition have been published (e.g. Groeger & Clegg, 2000; Groeger & Brady 2004). The latter provides convincing evidence of substantial and reliable improvements in driving skill in the course of training and that these improvements rely on both formal instruction and extensive practice. However, the post-driving test performance data in the study of Groeger and Brady (2004), together with the crash analyses of newly licensed drivers by, among others, Mayhew et al.(2003), demonstrated conventional approaches to training are unlikely to produce a lasting safety benefit. By failing to consider whether any substantial transfer of pre-licence learning to later driving should be expected, it is believed that too much conventional driver training has been required and there may be a danger of missing a further enhancement of GDL. Groeger and Banks' (2007) review has shown that transfer to more novel circumstances, which would be sufficient to enable appropriate more or less instantaneous reactions, as might be required in

hazardous situations, does not take place. They concluded that there is little theoretical or empirical foundation for the supposition that what is learned during or after training will have a safety benefit in later driving.

In contrast, Groeger and Brady (2004) examined the association between self-assessment and driver training (other than skid courses) and questioned the suggestion that young drivers are especially prone to overestimating their own driving ability compared with more experienced drivers. Further, Tronsmoen (2008) found that professional instruction was negatively associated with self-assessment of skills, while lay instruction was positively correlated to self-assessment, thereby arguing against unrealistic self-assessment as a side effect of professional driver training. Moreover, Tronsmoen argued that, despite evidence to suggest that young drivers are able to make a realistic self-assessment and given that drivers with the most self-critical judgment of their own abilities have the highest risk of being involved in a crash, there seems to be a need for continuing to strengthen skills training in driver education in order to reduce crash risk.

Crick and McKenna (cited in Haworth et al., 2000) suggested that there is still much to be understood about the benefits of driver education and training and 'the lack of evidence for the benefits of road safety education and training may be ascribed to a lack of methodological soundness in previous evaluations and/or to the content of the courses' (p. 15). In support of this, in his recent review, Lonero (2008) found that the majority of driver education programs received little formal evaluation and that 'past evaluations were severely limited in scope, power, and scientific rigor' and concludes that 'this field has developed in a strangely unsystematic manner compared with other research and evaluation fields'. As Lonero (2008) commented, most driver education and training evaluation studies fail to build on earlier research and scientific knowledge and did not develop through systematic replication of research. They typically lacked a comprehensive conceptual framework, in order to avoid definitive answers and do not incrementally build on knowledge and intermediate effects (Isler et al., 2009).

There is no doubt that previous evaluations have contributed little to the development and improvement of driver education. As Lonero (2008) pointed out they have typically addressed the general question of whether driver education and training 'works' and failed to answer specific questions such as 'do some types of driver education programs lead to better educational and safety outcomes than others? Indeed, Isler et al (2009) compared the effects of training in higher-order driving skills (e.g., perceptual, motivational, insight) and vehicle handling skill training in relation to on-road driving performance, hazard perception, attitudes to risky driving and driver confidence levels in young, inexperienced drivers. They found the participants who received higher-order driving skill training showed a statistically significant improvement in relation to visual search and the composite driving measure. This was accompanied by an improvement in hazard perception, safer attitudes to close following and to dangerous overtaking and a decrease in driving related confidence. The participants who received vehicle handling skill training showed significant improvements in relation to their on-road direction control, speed choice and the composite driving score. However, this group showed no improvement in hazard perception, attitudes to risky driving or driver confidence.

There is also evidence to suggest that simply listening to a commentary can improve hazard perception skills. McKenna et al. (2006) gave anticipation training to a group of drivers by showing them a 21min video of hazardous situations with a commentary provided by a police driving instructor. A control group saw the same video but without the commentary. Subsequently they found that the trained drivers had faster response times in a typical hazard perception test. Furthermore they were also found to give less risky responses on a battery of tests designed to assess speed choice, gap acceptance and violations. A second experiment demonstrated that the training only reduced speed-risk responses in those scenes that were considered particularly hazardous. McKenna et al. (2006) therefore argued that listening to a commentary improves hazard perception performance and decreases speed-related risk taking but only in the presence of hazards.

In addition, Isler et al. (2009) trained one group of learner drivers to produce a commentary while watching a series of hazard perception clips. When compared to an experienced group of drivers, the trained learners were found to detect fewer hazards prior to the commentary training, but were subsequently indistinguishable from the experienced group following commentary training. They also compared their trained learners to two control groups of learners (one of which saw the same training material but without instruction in how to produce a commentary). All learner groups performed equally poorly prior to training, but the trained learners outperformed the control groups after the training intervention.

Most recently, Crundall et al. (2010) investigated whether learner drivers would benefit from being trained to produce a commentary drive. The results showed that, in comparison with an untrained group, the trained group had fewer crashes, reduced their speed sooner on approach to hazards, and applied pressure to the brakes sooner. Conversely, the untrained drivers' behaviour on approach to hazards was symptomatic of being surprised at the appearance of the hazards. The benefit of training was found to be greater for certain types of hazard than others.

In summary, while the evidence of the effectiveness of driver training and education remains elusive, even though a stated objective of driver education is to produce safer drivers, typically defined as drivers less likely to crash (Mayhew, 2007), safer drivers are a pillar of the Safe System approach, and education and training continues in popularity. Driver education should complement graduated driver licensing and contribute to its overall safety benefits. Current and future efforts to improve driver education and better integrate it with graduated licensing programs need to be rigorously evaluated to determine what does and does not work to reduce young driver crashes, and as importantly, to understand why this is the case.

3.2 Graduated Driver Licensing (GDL) models

Traditional methods to address the young driver problem, such as standard driver education and training programs have been largely unsuccessful. An alternative is to introduce a range of requirements and restrictions on drivers in sequential stages as they learn to drive, that is, to mandate a GDL system.

The acquisition of experience is a crucial ingredient in driver education and training. The primary aim of GDL models is to reduce the inflated crash and injury risk of young novice drivers by allowing driving only in low-risk circumstances when first driving and gradually increasing exposure to higher-risk conditions based on increasing experience and maturity.

Restrictions in GDL programs appear to have had a major and successful impact in reducing your driver crashes and associated injuries to themselves and others, during the learner and intermediate stages of licensure with many demonstrations of success, albeit to varying degrees (Senserrick & Whelan, 2003; Foss, 2003; Langley, 1996; Shope, 2003, all cited in Simons-Morton, Hartos & Preusser, 2006; Williams et al., 2012). The evaluations of GDL in many countries have shown that if experience is gained under supervision and under safe circumstances, the crash involvement after licensing is reduced compared with gaining the experience alone. These conclusions apply to night-time restrictions, restrictions on BAC levels, and passenger restrictions. Furthermore, it appears that these systems enjoy wide public support, especially amongst parents of teen drivers (Simons-Morton et al., 2006).

The New Zealand GDL system consists of three phases: the first phase requires drivers to spend a minimum of six months under a learner licence, available at the age of 16 years. This allows the holder to drive only when under supervision of an individual who has held their full New Zealand licence for more than two years. In addition, the learner licence holder must display an 'L' plate when driving. At the end of the learner phase, the learner must pass a restricted licence test.

The second phase allows the holder to solo drive without passengers between the hours of 6am and 10pm under a restricted licence. The restricted phase lasts for a minimum of 18 months unless the licence holder completes an approved time-reducing educational course which shortens the period to 12 months. In order to move to the final stage the restricted driver must pass a full licence test.

In the final phase of the GDL system, all restrictions previously placed upon the driver are lifted and the driver holds a full licence (LTNZ, 2006). Under the current New Zealand licensing system, people can apply for a full drivers licence after 18 months of being on a restricted licence if under 25 year, whilst people can apply for a full drivers licence after 6 months of being on a restricted licence is aged 25 years or older.

Interestingly, Lewis-Evans (2010) examined crash involvement during the different phases of the New Zealand GDL system and found that for drivers licenced between 200 , while overall crash risk increases when the novice driver moves to the restricted phase, even with the restrictions in place, there appears to be a higher crash risk associated with gaining a full licence between 12 and 18 months after restricted licensure and opting to undertake the educational course, compared with gaining a full licence after 18 months. Lewis-Evans suggested that, despite the completion of an approved time-reducing educational course, there is greater benefit in remaining on the restricted licence for the full 18 month period. Indeed, he also notes that the practice of offering a time-reduction off licensing as an incentive for completing driver education is not common internationally, and is generally considered to be counter-productive as part of a licensing system (Mayhew, Simpson & Singhal, 2005; Lewis-Evans, 2010).

It has to be noted though, that it is very likely that drivers, who have completed a time-reduction educational course in New Zealand, are a special sample of young drivers who are motivated to drive more frequently and longer distances than the average young driver and therefore would be more at risk, even if they remained longer on a restricted licence. Also the largest increase of crash risk for a young driver occurs after the transition from the learner licence to the restricted licence rather than from the restricted to the full licence, when the time reduction is applied. One of the issues of the GDL system in New Zealand is the fact that the drivers on the restricted licence do not need to display an R plate and this makes it difficult for the police to enforce the restrictions.

Although the GDL practice-driving requirements are a step closer to achieving needed practice and gaining experience, the high crash rates that continue to occur in the transition to independent driving suggest that more is needed, and a better understanding of driving behaviour is required.

3.3 Attitudes and motivations for safe driving

3.3.1 Parental Involvement

While there is more to be learnt about how parents teach their teenage children to drive, decide when they are ready to test for a licence, and manage their early independent driving experience, there is growing research on the effectiveness of interventions to increase parental roles and management of newly licensed teens during the initial independent driving period (Simons-Morton et al., 2006; Williams, Braitman & McCartt, 2011; Whelan & Oxley, 2007) in the adoption of safe driving amongst novice drivers.

Monitoring is only one aspect of the protective influence of parental involvement. Parents are trusted sources of health and safety information and therefore serve as key informants and role models. In fact, family connection has been found to be pivotal in reducing vulnerability across all major risk domains (Ginsberg et al., 2009).

Parents have substantial opportunity to affect safe teen driving because they are involved from the beginning (Hartos et al., 2004) and through their behaviour both while they are driving themselves and their support of GDL systems. There is also evidence suggesting that parental style greatly influences adoption of safe driving

practices, and that there is a link between parenting style and young driver crash risk. One study suggests that having a parent with a driving history of three or more reported crashes increases the teenage child's risk of having a reportable crash (Ferguson, Williams, Chapline, et al., 2001). Hartos et al. (2004) also shows that low parental monitoring and lenient parent restrictions placed on teen driving, especially in terms of allowing teen passengers, are related to increases in teen risky driving, traffic violations, and crashes. Conversely, the research is quite clear that these behaviours and crash risks are lower amongst teens whose parents apply limitations. By having rules that regulate teen driving, parents can limit teen exposure to higher-risk driving conditions (Hartos et al., 2004).

Baumrind, Maccoby and Martin (cited in Ginsberg et al., 2009) described four discrete parenting styles: Authoritarian – parents who place restrictions with little warmth; Permissive – parents who provide warmth and emotional support with few restrictions; Uninvolved – parents offer neither support nor restrictions; and Authoritative – parents who closely monitor their children with warmth and emotional support, as well as responsiveness and firm boundaries. Authoritative parents most successfully promote positive behavioural and emotional outcomes in adolescents and best foster effective family connections. Although parenting styles vary according to socio-demographic group, the authoritative style has been found to benefit all adolescents, regardless of ethnicity, socio-economic status, or family structure. Ginsberg et al's (2009) findings confirm that safe driving belongs on the list of adolescent behaviours (including substance use, sexual initiation, delinquency, and aggression) known to be positively influenced by authoritative parenting. These findings also confirm that engaged parents, in contrast to uninvolved parents, were protective to youths in the domain of safe driving. Permissive parents (high support alone) had few statistically significant effects on driving safety. Notable exceptions were effects on driving while angry and attitudes about intoxicated driving. Parents offering strong rules and monitoring with little support had their greatest effect on topics reinforced by laws, including seatbelt use, speeding, racing and substance use. The authors concluded that youths who perceived their parents as involved, including those with orientations involving rules and support (authoritative), rules only (authoritarian), or support only (permissive), generally had more desirable attitudes and behaviours regarding driving safety than did those with uninvolved parents. However, adolescents with supportive and active parents (rules, monitoring, and support) were most protected. These results show that effective monitoring typically is most effective when given in a supportive context.

Despite the potential benefits of parental involvement in the management of independent driving amongst teen drivers, many parents may be less involved in their teen's driving than they could be despite the fact that they are in a prime position to influence their driving behaviours. Parents' perception of and reactions to teen crash risk are mixed. Parents believe their teenaged children are generally responsible, and, therefore, will avoid the behaviours that the parents believe to be the primary causes of teen crashes and resulting injuries. However, many parents do not fully appreciate the risks that teens experience in typical driving conditions. Parents of teen drivers generally recognize exceptional driving behaviours such as teen drinking and driving, as extremely risky, but fail to appreciate the considerable risks associated with common situations, such as driving with teen passengers, without safety belts, in bad weather, on the weekend, or in rain at night (Simons-Morton, Hartos, 2003).

Moreover, while many parents place at least modest limitations on driving by newly licensed teens, these limits tend not to be very strict and not to last very long (Beck, Shattuck & Raleigh, 2001; Simons-Morton et al., 2006). This is likely to reflect several factors including a lack of knowledge of the risks associated with young novice drivers, feelings of ambivalence about novice driving, a tendency to under-estimate risks associated with their own children and a lack of availability of clear guidelines and resources for parents on managing young driver risks.

Another critical parental responsibility is choosing the vehicle (Hellinga, McCartt & Haire, 2007; Rivara, Rivara & Bartol, 1998; Scully, Newstead, Oxley, French & Burke, 2012). Parents play a critical role in influencing vehicle ownership, access, and timing of vehicle purchase. First, parents usually own the vehicle in which the young driver learns to drive, and very soon after licensure it appears that many young drivers purchase their first vehicle (Scully & Newstead, 2011). Second, parents are likely to influence the available budget for the young driver's first vehicle as many young drivers purchase their first vehicle with monetary support from their parents, either in part or in full (Scully & Newstead, 2011), with very few purchasing based on obtaining a personal loan from a financial institution (see Figure 7).

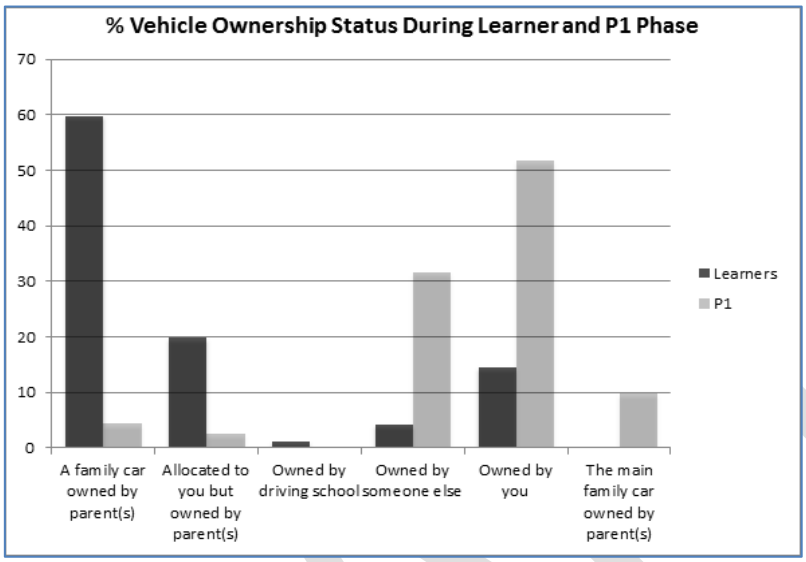


Figure 7: Vehicle ownership status during Learner and P1 phase
(Source: Scully & Newstead, 2011)

Therefore the vehicle driven by the young driver will play a significant role in keeping them safe and parents play a crucial role in vehicle access, timing, type, and budget when purchasing a first car. Given this important role, education on safe vehicle choice/access for young drivers should be delivered to both young drivers and their parents. However addressing the benefits of good vehicle choice is an emerging area of young driver road safety, so it is unlikely that there exists much information about how to address this issue.

In response, a number of educational resources available and few have been evaluated. One successful resource is the Checkpoints Program, developed and piloted in the US by Hartos, Nissen, & Simons-Morton (2001). Another is the Roads 2 Survival, an Australian resource. More recently, the 'Going Solo: A resource for parents of P-Plate Drivers' (Whelan & Oxley, 2007) has been developed for Australian parents, and a revised version was developed in New Zealand (Whelan, Oxley & Charlton, 2008). Evaluations of the resource indicate high acceptance of the resource and improved awareness of young driver issues by both parents and their teens, however, the effect on changing driving behaviour for both parents and young drivers was inconclusive (Whelan & Oxley, 2007; Zhao, 2008).

These interventions focus on increasing the involvement of parents during their teen driver's learner and intermediate phase of licensing and limiting their driving as they gradually build up experience in risky driving situations. For example, parents may be encouraged to limit their teen drivers' night-time driving and carrying of peer passengers within the first 6-12 months on their intermediate licence as their teen driver gains experience and becomes familiar with driving unsupervised.

More recently, Scully and her colleagues (2012) gathered evidence and information to understand the current state of play with regard to initiatives to promote the purchase and use of safer vehicles amongst young novice drivers in Australia, and to provide advice and guidance for the way forward to ensure an increase in use of safer vehicles amongst this driver group. They concluded that there is much scope for improvements to educate young drivers and their parents on safe vehicle choice. In the discussions with representatives from key stakeholders Government representatives were unanimous in their support to elevate the issue in young driver safety strategies and they agreed that a national focus was the best framework for the publicity strategy. Scully and her colleagues (2012) suggested the need for information about safe vehicles for young drivers to be disseminated at a national level to both young drivers and their parents.

There have been a small number of studies in New Zealand examining the role of parents/caregivers in the learning to drive process. These studies have shown that high parental monitoring of driving by teens can reduce risky driving and crashes, especially during the high risk first few months of driving, and interventions designed to encourage parental monitoring have shown promise (see Begg, Langley, Broughton et al. 2009).

3.3.2 Peer passengers

While much of the literature addresses the negative consequences of presence of peer passengers, there is recent evidence to suggest that there is potential for peer passengers to help improve driving behaviours (e.g., 'skillful co-piloting'). Williams et al. (2007) suggest that legislative approaches to restricting the number of peer passengers of young drivers could be implemented with a view to changing in-vehicle attitudes and behaviour in a protective or beneficial way.

While few studies have examined whether the influence of peers may potentially have a positive influence on young driver behaviour, there is some evidence to suggest that some peers do intervene in unsafe driving behaviour (Barry & Wentzel, 2006; Juarez et al., 2006; Buckley & Davidson, 2012). Buckley and Davidson (2012) found a number of factors that predicted intervening behaviour including expectation from peers (young drivers may be motivated to conform to the behaviour of their peers to gain social acceptance), high self-esteem, and gender (females were more willing than males to address unsafe driving).

3.3.3 Eco Driving

Sustainability has been an increasingly prominent global focus over the recent decades, for many reasons, including social demand to consider environmental protection (e.g., diminishing global fuel efficiency, air and noise pollution, etc.) and economic strains forcing the need to improve energy consumption. In particular, the transport sector is thought to be responsible for consuming a significant portion of a nation's energy and contributing to a substantial proportion of CO_2 emission. As examples, the transport sectors of the US consumed almost one-third of the nation's energy and Europe transport sector contributes to approximately 20 percent of the continent's CO_2 emissions (Killian, 2008; Trommer & Höltl, 2012).

Technological advances have the potential to aide drivers in maximizing fuel consumption, however such advancements may take not only years to develop and implement, but are an expensive solution to the global issue. CO_2 emissions in the atmosphere have increased at unprecedented rate, and since establishing the Kyoto Protocol for long term sustainability, nations are willing to adopt a remedy that is both inexpensive and provides immediate savings in fuel economy and greenhouse gas emissions.

One alternative is a relatively new approach; eco-driving. This approach is based upon modifying the behaviours of drivers to reduce fuel consumption, greenhouse gases and potentially collision rates. Recent developments in technology have enabled drivers to adopt eco-driving, as this 'green' driving is based upon a number of driving characteristics which were otherwise difficult to maintain and control (James, 2009; Sivak & Schoettle, 2012;

Barkenbus, 2009; Luther & Baas, 2011; Frith & Cenek, 2012; Young, 2011). These principals are primarily based on the following, but not limited to:

- Slow acceleration and deceleration
- Steady vehicle velocity
- Avoid excessive vehicle idling
- Avoiding high speeds
- Avoiding congestion
- Anticipating traffic flow

While adoption of eco-driving is reported to safe approximately 5-6 percent on fuel use and costs, (Fiat, 2010; Luther & Baas, 2011; Beusen, 2009) or more, up to 10 percent (James, 2009; Barkenbus; 2009), some research suggests that these saving are unrealistic, as it is often difficult to maintain eco-driving behaviours by drivers (Barbé & Boy, 2006). Regardless, a saving within a range of up to 10 percent is a substantial saving, considering the cost of implementing a change in driver behaviour. To put this into perspective: the potential impact if every driver in Europe adopted eco-driving behaviour would be: a reduction in use of 37 billion litres of oil, a reduction of 90 million tonnes of CO_2 in the atmosphere, and 50 billion Euros would be saved (Fiat, 2010). Indeed, many European countries have since begun to promote eco-driving, and countries such as the U.S., Japan and Australia are following.

In addition to the economic and environmental benefits of eco driving, safety benefits are also likely, and there is some evidence to suggest that this is, indeed, the case. Fleishman (2008) found that economical drivers, which by nature must generally adopt lower speed, were able to travel an additional 2 kilometres per litre of fuel in comparison to 'high risk' drivers or drivers who engaged in aggressive driving. A review conducted by Young et al (2011) further supports the connection between speeding and aggressive driving effects on eco driving. A New Zealand-based report by Frith and Cenek (2012) also indicated that driving actions such as reduced vehicle speed, reducing harsh breaking and to a certain extent, anticipatory driving, pertain to that of economical driving generally result in an overall safety improvement.

While Young et al. (2011) acknowledged the potential impact of the devices on safety, in general, the authors suggested that such devices have ancillary benefits for safe and green driving as they encouraged low speed and smoother traffic flow, which translate to reducing speed in congested traffic and increased headway times, and therefore enhanced safety.

Other studies support the argument that there are few disbenefits of promoting eco-driving. In a study of eco driving initiatives, Hallihan et al (2011) found that in-vehicle eco-driving information interfaces were able to reduce the acceleration of the driver, that visual glances at the interfaces for economical driving support were within safe limits, and have the potential to influence the behaviour of the driver to adopt eco-driving. An evaluation of another interface found that drivers could utilize the interface to drive economically and safety by modifying their behaviours based on the information provided by the interface without any reduction in safe driving behaviour (Yun, 2012). Berry (2010) also found that a reduction in aggressive driving can lead to greater fuel economy.

Another study conducted by Dogan et al. (2011) investigated the influence of multiple goals on driving behaviour, pertaining to that of safety, time and fuel savings using a simulation. They found that eco driving behaviours were

related to time and fuel saving goals, and that during the simulated drive, participants would invariably consider safety as their highest priority, especially in critical events such as vehicle interaction and traffic conflict.

Finally, a review by Frith and Cenek (2012) indicated that, with the adoption of fuel efficient driving metrics, the overall safety of organizations with vehicle fleets in New Zealand improved.

On the other hand, Luther & Baas (2011) acknowledge that if eco-driving behaviours (such as accelerating to target speed, maintaining constant speed and avoiding stopping) are taken too literally, this could have potent adverse effects in safety. These actions may cause shorter safety distances, decreased safety margins and increase rear collision risk. Furthermore, with the advent of in-vehicle systems providing feedback to drivers in relation to fuel consumption, such messages have the potential to distract drivers, thereby increasing risk. Young and her colleagues (2011) reviewed the effects of various information systems, which include satellite navigation systems, congestion assistants and intelligent speed adaptation devices (all designed, in some respect, to assist a driver to achieve economical driving) on safety. In addition, simulator-based studies by Rouzikhah (2012) assessing the distracting effects of eco driving messages found that messages directed to the driver would become a distraction.

While most studies investigating the benefits of eco driving revealed that safety can potentially increase as a result of adopting eco driving, no studies provided any insight into the potential benefits for young drivers specifically. It should be noted however, that several of the simulator-based studies exploring the disparity between fuel economy and saving, did include young drivers.

However, given that there is good evidence that at least some young drivers adopt 'risky' driving behaviours including high acceleration, speeding and 'aggressive' driving, it stands to reason that initiatives that aim to promote eco-driving that encourages safe driving behaviour could potentially decrease their risk on the road. Indeed, there are some new young driver initiatives that include eco driving. Luther and Baas (2011) reported that Germany, Finland, the Netherlands and Sweden have integrated eco-driving into their driving training and licensing systems, to the extent that learner drivers can fail the test if they do not pass their eco-driving component. Furthermore, Luther and Baas indicate that learner drivers are an easy target to reach, with the majority of learner licenses being issued at the ages of 15 and 16 (2003 -2006).

As eco-driving is in its infancy is countries such as Australia and NZ, including eco-driving into the Learner phase or graduated licensing scheme can potentially reach out to the younger cohort of drivers. However, there are some noted challenges in promoting eco driving to many drivers who may be resistant. For example, Schießl (2010) notes that young drivers appear to be motivated primarily by time and their driving style described as fast and dynamic. Therefore, the slower speeds associated with eco driving may not be readily adopted by young drivers.

Therefore, if eco driving is to be considered an effective method of addressing the safety of young drivers, appropriate communication and marketing, driver instruction training, policy support and research on behavioural factors and incentives should be considered (Killian, 2012). Indeed, Loumidi (2011) adds that rewards people like to receive for fuel efficient driving are in hierarchy order; money, convenience and fun. While multiple methods (Barkenbus, 2010) appear to have been implemented to introduce and maintain eco-driving among the driving fleet, special consideration may be required for the introduction of eco driving for young drivers.

Young adults, in comparison to older adults, are generally more environmentally conscious, as the previous two decades have witnessed a rise of environmentally sustainable practices, which have resonated into the educational sector. This presents them with a more inviting notion to accept ecological sustainability, thus educating students should be emphasized. Young adults are also motivated by cash, and it has been suggested that, to maintain eco driving practices among young drivers, monetary incentives should be employed (Harvey et

al., 2013). Young drivers generally do not command a high disposable income, and the vehicle is an important commodity, and a symbol of independence. Therefore any savings that a young driver may make based on eco driving should be emphasized through multiple means of marketing and advertising.

A major difficulty is to overcome the social norms, and young drivers are no exception to maintain social norms. Such norms such as driving risky and aggressive driving may be difficult to overcome, but with effective marketing strategies, social norms based upon driving can shift, such that eco-driving becomes a more adopted style of driving.

Overall, young drivers can be motivated to adopt eco-driving, though it will require a number of changes both in the educational sector, and the marketing sector. However, the benefits made by adopting eco-driving far outweigh the costs of implementation, as its ability to not only immediately save fuel consumption, but increase road safety.

3.4 Vehicle Safety, Choice and Technology

Driving safer cars is an integral component of a Safe System approach to road safety. This component aims to ensure that driver errors are less likely to result in serious injury or death, and it is estimated that Safe Vehicle actions will result in significantly fewer serious casualty crashes on our roads. More specifically, the estimates are: if all motorists upgraded their vehicles to the safest car in their desired class, overall safety across Australia could improve immediately by between 26 and 40 percent. More significant reductions, in the order of 17 to 85 percent, are estimated in serious injury and fatal crashes amongst novice drivers, associated with P-plate drivers' improved vehicle choice (Whelan, Scully & Newstead, 2009).

3.4.1 Vehicle purchase and use

One of the most promising approaches is to improve young novice driver safety through promoting the purchase and use of safer vehicles. Newer model vehicles are generally safer than older models because of improvements in vehicle crashworthiness over time and newer models are more likely to be equipped with safety technologies such as enhanced airbags, ESC, etc.

The relationship between vehicle safety and, while reduction of young driver road trauma through improved vehicle choice has received interest from policy makers, a limited number of young novice driver studies have focussed on this issue. A critical link between young driver road trauma and the safety of their crashed vehicle has recently been established, based on Police-reported crashes from five Australian states and New Zealand which have been collected as part large study on a consumer-based information resource providing information on safety ratings on vehicles, the Used Car Safety Ratings (UCSR) resource (Watson & Newstead, 2009). This study showed that, compared with experienced drivers (i.e. drivers aged 25 years or above), novice drivers aged 16-25 years were more likely to drive older vehicles, young females were more likely to drive small cars whereas young males were more likely to drive large cars, and the crashworthiness (i.e., the ability of the vehicle to protect occupants in the event of a crash) of young drivers' vehicle choice was inferior to vehicles driven by experienced drivers within each vehicle age group. That is, young drivers were crashing in vehicles of poor crashworthiness regardless of the age of the vehicle.

Based on these findings, Whelan et al. (2009) utilised the estimates of driver fatality and serious injury risk in a crash related to different makes and models of vehicle derived from the UCSR to model crash reduction benefits for young novice drivers resulting from scenarios for safer vehicle purchases. Specifically, the model estimated the trauma reduction benefits that would have resulted amongst crash-involved young novice drivers if, instead of vehicle they actually crashed, they had crashed the vehicle with the best possible crashworthiness from the same vehicle market group and same year of manufacture. Under this scenario it was calculated that a 20

percent reduction in fatalities and serious injuries among drivers aged 18-20 years could be observed. If the safest alternative vehicle was chosen to be of the same age but from any market group, serious trauma reductions of over 60 percent were estimated.

3.4.2 In-vehicle Technology

In recent years, various in-vehicle monitoring devices have been developed and used to promote driving safety, particularly by fleet owners, but more recently for use by families of young drivers. New in-vehicle monitoring systems can potentially offer great benefits in terms of promoting safer on-road behaviours by providing continuous measurements of various parameters of driving behaviour and provide different types of feedback to drivers and/or parents (Dingus et al., 2006; Toledo, Musicant & Lotan, 2008; Horrey, Lesch, Dainoff et al., 2012; Gesser-Edelsburg & Guttman, 2013). These approaches also represent a fundamental shift in the overall management of novice driver safety – from an approach that is highly regulatory in its focus to one that assigns additional responsibility to the individual and/or the parental/custodial unit. There are numerous strategies that offer promise as a way to support or augment the GLS such as the use of in-vehicle monitoring systems (telematics) to provide feedback to novice drivers on their driving behaviour and the extent to which drivers are complying with certain GLS restrictions.

These technologies allow vehicle owners (parents, or insurance agencies) to collect safety-specific information related to a driver's on-the-road behaviour and performance. They can be configured to automatically store data surrounding a critical event for later download and subsequent review. In this way, data derived from these devices can be reviewed for safety-critical learning opportunities. Some devices also provide drivers with real-time feedback following a critical event. Knipling (2009) noted several benefits of using such systems in commercial fleet operations: i) the system can document specific behaviours that might lead to crashes, incidents, or traffic violations and thereby provide an opportunity for pro-active corrective feedback; ii) the feedback and related evaluations are objective, timely, and frequent; iii) drivers can receive positive feedback and rewards for good behaviours (these rewards can also be structured to reinforce group or fleet-level achievements); iv) benchmarks for driving behaviours can be set in order to establish carrier or group norms and expectations; and v) these systems may replace time consuming ride-along observations.

Used traditionally in organisational contexts for monitoring drivers of work-based vehicles (both commercial fleet and private vehicles), developers of these systems are now marketing this technology to parents of teenage drivers as a means of extending parental monitoring into the vehicle and there is increasing evidence that in-vehicle monitoring systems are effective in reducing the instances of risky driving among novice drivers (e.g., Farmer, Kirley & McCartt, 2010; McGehee, Raby, Carney, Lee & Reyes, 2007). This has been found to be particularly true when the feedback provided through such systems is coupled with parental involvement (e.g., Simons-Morton, et al., 2013).

A further strategy that holds promise in changing novice driver behaviours is using individual financial incentives, as might be realised through a reduced vehicle insurance premium provided certain conditions on the insurance contract are met. Reagan, Bliss, Van Houten and Hilton (2013), for example, found that coupling an insurance-based incentive with in-vehicle speeding alerts was associated with fewer instances of speeding in excess of the posted speed limit. Similarly, trials of variable rate charging designed to reduce speeding, night-time driving and kilometres driven when monitored with telematics has also shown promise in relation to changing driver behaviours particularly in relation to speeding (Greaves & Fifer, 2011).

4 Implications of the findings: Where to next?

This review has highlighted the most recent and important research on the issues surrounding young driver safety, with a particular focus on understanding young novice driver behaviour and the ways that their safety can be managed through interventions addressing behavioural aspects. This section attempts to synthesise the findings, and draw some conclusions about what we know, where the gaps are in the evidence, and the most effective ways forward to address those gaps.

4.1 Summary of what we know and gaps in the evidence

While much progress has been made to address young driver crash risk, there is much that still remains to be understood and done. As noted by Senserrick (2006), with respect to what we know about adolescent development, heightened exploratory behaviour is an important component of adolescence as one begins to establish further independence from one's parents and become young adults. Some of this exploration is healthy, such as exploring new career roles and school or extra curricula programs. Some is not – e.g. binge drinking; risky driving. It is the engagement in less healthy behaviour that can place young people at risk, and contribute to the over-representation of death and serious injury by young drivers on our roads.

One of the major issues identified through this review is the ongoing debate regarding the 'novice' versus 'young driver' problem, that is, the distinction between unintentional and intentional risky driving. A body of research suggests that, for the most part, the problem is a result of inexperience, younger age, immaturity, etc. Others, in contrast, argue that the main problem is that of intentional risky driving such as deliberate speeding, driving while under the influence of alcohol or drugs, aggressive driving. It is most likely a combination of both, as Senserrick (2006) argues, that both inexperience *and* risk-taking (intentional and unintentional) are important variables to consider. It may also be an issue of stage of licensure, as argued by Simons-Morton (2011), newly licensed drivers are necessarily inexperienced and require a period of time to learn how to drive safely and this group can be considered the 'inexperienced group. On the other hand, there are the young drivers at a later stage of licensure who are at more likely drive in a more risky fashion.

- A major gap in our knowledge, then, is: it is **not yet clearly established** exactly what proportion of young drivers do drive, or how often they drive, in a deliberately risky manner—**is there a subgroup of drivers who always drive in a manner that** ''pushes the envelope'', or is their driving punctuated by spontaneous risk taking episodes, and what are the contributing factors to the propensity to engage in risky driving behaviours.

In addition, this review highlighted that it is a difficult process to disentangle the effects of the multiple, inter-related factors on i) the behaviour of young drivers, ii) their propensity to engage in risky driving behaviour, ii) crash and injury risk.

The complex interacting factors underpinning young driver risk pose a considerable challenge for the development of effective countermeasures. Notwithstanding these difficulties, the review identified the main initiatives that have been implemented to manage the safety of young drivers, and the evidence regarding their effectiveness. The key programs that currently show promise in addressing young driver safety are:

- GDL models
- Parental involvement:
    - Agreements to comply with GDL restrictions

    - Behaviour role model
    - Vehicle purchase and use
    - Awareness and adoption of safe driving practices
- Education and training: appropriate hazard perception training programs and programs that address higher order attentional and motivational attributes
- Promotion of safer driving practices (e.g. eco driving)
- Purchase and use of safety vehicles, including new technologies and insurance schemes
- Enforcement of risky driving (including laws, sanctions, and compliance with GDL restrictions)
- It is also important to recognise that initiatives must go beyond the notion of young drivers as a homogenous group, to address higher order driving skills and life goals and be sensitive to family, neighbourhood, community, and societal differences, which may well show differing trends over time.

Within each of these areas, there are still unanswered questions as to their effectiveness and how they may be enhanced in order to make further gains in reducing young driver fatal and serious injury crashes. Examples include:

- GDL: Despite the evidence suggesting that GDL system is most likely the most effective intervention for young driver safety and has had a major impact in reducing novice driver fatal and serious injury crashes, there is still more to be learnt about its effectiveness and this is limited by a number of factors, including i) the debate ongoing debate as to which components are most effective, ii) the fact that implementation of GDL systems varies across jurisdictions and key measures which have been shown to reduce crashes have not been implemented universally or systematically, and iii) evidence that GDL systems are constrained in their ability to fully address a number of important risk factors. For example, low compliance to elements of the GDL is a factor that has often been cited as limiting the potential efficacy of passenger restrictions. Further, some component have a strong evidence base, including the increased minimum duration for the learner period, mandating minimum supervised driving hours, zero blood alcohol concentration (BAC) limits and increasing the minimum period for a provisional licence. However, some other GDL components are not well supported by evidence including speed restriction on learner drivers, high performance vehicle (HPV) restriction, the extent of the 120 hour requirement for supervised driving, etc.

- Education and training: There is little evidence attesting to the benefits of education and training, and indeed, indication that some training (e.g., advanced driver courses focused on car handling skills, emergency braking, skid training, etc.) can result in a disbenefit in the form of producing over-confident young drivers (without increasing appropriate driving skills). However, some recent evidence, based on improved evaluation techniques and driver training (e.g., coaching rather instructing)suggesting that programs addressing higher-order skills, attitudes and motivations show some promise in delivering safety benefits

- Parental involvement: This is an emerging and promising are of research and intervention. Parents are in a prime position to play a major role in many aspects of young driver safety including: i) role model, ii) support for GDL restrictions, iii) adoption of safe driving practices, and iv) purchase and use of safer vehicles. However, there are still few resources available to provide knowledge to parents and assist them to engage fully and effectively with their young driver.

Providing answers to most of these questions and gaps in our knowledge, requires an in-depth understanding of young novice drivers' driving patterns, behaviour and motivation to engage in various driving behaviours.

5 Approaches to understanding behavioural risk factors for young driver risk

This section briefly describes the range of methodological approaches to understand behavioural risk factors for young driver risk and the advantages and limitations of each.

5.1 Traditional approaches and limitations

As identified in the review, numerous approaches have been employed to examine the many issue surrounding young driver crash risk and the evaluation of promising approaches. These approaches can be broadly grouped into three thematic methodological approaches, as follows: i) crash and injury data analysis, ii) self-reported data, and iii) simulation technology.

The past successes of road safety, globally, and in Australia and New Zealand, have been due, in large part, to the development of road safety strategies with prioritised interventions with a very strong evidence base. To date, this evidence base has been derived primarily from crash data collected by police, in-depth crash investigations, Coroners' and hospital data and from data from surveys and interviews on driver exposures to risk. While all of these methods have their advantages there are also some disadvantages, the most important being that these data sources are limited in the depth and quality of information they provide about driver and road user behaviour, which are major contributing factors in most collisions (Antin et al., 2011). Such data can often only be inferred, if at all, from available evidence after a crash or from surveys with confounding unknown self-reported biases (Gordon & Regan, 2012). Existing data collection methods in road safety in Australia rely on the limited post-crash accuracy and biases of driver and witness recall of events and on retrospective physical evidence from crash scenes - with little or no pre-crash information about other vehicles and road users involved.

5.1.1 Crash and Injury Data Analysis

Epidemiological studies using the analysis of crash and injury data have provided the basis for road safety research and implementation of initiatives for many years, and there are many advantages associated with the existence of these data sources. For instance, Police-based crash data and hospital-based injury data, particularly when they are linked, provide valuable information about crashes and injuries at the level of groups within populations.

However, these data sources are somewhat limited in their scope. Only basic information on crash victims is provided, such as age, gender, seating position and seat belt use. When crash databases are linked to roadway network and vehicle features, researchers are able to estimate crash frequencies and severities as a function of roadway and vehicle design attributes. But there are no databases that capture the crash histories of those involved, so researchers have been unable to robustly link personal characteristics to crash risks. Moreover, the police mainly collect information with a view to the legal settlement of the crash. This type of information is therefore not sufficient for gaining insight into the factors that contributed to the cause or outcome of the crash.

Likewise, hospital-based trauma databases are valuable tools for country health care system and identifying areas that require quality improvement policy implementation. In addition, they have been shown to provide essential data on which we can more fully understand the nature and extent of trauma, implement more effective treatment management systems to aide injured patients, and indeed contribute to improved survival rates and outcomes of injured patients.

Wundersitz (2012) also notes that "It is generally acknowledged that the majority of road crashes are caused by more than one factor and these different factors often interact together with one facilitating another. In many police crash reporting systems, only one contributing factor or error is designated per crash. Consequently, these crash reporting systems are subject to over-simplifying crash events that often have quite complex causes and "many crash causation classification systems …. do not separate errors (or human failures) from the factors which lead to these failures".

Further, Langley and colleagues (2012) noted that most New Zealand research on young drivers to date has used routinely collected crash data, such as the police traffic crash reports and the national hospital inpatient records, but has been limited in that these databases do not, and realistically cannot, include the level of detail required to ensure that learner driver policy and programmes are based on sound scientific evidence applicable to young drivers in the current New Zealand context.

5.1.2 Self-Reported Data

Another popular method to inform road safety policy and practice is to ask people directly about crash involvement, behaviour and attitudes toward road safety. These methods, known as self-report, mainly take the form of surveys, questionnaires, interviews and rating scales.

The great advantage of self-report is that it gives information on a respondents' own views directly and provides access to phenomenological data, i.e., respondents' perceptions of themselves and their world, which are unobtainable in any other way. There are numerous other strengths to self-report methods, including i) ease of administration and not time consuming; ii) less need to use sophisticated methodology or equipment, iii) self-reporting methods which are validated can feasibly be used in clinical settings, and iv) self-reporting can gather social, situational, behavioural and attitudinal factors.

There are, however, weaknesses to self-report methods. Reliance on self-report for the measurement of both dependent and independent variables raises concern about the validity of causal conclusions for a range of reasons, including:

- Systematic response distortions, method variance and mono-method bias;
- Reliability and validity of psychometric properties of questionnaire scales;
- Concern about the context in which self-report measures are used, in terms of the design of studies, as well as the statistical treatment of questionnaire data at the analysis stage;
- Inaccurate self-reporting can be caused by recall bias, social desirability bias and errors in self-observation; and,
- Self-reporting has the problem of over- estimation bias and poor recall.

5.1.3 Simulation Technology

For a long time, controlled experiments, often in a driving simulator, were the standard method of studying driving behaviour. The major advantage of this kind of experiment is the large degree of control over the variables that (may) affect driving behaviour. For instance, the width of the road can be adjusted quite systematically, while other factors remain the same. On the other hand, however, controlled experiments are most often conducted in a created environment, such as in a driving simulator or on a test circuit. This makes the transfer of the results to actual traffic more difficult.

Researchers have attempted to verify whether there are indeed differences in skills associated with driving performance that differentiate novice and experienced drivers. Driving simulators have been a critical part of the evaluation because simulators provide a safer and controlled method of assessment, with precise control of the inherent dangers present in the scenarios that differentiate novice and experienced drivers. For example, with a driving simulator it has been shown that the attention maintenance skills of novice drivers are much poorer than those of experienced drivers in the presence of several different types of distracting, secondary tasks. Additionally, with a driving simulator, it has been shown that hazard anticipation skills of novice drivers are seriously compromised across several different scenarios with potential hazards (Taylor et al., 2011).

5.1.4 Innovative Approaches

Observational techniques are another popular method to understand behaviour, interactions and establish causal factors for collision risk. These techniques range from roadside observations, positioning of fixed cameras at roadsides, and instrumenting vehicles, otherwise known as Naturalistic Driving Studies (NDS). NDS is a relatively new research method that has the potential to overcome many of the limitations in using other data collection and analysis methods as noted above. In an NDS, volunteer participants drive an instrumented vehicle (usually their own), fitted with an unobtrusive Data Acquisition System (DAS) which continuously records their driving behaviour (e.g. where they are looking), the behaviour of their vehicle (e.g. speed, lane position) and the behaviour of other road users with whom they interact (e.g. other drivers, motorcyclists, cyclists and pedestrians) - in normal and safety-critical situations (Regan et al., 2013).

A few studies, internationally, have employed NDS to understand the driving behaviour of young novice drivers.

Simons-Morton and his colleagues (Simons-Morton et al., 2011; Klauer, Simons-Morton, Lee, et al., 2011), for example, instrumented vehicles of 42 newly licensed teenagers (M = 16.4 years old; SD = 0.2, 20 males and 22 females), within approximately 2 weeks of obtaining a provisional driver's licence allowing independent driving. Some of the key findings include:

Average vehicle miles travelled (VMT) or average nighttime VMT for teens did not increase over time. Teenagers consistently drove 24 percent of VMT at night, compared with 18 percent for adults. Teenagers drove 62 percent of VMT with no passengers, 29 percent of VMT with one passenger, and less than 10 percent of VMT with multiple passengers. Driving with no passengers increased with driving experience for these teens. Teenage drivers who owned their vehicles, relative to those who shared a vehicle, sped 4 times more frequently overall and more frequently at night and with multiple teen passengers.

A total of 1,721 hard braking events were recorded, and the video footage of a sample (816) of these events was examined to evaluate validity and reasons for hard braking. Of these, 788 (96.6%) were estimated valid, of which 79.1 percent were due to driver misjudgement, 10.8 percent to risky driving behaviour, 5.3 percent to legitimate evasive manoeuvers, and 4.8 percent to distraction. Hard braking rates per 10 trips among newly licensed teenagers during the first 6 months of licensure were significantly higher when driving with teen passengers and lower with adult passengers than driving alone; rates per 100 miles were lower with adult passengers than with no passengers. Simons-Morton and his colleagues suggested that that novice teenage driving performance may not be as good or safe when driving alone or with teenage passengers than with adult passengers. These findings provide support for the hypothesis that teenage passengers increase driving risks, particularly during the first month of licensure.

McCartt, Farmer and Jenness (2010) assessed the perceptions and experiences of participants in a study of a device that monitored teenagers' driving by installing a device that continuously monitors and reports risky driving manoeuvers in vehicles of 84 newly licensed teenagers. The findings revealed a number of difficulties recruiting parents and teen. The majority of parents who declined said their teenagers opposed it, or they were

concerned about intruding on the privacy of their children or jeopardizing trust with them. Both parents and teenagers thought in-vehicle alerts helped teenagers drive more safely, although two thirds of teenagers tried to drown out the alerts with loud music. Parents found the Web site useful but reported fewer Web site visits over time. Most parents would prefer receiving information through summary report cards rather than through a Web site. Both parents and teenagers thought the overall system was effective in improving teenagers' driving. Most parents said the Web site and/or device helped them talk to their teenagers about their driving. Parents thought the most effective system would be an in-vehicle alert with immediate parental notification; teenagers preferred a system allowing them to correct behaviour before parental notification. Moreover, although many teenagers were annoyed by the technology, most said they drove more safely because of it. Sending report cards to parents and allowing teenagers to correct behaviour before parents are notified may increase the usefulness and acceptability of monitoring systems.

6 Understanding the behaviour of young drivers in New Zealand: Development of a Naturalistic Driving Study

A comprehensive understanding of the risky driving behaviour of young novices is fundamental if effective countermeasures are to be developed and implemented. As noted previously, NZTA 's 2010-2020 road safety strategy, '*Safer Journeys*', identifies the need to increase the safety of young drivers as an 'area of high concern' (Ministry of Transport, 2010), thus emphasising the critical need to identify and implement effective solutions to reduce the number and severity of young driver injury crashes.

The remainder of this report describes an international collaborative partnership for a novice driver Naturalistic Driving Study (NDS) – a New Zealand first. The study will use real-world driving measures to track young drivers over the first six months of the critical high-risk period of restricted licensure. This section outlines the design, methods, benefits and costs of the project. The project was initiated by the AA Research Foundation in order to support cutting edge research that will inform evidence-based intervention and policy changes. The study design was developed by the project research team from Monash University Accident Research Centre (MUARC) and the University of Waikato (UW), with input from a NZ Steering Group comprising scientists, policy managers and service providers in the road safety/driver licensing/training domain.

The NDS method championed by the Virginia Tech Transportation Institute (VTTI) in the 100-car study (Dingus et al., 2006) and used extensively by MUARC and UW teams, offers the potential to overcome many limitations of survey and laboratory-based methods and can provide detailed insight into driver behaviour and how driving performance can be influenced by human factors such as inattention, distraction and fatigue, as well as environmental factors.

100 volunteer novice drivers will have their own vehicle instrumented for 6 months with a Data Acquisition System (DAS) which will record continuously their driving behaviour (e.g. looking behaviour, speeding, braking, lane keeping), and their interactions with other road users and the road infrastructure.

Findings will provide new insights into the driving patterns and behaviours that contribute to the high crash risk of young, novice drivers. Findings will have immediate relevance for GDL policy, enforcement, road safety education, driver training programs, as well as providing access to a rich data source which can be mined in depth and used to inform future countermeasures development.

The naturalistic driving study (NDS) approach is very resource demanding in terms of sample size, equipment, data gathering processes, data storage, reduction and analysis. The budget is conservatively estimated at around 750,000 NZD. To ensure adequate resources and to facilitate translation of outcomes into practice and

policy, it is recommended that relevant stakeholders be invited to participate in the project including licensing agencies and road safety policy makers, insurance companies, driver training program providers, the automotive industry, research foundations, Police, telco and technology companies.

The proposed project represents value for money, given the importance of the research questions, the quality of the research team and the potential to produce outcomes that will directly inform initiatives to reduce death and serious injury of young New Zealand drivers.

6.1 Naturalistic Driving Study Approach

A cornerstone of Australasia's success in road safety has been the development of strategies which are strongly evidence-based. To date, this evidence has been derived from crash data, hospital data, self-report, driving simulation and crash epidemiological studies. However, these data collection methods are limited in the depth and quality of information they provide, particularly regarding the understanding of real-world driving performance and behaviour in general, and more specifically about behaviours associated with collisions.

The Naturalistic Driving Study (NDS) research method, pioneered by Virginia Tech Transportation Institute (VTTI), in the United States (Dingus et al., 2006), and implemented in Australia by MUARC (e.g., Charlton et al., 2013; Marshall et al., 2013; Regan et al., 2013) and by UW in New Zealand (e.g., Isler, Starkey & Sheppard, 2011), has potential to overcome many of the limitations of the above data collection methodologies and has changed the focus of road safety research from primarily examining the causes of safety critical events (often only inferred from available evidence after a crash) to including studies of what drivers do in everyday real-world driving.

The NDS approach offers a new and innovative approach to existing methods for understanding driver and vehicle behaviour in normal, impaired and safety-critical situations and, more importantly, support the development of new and optimized road safety-related policies, strategies and countermeasures. Regan et al. (2011) identified several advantages of NDS, including i) Exposure: new and more detailed data can be collected on driver exposure to a wide range of factors that increase crash risk; ii) Crash risk: with better exposure data, it is possible to calculate odds ratios (relative risk) and population attributable risk percentages (proportion of crashes) for a broader range of risky activities; iii) Near-crashes: collection of data on how near-crashes come about and how these are prevented is available. Such data can be used to optimize training and education programs, optimize the design of in-vehicle and out-of-vehicle Intelligent Transport System technologies, traffic management systems and the road environment; iv) Crashes: the contributing factors that lead to crashes can be identified, and a better understanding of the critical differences between near-crashes and crashes can be achieved; v) Normative data: the NDS allows collection of fundamental data on how people drive – how they avoid crashes, navigate, maintain speed, control the vehicle, and how these vary according to driver factors (experience, inattention/distraction, fatigue and condition/impairment).

A full scale NDS study of young driver behavior has not yet been conducted in New Zealand, however a pilot study conducted in 2008 suggests that such a study is feasible and acceptable to young drivers (Isler, Starkey, Sheppard & Yu, 2008). After completing a driver training camp (Isler et al., 2011), telemetric data trackers (SmarTrak Lite GPRS / GPS) were installed in the vehicles of eight participants (with restricted licences) for 32 weeks. Data collected included distance driven, number of trips, mean speed per trip, maximum speed, speeding violations (>100km/h) and large G-forces (>0.50g). Valid telemetric data was obtained for 6 of the 8 participants for the entire 32 week period. The average weekly distance driven by the participants ranged from 0-1317 km per week; over an average of 42 trips. The participants' maximum speed ranged from 111-141 km/h and every participant received at least one speeding violation. The two drivers who lived rurally drove the greatest distances and also drove at the highest speeds. Although limited in sample size, this study clearly demonstrates the type and depth of information that could be obtained from a larger scale NDS study of young drivers.

Moreover, no video data were collected which precluded direct observation of in-car behavior and insights into driver distraction, and fatigue.

Given the many benefits of NDS in general and the specific benefits for understanding young driver behaviour and risk factors for crashes, a detailed study design for a New Zealand young driver NDS was commissioned by AA Research Foundation and developed by the MUARC and UW research teams in consultation with a Project Steering Group. Details of the study design and methods are presented below.

6.2 Methods for a young driver NDS in New Zealand

A New Zealand young driver NDS is proposed with the overall aim of enhancing understanding of the driving patterns and behaviours that contribute to the high crash risk of this group during the initial licensure phases. Specific attention will be directed towards measuring compliance with GDL (e.g. no solo driving 10pm-5am), adoption of risky behaviours such as engaging in distracting activities, speeding, driving while impaired, as well as drivers' performance in response to hazardous events.

6.2.1 Participants and Recruitment

A sample of 100 New Zealand novice drivers aged between 16.5 years and 19 years will participate in the NDS. Parents' consent for their child's participation will also be required to address the potential issue of low vehicle ownership by the target group. Parents will also participate in a survey component of the study.

It is proposed that the catchment area for recruitment will be the city of Hamilton (148,200 residents) and the Waikato (64,700 residents) district in the central North Island of New Zealand. If required, adjacent localities in the Bay of Plenty (300,000 residents) will be used for additional recruitment. The demographic profile of this region (including ethnicity, number of urban and rural dwellers, and the socio-economic structure) is representative of NZ as a whole (Statistics New Zealand, 2009).

Participants will be recruited at first licensure, that is, upon passing their licence test, regardless of previous unsuccessful attempts. Recruitment will be conducted in two steps: first, with the cooperation of the licensing authority/agency, letters of invitation (postcard) will be distributed to Learner drivers (and their parents) following their registration/appointment with the agency to take their restricted licence test. Participants will be invited to register their interest in the program with the research team, using one of a number of options including on-line response, phone or in person at the licence test site on day of licence test. Second, potential participants (drivers and parents) will be approached face-to-face, by a member of the research team at licence testing sites. If parents are not present at the licence test station, they will be followed up with an invitation by telephone, once driver consent is obtained. While the recruitment method will be opportunistic, efforts will be taken to ensure the sample has appropriate socio-economic diversity, particularly with respect to representation of Maori/European/other ethnic groups, males/females and rural/urban dwellers.

In order to achieve the proposed sample size (n=100), it is expected that approximately 500 eligible drivers will need to be approached (i.e. expected recruitment rate of not more than 20%). Based on advice relating to similar novice driver NDS studies, we propose to recruit 105 participant pairs, with the aim of retaining 100 pairs throughout the study (Klauer, October 01 2013, personal communication).

A preliminary evaluation of licence testing was conducted to assess recruitment feasibility using estimates provided by the NZTA. During July 2012, 610 restricted licence tests were taken in the Waikato and Bay of Plenty Area by drivers aged 16-19 years, of these 372 people passed their test (61%). If recruitment occurs over a 3 month period, this would provide a pool of 1116 potential participants (i.e., well in excess of the desired sample could be achieved, assuming a 20% recruitment rate).

Pilot Study of Recruitment Strategy Feasibility

To ensure participant recruitment is feasible within an appropriate time frame, we suggest a pilot study be conducted of our recruitment procedures and processes prior to the full study commencing. The pilot study could be conducted as though we were recruiting for the full study (as outlined above). This would involve obtaining the appropriate approvals (i.e., from ethics committees and licensing agencies), appointing research assistants, developing letters of invitation, postcard reminders and evaluating how many people express an interest in participating over a one month period. This will not only allow us to properly evaluate recruitment rates, it will also allow us to fine tune our procedures and begin to develop relationships with the necessary stakeholders. The time required for completion of the pilot study is dependent upon co-operation of the licensing authorities and the time taken to obtain ethical approval for the study, but it is likely to take at least 3 months.

Inclusion criteria

- Age 16.5 – 19 years
- Reside within 120 km of Hamilton GPO (urban dwellers), or
- Reside in Waikato district and 120 km from Hamilton GPO
- Passed their 'restricted licence test' for the first time not more than one month prior to recruitment into the study.
- Access to own/family-owned private motor vehicle (age of vehicle should not be a barrier to inclusion because irrespective of type of data acquisition device used, video and GPS data will be accessible).

Exclusion criteria

- have previously held a driver licence in New Zealand or elsewhere
- are not holders of a valid restricted driver's licence to drive a private motor vehicle
- do not have vehicle access: Owners of, or have regular (unrestricted) access to vehicles that they can drive
- are not active drivers: driving at least 4 times a week
- do not reside in the Hamilton, or wider Waikato (or Bay of Plenty) district
- do not consent to release of personal driving record information from the LTNZ/NZTA/Police for the duration of the study
- Are aged below 16.5 years or older than 20 years
- Have a planned move out of the study region
- Have an absolute contraindication to driving), identified by self-report on driver screening, as defined by the Medical aspects of fitness to drive: A guide for medical practitioners (2009).

Incentives

It is expected that an incentive will be critical to the success of the project in order to motivate participation. There is a large body of literature on effectiveness of incentives relevant to research recruitment. Critical issues for consideration are the age and gender mix sought for the study, and the motivations that are appropriate for the target group (e.g., see Gneezy, Meiier & Rey-Biel, 2011). Potential incentives considered for this study were money, vouchers for a product or service, an insurance discount, and entry for a lottery to win a desirable product (e.g. computer tablet). Importantly, the incentive should not influence the specific behaviours of interest in the study. For these reasons, it was proposed that cash may evoke fewer performance biases than vouchers for petrol or car insurance discounts.

Consideration was also given to how the incentive should be offered. For example, incentives can be offered as various tasks are completed, or clustered following completion of sets of activities, or at set times through a long intervention or study period. Evidence suggests that clustering may be more effective than providing incentives on a one-for-one basis and that in the case of lotteries, it is more effective to offer one large amount (1 in 100 chance to win $1000) rather than several smaller valued amounts or items (e.g. 10 in 100 chances to win $100) – i.e., size of the prize matters, not probability of winning (Gneezy et al., 2011).

Examples of appropriate incentives were sought from similar young driver studies. A study currently underway at Virginia Tech Transportation Institute (VTTI) provides a total of $750 USD (approx. $900 NZD) to each participant over a 15 month study period ($50 USD per month). Payment is made directly into participants' bank accounts after specified time periods and on completion of required tasks and interviews. To encourage continued participation, each driver receives a completion bonus at the end of the study (Klauer, personal communication October 1, 2013). Taking into account the current exchange rate and a shorter study period, for the proposed New Zealand NDS, this would equate to approximately $360 NZD per participant ($60 NZD per month). It is proposed that this amount should be sufficiently attractive to young people yet not so much as would be coercive.

6.2.2 Design and Procedures

Drivers' vehicles will be instrumented following receipt of informed consent of both driver and parent, and as soon as practical (not later than one month) after participants gain their restricted licence. Drivers will receive no special instruction about their driving or vehicle use other than to drive as they normally would for the 6-month period of the study. Periodic (remote) data checking/downloading may be conducted for quality control but this will not require personal contact with participants. At the end of the 6-month study period, DAS units will be removed from the vehicle. A Driver/Parent Questionnaire (driver and parent components) will be administered in two parts: at the start and end of the study period. Crash involvement follow-up surveys will be administered in the event of a crash in the immediate 24 hour period post crash.

The research team will have contact at end of first week and bi-monthly thereafter (to be confirmed) with participant drivers to check potential anomalies in DAS operation or other matters that may affect data collection (e.g. changed cars).

Ethics requirements

This project will adhere to the principles of Ethical Conduct in Human Research. All research involving humans conducted by Monash University and Waikato University is required to be approved by the respective University Human Research Ethics Committees of those institutions.

6.2.3 Equipment

Extensive searches were made of the academic literature to identify data acquisition systems (DAS) suitable for use in the proposed study. In addition, information was gathered more widely from the internet, particularly focusing on fleet management systems to identify any promising commercially available products which have not been used for research purposes. Details of the searches and summaries of the systems can be found in Appendix B.

The devices identified in the search were screened against a set of requirements deemed to be important for the study. Key criteria were:

- Continuous data recording (rather than 'event' recording)
- Incorporates cameras (road ahead and the driver), a GPS, and accelerometer

- Relatively quick and easy to install
- Can be used in vehicles of any age
- Availability of software for data extraction and analysis
- Reliability of operation
- High level expertise and reputation of the developer.

Using these criteria, two suitable options were identified:

Option 1: Virginia Tech Transportation Institute (VTTI) Miniature Data Acquisition System

The VTTI Miniature Data Acquisition System (miniDAS) is a purpose-built device which is mounted to the windscreen of the vehicle. The system is small (10.1cm x 12.7cm x 2.5cm), easily installed (either to the OBDII connection or via the cigarette lighter). The system includes GPS, microphone, inertial measurement sensors (accelerometer, gyroscope, magnetometer), two cameras (forward roadway; driver), and collects/stores a continuous record of vehicle parameters. The driver camera is focused in such a way to maximise driver head/torso view (to aid analysis of behaviours related to distraction) and minimise cabin view (privacy reasons). Therefore little/no information on passengers can be derived from the system. Audio may provide information on presence of other passengers. Data is stored on an SD card which would be transferred to VTTI for storage and data extraction.

VTTI have extensive experience and are world leaders in the conduct of naturalistic driving studies and would be an asset to the project. Use of the purpose designed miniDAS would directly facilitate comparisons between NZ NDS data and a US-based young driver dataset (study in progress). The Monash-UW research team has had extensive communication with VTTI regarding potential use of miniDAS for the proposed NZ novice driver NDS.

In August 2013, MUARC-UW Team acquired a miniDAS from VTTI for the purpose of conducting a trial to explore feasibility and ease of use. For the trial period, there was no cellular phone capability or the interaction with the vehicle network. Pilot testing with the device confirmed that installation of miniDAS was straightforward (see installed miniDas – Figure 8) and can be achieved in less than 3 minutes. Several test drives were conducted and the data was recorded on an SDI card. The data was then processed and decrypted via Dropbox by VTTI. Output from the pilot showed the correct time stamps for all the measured variables from the miniDas. A Screenshot of the video output can be seen in Figure 9, showing the view of the driver head and upper torso, hand positions on the steering wheel and eye and head position in relation to the road ahead. Note that clarity of driver view will be important and piloting will be conducted to determine best installation position to achieve good accuracy for coding direction of looking behaviour and engagement in secondary activities (cell phone use etc). Overall, the miniDAS was found to be suitable for purpose and met the criteria outlined above.

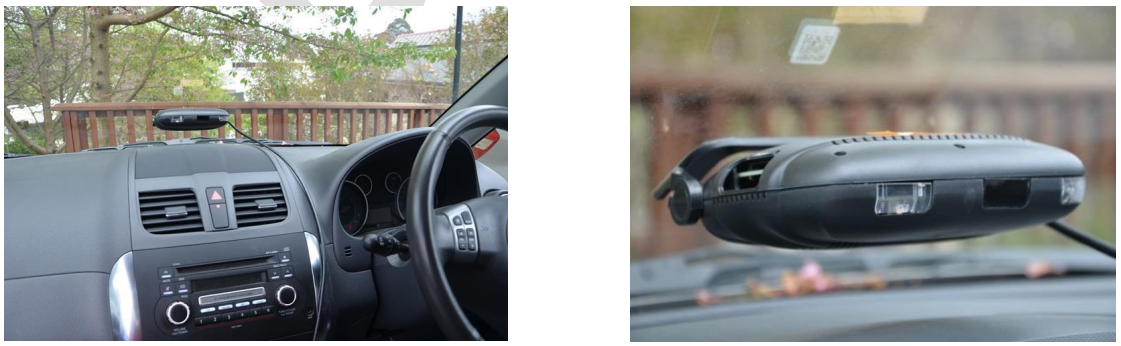


Figure 8: Image of cabin interior of pilot study vehicle showing window mounting (left) and close-up (right) of miniDAS device

Figure 9: Composite view of miniDAS video camera image of forward roadway and driver

It has been determined that development work (estimated at around 4 months) would be required in order to make the miniDAS is New Zealand compatible. Specifically, the additional compatibility work would involve:

- Implementing the GSM style modem on the miniDas
- Reversing the image (upside down) or printed plastics
- Accommodating the New Zealand vehicle network
- Establishing a data base and a method of harvesting the data remotely.

Recommendation: From a cost- and time-effectiveness point of view, Option 1 is recommended. For details of the budget implications of VTTI miniDAS, see Budget section.

Option 2: IMARDA DAS, NZ based provider

A comprehensive search of Data Acquisition system (DAS) units commercially available in New Zealand identified a number of systems developed for fleet management. However, only one company (Imarda.com) was found to offer a comprehensive vehicle and driver behaviour monitoring system which included video data (Driver

behaviour and front scene). The Imarda system can be configured in a way that would be comparable to the miniDAS. However, while the device meets most criteria for the proposed study, it is noteworthy that the system has not yet been deployed in a research context. The system includes comprehensive data extraction and analysis routines.

In their communications with the MUARC-UW researchers, Imarda has expressed an interested in participating in the project as a provider of DAS units. A quotation for purchase of Imarda DAS system and services requires very specific input on study requirements (not available at time of reporting). An option for leasing Imarda DAS units has also been discussed. A preliminary estimate of the *lease* cost per unit is $245 per month per user including data management (not including video data post-processing). This would result in a total amount of $122,500, assuming a 10 month data collection period. The additional video data management costs could be expected to vary depending on the study specifications and these video post-processing costs would be the same, regardless of whether Option 1 or 2 was adopted. An estimate of the personnel costs for this component of the project is outlined in the Budget.

Other promising options:

A number of other more sophisticated DAS units were identified. Two promising units include those identified for use in (i) the UDrive project, a large-scale European Naturalistic Driving Study, currently in the planning and development phase and (ii) the Australian NDS. The UDrive project is led by SWOV (Dutch national research centre) and involves a consortium of members from 7 European countries. A similar study underway in Australia, led by University of New South Wales and involving a consortium of four research centres in including MUARC, will use a DAS provided by VTTI similar to that used in the SHRP2 project currently underway in the United States. Generally, the systems proposed for use in these large-scale studies meet the criteria for the New Zealand NDS as described above, with the exception that a considerable amount of time and technical expertise is required for installation. The complexity of these systems also means that the cost is inherently high compared with the simpler miniDAS and Imarda units. For example, the UDrive has earmarked 800,000 Euros for purchasing 235 DAS units (3,404 Euros per unit, approximately 5,656 NZD). While this cost is likely to be prohibitive for the proposed NZ NDS, it is possible that these units may be available for lease at the conclusion of the respective studies, in around two years' time.

6.2.4 Dependent Measures

Driver behaviour variables

A range of variables has been identified from the critical review of the literature and will include driver and vehicle information and environmental information. More detailed descriptions and definitions of variables are presented in Appendix B. Key measures of interest available from DAS units are defined in Table 1.

Table 1 Summary of dependent measures available from Option 1 DAS

Driver-based measures (derived from video of driver)*	head position (proxy for inattention to forward roadway); hands off wheel (0,1,2; time); passengers (yes/no); fatigue (eye close/open; duration closed); secondary activity (category/type: cell phone use; eating; talking..etc)
Vehicle-based measures	trip summary measures duration, distance, average speed, start/end time); responses to 'hazardous events' (e.g. lane departures, hard turn, hard braking/acceleration, swerve)
Road infrastructure, traffic and environmental measures	road type, speed zone, GPS location; traffic volume, weather…

Driver/parent characteristics

Variables considered for inclusion in the questionnaire and functional assessments were identified as part of the review of literature and were prioritised for inclusion in the protocol. The items are summarised in Appendix A (see highlighted measures in table). Measures were selected for their relevance to the research question and capacity to share/compare data across similar studies. In addition, participant burden for the target group/s (particularly the young adults) was an important consideration in selection of assessment instruments and care was taken to keep face-to-face testing to a minimum in order to maximise recruitment potential. Thus, while functional performance instruments were considered useful for gaining information on general functional characteristics of novice drivers, it was proposed that test items be limited to those which could be administered quickly and/or required minimal face-to-face time whilst providing key information about participants, their driving behaviour, attitudes to functional abilities that are thought to be of primary importance in risk-taking behaviour in general and risky driving in particular. General items proposed for inclusion in the study are summarised below:

A Driver Questionnaire will be developed in two parts. Part 1 will be designed to elicit basic demographic information (age, gender, education, employment, income, ethnic group etc.), health habits (smoking, drugs, alcohol, sleepiness) and medical history. In addition, measures of driving-related information will be included, tapping into driver training and supervision experience, driving habits knowledge of road rules, attitudes and motivations related to driving, risky driving perceptions about crash risk, self-rated driving skills (e.g. Driver Behaviour Questionnaire, Reason, Manstead, Stradling, Baxter & Campbell, 1990; Horswill, Waylen & Tofield, 2004), vehicle choice and purchase, etc. part 1 will be administered prior to commencement of the driving study period. In Part 2, a short assessment battery of relevant cognitive functions and personality measures will be administered (post 6-month driving period) including sensation-seeking, impulsivity, aggression-hostility measures (Begg et al., 2009) and the Behaviour Rating Inventory of Executive Function-Adult Version (BRIEF®-A), (Roth, Isquith & Gioia, 2006) a measure of executive function which can be completed by the participant (self-report) and an informant (i.e., parent).

A Parent Questionnaire will be developed to elicit basic demographic information (age, gender, education, employment, income, ethnic group, etc.) as well as questions relating to supervision of driving, rules about driving and vehicle use, etc.

Crash involvement

Collision involvement during the study period will be identified using three methods. (i) During the naturalistic driving data collection phase, any near-collision or collision will be identified and recorded and DAS unit and video data will be examined to identify contributing factors and driving behaviours prior to an during the event. (ii) Participants will be required to notify the Research Team of any crash involvement and will complete a (self-report) *Short Collision Follow-up Report Form* including details of the location, injuries, context etc.; and (iii) be accessed up to 6-12 months following naturalistic data collection phases.

6.2.5 Data Analysis

A number of analyses are proposed including:

- General Exposure Measures: These analyses will include descriptive data such as overall driving distance, total number of trips, number of trips per week, average trip distance and duration;
- Specific Trip Summary Measures: Percent of trips (during the day; < 5/10/15/20+ km from home; at night; driving on 80km+ roads, etc.);

- Non-Compliance and Infringements: Percent of drivers/trips with non-compliance with (i) GDL system including night driving 10pm-5am with passenger (ii) excessive speeding (over the speed limit – by speed zone; by road type; in rural/urban areas);

- Cross-tabs with relevant driver characteristics (gender, SES, driver attitudes, risk taking;)

- Cross-tabs with relevant environmental factors (manoeuvre type – straight/curve driving, intersection, lane change etc.; road types; rural vs urban; traffic volume; weather; time of day; day of week); and,.

- Event-based analyses: Frequency of collisions, near-collisions and events (hard braking, lane departure, swerving); driver behaviour preceding the event (video-based analysis of distraction- away from forward motorway > 2 seconds; engagement in secondary behaviours; hands off wheel). In addition, regression analyses can be employed to determine key risk factors for near-collision and collision involvement.

6.2.6 Deliverables

The potential significant outcomes of the study have been identified by the research team. These include a report providing the findings of the young driver NDS including exposure variables and risky driving patterns. Key measures could include:

- Driving patterns and exposure measures including – trip distance, types of roads used;

- Number/rate of crashes, near-crashes and other 'events' (hard braking, lane dep., etc.);

- Number/rate of distraction (engages in secondary activities; eyes off road/hands off wheel);

- GDL compliance (% time driving at night, phone use etc.); and,

- Road rule compliance (% time exceed speed limit by 5, 10, 10+km/h coded by speed zone).

More importantly, these findings will have immediate relevance for existing measures in the management of young driver safety such as GDL policy, enforcement, road safety education, and driver training programs in New Zealand, as well as providing access to a rich data source which can be mined in depth and used to inform future countermeasures development. Table 2 provides an overview of the identified research questions, the associated deliverables and the potential recommendations and benefits derived from the findings.

Table 2 Summary of research questions, deliverables and potential recommendations and benefits

Research Question	Deliverables	Potential Recommendations	Potential Benefit areas
What are the general driving patterns of young drivers (e.g. how far, where, when)	Descriptive data including overall driving distance, total number of trips, number of trips per week, average trip distance and duration, trips/km per day of week/time of day; trips/km by road type, distance from home; rural/urban. Validation of current findings with real-world driving data.		Enhanced driver education Objective exposure data for calculating crash risk
Do young drivers engage in speeding behaviour? If so, when, where, under what conditions?	Proportion of drives/trips when engaged in excessive speeding (over the speed limit – by speed zone; by road type; in rural/urban areas). Comparison with self-reported risk-taking behaviour of NZ young drivers (Begg et al., 2009)	Recommendations regarding enhanced speed management and enforcement strategies for P-Plate drivers Recommendations for the implementation of ITS technologies for P-Plate drivers such as ISA to reduce speeding Recommendations for adoption of eco-driving behaviour	Enhanced enforcement Enhanced driver education and training programs Increased parental involvement
Do young drivers comply with GLS restrictions?	Proportion of drivers/trips with non-compliance with (i) GDL including night driving 10pm-5am with passenger Age-based comparisons of compliance with GDL restrictions Comparisons of effectiveness of NZ GDL with GDL in other jurisdictions (pending availability of data including SHRP2, VTTI, UMTRI, Australian NDS)	Recommendations for enhancing GDL policy, such as i) potential for increasing driver licence age from 16 years to 18 years of age, ii) consideration of additional or revised restrictions.	Enhanced GDL policy Enhanced enforcement Increased parental involvement
What are the characteristics of drivers who engage in risky driving behaviour?	Identification of relevant demographic/driving/skills/personal characteristics of driver that predict risky driving behaviour (e.g., defined by excessive speed; engagement in distracting	Recommendations regarding the specific skills that require improvement amongst younger drivers Recommendations for enhanced driver education and training programs to	Enhanced driver education and training programs Enhanced enforcement

	activities etc.)	address specific risky driving behaviours. Recommendations for the promotion of low-risk driving and eco driving behaviours.	
What type of collisions/near collisions/safety-critical events are young drivers involved in?	Objective pre-crash data on driver behaviour, relevant traffic, road and other road user data. Frequency and type of collisions/near collisions and safety critical events	Recommendations to enhance strategies by integrating targets and initiatives to address specific high risk behaviours such as speeding, night driving, vehicle manoeuvre, etc.	Enhanced driver education and training programs Enhanced enforcement

6.2.7 Significance and Benefits of Study Outcomes

The proposed NDS project represents value for money, given the importance of the research questions, the quality of the research team and the potential to produce outcomes that will directly inform initiatives to reduce death and serious injury of young New Zealand drivers. It is expected that the findings from this study will lead to the development and adoption of effective policies and countermeasures which can significantly reduce the number and costs associated with young driver casualty collisions. For every crash prevented, there could be a cost saving to the NZ community in the order of $2.4million for each fatality, $214,000 for each hospitalized injury and $2,100 for each non-hospitalised injury (figures based on BITRE estimated costs) (BITRE, 2009).

6.2.8 Stakeholder Involvement

As demonstrated by NDS efforts elsewhere in the world (the Australian NDS, the European Prologue project and the SHRP2 project) broad stakeholder input/support is considered crucial so that the results are useful for as many people as possible. In a survey of 72 stakeholders representing 18 countries (local/regional/national government, police, licensing authorities, research, industry (motor vehicle, insurance), other non-government organisations), the European PROLOGUE study reported that almost all respondents were interested in road safety topics, and many (particularly industry organisations) were also interested in eco-driving and environmental effects of traffic management-related topics. Key issues of interest to stakeholders included: risk taking behaviour, pre-crash behaviour (speeding, alcohol use), crash avoidance behaviour, and driver condition (fatigue, stress, use of medication), normal behaviour (gap acceptance, overtaking, etc.). Stakeholders identified the usefulness of these topics primarily for road safety purposes, and to a lesser extent for human-machine interface design (Van Schagen et al., 2010).

A similar consultation process with potential stakeholders for the NZ novice driver NDS was established to guide the development and scoping of the proposed study and it is recommended that consultation with this group continues through the implementation phase.

6.2.9 Project Costs and Timing

The proposed novice driver NDS will require considerable partner, stakeholder and researcher input and funding resources to implement. The project will be conducted over two years with a total cost estimated at NZ$916,465 (GST exclusive; international currency exchange rates at 6.2.2014). Budget items are outlined in Table 3 by year of expenditure:

Table 3 Budget

	Y1	Y2	Total
MiniDAS Equipment lease, data cleaning	394,000		394,000
Equipment (laptop, cell phone)	2420		2,420
Participant incentives	37,800		37,800
Personnel: Management, ethics, recruitment, data collection	104,662	52,331	156,993
Pilot test recruitment methods (optional)	15,000		15,000
Analysis and reporting		256,993	256,993
Travel (for installation and recovery of devices/participant testing)	5,197	5,198	10,395
Travel (for Chief Investigator project meetings)	6,700	6,700	13,400
Specialist Technical Training (international partner, including travel and personnel costs)	25,500		25,500
Other (consumables/incidentals)	2,000	1,964	3,964
TOTAL	**593,279**	**323,186**	**916,465**

Timelines for the study are detailed in Table 4, below.

Table 4 Project timelines

Study Tasks	Month 1-4	Month 5-14	Month 15-22	Month 23-24
Ethics; develop/adapt DAS and survey instruments				
Pilot study (recruitment feasibility)				
Recruit, install DAS, data collection				
Analysis				
Reporting		Prelim reporting	Prelim reporting	Final

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APPENDIX A

Summary of demographic, risk-taking, driving behaviour, emotional, psycho-social and functional measures used in previous studies

Authors, reference citation	Measure	Ref details for the original source of the measure
Begg, D., Sullman, M., & Samaranayaka, A. (2012). The characteristics of young pre-licensed drivers: Evidence from the New Zealand Drivers Study. *Accident Analysis & Prevention*, *45*, 539-546.	**1. Self-administered q'aire:** (i) Sociodemographics: age, gender, ethnicity, place of residence	NZ census definition ethnicity(www.) Statistics of NZ
	(ii) Social Deprivation	NZDep2006 score : Health Services Research Centre
	(iii) personality factors: sensation-seeking, impulsivity, aggression/hostility	Zuckermann IMP-SS scale (Zuckermann et al 1993)
	(iv)Other: chronic sleepiness, alcohol and drug use	Alcohol use: 1st 3 q's from Audit-C (Barbor et al 1989)
	(v) Driving: age first drove car on road; .. etc	
	2. Age of first licensure derived from d.o.b. and date of licence issue	n/a
Møller, M., & Gregersen, N. P. (2008). Psychosocial function of driving as predictor of risk-taking behaviour. *Accident Analysis & Prevention*, *40*(1), 209-215.	**1. Self-administered q'aire** (i) Risk-taking behaviour (9Q): Racing, Driving close to front vehicle, speeding, etc	Q'nair consist of combination of questions from Quimby et al (1999) and Carstensen (2002) – (Habits, attitudes, etc)
	(ii) Psychosocial function of driving (9Q): Status, freedom, adventure, etc	
	(iiia) Leisure time activities (13Q) : Sports, working out, comp games, etc	Q's based on previous study by same author : Møller, M., 2004b
	(iiib) Leisure time activities : Driver related interaction in vehicle (w friends)	
	(iv) Educational attainment : Current/ex participation in education programs	
Blows, S., Ameratunga, S., Ivers, R. Q., Lo, S. K., & Norton, R. (2005). Risky driving habits and motor vehicle driver injury. *Accident Analysis & Prevention*, *37*(4), 619-	**1. Self-administered q'aire** **(**i) Demographics : Age, gender	Previous Methodology: New Zealand Blood Donors' Health Study (Ameratunga et al., 2002) NZ socioeconomic score (Davis et al 1999)
	(ii) Drug/alcohol use,	'CAGE' screening test for hazardous

624.	smoking	drinking (Ewing (1984)
	(iii) Social situation	
	(iv) Sleep habit, mental health, medical history	Epworth Sleepiness scale score (Johns, 1991)
	(v) Injury Information	Injury information coded to New Zealand Ministry of Health, Wellington
	(ii) Risky Driving behaviour: Over legal BAC, racing other drivers, speeding 20 km/h over limit, seatbelt use, driving without licence.	
	(iii) Traffic convictions (in past 12 months)	
	(iv) Injuries sustained (in past 12 months)	
Braitman, K. A., Kirley, B. B., McCartt, A. T., & Chaudhary, N. K. (2008). Crashes of novice teenage drivers: Characteristics and contributing factors. *Journal of Safety Research*, *39*(1), 47-54.	**1. Structured Telephone interview** 16 yo drivers involved in crashes to be identified from records (see ref) • Interviewed participants to have been involved in crash within 4-17 weeks prior • Interview audiotape and transcribed	Crash profiles of fatal/non fatal : Connecticut Department of Transportation Police reports accessed for contact details of driver involved to conduct phone interview Crash categorized from police rep using approach based on driving action and vehicle movement immediately prior to crash (McCartt, Shabanova Northrup, & Retting, 2004 , Retting, Williams, Preusser, & Weinstein, 1995)
	2. Crash characteristics: (i) Fault/Non-fault, gender, crash severity, crash type, crash location, reasons for travel	
	3. Contributing factors (Driving) (i) Course: Illegally deviating from lane/norm traffic patterns	Factors adapted from Snyder and Knoblauch (1971)
	(ii) Search and detection: Failure to see/detect other vehicle/traffic ctrl devices	
	(iii) Evaluation: Misjudge other vehicle/ driving environment	
	(iv) Speeding	
	(v) Swerving to avoid obstacle	
	(vi) Driver impairment	
	(vii) Control loss/skid	
	(viii) Vehicle mishandling	
	(ix) Caravanning with other	

	teens	
	4. Contributing factors (Non Driving) **(i)** Unfamiliar vehicle/roadway, vehicle failure	
Bingham, C. R., Shope, J. T., Parow, J. E., & Raghunathan, T. E. (2009). Crash types: markers of increased risk of alcohol-involved crashes among teen drivers. Journal of studies on alcohol and drugs, 70(4), 528.	**1. Police Record Analysis** (0) Gender, age group (i) Alcohol Crash types: (time, passengers, speed, day)	Michigan State Police crash records
	(ii) Alcohol casualty crash type: time, passenger, speed, day	
McKay, M. P., Coben, J. H., & Larkin, G. L. (2003). Driving beliefs and behaviors of novice teen drivers and their parents: implications for teen driver crash risk. In *Annual Proceedings/Association for the Advancement of Automotive Medicine* (Vol. 47, p. 197). Association for the Advancement of Automotive Medicine.	**1. Random Sample Mail Survey – Self admin q'aire (16-17 yo)** (i) Demographics- age, gender	Survey questions based on previously performed telephone surveys and published results: • (PennDOT Junior License Survey; California New Driver Survey) • (MMWR, 1994; Williams, Ferguson, Leaf, et al., 1998; Ferguson and Williams, 1996; Begg, Langley, Reeder, et al., 1995)
	(ii) Length of supervised driving	
	(iii) Number of crashes and violations- Cell phone/radio use	
	(iv) Speeding	
	(v) Driving behaviour (6) – 2 protective, 1 aggressive (shouting/gesturing etc), 3 risky behaviour (speeding through amber signal, tailgating etc)	
	(vi) Teen crash risk to personal crash risk	
Vassallo, S., Smart, D., Sanson, A., Harrison, W., Harris, A., Cockfield, S., & McIntyre, A. (2007). Risky driving among young Australian drivers: Trends, precursors and correlates. *Accident Analysis & Prevention*, *39*(3), 444-458.	**1. Self admin q'aire** (Participants involved born since 1982-1983 for ATP study. Some participants no longer involved. 13 waves of data collected prior) (i) Demographics: Gender, age	Australian Temperament project (ATP) (Prior et al., 2000) Participants not involved (Ruschena et al., 2005)
	(ii) Licensing (L permit/ probationary for car/motorcycle) & age since licensed	Consolidation across time points undertaken for development phases of participants – toddler, e/m/l child hood, e/m/l adolescent, e adulthood (Piaget and Inhelder, 1969; Sorrentino et al., 1990) (Full list in Appendix of article) Legend: e=early m=mid l=late
	(iii) Experiences as Learner : # Professional driving lessons, frequency of practice, degree of stress while practicing	
	(iv) Driving exposure (after	Likert style responses

	licensed): # hrs driving, crash exp, enforcement exp	
	(v) Engagement in risk driving : Speed, seatbelt/helmet wearing, fatigue, alcohol/drug influence,	
VTTI study – see doc from Klauer et al	Q'naire?? (i) Demographics: Teen & Adult	
	(ii) Risk perception	
	(iii) Risky driving behaviour: thrill seeking	
	(iv) Licensure	
	(v) Driving exposure	

Note: highlighted variables are selected for relevance to the proposed research questions and importance for comparisons of NZ NDS sample with findings from other studies.

Appendix B: Identification of NDS Systems

Overview

To identify NDS systems, searches were conducted on the internet generally (using google), on specific transport related websites and in the academic literature. The following sections provide more detail of how the searches were undertaken and the systems identified.

I. Academic Studies search

1. Initial information was obtained from the paper "Naturalistic Driving Studies: Literature Review and Planning for the Australian Naturalistic Driving Study" by Regan, Williamson, Grzebieta and Tao (2013). This paper was presented at the 2012 Australasian College of Road Safety (ACRS) National Conference: 'A Safe System: Expanding the reach!' The paper provides an overview of the Naturalistic Driving Study (NDS) as a research method, together with a brief review of about 40 naturalistic driving studies that have been undertaken previously in various countries. It is noted that such studies are becoming a routine method for data collection in some countries. Advantages of the NDS method in complementing existing data collection methods are outlined, as well as some of the limitations. Then a rationale for running a large-scale NDS in Australia is offered, and the benefits of such a study for Australia are discussed. Finally, a project, created and led by Transport and Road Safety (TARS) Research, at the University of New South Wales in Sydney, is described: The Australian Naturalistic Driving Study, which will culminate in Australia's first large-scale NDS, and support the running of similar studies in Australia in the future. This international project will bring together researchers from four Australian universities and VTTI, as well as road safety-related stakeholders from government and industry in Australia. It will ultimately lead to the creation of a national facility, like that at VTTI in the USA. Collaboration with VTTI in terms of equipment is described: e.g., 25 VTTI-supplied DAS units for use in each of 4 Australian states, and associated data management systems.

The 40 articles cited in the paper were accessed online through the University of Waikato (UoW) online library databases, and an e-copy of each was downloaded and a hard copy printed. The abstract and methods sections (and sometimes also the introduction) were read. The summary of previous studies is organised thematically in the paper, with the studies grouped within seven broad research areas: these include various aspects of the driver's experience, interactions between vehicles, driver assistance systems, and eco-driving. The studies were reclassified for current purposes into the following four categories, based on the instrumentation and data collection system that was used: Custom systems developed by Universities; Off-the-Shelf / Commercially-developed systems; Custom Systems (commercial) and Other (see Table 1).

Table 1. Classification of academic studies according to technological system used

Category and technology systems
1. Custom systems: Developed by universities and described in various peer-reviewed published academic studies: • The Data Acquisition System (DAS) developed by VTTI and used by various research teams (including the 100-Car Study, Naturalistic Teen and Truck Driving Studies, and the Second Strategic Highway Research Program or SHRP-2); other data acquisition systems, developed by Monash University Accident Research Centre (MUARC), and University of Michigan Transportation Research Institute (UMTRI); Video Logging Systems developed at the Universities of North Carolina and Ohio; and the OttoView CD autonomous data logging system developed for Candrive II / OzCanDrive Study
2. Off-the-Shelf / Commercially-developed systems described in other peer-reviewed published academic studies: • CarChip & Otto; DriveCam; DriveDiagnostics; GreenRoad Technology; Valentine Research
3. Custom Systems: • Black Box, Econen, Smart Car, Smart Car Technology Pty Ltd
4. Others: including systems which did not seem to fit into any of the other categories: • In-Vehicle Information Systems used as Data-Collection Systems: In-Vehicle Warning System; ISA • Eye-tracker • No details given (systems described only as *"a computer"* or *"a monitoring device")*

2. Further information was provided by the article “In-vehicle data recorders for monitoring and feedback on drivers’ behavior” by Toledo, Musicant, and Lotan (2008), in Transportation Research Part C: Emerging Technologies, 16, 320-331. The authors describe various commercial and research applications of in-vehicle data recorder (IVDR) systems, for monitoring driving behaviour and providing feedback to drivers, and for collecting and recording information on the performance of the vehicle and driver. They note the difference between event data recorders (EDR), which store information on the states of the vehicle’s systems for a short time (about 30 s) before, during and after crash events; and systems that monitor and measure drivers’ behaviour continuously. Applications of the technology, both academic and commercial, are briefly discussed, including the 100-Car Study in the USA; the use of IVDR data by some insurance companies to determine insurance rates (installation of the system entitling drivers to a discounted premium); and the GPS-based SAGA system developed, in Iceland and installed in Iceland Post vehicles. A detailed description of a specific IVDR system is provided: the DriveDiagnostics system. The use of this system in an experiment is described, and results reported that demonstrate its potential to measure and monitor drivers’ behaviour and provide feedback. Some of the cited articles were again accessed through the UoW online library databases, and electronic and hard copies of these were obtained.

3. The titles of the extensive collection of articles collected by MUARC, available on the UoW TARS shared database, were reviewed for any additional relevant articles, using words in the titles as an indication of relevance.

4. A final search was performed on the UoW university databases (PsycInfo Elsevier/ScienceDirect, ProQuest, and Google) using appropriate keywords including “*in-vehicle; in-car; in-truck, on-board; plug-in*” and “*data / video / event; recording; monitoring; reporting; observation; measurement; tracking*” and “*logger; tracker; device; recorder; unit; system; instrument/ation*” and “*naturalistic driving; instrumented vehicle / truck / car*” and “*NDS; naturalistic driving study; data collection; instrumented vehicles; DAS; data acquisition system*”. The same searches were conducted with “*New Zealand*” as keyword to ensure any previous NDS studies conducted in New Zealand were identified.

5. The search resulted in a final count of about 70 articles: including mostly peer-reviewed studies, and some technical reports and conference papers. About 50 of these articles include descriptions of systems, and have been included in the overview of systems (See Table 2a, 2b, 2c and 2d).

Table 2a. Custom systems: Developed by universities and described in various peer-reviewed published academic studies

SYSTEM: Data Acquisition System (DAS) developed by Virginia Tech Transportation Institute (VTTI) Technical Operations staff: used by various research teams

100-Car Study:	**Naturalistic Teen Driver Study:**	**Naturalistic Truck Driver Study:**	**Second Strategic Highway Research Program (SHRP2):**
• Dingus, Klauer et al., 2006 • Guo & Fang, 2012 • Hanowski et al., 2006 • Klauer et al., 2006 • Neale et al., 2006	• Lee et al., 2011 • Simons-Morton et al., 2011 • Simons-Morton et al., 2012 • Simons-Morton et al., 2013	• Blanco et al., 2006 • Blanco et al., 2011 • Dingus, Neale et al., 2006 • Hanowski et al., 2003 • Hanowski et al., 2005 • Hanowski, Hickman, Wierwille et al., 2007 • Hanowski, Hickman, Fumero et al., 2007 • Hanowski et al., 2009 • Soccolich et al., 2012	• Antin et al., • Boyle et al., 2012 • Campbell et al., 2012 • Hallmark et al., 2013

- An advanced in-vehicle data acquisition system, video recorders and network of sensors distributed around the vehicle collect driver performance and vehicle data
- Monitoring systems incorporate both vehicle network and VTTI-installed sensors
- Data is collected continuously in real-time while the vehicle is operating
- Unobtrusive equipment: small video cameras / main DAS unit mounted in inconspicuous location
- Main unit (core of DAS): a computer with custom software / removable external hard drive that receives and stores data from video recorders and sensors
- The central computer encrypts and records all raw vehicle data on a removable hard drive that must be replaced every few months
- Encrypted data is transferred via secure high-speed networks to VTTI for processing, quality control, and addition to NDS database
- Data is saved to VTTI's network-attached storage server (NAS), and copied onto DVDs; VTTI stores all NDS data
- Multiple unobtrusive digital video cameras continuously monitor interior / exterior of vehicle
- Cameras provide almost complete coverage around vehicle
- Cameras are positioned to provide views of the forward / rear roadway; driver- and passenger-side road view; driver's face; steering wheel, instrument panel, pedals, driver's hands / feet (from over the driver's shoulder)
- The multiple camera images are combined in a single frame for simultaneous monitoring of all video channels
- All video data is time-stamped, to synchronize with corresponding vehicle / driving performance data; and compressed for storage to preserve space on hard drives / server
- A continuous video record of driver and driving environment is obtained
- Multiple sensors measure driver performance
- Vehicle network sensors record vehicle speed, brake activation, accelerator pressure, turn-signal use, ABS, gear position, steering wheel angle, seat belt use
- Other sensors include: accelerometers; a GPS which collects information on vehicle position, heading and speed, provides time / date data, and enables geo-spatial analysis and

sampling; a radar unit providing forward / rear headway detection and a side clearance detector (crash-avoidance sensor); a lane position tracking system; and cellular communications system

- GPS is used in conjunction with cellular communication subsystems
- System also includes an automatic collision notification system; vehicle tracking and system diagnostics; an incident button for drivers to flag unusual events; and other sensors if required (e.g., an alcohol sensor)
- Vehicle network data is integrated with DAS data via a VTTI-developed interface
- The driving performance data provides post-hoc triggers to identify where a crash, near-crash, or incident has occurred in the video data: specific video segments are flagged for more in-depth examination when vehicle sensor readings exceed preset thresholds
- Types of triggered events for which DAS may be programmed include: lateral / longitudinal acceleration; forward / rear time-to-collision; yaw rate; vehicle swerves; lane deviation. When the system detects a trigger, the computer collects video / driving performance data for a specified period before (e.g.,1.5 min) and after (e.g., 0.5 min) the triggering event
- Data is saved only when pre-determined sensor thresholds are exceeded (i.e., when sensors detect a potential event)
- Crashes, near-crashes, and other incidents (events) are identified through a software program which searches through data files for triggers (indicating possible events), then validated by researchers viewing the associated video and corresponding driving performance data for the event (to confirm that a conflict has indeed occurred)
- Video data is used to validate vehicle and electronic driver performance data from sensors
- Raw data collected from vehicles is reduced through event analysis: data for triggered events are reviewed and analyzed by trained analysts. Data reductionists can reduce an average of 4 events per hour.
- Reduced data is entered into a database and used to investigate the relationship between various driving behaviors and crashes, near-crashes, incidents. Multiple analyses are conducted on the data.

Comments:

1. A very flexible, centralized, and expandable data collection system: it can be configured according to specific research questions; budget; time and other constraints of a project
2. Camera-arrangement and sensor-selection can specifically target behaviours of interest and obtain the required data
3. An unobtrusive and compact system: the small size of individual components allows concealment
4. Reliable for long data collection intervals with no experimenter present
5. State-of-the-art, and the most developed system currently available: it has been developed by experts over a 20-year period
6. Supported by considerable expertise: data is sent to VTTI to be reduced and stored
7. Has been extensively tested and refined: it has been, or is being, used successfully in several major high-profile projects overseas (see references above)
8. Provides extensive and very rich data
9. Results are comparable with other published studies: its use in the current project will establish an NZ presence within a framework of large scale international studies
10. DAS is configured as a modular system, but each sensor subsystem is independent: any single sensor failure does not affect data collection from other sensors in the network: very few sensor failures that resulted in loss of driving data have been reported
11. Several weeks of data storage is available on the system's hard drive before data downloading or hard drive replacement is necessary
12. Rugged, durable

BUT:

13. Expensive
14. Requires considerable technical support
15. Data analysis is labour-intensive and time-consuming
16. In-vehicle installation takes approximately 3-4 hours: vehicle must be taken to an installation facility to be fitted by technical staff.
17. Regular checking / careful ongoing maintenance is required

18. Regular data downloading is necessary: drivers need to provide regular access to their vehicle, so that the hard drive can be removed and replaced every 4-6 months
19. The cameras (and sensors?) could be tampered with or removed (deliberately or inadvertently), resulting in data loss
20. Special brackets may be required (and need to be designed) to allow the instrumentation to be installed in vehicles
21. The high costs of using this type of equipment limits sample size
22. The complex data requires an extensive data reduction process by a large team of specially-trained data reductionists; and ongoing training / checks of inter- and intra-rater reliability due to the subjective nature of data coding and the involvement of several analysts

PRICE

- VTTI mini-DAS: A tentative quote has been received from VTTI for leasing 100 units at $40 per month per unit; this includes data storage, access to all analysis software, but not any post-processing of data

SYSTEM: Data acquisition system developed by Monash University Accident Research Centre (MUARC)

- Charlton et al., 2013; Koppel et al., 2011

- One instrumented vehicle: a large, luxury model family sedan with automatic transmission
- Data acquisition unit: Motec ACL/ADL3a data recorder
- In-vehicle video recording and vehicle data logging equipment
- Camera recording system: Appro® DVR with 250 GB hard disk – Mobile Vehicle Video Recorder DVR-3064; 25 frames/s
- Multiple small in-vehicle CCD cameras (concealed) / 2 wide-angle cameras on roof
- Interior camera views of: road ahead, to the side, and to the rear; vehicle interior including driver / passengers, instrument panel, pedals
- Cameras send data to one of two digital 4-channel video recorders (DVR) mounted in trunk
- System recorded trip distance, vehicle speed, acceleration, braking, steering wheel angle and indicator use
- Data downloaded to a laptop
- Vehicle data / video files could be synchronised
- Instrumentation start-up / shut down triggered automatically with vehicle ignition
- Recording system operated by a microcontroller, activated when a passenger door was opened; could also be de-activated by the driver
- Data coding conducted with Snapper software (Copyright, Webbsoft Technologies, 2008): this viewing platform facilitated logging of events into a database

Comments:

1. A very rich data source

SYSTEM: Data acquisition system developed by University of Michigan Transportation Research Institute (UMTRI)

- Bao et al., 2012; Eby et al., 2012

- Data collected through an in-vehicle integrated crash warning system developed for the Integrated Vehicle-Based Safety System (IVBSS) program
- A suite of sensors and cameras collected inertial, video, radar, and GPS information
- Data acquisition system main module mounted in trunk: central processing unit (CPU), data storage, power management electronics, interfaces for the sensors, keyboard / monitor
- 4 unobtrusive in-vehicle video cameras continuously provided two forward views, and views of driver, vehicle interior / exterior
- Infrared cabin illumination at night

- A long-range forward radar system measured relative speed and distances to vehicles and other objects in front of the vehicle
- A two-axis accelerometer measured lateral/longitudinal acceleration; a yaw rate sensor determined degree of turn around a vertical axis
- GPS provided data regarding speed, time of day, latitude, longitude, and heading
- System also provided forward-collision, lane-change or merge, and lateral-drift warnings
- A microphone continuously recorded audio data
- Driver-vehicle interface (DVI): dash-mounted visual display device (situational information and visual warnings) and 2 blind spot indicators; auditory information
- Information captured: driving environment, driver activity, system behaviour, and vehicle kinematics
- Data were reduced and analyzed using a set of algorithms / heuristics developed by the research team using SAS: an integrated series of automatic calculations and analyst reviews of video, audio, and other sensor data.

Comments:

1. Installation / removal of in-vehicle technology must be done by highly qualified engineers
2. Installation requires an average of 55 h per vehicle
3. Resources required for installation greatly limits number of drivers in study
4. Drivers require training on use of the integrated crash warning system
5. Labour-intensive data analysis: limits amount of data processed
6. Data analysts require extensive training

SYSTEM: Video Logging

- **Systems developed at University of North Carolina (Stutts et al., 2005); and University of Ohio (Mollenhauer et al., 1997)**

University of North Carolina

- An unobtrusive in-vehicle video camera system: camera / recording units, trigger and connecting cable
- Continuous recording of driving behavior
- Camera unit: 18 cm x 6 cm x 5 cm, mounted on front windshield: 3 miniature video cameras providing views of driver's face, vehicle interior, roadway immediately ahead of vehicle; also a microphone
- Simultaneous monitoring of 3 video screens on monitor display
- Cameras concealed from driver by near-infrared filters: infrared light source for recording in low light
- Trigger cable connected to vehicle's accessory fuse powered cameras when vehicle ignition turned on
  A large locked box stored in trunk contained a video recorder, quad processor, and battery pack
- Data coded using special video reduction software: simultaneously coded individual data "channels"

University of Ohio

- One vehicle: an ABS-equipped Oldsmobile Trofeo with multiple sensors, event / data recording instrumentation
- 3 unobtrusive "lipstick case" video cameras provided views of accelerator / brake pedals; wide view of forward roadway; driver's face / steering wheel
- The 3 camera views were input to a video multiplexer and combined into one SVHS picture: this facilitated accurate manual reduction of data by simplifying the process, as views were synchronized and points of reference provided for where data should be analyzed
- Post hoc analysis of videotapes (with audio in some borderline decisions)

Comments

1. Drivers must come to research offices to have equipment installed in vehicle and removed
2. Installation of the equipment generally requires 30 min or less, removal about 15 min

3. Data processing is time-consuming

SYSTEM: OttoView CD autonomous data logging device: system developed for Candrive II / OzCanDrive Study

- Langford et al., 2013; Marshall et al., 2013; Vlahodimitrakou et al., 2013

- Custom-designed in-vehicle recording device and software suite developed for Candrive by Persen Technologies Inc. (Winnipeg, Manitoba)
- Powered by vehicle through on-board diagnostic system
- Continuous monitoring of driving patterns
- Vehicle information collected: time / date of trip, speed, distance travelled, and vehicle parameters
- A dash-mounted GPS and receiver in the main device box enabled collection of vehicle location information
- An optional radio frequency identifier system (antenna plus key chain fob) for shared vehicles (to identify vehicle driver)
- An SD memory card used to store data at a rate of 1 Hz, to allow information to be collected over a period longer than 4 months
- The memory card in the device needs to be exchanged approximately every 4 months
- Memory card data files sent to Winnipeg site using a file transfer protocol server at the University of Manitoba to be processed.

Comments:

1. Participants report when vehicle has been serviced by a mechanic in case of any disruptions to the device, such as disconnection from the OBDII port.

Table 2b. Off-the-shelf and commercially-developed systems described in other peer-reviewed published academic studies

SYSTEM: CarChip & Otto

- Blanchard & Myers, 2010; Blanchard et al., 2010; Myers et al., 2011

CarChip (Davis Instruments, Hayward, CA)

CarChip E/X® and CarChipPro ®

- An in-vehicle electronic recording device
- Plugs into on-board diagnostic port of vehicles with no alternating power source (i.e., non-hybrid)
- Can record up to 300 h of detailed trip data: including distance, duration, speed, number of trips, stops, time of day
- More accurate than GPS devices in recording distance: minimal error
- Collects date- and time-stamped information
- Logging begins automatically when engine turned on

Comments:

1. Small, unobtrusive
2. Device may be removed deliberately or inadvertently (e.g., during vehicle servicing)

Otto (Persen Technologies Inc., Winnipeg, Manitoba)

Otto Driving Mate® / Otto Driving Companion®

- GPS device
- Mounted on vehicle dashboard
- Can record up to 320 h of driving data at a 1 s sampling rate
- Collects date- and time-stamped information
- Logging begins automatically when engine turned on
- Can determine vehicle position (i.e., roadways, turns) when paired with digital maps
- GPS data and digital maps (i.e., Google Earth) can be used to examine trip characteristics, e.g., roadways driven / manoeuvers made

Comments:

1. Small, lightweight
2. Loss of satellite signals can result in missing GPS data
3. Several days of data recording necessitate using vehicle's power source: device is activated when ignition is turned on, so 'cold starts' at the start of trips can result in lost or missing GPS data, especially for short trips
4. Connectivity problems (e.g., a loose connection) may cause data loss

SYSTEM: DriveCam

- Carney et al., 2010; Hickman & Hanowski, 2011; Hickman & Hanowski, 2012; McGehee, Raby et al., 2007; McGehee, Carney et al., 2007 (4th IDS)

DriveCam (DriveCam, Inc., San Diego, CA)

- An in-vehicle event-triggered video recording system
- The device is triggered when an acceleration threshold is exceeded, causing an event to be recorded: 20 secs of data are written to internal memory
- The 20-sec video clips capture the 10 secs before / after an event (e.g., abrupt braking / steering manoeuvres)

- Threshold levels are determined for each acceleration-based trigger (lateral, longitudinal, or shock), measured in g-forces
- Manual triggering of the system is also possible
- Records acceleration, date, time
- Audio-video data are continuously buffered
- 2 video cameras (views of forward roadway / vehicle interior), integrated with 2- or 3-axis accelerometer, 20-sec data buffer, microphone, infrared illuminator (lights interior at night), wireless transceiver
- Mounted on windscreen
- Wired into vehicle electrical system
- Also provides immediate video feedback to driver via blinking LED and "report card" (cumulative graphical / written performance data)
- DriveCam is responsible for data collection: data are automatically sent to DriveCam via cellular transmission, and are reviewed, reduced and uploaded to a web server in approximately 24–48 h from time the event is captured
- Encrypted data can then be downloaded for coding and analysis

Comments:

1. Small: a palm-sized device
2. Installation takes approximately 30–45 minutes per vehicle

SYSTEM: DriveDiagnostics (GreenRoad Technology)

- Toledo et al., 2008

The DriveDiagnostics system (IVDR)

- An in-vehicle data recorder (IVDR) system: monitors on-road behavior and provides feedback to drivers, may also connect to vehicle on-board diagnostics system
- The sensor unit with accelerometers and data recording / analysis unit are installed together under panel beneath handbrake: combined size of about 11 x 6 x 6 cm / requires a small amount of power (<250 mA) so wired to car battery
- Information collected on vehicle, driver, trip start / end times, trip duration, distance travelled
- Sensors measure vehicle speed and acceleration at high resolution: lateral / longitudinal acceleration (measured by accelerometers); speed / location (derived from GPS receiver data or vehicle speed sensor)
- Applies pattern recognition algorithms to raw measurements to reduce data and calculate risk indices and other statistics
- Can identify a set of manoeuvres, classified by their relative direction / level of severity
- Data is automatically transmitted to a server using wireless networks
- The server maintains a database with vehicle-specific and driver-specific records (trip statistics, vehicle usage patterns, recorded manoeuvres and severity ratings): drivers can access web site to review their data
- Driver feedback is provided off-line through summary reports, real-time text messages, or in-vehicle display; and in real-time through warnings provided as text message (SMS) or on in-vehicle display unit

Comments:

1. A large amount of raw data is generated

SYSTEM: GreenRoad Technology

- Prato et al., 2009; Prato et al., 2010

- An in-vehicle data recorder (IVDR) system
- Monitors all trips made by vehicle
- Records driver identity, trip start / end times, trip durations, vehicle usage patterns, manoeuvres with severity ratings
- Sensors measure / record speeds and accelerations at high resolution: speed / acceleration profiles generated
- Identifies and classifies manoeuvres
- Records of manoeuvres and their severity ratings used to calculate compound risk indices (measures of risk taking behavior of drivers)
- Employs pattern recognition algorithms to reduce data
- Processed information is transmitted through wireless networks to a web-site database with vehicle-specific and driver-specific records (including the calculated risk indices)
- Drivers can access personal web pages to view the data collected on their driving behavior and the risk indices; and to receive feedback

Comments:

1. Generates a large amount of raw data

SYSTEM: Valentine Research

- af Wåhlberg, 2000

- A g.analyst, connected to a lap top computer for storing data
- Consisted of a measuring device (transducer) and control unit (display head) with digital display
- Measured / recorded g-forces (acceleration force) in 2 dimensions (gas/brake, right/left turn)
- Transducer sampled the g-force ten times a second to a hundredth of 1 g (gravity at sealevel, about 9.81 m/s^2)
- Also measured mean driving speed
- Event marks were recorded separately (time of event)

Comments:

1. Unobtrusive equipment
2. Small: control unit is about 25 by 12 cm

Table 2c. Custom systems

SYSTEM: Black Box • Farmer et al., 2010
• An in-vehicle monitoring and feedback device • A shoebox-size black box: GPS, satellite modem, and small speaker box installed beneath front dashboard / in vehicle's cargo area • Vehicle / driving behaviour monitored: detects sudden braking / acceleration (longitudinal deceleration / acceleration of more than 0.5 g), and nonuse of seat belts; and transmits a record of these events via satellite to a central computer • In-vehicle feedback: audible alerts immediately after event (buzzes, beeps) • GPS also used to continuously monitor vehicle speed and compare it with a database of posted speed limits: instances of exceeding a posted speed limit reported to central computer. • Website notification: report cards generated with descriptions of events / location and time information posted on password-protected driver-specific internet website • Drive website access: driver can review events using a map showing their location and information about their nature • Website notification: can be immediate or delayed (an audible alert sounded in vehicle but driver given 20 seconds to correct behaviour)
SYSTEM: Econen • af Wåhlberg, 2007
• An automatic logging device • Driver acceleration behavior measured / recorded • Measured speed at 10 Hz and distance travelled: calculated from pulses from speedometer • Acceleration, deceleration (calculated at 2.5 Hz) and speed measured • Econen meters: feedback device indicating fuel consumption
SYSTEM: Smart Car • Boyce & Geller, 2001
• An in-vehicle information system (IVIS) developed: also capable of unobtrusive recording of ongoing driver behavior • Vehicle exterior and interior modelled on a 1995 Oldsmobile Aurora • Various cameras, sensors, compilers, and a computer: provided computer-generated data and real-time video recordings • Steering wheel, speed, acceleration, and brake sensors • A custom interface: integrated data from experimenter control panel, sensors, event flagger, and speedometer with in-vehicle computer • 4 hidden pinhead-size cameras provided continuous views of the forward / rear roadway, vehicle interior including driver's face and hands, lane-tracking • A quad-multiplexer integrated the 4 camera views and placed a time stamp onto a single videotape record • The video configuration was shown continuously on a video monitor: a PC-VCR which operated in an S-VHS format so that each multiplexed camera view had 200 horizontal lines of resolution. • The PC-VCR displayed the time stamp continuously on the multiplexed view of the videotaped record: enabled video / computer data records to be synchronized • Electronic / videotape records were converted to indexes of driving behavior / risk taking (time-sampling of speed, driver behaviours, and critical events)
SYSTEM: Smart Car Technology Pty Ltd • Meredith et al., 2012
C4D Data Recorder with connected External GPS Receiver ('black box')

- In-vehicle monitoring system with incorporated GPS
- Speed and deceleration measured by accelerometers
- GPS used to determine location of vehicle at any position on the earth through navigational satellites
- Data logger transmitted deceleration data / GPS transmitted location data via mobile telecommunications network (location integrated with custom road network database)
- Accelerometer data captured continuously using an Applied Measurement data acquisition system at 10kHz, and processed using custom MATLAB algorithms
- Data processed to obtain and plot peak deceleration and change in velocity

Comments:

1. Small portable device
2. Easy to install in vehicles
3. devices hardwired to vehicle in a concealed and unobtrusive location

Table 2d. Others

SYSTEM: In-Vehicle Information Systems used as Data-Collection systems	
In-Vehicle Warning System • Sullivan et al., 2008; McLaughlin et al., 2008	**ISA** • Faulks et al., 2012; Lai & Carsten, 2012
Sullivan et al., 2008: • Driver responses to lateral drift warnings (LDWs) were measured: driver reaction time, i.e. latency to initiate a corrective steering response after a warning (calculated as the time delay between the warning and the detected start of a corrective steering response) • Focused on the operation of the LDW system used in a road departure crash warning (RDCW) field operational test • The start of the corrective manoeuvre was determined by examining the rate of change in the steering wheel angle within a period of 3 s before and 3 s after the warning • Steering wheel angle was then converted to steering rate of change and examined for events that exceeded a ±3°/s threshold within a 6-s period centred on the time of an LDW warning (these criteria were developed through inspection of the video and time series data) • A steering response detection algorithm was devised which identified the start times of relatively abrupt steering actions at the time of an LDW Faulks et al., 2012 (a non-peer reviewed article) • A protocol was developed to evaluate in-vehicle navigation devices offering an ISA capability and providing speed information to drivers • Four ISA devices available in Australia were tested on-road against 20 criteria in freeway, commercial and residential environments • 3 Sat Nav based ISA products and one smartphone based ISA product were assessed: the OttoMobile (for iPhone); the Navman Ezy30; the Navig8r M35; and the TomTom GO • Two test routes were used: a route in Melbourne comprised mainly of motorway sections; a route in Sydney that passed through several speed zones and included urban, suburban and motorway road types McLaughlin et al., 2008 • Used naturalistic driving data to develop a method for evaluating the performance of collision avoidance systems • Data on following-vehicle speed, relative speed, and headway had been collected through a range of in-vehicle sensors and video, and/or equations of motion • Seventy-three events collected during driving were used to provide data to test the method and develop analysis algorithm models • A kinematic analysis of the events was conducted to determine when different responses would be required to avoid collision • In-house data visualization software was used to review rear-end striking crashes and near-crashes in detail. This software permits frame-by-frame review of five video views along with numeric data collected during the event • Software was developed that would present time-series data to independent alert algorithm models which would then generate a time-series output indicating when the alerts would have occurred Lai & Carsten, 2012: • An on-board data-logging system recorded a wide range of data at high resolution, which facilitated sophisticated data analysis of vehicle speed and drivers' overriding patterns against speed limits as well as road categories	
SYSTEM: Eye-tracker • Dukic et al., 2006	
• An instrumented Toyota Corolla with dual controls • Visual time off road (in ms), and steering wheel deviations (in degrees) were measured during driving • Car data were recorded in a vehicle information file with a sampling rate of 10 Hz • Eye movements were recorded with a head mounted eye-tracking system, SMI iView, using infrared cameras to capture the positions of the pupil and the corneal reflex at 50 Hz. Two	

signals were recorded: a video image of the right eye pupil; and a video image from a camera placed on the head set recording the scene from the driver's perspective (a cross indicated the driver's point of gaze)
- Both video signals from the eye-tracking system (sampled at 25 Hz) were passed on to a video splitter and recorded on videotape
- A manually operated control unit connected the video system and the recording unit for the car data. The control unit synchronized the two systems by placing an indication in both the video file and the car data file

SYSTEM: No Details Given
- af Wåhlberg, 2007; McCartt et al., 2010

af Wåhlberg, 2007:
- Speed change data had been measured repeatedly over three years in Volvo buses equipped with *a computer* (mounted under the dashboard), which tapped the speedometer signal, calculated speed at 10Hz and transformed this to longitudinal speed changes at 2.5Hz, using a simple smoothing function

McCartt et al., 2010:
- Vehicles were fitted with a *monitoring device* that detected sudden braking and acceleration, hard turns, and nonuse of seat belts, and transmitted a record of these events via satellite to a central computer. The device also continuously compared vehicle speed to a database of posted speed limits, and instances of speeding were reported to the central computer
- Neither video nor audio recordings were made
- Monitoring of driving was continuous
- Audible alerts sounded for specified driving behaviours: a short, low-pitched buzz; a continuous low-pitched buzz; a single beep, followed by continuous beeps. Alerts were designed to be louder than the radio and surrounding traffic
- Information about the specified driving behaviours could be immediately posted on a password-protected Internet Web site specific to the driver. Access to a Web site that summarized the driver's driving and in-vehicle alerts provided feedback.
- Drivers could also correct behaviours within 20 s of an alert to avoid having the behaviour reported (conditional notification mode)

Comments
1. They note that "problems with the device were documented"

II. Non-Academic / Commercial Information search

1. For information about other instrumentation and data-collection systems, especially commercially-available plug-in devices not described in the academic studies, a number of online keyword searches (see Figure 1 for the keywords) were conducted on Google, using various combinations of the keywords listed below. These searches generally generated vast numbers of hits (thousands, tens of thousands, even millions), but on closer inspection many of the hits were found to be not relevant. Many websites could be excluded (e.g., those products used specifically in aviation contexts or racing cars). However, this still left a considerable number for review. For the results of most searches, the first ten pages of hits were skimmed through, and any websites which seemed relevant were selected for further inspection. The websites of various relevant companies selling appropriate technology were then consulted. Hard copies of the promotional materials from these websites were downloaded, including product descriptions and pictures of the devices, and information about costs. Sites such as TradeMe, eBay and Amazon were also consulted, to obtain information about local sales (and prices) of such technology.

2. The searches also revealed some online articles by consumer organisations and special-interest groups (e.g., technology and road safety groups). Some of these articles reported the results of a trial of some of the products which had been conducted, and highlighted the products which were judged to be of the best quality. Others provided an overview or explanation of the products (e.g., sites explaining how parents could use the technology to monitor their children's driving). A few newspaper articles from quality newspapers (e.g., the Guardian or Observer), aimed at educating the general public about the devices, were also uncovered. Together, these articles provided useful background information with which to limit the search: by demonstrating the array of products available on the market, and by assisting an understanding of how the products work, differences between them, and how they can be used to monitor driver behaviour. Hard copies of all of this material were also downloaded. A selection of the commercially available products are summarised in Table 3.

Figure 1. Keywords used to conduct on-line Google search for NDS data-collection devices

in-vehicle (in-car) on-road / on-board plug-in dash(board)-mounted windshield/screen-mounted	driver / driving; driving behaviour / performance; driving events; driving / travel patterns; vehicle usage / operations; driver support / feedback; black box	event-triggered video (recording); event recording; data collection / logging / recording; (electronic) data logger / datalogger / recorder; monitoring / recording / reporting / observation; measurement / assessment / evaluation; tracking; video; camera; video camera	device; unit; system; equipment; instrument/ation; recorder; computer system; technology/ies technological system; package; tool

Table 3. Commercially-available instrumentation/ data acquisition systems: company websites found through Google search

COMPANY, SYSTEM / DEVICE, DATA COLLECTION FEATURES	COMMENTS	PRICE
Zetronix Corp, Boston, MA, USA: HD Dashboard Cameras (DashCams) All products can run from car cigarette lighter or built-in battery, record vehicle front/sides	Some negative online blog comments about company and products (junk/never worked properly/rip-off)	
zDrive-HDi 720p HD Ultra-wide Angle Night-vision car/truck DVR Dash Camera Autostart recording, webcam mode, continuous loop recording, 120° wide-angle view, night-recording car/truck DVR camera	Ultra-clear 720p HD image sensor, 2.5" LCD screen with live view / playback	US$300
zBlackBox-2000HD 720p HD Wide Angle Dual Car Camera with GPS and Night-vision Dash Cam Records inside/outside vehicle, IR-LEDS for night-driving, continuous loop recording, video output for t.v. / monitor playback, GPS and gyro tracking for accurate motion display on Google maps during playback	compact rigid design	US$390
zBB 500HD Wide Angle 1080p HD Camera with GPS Compact Dash Camera 1080p HD CMOS sensor, 120° wide-angle lens, HDMI and video output, continuous loop recording, low-light sensor for night-driving, GPS and gyro tracking for accurate motion display on Google maps during playback	simple to use	US$339
zDrive-I Wide Angle car/truck Dash DVR cam Records audio/video, 8 IR-LEDS for night-driving video, continuous loop recording		US$130
Vacron (Fuho Technology, Taiwan) All-in-one Vehicle Video recorder HD 720P / VGA 2CH A black box device: records interior and exterior of vehicle, driving, sound, G-Sensor and GPS data. G-sensor sensitivity can be adjusted according to road situations. When a strong shock detected, system starts emergency recording and keeps the files. 120° front view angle/170° back view angle approx. Time/date stamp displayed on-screen. Recording track of driving routes can be shown on Google Map reviewing the video. Uses micro SD memory card Class 10 or above. This company has about 20 models of this type of product	Small size, easy to install / use, does not affect driver's line of sight, just insert card and power on to start recording.	POA
DashCamUSA, Springfield, MO, USA SmartCam HD2 Dash Cam DVR	Portable, high-quality, full HD, affordable,	$US140

Plugs into car cigarette outlet / also has own internal battery, starts recording when vehicle ignition turned on, records/ saves digital video files continuously to standard SDHC card, automatic loop for 24/7 recording SmartBox HD Dash Cam DVR G-sensor, long video play	quick and easy to install (takes a few minutes)	(+$20-50 for accessories) US$100 (+$15-4 for accessories)
10-8 Video USA, Fayetteville, TN 10-8 Police Car Video Camera 1- or 2-camera systems with in-vehicle audio recording; Sony CCD cameras; G-sensor; GPS displays speed and coordinates/ Google map o playback ; starts recording when car started; pre- and post- event recording; activated manually or with emergency lights **Systems can be customised**	Quick and easy to install / easy to use, easy storage: uses SecureDigital (SD) cards / reliable	Contact for prices
Pro-Vision Video Systems, USA In-Car Video System (Base Kit, additional cameras and many other accessories available separately) 4-camera capable (interior/exterior), integrated GPS mapping, direct to SDXC Card Technology: 260 hrs recording per SDXC Card, wireless file transfer, smart video file mgt, HD Zoom camera, 2.4GHz wireless microphone system, Zoom dash camera	Reliable, simple to use	
Nedap AVI: Vehicle Management Control (VMC) system (?)	Easy integration, operational out of box	
BioEnable Technologies Pvt Ltd, Pune, India AVMS-100 (Advanced Vehicle Monitoring System) Monitors and logs vehicle trip information, including detailed driver performance (and engine) data; transmits data to remote server through GPRS: similar to a black box. Alerts. Data recorded: harsh braking (hard acceleration/deceleration), average speeds, distance travelled, date & time, gear skips, rash (?) driving	Easy to install: no tools / auto-motive expertise needed: just plug into OBDII port (under dash -board/steering wheel), it reads and stores data from car's onboard computers, logs driver / engine performance continuously	POA
Otto, Persen Technologies Inc, Winipeg, Manitoba, Canada Otto Driving Companion A black-box recording device, uses GPS technology: records where / how quickly a vehicle was driven / can calculate speed & location of vehicle. Preloaded coverage maps. Notifies driver of speeding – alerts. Trip recorder and stores trip information in memory: device can be connected to a PC using supplied USB cable. Can upload trip diary to website, and generate / print off reports. Device also provides driver with information about their driving environment Designed to complement existing roadway signage. Has digital speed map of posted speed limits in community along with designated safety zones points of interest (e.g., red-light camera controlled intersections). Can all be configured. Audible/visible notifications	Small (size of a pocket calculator) Portable device Simple to use	CDN$225
Davis Instruments USA: CarChip Pro (basic system: includes software)	Up to 300 hrs of data	US$100

CarChip Fleet Pro (plus additional fleet management software: sold separately) A black box that plugs into car's diagnostics recorder: system can record speed, mileage, extreme braking/acceleration, and other data. Once downloaded, provides driving history. Can also provide alarms (beeps) if speeds exceeded / braking too hard / other risks. Creates automatic accident log. User-set thresholds DriveRight 600E (4 models: On-board Diagnostics, Vehicle Speed sensor, General-Duty, Heavy-Duty) Continuously monitors vehicle's speed, sends data to interactive onboard LCD display console (displays time, distance, top / average speed). Audible alarms. Creates accident log automatically if sudden deceleration occurs.	Stores up to 1200 hrs of data Easy installation: "plug and drive", plugs into OBDII port tiny device Enough memory for 600 trips / 10 accident logs	US$150 US$380 -400
Inthinc, Utah, USA TiwiPro GPS-based system. Monitors drivers in real time: provides in-vehicle verbal feedback to driver when speeding, not wearing seatbelt, driving aggressively; also notifications (e.g., to parents) of unsafe driving behaviour through text/voicemail/email),all info reported though an internet-based portal for later discussion. Can decide events which will trigger system (in-vehicle audible alerts: beeps/verbal warning & driving reports). Can compare speed with posted speeds, can allow driver chance to correct behaviour		
DriveCam, San Diego, Calif DriveCam (a video system) In-car camera system (without GPS tracking): mounted behind rearview mirror, captures sound inside vehicle/views of interior & road; records risky driving behaviour, and sends to DriveCam for 3rd party assessment by analysts (scored & recommendations made for safer driving), reports can be sent (e.g., to parents). Saves images of events. Device's green light blinks red if a recoding triggered. Data (10 secs of audio/ video before/after event). Everything uploaded to a website		
CarCheckUp: driving monitoring system Plugs into car and records data: speed, distance/duration of trip, time driven in speed bands, hard/extreme braking and acceleration, graphs plug USB into computer and download/review data on personal account		US$150 [+ $20 for cable]
Automatic (Calif, USA): Automatic Link Small box / a software app linked to device that plugs into onboard diagnostics port / connection (computer) – sends reports to smartphone – fuel efficiency, mileage, problems with car, deceleration	Only available in US at the moment (but company is trying to change this)	$US70
Smartrak / Smartrak NZ: Automatic Vehicle Locator (AVL) AVL with GPS Unit, 3-axis accelerometer cellular modems and optional satellite modem: Fleet Mgt system & GPS tracking system	Australasia's best-selling GPS tracking system	

ViewTech: Camos 2-Channel Drive Recorder & Truck Cam Blackvue DR400II Full HD Drive camera Miracleon 4CH Vehicle DVR (with g-sensor, GPS and Google Maps) Makes: Dash and Truck Cam / Vehicle Digital Video Recorders / Vehicle cameras, monitors **Customised Camera & DVR Systems** Can also design and build customized vehicle recording systems: can feature forward facing, rear+side-facing or cabin-facing cameras, night vision capabilities, etc Has a New Zealand office		Mostly POA (others between $US165-360)
Imarda: designs and builds flexible felt management software including telematics devices, which monitor/record the dynamics variables of the vehicle (speed and g forces (x,y,y) and also provide video surveillance cameras (HD) filming driver behaviour and road scenes/ Cloud based file storage system. Offices in New Zealand, Australia and USA.	Can only be fitted to cars which have a vehicle diagnostic system bus.	
NavMan: MiVue 338 / MiVue 358 / MiVue 388 In-Car dashboard Camera with GPS tracking and 360deg rotating mount. Records direction travelled, speed, location. Videos recorded in 1080 full HD through 120deg wide-angle digital video camera lens	Larger 2.4" LCD screen and sharp 5.0 mega-pixel camera	
AA Drivesafe (UK): Drivesafe Box (plus Drivesafe Dashboard) [insurance] Telematics device monitors/records info about driving of vehicle: records info about speed, cornering, braking when car driven on diff types of road – Drivesafe score – premiums calculated. Captures vehicle data / electronic feed translates GPS coordinates from box into a specific location which provides road data/info (type, surface, speed limit). Info used to build profile of how/where/when vehicle driven. Personalised online dashboard: can view personal data	Box must be fitted by a qualified engineer / uses GPS to send info to AA on how car is being driven	