



**Association between driver training, involvement in four-wheeled  
motor sport, and crashes on public roads**

**Report on Literature Review**

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## **EXECUTIVE SUMMARY**

### **Report objectives and scope**

This report presents a review of the literature on the association between road safety and (1) pre-licence driver training, (2) post-licence driver training and (3) motor sport involvement. Road safety outcomes that were considered were crash rates and driving offences. Motor sport involvement included participation as a motor sport driver, a motor sport passenger, and/or a spectator at motor sport events.

Since 2010, there have been numerous reviews conducted to examine the association between road safety and driver training programs. This report summarises the findings of those reviews and discusses the few studies that have been conducted since the last review was conducted. In contrast, few studies have been conducted to examine the effect of motor sport involvement on road safety. Therefore, all studies that could be located were reviewed for this report.

### **Main findings for driver training programs**

There is limited evidence to show that technical skills acquired from driver training programs directly reduce road crash risk. Rather, evidence shows that the combination of acquired technical driving skills, frequent engagement in driving practice, and desires to develop and engage in safe driving behaviours is more important in reducing road crash risk than acquired technical driving skills alone. Graduated driver licensing systems with components that delay time to full licensure and impose driving restrictions on learner and probationary licence drivers have been shown to be effective in reducing road crash risk in young drivers. Post-licence driver training programs that specialise in teaching technical driving skills do not improve on-road safety and may be detrimental, but there is some limited evidence that training that focuses on teaching higher-order cognitive skills promotes safe driving behaviours. These findings suggest that driver training programs that teach cognitive skills, encourage mastery of driving skills, and promote safe driving behaviours are more effective at reducing crash risk than driver training programs that only teach technical skills.

However, evaluations of driver training programs often have methodological issues that weaken the validity of findings. These include poor sampling, inappropriate control or comparison groups, short evaluation time frames, reporting bias, and failure to control for important confounding factors in the analyses.

## **Main findings for motor sport involvement**

The evidence to date indicates that motor sport involvement is associated with engaging in risky on-road driving behaviours and reporting of driving offences, especially speeding. However, the number of studies that has examined these associations is too few to draw reliable conclusions and the studies suffer from methodological issues. In particular, most studies have not considered the range of potentially important confounding factors, such as exposure (hours spent driving or kilometres driven on public roads), demographic characteristics of the population beyond age and gender (e.g., socio-economic status), and attitudes about driving. Studies have also not examined the 'dose' or type of motor sport involvement that could affect road safety.

## **Recommendations**

Future research should use more rigorous research methods to examine the effectiveness of advanced driver training in improving road safety and to assess the influence of motor sport involvement on driving behaviour and road safety outcomes. This research should consider the full range of factors that could influence the associations between both advanced driver training and motor sport involvement and road safety. These include factors associated with the individual driver, including their attitudes towards driving and risky behaviour tendencies; factors associated with driver training or motor sport involvement; and factors associated with road safety outcomes (e.g., circumstances surrounding a crash or driving offense). Also, appropriate control or comparison groups are needed to increase the validity of the conclusions drawn,, and sample sizes need to be large enough to detect statistically significant differences between the groups being compared.

## DEFINITIONS

**Basic cognitive driving skills training:** Pre-licence driver training that teaches visual and mental skills, such as detecting on-road hazards while driving and developing safe driving behaviours.

**Basic vehicle handling skills training:** Pre-licence training that teaches procedural skills about general vehicle operations, controls, and configurations.

**Crash:** Any unplanned event involving a road vehicle on a road that results in death, injury or towed vehicle and is reported to the police.

**Defensive vehicle-handling skills training:** Post-licence driver training that teaches procedural skills that can be used to maintain vehicle control during dangerous driving situations.

**Driver:** The controller of a motor vehicle that has four-wheels.

**Fatality:** A person who dies from injuries received in a road traffic crash within 30 days of that crash.

**Graduated driver licensing systems:** A hierarchy-based licensing system with three licensing levels (learner's permit, probationary licence, open licence). It is designed to limit the exposure of young drivers to dangerous driving situations by imposing restrictions at the learner's permit and probationary licence level. Drivers may upgrade their licensing level by fulfilling criteria of the graduated driver licensing system in their country or state.

**Hazard perception skills training:** Post-licence driver training that teaches drivers to anticipate potential hazards and to respond appropriately.

**Higher-order cognitive skills training:** Post-licence driver training that teaches hazards perception, situation awareness, and insight skills.

**Insight skills training:** Post-licence driver training that focuses on helping drivers to be more aware of their own abilities while they are driving.

**Intersection crash:** A crash where the first impact occurs at or within 10 metres of an intersection.

**Motor sport:** A competitive activity on closed tarmac or gravel roads/tracks, either in a race or time trial format. Examples of motor sport are kart racing, circuit racing, rallying, touring car racing, and stock car racing.

**Pre-licence driver training:** An activity that involves teaching basic driving skills (procedural and/or cognitive) to drivers who possess a learner's permit. Activities can include professional driving instruction, school-based driver training, and simulator training.

**Post-licence (advanced) driver training:** An activity-based course or training program intended to enhance the driving skills of licensed drivers, including those who possess a probationary licence. Activities include learning defensive vehicle handling skills and higher-order cognitive skills.

**Professional driving instruction:** Practical driver training supervised and taught by an accredited driving instructor.

**School-based driver training:** Driver training that is taught in a group or classroom-like environment.

**Sensation seeking tendency:** An individual's predisposition to participate in activities or behaviours for the purpose of thrill seeking.

**Simulator training:** Practical driver training provided through the usage of a driving simulator machine.

**Single vehicle crash:** A crash involving only one vehicle.

**Situation awareness training:** Post-licence driver training that teaches drivers to have a broad understanding of events that could occur while they are driving.

## **LIST OF ABBREVIATIONS**

<b>ADT</b>	Advanced driver training
<b>AIMSS</b>	Australian Institute of Motor Sport Safety
<b>CAMS</b>	Confederation of Australian Motor Sport
<b>GDL</b>	Graduated driver licensing
<b>US</b>	United States of America



## SECTION 1: BACKGROUND

The role that driver training and motor sport play in modifying driver behaviour on public roads is a highly emotive and politicised topic that engenders widely differing views. This report is the first deliverable of a project that sought to review the current state of knowledge about the role that both driver training and four-wheeled motor sport play in road safety. Road safety was conceptualised as crash rate and driving offenses.

The project was undertaken as a commercial research project funded by the Australian Institute of Motor Sport Safety (AIMSS) and Royal Automobile Club of Queensland (RACQ). The overall aim was to determine whether there is an association between safety on public roads and (1) pre-licence driver training, (2) post-licence driver training and/or (3) four-wheeled motor sport involvement.

### *1.1 Scope of the literature review*

The first component of the project required a review of the literature, and this report summarises the findings of that review.

The scope of articles on driving training to include was limited to address the requirements of this project. Specifically, for an article to be eligible for inclusion in the current review of the driver training literature, it had to review studies that described an evaluation of a driver training program that:

1. Included practical (on-road or simulated on-road) driver training;
2. Was aimed at the general population; and
3. Reported road crashes and/or driving offences as outcomes.

Reviews of driver training programs for specific populations, including heavy vehicle training and licensing and motorcycle rider training, were excluded. Reviews of programs labelled 'driving education' and 'driving training' were considered as these terms were found to be used interchangeability in the literature.

As the literature on driver training is extensive with many reviews of that literature already published, a scan of review articles published in English since 2010 was conducted. These review articles typically summarised the results of the most current studies as well as results from earlier reviews and studies. In addition, the few articles that have been published since the last review are included.

To search for relevant articles about driver training programs, the Cochrane Library, Scopus, and the Transportation Research Information Database were searched. Search terms were:

Driv\* or Road\* AND

Train\* or Instruct\*AND

Crash\* or Accident\* or Collision\* or Skill\* or Safety

The English-language literature on motor sport involvement is much more limited than the literature on driver training. To include all possible studies on the road safety outcomes of motor sport involvement, all published studies that met the following inclusion criteria were included:

1. Included research on four-wheeled motor sport;
2. Included motor sport drivers, passengers, and/or spectators as participants; and
3. Examined associations between motor sport involvement and road crashes, driving offences, driver attitudes, and/or driver behaviours on public roads (but not racing on public roads).

Articles were searched from the Cochrane Library, Scopus, and the Transportation Research Information Database. Search terms were:

Motorsport\* or Motor Sport\* or Racing or Kart\* or Rally\* or NASCAR or V8 or Formula One or Circuit Racing or Drifting or Targa Event\* or Hillclimb\* or Autocross\* AND

Road\* or Track\* or Course\* or Speedway\* or Racetrack\* AND

Behav\* or Attitude\* or Perce\* or Confiden\* or Crash\* or Accident\* or Collision\*

The general search function available in the QUT Library online platform was also used to search for relevant articles on driver training programs and motor sport involvement. References of eligible articles were also searched. Last, an internet search was conducted to retrieve reports by government and road safety organisations.

## *1.2 Structure of the report*

This report is divided into three sections, representing each component of the literature review. In Section 2, the literature on driver training programs is summarised, separately for pre-licence driving training programs and post-licence (advanced) driver training programs. Details about the reviews and articles included in the summary are described in tables at the end of this section (Tables 1 and 2). In Section 3, the literature on motor sport is summarised. Each study is discussed separately, beginning with the earliest study and finishing with the most recent. Details about the articles included in the summary are detailed in a table at the end of Section 3 (Table 3). Section 4 provides an overall summary of the literature review. In short, the sections are the following:

- Review of the driver training literature: Section 2
- Review of the motor sport literature: Section 3
- Conclusion: Section 4

## SECTION 2: REVIEW OF THE LITERATURE ON DRIVER TRAINING AND ROAD SAFETY

Of the many training programs offered worldwide, few have been evaluated. Those that have been evaluated include pre-licence driver training for novice (typically young) drivers, training programs within broader graduated driver licensing systems, and post-licence (advanced) driver training. This review therefore looks at the evidence about the road safety benefits of participation in these three types of training programs. First, the literature on each type of training program is summarised separately in text and then tables detailing the reviews and studies discussed in text are provided.

### *2.1 Review of the literature on pre-licence driver training*

Driver training is essential for teaching individuals how to operate motor vehicles appropriately, promoting safe driving behaviour on the road and minimizing the risk of road crashes while driving (Beanland et al., 2013; McDonald et al., 2015; Russell et al., 2011). Driver training provides practical on-road experience to teach individuals about vehicle handling and cognitive driving skills. Vehicle handling training focuses on teaching procedural skills, which may become instinctive to the individual, with practice, over time. These include elements of vehicle operation, such as steering, accelerating, braking, gear-shifting and using the various interior controls. Cognitive driving-skills training focuses on teaching visual and mental skills, such as detecting on-road hazards and developing safe driving behaviour.

Pre-licence driver training can be provided by accredited driving instructors, group-based driving courses, driver simulator machines as well as by family (typically parents) or friends. Each of these training approaches emphasize different driving skills. Therefore, it is recommended that individuals participate in various types of driver training to sufficiently practice and integrate vehicle handling and cognitive driving skills (Bates et al., 2013). However, any benefits received from driver training become diminished if the individual does not spend sufficient time practicing and developing those skills (Bates et al., 2013; Beanland et al., 2013).

Reviewers of studies on the effectiveness of pre-licence driver training found that although this training is effective in teaching basic vehicle handling skills and the road rules for driving on-road, there is no strong evidence to suggest that this training has a direct effect on reducing the risk of road crashes in the long-term (Helman et al., 2010; Peck, 2011; RACV, 2016; Road Safety Observatory, 2014). However, individuals who spend more time

practicing driving skills under supervised conditions and have fewer risk-taking tendencies while driving are less likely to be involved in a road crash than those who do not (Peck, 2011). A recent review (RACV, 2016) reported that 118 hours of supervised training significantly reduces the risk of crashes and that supervision exclusively by a professional driver instructor does not have any benefits in terms of reducing crash risk over supervision exclusively by friends or relatives who are experienced drivers. These findings suggest that pre-licence driver training that includes supervised practice is necessary for learning to drive, but it is more likely that an individual's driving practices and desire to develop safe driving behaviour have a greater impact than pre-licence driver training on reducing the risk of being involved in road crashes.

In previous reviews of the literature on the effectiveness of pre-licence driver training, the review authors have identified notable methodological issues with the studies. First, in intervention studies the people who were recruited to serve in control groups (groups that do not get the intervention) were usually from populations different from those from which intervention groups were recruited (Bates et al., 2013; Beanland et al., 2013; Lonero & Mayhew, 2010). As a result, intervention and control participants were not easily comparable because they could have differed in ways that were unknown to the researchers and therefore could not be accounted for in analysis. A second issue is that some studies recruited too small of samples of participants to determine whether the driver training reduced the risk of road crashes (Lonero & Mayhew, 2010; Peck, 2011). Large samples are needed to detect crashes, a relatively rare event. Third, most studies focused on short-term (less than one week) evaluations due to ethical considerations and, therefore, the effectiveness of driver training on directly reducing the risk of road crashes in the long-term is still unclear (Bates et al., 2013; Beanland et al., 2013; Lonero & Mayhew, 2010). Fourth, most studies asked participants to self-report crashes, and such measures are prone to reporting and recall bias due to people's tendencies to report only the most serious road collisions and driving violations, thereby underreporting less serious ones (Beanland et al., 2013). Fifth, in the analysis for many past studies the researchers accounted for factors related to driving experiences that could have influenced the associations examined, but they did not account for level of confidence or non-driving-related factors, such as individual demographic characteristics (e.g., age, socio-economic status), personality traits, lifestyle factors, and physical attributes (Bates et al., 2013; Beanland et al., 2013; Peck, 2011), which could have a large impact upon crash risk.

Noting that few driver training programs have been evaluated, authors of reviews have also identified issues with the driver training programs that were evaluated. One issue is that most lacked a theoretical framework to inform a logical progression through content provided to meet program objectives (Bates et al., 2013; Kinnear et al., 2013; Lonero & Mayhew, 2010; McKenna, 2010). Likewise, few studies evaluated the effectiveness of any theories used (Lonero & Mayhew, 2010). Another issue is that programs have traditionally focused on vehicle handling skills rather than the way drivers choose to drive (i.e., driving

'style'), although 'style' is linked to behaviours, such as tailgating, speeding, and involvement with distractions like smartphones, that can lead to crashes (Bates et al., 2013; Helman et al., 2010; Peck, 2011).

In summary, pre-licence driver training is necessary for teaching new drivers about basic vehicle handling skills and road rules required for on-road driving, but the available evidence indicates that practicing those driving skills and developing safe driving behaviours (a safe-conscious driving 'style') are more important in the long term for reducing the risk of being involved in a road crash. Many previous studies that looked at the effectiveness of pre-licence driver training suffered from methodological issues, such as poor sampling, short evaluation time frames, and failure to adjust for likely important confounders in the analyses. More rigorous research methods are needed to determine the long-term effectiveness of the variety of pre-licence driver training that is currently offered.

## *2.2 Review of the literature on graduated driver licensing systems*

In Australia, Europe, and North America, graduated driver licensing systems have been implemented to ensure that young drivers (aged 25 years or younger) participate in a mandatory amount of time in driver training and gain supervised driving experience on-road before they receive driving licensure (Austroads, 2015). The graduated driver licensing system is a hierarchy-based system designed to minimize the risk of road crashes of young drivers by limiting their exposure to dangerous driving situations. This is done by imposing specific driving restrictions based on licensing levels (Beanland et al., 2013; Helman et al., 2010; Russell et al., 2011). The structure of graduated driver licensing systems varies among countries and states, but generally it is divided into three progressing levels: learner's permit (pre-licence), probationary (restricted) licence, and open (unrestricted) licence (Austroads, 2015). Individuals first obtain a learner's permit, which allows them to drive only when supervised by a passenger who possesses an open licence. They may upgrade to a probationary licence, which allows them to drive independently but with restrictions (e.g., night-time driving curfew). The final level is an open licence, which allows individuals to drive independently under standard laws. In order to progress to higher driver licensing levels, individuals must have sufficient driver training and on-road driving experience, have held their current licence for a mandatory amount of time, and have successfully passed mandatory driver testing requirements, or achieved a mixture of these criteria. In some countries and states, individuals are offered incentives to upgrade their licence early by completing specified components of driver training.

There is an abundance of evidence that graduated driver licensing systems improve on-road driver safety, including reducing crashes, in young drivers during the probationary licensing period (Bates et al., 2013; Bates et al., 2014; Helman et al., 2010; Kinnear et al., 2013; RACV, 2016; Russell et al., 2011). Because these systems vary, the magnitude of improvement varies across systems (Russell et al., 2011). The effectiveness of these systems post-licensure is inconclusive (Helman et al., 2010).

The most recent review indicates that the effects of offering these systems during the probationary licensing period are strongest in the few 2 years of independent driving (RACV, 2016). An Australian road safety publication that reported on the effectiveness of different types of graduated driver licensing systems in Australia, Europe, and North America identified six factors that are the most effective at reducing the risk of road crash and injury in young drivers (Austroads, 2015). All factors are driver restrictions that target individuals who possess a learner's permit or probationary licence. They include: a minimum age of 16 years to obtain a learner's permit, a minimum learner's permit possession period of 12 months, a minimum age greater than 16 years to obtain a probationary licence, a night-time driving curfew, a limit on the number of passengers in the car with the young driver, and zero blood-alcohol concentration levels (Austroads, 2015). These are discussed as well in

other reviews (Helman et al., 2010; Kinnear et al., 2013; RACV, 2016). Austroads (2015) also reported that lengthening supervised driving hours during the learner's permit level (80-120 hours) was associated with reduced risk of being involved in a road crash. An earlier review (Bates et al., 2014) reported that about 120 hours is required.

The review by Bates et al. (2014) also indicates that parental involvement, more so than police enforcement, is critical to the success of graduated driver licensing systems. The review authors report that young drivers with parents who place strict driving restrictions on them are less likely to engage in risky driving behaviour and to have fewer crashes and driving offences than are young drivers who do not have such parental restrictions.

There are also factors that counteract the benefits of graduated driver licensing systems. Findings of the literature reviews indicate that young drivers who obtain a probationary or an open licence earlier than normal because they completed driver training that offered earlier licensing as an incentive are significantly more likely to be involved in a road crash than those who did not opt for the early-licence incentive (Bates et al., 2013; Beanland et al., 2013; Lonero & Mayhew, 2010; Peck, 2011). Authors of these literature reviews suggest that the association between earlier licensing and increased risk of road crash may be due to individuals being exposed to potentially high-risk driving situations after only limited driving experience (Bates et al., 2013; Lonero & Mayhew, 2010). These high-risk driving situations include driving at night, in high-speed zones, and in rainy weather. Overconfident about their driving abilities, these young drivers may not have sufficient experience to react safely and appropriately in such situations (Lonero & Mayhew, 2010). Furthermore, individuals who have completed specified components of driver training with the primary purpose of earlier licensing may be less motivated to develop safe driving skills and, therefore, may be less likely to incorporate the learnings and skills from driver training (Beanland et al., 2013).

These findings suggest that an ideal graduated driver licensing system would not allow for the time needed to obtain a probationary or an open licence to be shortened. Young drivers need to build their driving experience in a controlled environment that gradually exposes them to higher-risk driving situations as they develop their skills so that, when they obtain an open licence, they will have sufficient experience to drive independently and be capable of handling high-risk driving situations.

However, authors of reviews caution that a system that is considered ideal in one country (or state) may not be ideal in another. Although systems can be compared, review authors have noted that it can be difficult to evaluate which systems are superior due to differences in geographic location, local culture, and road rules under each system (Austroads, 2015; Russell et al., 2010). Therefore, generalizing findings from a study in one context to other contexts warrants caution.



Other limitations of the research that has been noted in reviews include the lack of inclusion of individual-level confounder factors, such as socio-economic status (Austroads, 2015), maturity level (Helman et al., 2010), exposure to risky situations (Helman et al., 2010), and higher-level confounder factors, such as the road network, speed limits, and road and safety culture (Russell et al., 2011), that could be associated with crashes. The exclusion of such factors in analyses reflects the reliance on ecological study designs due to logistical and feasibility concerns (Russell et al., 2011).

In summary, there is solid evidence that graduated driver licensing systems are effective measures for reducing the risk of road crashes in young drivers. Evidence shows that having a high minimum age requirement to receive licensure, lengthening the time to obtain a probationary or an open licence, and limiting exposure to high-risk driving situations are effective at reducing the risk of road crash in young drivers. Young drivers need to first practice their driving skills and gain sufficient on-road driving experience in a controlled environment before they can drive independently. However, previous researchers have suggested that overconfidence in one's driving abilities and tendencies to engage in unsafe driving behaviours may counteract the benefits offered by graduated driver licensing systems. Further research is needed to more comprehensively examine how driver attitudes and behaviours, risk-taking tendencies, and personality traits affect the effectiveness of graduated driver licensing systems.

### *2.3 Review of the literature on post-licence (advanced) driver training*

Post-licence (advanced) driver training is available to individuals who possess a probationary or an open licence. While standard driver training at the learner's permit level teaches basic vehicle handling and cognitive driving skills that are necessary for normal driving, post-licence driver training covers defensive vehicle-handling and higher-order cognitive skills. Unlike standard driver training, which simultaneously teaches both vehicle handling and cognitive driving skills, post-licence driver training often specializes in defensive vehicle-handling skills or higher-order cognitive skills (Beanland et al., 2013). Defensive vehicle-handling skills training focuses on procedures to maintain vehicle control during dangerous driving situations, including emergency braking, skid control, and quick obstacle evasion (Usami et al., 2016). Higher-order cognitive skills training focuses on hazard perception, situation awareness, and insight skills (Bates et al., 2013; Beanland et al., 2013). Hazard perception is the individual's ability to anticipate potential on-road hazards and avoid danger by reacting responsively and appropriately. Situation awareness is the individual's broader knowledge and understanding of the events occurring in a driving environment. Video footage of traffic scenes or driving-simulator machines are often used for both hazard perception and situation awareness training and testing. Insight skills training focuses on awareness of one's own driving abilities and addressing overconfidence in one's driving skills.

Reviews of studies that examined the effectiveness of post-licence driver training found no strong evidence to suggest that defensive vehicle-handling skills training reduces the risk of crashes (Bates et al., 2013; Beanland et al., 2013; RACV, 2016; Washington et al., 2011). Instead, this training may have unintentional and negative effects: individuals who participate in defensive vehicle-handling skills training can become overconfident about their own driving abilities and become less risk-adverse while driving (Bates et al., 2013; Beanland et al., 2013; RACV, 2016). Indeed, Washington et al. (2011) reports that there is strong evidence that the traditional training that focused on low-level skills like speed control decreases road safety by making drivers overconfident in their driving. In a recent study, Italian researchers found that individuals who had participated in this type of training were significantly more likely to obtain driving offences than those who had not (Usami et al., 2016). These findings suggest that defensive vehicle-handling skills training promotes unsafe driving behaviour that offset any benefits from the training.

Conversely, higher-order cognitive skills training has been shown to promote safe driving behaviour although the results are not conclusive. Washington et al. (2011) found that this new type of advanced driving training has an estimated effect of 5%-13% on reducing crash rates. In the limited studies to date, individuals who participated in hazard perception or situation awareness training specifically could identify more hazards, scan their driving environment more effectively, anticipate hazards more quickly, and slow down more when

approaching hazards than those who did not participate in such training (Bates et al., 2013; Beanland et al., 2013; McDonald et al., 2015; RACV, 2016). These findings suggest that hazard perception and situation awareness training can sharpen a driver's vigilance and contribute to safer driving behaviour.

Although the results are promising, authors of reviews have noted that hazard-perception and situation-awareness training and testing are conducted in simulated environments or are computer-based (Bates et al., 2013; Beanland et al., 2011 and 2013; McDonald et al., 2015; RACV, 2016). There appear to be no studies that have looked at the direct association between higher-order cognitive skills training and road crash risk (Beanland et al., 2013; McDonald et al., 2015). Also, studies have tended to include small samples and have not controlled for important confounders like age and driving experience (McDonald et al., 2015). Furthermore, because most studies have assessed outcomes within one week of training (McDonald et al., 2015), the longer-term benefits are unknown.

There is also limited research on the effectiveness of insight training on reducing the risk of road crashes. Bates et al. (2013) report that in some studies insight training promoted safer driving behaviour, such as keeping a greater following distance while driving, slowing down more often when approaching hazards, and being more sensitive about the possibility of being involved in a road crash. Therefore, there is preliminary evidence that insight training is effective at encouraging individuals to be more cautious while driving. However, because most studies used qualitative study designs, collected self-reported driving data, or lacked a control group (Bates et al., 2013; Beanland et al., 2013), there is not sufficient robust evidence to conclude that insight training is effective for reducing the risk of road crashes.

In summary, evidence to date does not support post-licence driver training programs that teach defensive vehicle-handling skills, and there is evidence that these programs unintentionally promote overconfidence in one's abilities, thereby counteracting any benefits intended to promote driver safety. There is, however, early evidence that post-licence driver training programs that teach higher-order cognitive skills improve driver safety by teaching individuals to be more aware of their driving environment and their own driving abilities. However, stronger study designs that control for confounders and include sufficient sample sizes are needed to confirm the findings of the studies of these types of programs that have been conducted to date. Likewise, insight training has shown promise in reducing road crash risk but the evidence is limited.

*Table 1.*

*Details of previous literature reviews included in the current review of the driver training literature (most recent first)*

Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>RACV (2016)</p> <p>International</p>	<p>To assess the empirical literature on the effectiveness of driver training and education programs for learner drivers, young drivers, recently licensed drivers, and experienced drivers on reducing the risk of crashes</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Studies that evaluated driver training or education programs and reviews of such studies</p> <p><b>Publication types searched:</b> Peer-reviewed journals articles, conference proceedings, government reports, university reports, and reports of research organisations.</p> <p>Literature from the mid-1970s to 2015 were included.</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>Evidence that traditional driver training or education reduces crash risk is not supported by the literature. Newer ways of approaching training, such as through graduated driver licensing systems (GDLs), focusing on on-road experiences, and insight training from Europe, are promising.</p> <p><b>Pre-licence driver training and education:</b> Programs that are compulsory in high schools have not been shown to decrease crash risk. Evaluation of pre-licence driver training programs have generally found no significant differences in the number of reported crashes or driving offences between learner drivers trained off-road (at facilities) and those trained on-road (in real world driving conditions).</p> <p>Drivers who engage in about 118 hours of supervised driving experience during the learner period have 35% fewer crashes than those who engage in 41-47 hours of supervised driving experience. Drivers who practice more often as learners have fewer crashes post-licence and make fewer safety-related driving errors than drivers who do not practice as often.</p> <p>Studies to date suggest that the ideal learning environment for novice drivers is on-road supervised driving with an experienced driver or instructor. Studies show no differences in post-licence crash risk between those trained exclusively by a professional driving instructor and those trained exclusively by parents, relatives, or friends. In Europe, there is a trend towards using a coaching approach to driving. Incentives that offer earlier licensing after taking an approved driver training or education program</p>	<p>Study samples in the most recent and earlier studies have been small and there are issues with methodologies. No elaboration was provided.</p> <p>The review does not describe the methodological limitations and strengths of the methods used in studies.</p>

			<p>have been shown to increase crash risk among new drivers.</p> <p><b>Graduated driver licensing systems (GDLs):</b> Evidence shows that these systems can reduce crashes in novice drivers. The effects are strongest in the first 2 years of independent driving. Restrictions on the number of passengers and a night-time driving curfew in the first 6 to 12 months of independent driving are effective measures for reducing crash risk. Minimum learner permit possession periods, delaying licensure and having a zero-blood alcohol concentration level while driving are also effective for reducing crash risk.</p> <p><b>Post-licence programs for young and recently licensed drivers:</b> There is little evidence that these programs reduce crash risk. Rather, these programs lead to overconfidence in driving skills and sometimes increase crash risk for novice drivers, particularly young men.</p> <p><b>Advanced driving training programs:</b> There is no evidence that traditional advanced or defensive driving skills training programs reduce crash risk of experienced drivers. Some evidence shows that training for older adults improves driver performance and knowledge.</p> <p>Hazard perception training through computer-based or driving simulator technology has improved drivers' detection and anticipation of hazards, attention maintenance, visual scanning behaviour, and road hazard handling in simulated driving environments. Simulated driver training programs are new and the evidence is not sufficient to determine its effectiveness, but they show promise in improving on-road driving for older adults.</p>	
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			<p>Evidence shows that traditional driver training and education programs that aim to improve driving skills and knowledge do not necessarily change driving behaviour or reduce crash risk. Authors suggest that young drivers may take risks that are unrelated to their driving skills and knowledge, but rather other influences or beliefs motivate them to engage in risky driving behaviours. Conventional programs also do not improve cognitive skills like hazard perception, which research suggests are developed through on-road driving. Tradition programs do not always provide enough, or the most effective, on-road driving to effectively reduce crash risk. Short-term programs are not likely to be long enough to overcome underlying motivations, beliefs, attitudes, practices, and experiences.</p> <p>The few evaluations of new programming from Europe, called 'Insight' training, indicate that these programs result in lower crash risk. These programs address higher-order cognitive skills and overconfidence in driving skills. Limited evidence from Australia and New Zealand indicates that addressing resilience, risk reduction and higher-order cognitive skills results in reduced crash risk.</p>	
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Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Austroads (2015)</p> <p>Australia, Europe, North America</p>	<p>To examine the effectiveness of different components of graduated driver licensing systems (GDLs).</p> <p>Research questions:</p> <ol style="list-style-type: none"> <li>1. Is there evidence that that a GDL component addresses a factor that contributes to crashes and injuries in young drivers?</li> <li>2. Is there evidence that a component is effective in reducing the risk of those crashes and injuries in young drivers?</li> <li>3. What is the potential impact of the component on young driver crashes and injuries?</li> </ol>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Studies that examined effectiveness of GDL systems (e.g. demonstrating evidence that a component of GDL has an impact on crashes and injuries in young drivers) with quantifiable outcomes.</p> <p><b>Publication types searched:</b> Peer-reviewed journal articles, books, government reports and publications, road administration websites, road safety research organisation publications and internal unpublished reports by Australasian jurisdiction road administrations. Reviewed literature from Australasia, North American and high income European countries published from 2002 to early 2013.</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>The evidence that GDL systems are effective in reducing crashes in provisional drivers is well-established with reductions ranging from 20%-40%. There is evidence that each component of GDL that was examined addresses an important factor contributing to crashes or injuries in young drivers. Not all components were evaluated within the context of a GDL system. The components of GDL with the most examples of quantifiable benefits for reducing crashes and injuries in young drivers (e.g., the most well-evaluate components) are:</p> <ul style="list-style-type: none"> <li>• Minimum age of 16 years to obtain a learner’s permit</li> <li>• Minimum period of 12 months holding a learner’s permit</li> <li>• Minimum age &gt; 16 years to obtain a probationary licence</li> <li>• Night-time driving restrictions</li> <li>• Peer-passenger restrictions</li> <li>• Zero blood alcohol concentration limit while driving</li> </ul> <p>Some evidence showed that engaging in 80-120 hours of supervised driving as a learner driver and including hazard perception tests reduces the risk of crashes in young drivers although the stage of GDL when hazard perception tests are most effective is not clear from the literature.</p> <p>Evidence showing that education programs that aim to improve cognitive skill deficits, involve parents and build resilience reduce crashes in young drivers is emerging, but these programs have not yet been adequately evaluated.</p> <p>Evidence indicates that education programs that aim to improve driving knowledge, awareness,</p>	<p>Because GDLs comprise multiple components, isolating the components individually for comparison and analysis may produce misleading information about what is effective at reducing the risk of road crashes in young drivers. The effectiveness of any one component may be dependent on the presence of other components.</p> <p>Most studies were conducted in North America, particularly from the US. The benefits of GDLs for Australasia may differ from those found in the evaluations of GDLs in North American due to variations in compliance to the driver restriction components. For example, benefits may vary depending on how strongly the restrictions are enforced (e.g., due to culture or environment). Furthermore, driver restriction components vary between states and countries, making it difficult to make comparisons and to understand which components are consistently most effective.</p> <p>Most studies reviewed did not take into account individual driver differences.</p>



			<p>and/or attitudes are not effective in reducing the risk of crashes in young drivers.</p> <p>Evidence shows that education programs that offer incentives to accelerate the upgrading of licensure from learner's permit to probationary licence and those that provide skid training increase risk of crashes in young drivers.</p> <p>Consensus is growing in countries using GDL systems that the appropriate minimum age for starting driver as a learner is 16 years. The evidence to support this consensus comes from both empirical data on crash reports and insurance claims and from a theoretical basis in road safety and neurobiological development.</p>	
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Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>McDonald, Goodwin, Pradhan, Romoser, &amp; Williams (2015)</p> <p>International</p>	<p>To assess the empirical literature on hazard anticipation training programs for young drivers.</p>	<p><b>Study design:</b> Systematic Review</p> <p><b>Inclusion criteria:</b> Studies that described training in hazard anticipation, perception, awareness, recognition, or similar terminology for young drivers. Studies had to include an assessment of safety-related outcomes of a hazard anticipation training program, and include at least one group that uniquely comprised a cohort of participants aged &lt; 21 year (due to international variation in licensing age).</p> <p><b>Publication types searched:</b> Peer-reviewed journals and conference proceedings available in English and published between 1980 and 2013.</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>Of 19 studies found, 11 used an interactive computer-based approach for training, 5 used videos, 2 conducted training in a driving simulator, and 1 used a combination of training methods.</p> <p>Approaches used in the studies were: Act and Anticipate Hazard Perception Training, Risk Awareness and Perception Training, Video-Based Approach, Simulator Training Studies, and a Multiple Method Approach.</p> <p>While the training programs, outcome measures, study designs, length of follow-up, and level of driving experience among participants varied across studies, all studies reported some type of positive training effect on young driver's hazard anticipation behaviour. Participants who took hazard perception training showed greater improvements in awareness of the driving environment, visual scanning strategies, speed and accuracy in detecting potential risks, and cautiousness when anticipating potential hazards than participants who did not.</p>	<p>Many studies had small samples: &lt; 20 participants per group. Many studies often did not control for confounders, and therefore, it is difficult to understand the effects of training programs across different populations. Also, studies needed to have a better distinction between age and driving experience because people can obtain licensure at different ages.</p> <p>The effectiveness of hazard perceptions training depends on the driver's experience (rather than being under or over 21 years of age). Drivers who have not yet mastered basic vehicle handling skills need to first focus on attaining and practicing those skills. When those skills become instinctual, drivers can then begin learning how to effectively detect, anticipate, and respond to road hazards.</p> <p>Because hazard perception training has been conducted through computers or driving simulators, it is not clear if results are generalisable to on-road situations where driving conditions vary (e.g., night driving, driving with multiple passengers).</p> <p>Outcomes were often assessed in the short-term (&lt; 1 week).</p> <p>The studies did not look at training at the learner licence level or at the first 6 to 12 months of obtaining a probationary licence.</p> <p>None of the studies used a naturalistic observational method, such as in-vehicle cameras, to measure driving behaviours and none asked participants to engage in activities outside a laboratory.</p>

Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Bates, Allen, Armstrong, Watson, King, &amp; Davey (2014)</p> <p>International</p>	<p>To summarise the literature on graduated driver licensing systems (GDLs) and describe the steps to upgrade from learner's permit, to probationary licence, and to an open licence.</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Not discussed</p> <p><b>Publication types searched:</b> Not discussed but literature that was published between 2000 and 2013 was cited.</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>GDL systems are effective at reducing crash risk for both young drivers and older novice drivers. The most important components for reducing crash risk included holding a learner's permit for a minimum of 12 months, passenger limit restrictions, a zero-blood alcohol concentration level while driving, and a night-time driving curfew. Engaging in a high number of hours of supervised driving practice (approximately 120 hours) as a learner driver reduced crash risk when these drivers began to drive independently.</p> <p>Young drivers with parents who impose strict driving restrictions are less likely to engage in risky driving behaviour and have fewer road crashes or citations for driving offences than those with parents who are lenient. For at least the first 4 months of supervised driving, parents tend to focus on vehicle handling and operations. Parents continue to supervise driving behaviours as the learner driver progresses to independent driving. The researchers concluded that parental involvement and enforcement is crucial to the success of GDL even more so than police enforcement.</p> <p>Some studies showed that learner drivers do not gain much experience in driving in high-risk situations (e.g., at night, in rain). However, these drivers quickly become confident of their driving abilities as they get closer to upgrading to a probationary licence. This finding suggests that more hours of supervised driving are needed for a learner driver to increase their driving skills and confidence. At the probationary licence level, there was not enough evidence to determine if an exit test for upgrading to an open licence is effective at reducing crash risk.</p>	<p>The benefits of GDL may be unrealised if drivers do not wish to comply with the restrictions.</p> <p>Police may find enforcement of certain components of a GDL challenging if their understanding of GDL is limited.</p> <p>There are limitations to relying on parents to provide supervised driver practice. Parents may only teach a limited set of driving skills and fail to teach higher-order cognitive skills, such as hazard perception and situation awareness. Parents may also be unaware of mandated hours for learner drivers.</p>

Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Road Safety Observatory (2014)</p> <p>International</p>	<p>To critically evaluate the literature on driver training or driver education to inform policy in Great Britain.</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Reviews and some individual studies of pre-driver, pre-licence and post-licence driver training or driver education. Searching for driver training studies was restricted to those published between 2010 and 2013. The researchers also searched for studies specifically involving a Certificate of Professional Competence but had no date restrictions on that search because there were too few recent studies to limit the search to the most recent studies.</p> <p>For driver training, 167 potentially relevant studies were identified. For Certificate of Professional Competence, 29 potentially relevant studies were identified.</p> <p><b>Publication types searched:</b> Peer-reviewed academic journals, conference proceedings, books, government reports, and consultant reports</p> <p><b>Quality assessment criteria:</b> <b>Rated relevance:</b> High: Clearly relevant Medium: Probably relevant to UK (targets behaviour but not always reducing crashes)</p>	<p>There was no strong evidence to indicate that driver training or education has an effect on improving the safety of pre-drivers, learner drivers, or novice drivers. However, driver training and education are important for developing cultural values, beliefs, and skills as well as legitimising safety-focused legislation like graduated driver licensing (GDL) systems.</p> <p><b>Pre-driver training:</b> There is no evidence that pre-driver training or education programs directly improve driver safety. Some evidence indicates that programs result in short-term changes in attitude, but most programs were not evaluated well enough to determine if changes in attitude were consistent across programs. Evidence suggests that road safety education may result in a small reduction in crash risk where a GDL system is used.</p> <p><b>Learner drivers:</b> Some evidence indicates that performing well on a hazard perception test is associated with reduced risk of crash when driving with an open licence. However, it is unclear if this finding was due to the effect of a program or that the test assessed an important aspect of safe driving competency. Evidence to suggest the best way to test or train higher-order cognitive skills is limited.</p> <p><b>Licensed drivers:</b> As drivers develop more on-road driving experience and increase in age, their crash risk also reduces. Evidence is consistent that driver training and driver education have no direct effect on crash risk for new drivers.</p>	<p>Few driver training and driver education programs have been evaluated.</p> <p>Driver training and education programs are often focused on preventing crashes and fatalities. Therefore, the outcomes measured tend to be crashes or fatalities. However, it may not be realistic that a short-term (half-day) program would have a direct effect on reducing crash or fatality risk. Programs should not be expected to reduce crash and fatality risk on their own, but they could be part of larger, more holistic systems like a graduated driver licensing system.</p> <p>Limitations provided by McKenna (2010) were discussed (See later in this table).</p> <p>Programs should be based on formal theory and knowledge from psychology or behavioural sciences. They should use rigorous evaluation designs.</p>

		<p>Low: Data not relevant</p> <p><b>Rated quality:</b>  High: High-quality peer-reviewed publication with clear and appropriate methods  Medium: Academic source but not peer-reviewed or having some methodological issues  Low: General source, such as a conference or trade publication, and methods are weak or inappropriate</p>	<p>There are promising new approaches that address higher-order cognitive skills, such as perception, motivation, and insight, rather than defensive driving skills, but further evaluation of these programs is needed.</p>	
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Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Bates, Filtness, Fleiter, Watson, Tone &amp; Williamson (2013)</p> <p>International but focus on jurisdictions comparable to Queensland, which included other Australian states, Europe, New Zealand, UK, and US</p>	<p>To assess the effectiveness of driving training and driver education programs in reducing crashes in novice drivers</p> <p>To assess the strength of the evidence and how much of the training reflects the full scope of the Goals for Driver Education principles</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Pre-licence and post-licence driver training, particularly for novice drivers. For example, professional driving instruction, school-based pre-licence training, driver training and graduated driver licensing system, simulator training, procedural skills training, cognitive skills training, resilience training, and insight training.</p> <p>Studies published between 2003 and 2013 were considered, although older literature was also reviewed when deemed appropriate. The review included literature published in English.</p> <p><b>Publication types searched:</b> Peer-reviewed academic journals and websites of recognised road safety organisations. The number of studies and articles reviewed was not provided.</p> <p><b>Quality assessment criteria:</b> Rated effectiveness: 1-5 stars. Strength of evidence: 1-3 stars. Scope of training: A, B, C, D.</p>	<p><b>Pre-licence rating of the evidence:</b> No single training method addresses all the required skills for safe driving. For example, driver training through professional driving instruction can help young drivers develop safe driving attitudes and behaviours; whereas supervised driving through family or friends can provide young drivers with more driving experience. Simulator training and computer-based training that use high fidelity machines can improve higher-order cognitive skills. Resilience training can reduce risky driving behaviours. There is no evidence, however, that high-school driver education improves driver safety.</p> <p>The authors note that each training method has the potential to improve the safety of novice drivers by promoting safe driving attitudes and behaviours or improving hazard perceptions skills. However, almost all training methods also have the potential to increase crash risk by unintentionally promoting attitudes and behaviours that encourage earlier licensing and independent driving rather than mastering the required skills. More research is needed to determine whether these programs reduce crash risk.</p> <p><b>Graduated driver licensing systems:</b></p> <ul style="list-style-type: none"> <li>• Effectiveness: yes (5 stars)</li> <li>• Evidence: strong (3 stars)</li> <li>• Scope of training: all covered (A, B, C, D)</li> </ul> <p><b>Professional on-road driving instruction:</b></p> <ul style="list-style-type: none"> <li>• Effectiveness: yes, in certain situations (4 stars)</li> <li>• Evidence: strong (3 stars)</li> <li>• Scope of training: missing curriculum on goals for life/skills for living (B, C, D only)</li> </ul>	<p>There is a lack of theoretical approaches to driver training and education.</p> <p>In many studies, the effectiveness of a driver training or education program has been measured in terms of crash risk reduction. However, crashes are infrequent and have various determinants; only some effects can be addressed by driver training and education programs. It is difficult to find crash-related differences between those who have and have not taken a driver training or education program. Using driving offences as an outcome has similar limitations.</p> <p>Only a few types of driver training and education programs have been well evaluated.</p> <p>Few randomised controlled trials have been conducted, which limits the rigour of the data used to evaluate the effectiveness of the programs. However, it is unethical to deny a program to a group, particularly when licensure depends on the completion of a program. Studies that recruited in other ways to form control groups often have problems with the comparability of the intervention and control groups. There are also issues with differential losses to follow-up between intervention and control groups.</p> <p>Reliance to date on short-term follow-up periods prevents the determination of the long-term effectiveness of programs.</p> <p>Some studies failed to control for confounding variables and had sampling issues.</p>

		<p>The more stars, the more effective the program was or stronger the evidence was.</p> <p>For assessing the scope of training, a letter was given each program to represent the type of driver training that was addressed:  A: Goals for life/skills for living  B: Driving goals and context  C: Mastery of traffic situations  D: Vehicle manoeuvring</p> <p>The scope of driving assessment used the Goals for Driver Education matrix as a framework.</p>	<p><b>Supervised on-road driving experience:</b></p> <ul style="list-style-type: none"> <li>• Effective: yes, in certain situations (4 stars)</li> <li>• Evidence: some high-quality studies (2 stars)</li> <li>• Scope of training: missing curriculum on goals for life/skills for living (B, C, D only)</li> </ul> <p><b>High-school driver education, including practical driver training on-road</b></p> <ul style="list-style-type: none"> <li>• Effective: undetermined/mixed results (2 stars)</li> <li>• Evidence: weak (1 star)</li> <li>• Scope of training: missing curriculum on goals for life/skills for living and driving goals and context (C, D only)</li> </ul> <p><b>Simulator training:</b></p> <ul style="list-style-type: none"> <li>• Effective: likely (3 stars)</li> <li>• Evidence: some high-quality studies (2 stars)</li> <li>• Scope of training: missing curriculum on goals for life/skills for living and driving goals and context (C, D only)</li> </ul> <p><b>Computer-based hazard perception driver training and education:</b></p> <ul style="list-style-type: none"> <li>• Effective: likely (3 stars)</li> <li>• Evidence: some high-quality studies (2 stars)</li> <li>• Scope of training: missing curriculum on goals for life/skills for living; driving goals and context, vehicle manoeuvring (C only)</li> </ul> <p><b>Resilience training:</b></p> <ul style="list-style-type: none"> <li>• Effective: likely (3 stars)</li> <li>• Evidence: some high-quality studies (2 stars)</li> <li>• Scope of training: missing curriculum on vehicle manoeuvring and mastery of traffic situations (A, B only)</li> </ul> <p><b><u>Post-licensing rating of the evidence:</u></b>  No evidence that advanced or defensive driver training reduces crash risk. Conversely, higher-</p>	<p>The content of programming is usually not reported. Therefore, it is often unclear how the findings apply to other programs.</p> <p>Programs have tended to address only mastery of traffic situations and vehicle manoeuvring. They do not address the higher-order factors like goals for life/skills for life, driving goals and context, which are also required when driving.</p>
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order cognitive skills training may improve driving attitudes and reduce overconfidence. However, few evaluations have been conducted in real-world conditions as most rely on simulators. Therefore, the translation of the findings to real road conditions is unknown.

**Procedural skills training:**

- Effective: limited or no high-quality evidence (1 star)
- Evidence: weak (1 stars)
- Scope of training: missing curriculum on goals for life/skills for living and driving goals and context (C, D only)

**Hazard perception education:**

- Effective: likely (3 stars)
- Evidence: some high-quality studies (2 stars)
- Scope of training: missing curriculum on goals for life/skills for living and driving goals and context (C, D only)

**Situation awareness:**

- Effective: likely (3 stars)
- Evidence: weak (1 star)
- Scope of training: missing curriculum on goals for life/skills for living and driving goals and context (C, D only)

**Insight training:**

- Effective: undetermined/mixed results (2 stars)
- Evidence: weak (1 star)
- Scope of training: missing curriculum on goals for life/skills for living, driving goals and context, and vehicle manoeuvring (C only)



Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Beanland, Goode, Salmon, &amp; Lenné (2011; 2013)</p> <p>International</p>	<p>To critically evaluate whether driver training is, or could become, an effective means of improving young novice driver safety.</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Studies had to examine the effectiveness of pre-licence and post-licence driver training, particularly for novice drivers aged 25 years and younger. These included professional driving instruction, school-based pre-licence training, driver training and graduated driver licensing system, simulator training, procedural skills training, cognitive skills training, resilience training, and insight training.</p> <p><b>Publication types searched:</b> Peer-reviewed academic journals, conference proceedings, books, government reports, and consultant reports that were published from 2001 to 2011. The number of studies and papers reviewed was not mentioned.</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>Some forms of pre-licence driving training improve driving skills but evaluation of post-licence driving training are too limited to draw any conclusions.</p> <p><b>Pre-licence driver training:</b> Some driver training programs that address procedural skills (vehicle handling), including professional driving instruction and formal driver training programs, are effective in improving the targeted skills and improving road safety in learner drivers. However, reduced hours of supervised practice or attending driver training programs that shorten the time to full licensure increases the risk of reporting road crashes and driving offences. It is unclear whether personal motivation to drive more safely or quality of training was more strongly associated with safer driving.</p> <p><b>Post-licence driver training:</b> Evaluations are limited, and thus it is not clear if such training improves road safety. Some programs improve skills, including programs that address vehicle handling skills and ones that address cognitive skills. Those that teach vehicle handling skills can improve driving skills, but novice drivers often do not apply these skills appropriately. The limited evidence indicates that training that addresses cognitive skills like hazard perception would reduce crash risk, but the association has not been tested directly.</p> <p>Hazard perception training can significantly reduce crash risk, but the results are from computer-based testing, not from on-road driving. Results from evaluations of hazard perception training also suggest that some young drivers are</p>	<p>Evaluations of driver training programs have many flaws that put the validity of their findings into question.</p> <p>Many studies had short-term (&lt; 1 week) evaluations because it was deemed unethical to prevent control participants from accessing drive training long-term. Longitudinal comparisons (e.g., over 3-6 month intervals) are needed to fully assess the effects of training and to observe whether or not short-term training decays over time.</p> <p>Studies have tended to have inappropriate control groups. Control groups have included samples from different demographic populations than the intervention group. Some studies have recruited individuals who have self-selected into a group. There are also issues with differential losses to follow-up between intervention and control groups, which impact the internal validity of the study findings.</p> <p>The studies have often focused on crash rates but have not accounted for crash conditions, type, severity, and causes (or time of obtaining licensure to first crash experience).</p> <p>Most of the studies have measured self-reported crashes. Reporting of crashes is subject to reporting bias because people generally report more serious crashes (e.g., resulting in injury or major vehicle damage) more readily than less serious crashes (e.g., vehicle scratches, bumps). Also, crash rates are unreliable because they vary over time, are of various kinds, and have different causes. Training is not likely to address all causes of all crashes. Studies do not tend to differentiate between crashes of differing severity or causes. A</p>

			<p>ignorant as to what is a risky situation and fail to take appropriate precautions while driving.</p> <p>Resilience training that focuses on reducing risk-taking behaviour through improving interpersonal skills is showing promising results, but the evidence is limited.</p> <p>Insight training, which encourages drivers to realistically evaluate their driving abilities, has reduced overconfidence, but again, the evidence is limited.</p>	<p>better measure would consider both the type and severity of a crash or would use behaviour as the outcome instead of crash involvement.</p> <p>Studies have not adjusted for important confounders, such as accelerated licensure (in evaluations of pre-licence driver training), gender, and overconfidence.</p> <p>Studies have not typically included an 'exit test' to assess whether participants learned the knowledge and skills addressed in the program. Thus, evaluations cannot differentiate between failures to learn and failures to apply learning.</p>
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Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Kinnear, Lloyd, Helman, Husband, Scoons, Jones, Stradling, McKenna, &amp; Broughton (2013)</p> <p>International</p>	<p>To synthesise the evidence in support of strategies for improving driver safety of young and novice drivers</p>	<p><b>Study design:</b> Systematic Review</p> <p><b>Inclusion criteria:</b> Studies of pre-licence driving training programs for people aged &lt;17 years and studies of graduated driver licensing (GDL) systems for people of all ages.</p> <p>Only the summary of this review was located. The full report could no longer be found online.</p> <p><b>Publication types searched:</b> Not discussed</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p><b>Pre-licence driver training and education:</b> Short-term improvements in attitudes towards road safety have been demonstrated, but the effects last no longer than a few months, are inconsistent, and do not guarantee safety benefits. Some driver training and education programs produce negative effects, such as encouraging earlier licensing and therefore, exposing drivers to risk at a younger age.</p> <p><b>Graduated driver licensing systems:</b> Consistent and strong evidence shows that GDL systems are effective in reducing crashes of novice drivers of all ages. The effectiveness is related to the number of components included in the system, the strictness of the components, and the enforcement of the components.</p> <p>Components that reduce crash risk at the learner's permit level are minimum learning periods, amount of time engaging in supervised driving practice, and minimum age at which the driver can upgrade their licence.</p> <p>Components that improve effectiveness at the probationary licence level are night-time driving restrictions and restrictions on carrying passengers aged &lt;30 years for novice drivers who are aged &lt;30 years.</p> <p>Having a low-blood alcohol concentration limit while driving and prohibition of using hands-free mobile phone while driving are both likely to reduce crashes in novice drivers and encourage safe driving behaviours.</p>	<p>Pre-licence driver training and education programs are not based on formal theory that can inform their content.</p> <p>Very few evaluations use rigorous designs that allow for clear conclusions to be drawn.</p> <p>Some drivers may misinterpret the meaning behind components of a GDL. For example, minimum number of hours of practice may be perceived by novice drivers as a target to achieve rather than as a minimum requirement for practice to become effective. It may be important to look at the effect of motivation in developing safe driving behaviours in addition to hours spent in supervised driving practice.</p>

Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Peck (2011)</p> <p>International with a focus on North America</p>	<p>To re-examine the key research evidence concerning the effects of driver training for novice drivers on per capita and per licence crash rates prior to graduated drivers licensure (GDL). Critically examined research design flaws in previous research and detailed the most well-designed study</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Studies that described evaluations of driver education and training, both classroom and behind the wheel, as well as previous literature reviews and reviews of prior reviews.</p> <p><b>Publication types searched:</b> Reviewed ecological studies, quasi-experimental, and randomised controlled trials that were conducted after the late 1960s. The most recent citation was for an article published in 2008.</p> <p>The author noted that earlier studies were not valid because enrolment was voluntary and sometimes based on academic performance. Therefore, program participants differed from control participants. Other limitations of the studies conducted earlier in the 1960s included confounders by socioeconomic factors, gender, grade-point average, and IQ.</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>Overall, studies from before GDL showed that driver training had little effect on crashes, and any benefits were counteracted by the effect of offering early licensing for the participants aged 16-17 year who participated in the driver training.</p> <p>Using a per capita crash metric, the evidence suggests that there is an increase in crashes caused by driver training taken in a state that does not have a GDL system compared to states that do. The author argues, however, that it may not be problems with the driver training, but with the minimum licensing age.</p> <p>Initial analyses of data from a large (N=16,000) randomised controlled trial from DeKalb County, California showed no difference in crashes or driving offences in any year of follow up between a safe performance curriculum (on-the-road training, simulation instruction, and classroom training [70.5 hours in total]) and a pre-driver licence training (classroom simulation, 1-hr on-road supplemented by parental training [21 hours in total]). Subsequent analysis showed that for both groups the time to licensure had decreased.</p> <p>Subsequent analyses also found no differences between participants taking the safe performance curriculum or the pre-driver licence training combined and participants in the control group in driving offences or crashes reported in follow ups that took place yearly for 4 years post-training. Although in the first year after training, controls participants had significantly fewer crashes and driving offences than either training group.</p> <p>Studies have shown that attitude and lifestyle factors affect crash rates of young drivers. In the DeKalb County study, the Mann driver attitude</p>	<p>In the DeKalb County subgroup analyses of only those who had gotten a driver's licence and separately of those who had completed training, there was no analysis of assumed non-random factors that affected the safe performance curriculum and the pre-driver licence training comparisons.</p> <p>The subsequent analyses of the DeKalb County data, which had more follow-up periods than the initial analysis, did not control for temporal exposure while licenced.</p> <p>Few studies since the DeKalb County study have used random assignment, and they suffer from methodological flaws, including self-selection bias, insufficient sample sizes, and use of self-reported driving data.</p> <p>Small sample sizes in previous studies could have resulted in findings of no differences between groups simply due to the small number of participants. No study has been powered to detect a 5% reduction in crashes, which would require 70,000 participants per group, using California data. To detect a 10% reduction in the 12-month crash rate with 80% confidence, 175,000 participants per group would be required.</p> <p>On-road driving training programs focus on skill, which has not been shown to be correlated with driver crash rates. Instead, studies suggest that attitude and lifestyle impact crash rates. Therefore, studies need to consider these factors in examining crashes.</p>

			<p>inventory was a stronger predictor of crash rates than road tests.</p> <p>Reviews and reviews of reviews since the DeKalb County study indicate that there is no strong evidence that driving training reduces the crash rate of novice drivers. Also, any benefits of driver training are offset by negative outcomes of early licensing. Some reviews find that driver training increases crashes by shortening time to licensure and increasing crash exposure.</p>	
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Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Russell, Vandermeer, &amp; Hartling (2011)</p> <p>International</p>	<p>To examine the effectiveness of graduated driver licensing (GDL) systems in reducing crash rates among young drivers</p>	<p><b>Study design:</b> Systematic Review</p> <p><b>Inclusion criteria:</b></p> <ul style="list-style-type: none"> <li>• Studies that compared outcomes pre- to post-implementation of GDL system within the same jurisdiction, between jurisdictions with and without a GDL system, or both.</li> <li>• Studies that reported at least one objectively-measured outcome that was related to crashes</li> <li>• Studies that had data on drivers aged &lt; 20 years</li> <li>• GDL had a minimum of three stages that allow the new driver to progress from lower to higher risk driving conditions: an initial period limited to supervised driving, intermediate stage allowing for unsupervised driving under one or more conditions that involve lower risk, and lastly, unrestricted full licensure.</li> </ul> <p>The review included 34 studies that evaluated 21 GDL systems and 2 analyses of GDL systems from over 40 US states. GDL systems were implemented in the US (n=16), Canada (n=3), New Zealand (n=1), and Australia (n=1) and varied in their restrictions during the intermediate stage.</p>	<p>Quality of the GDL systems: 11 systems were good, 4 were fair, 5 were marginal, 1 was poor, and 2 could not be assessed.</p> <p>A reduction in crash rates was consistently seen in all jurisdictions and for all crash types. Stronger GDL systems resulted in greater reductions in fatalities. The analysis could not identify the GDL components that had the greatest effects. The magnitude of the effects varied across jurisdictions.</p>	<p>Due to logistics and feasibility, most research on GDL systems used an ecological design. The main concern of these types of studies is that they are unable to fully control for confounders and other explanatory factors, such as the effects of the road network, speed limits, resources for patrolling the roads, and differences in road and safety culture.</p> <p>The design and the effectiveness of a GDL system may be affected by where the program is implemented and whether or not people comply with it. For example, GDLs that contain a night-time driving restriction component may be ineffective in rural communities because people living in those communities may be reluctant to adopt an early night curfew that limits a teenager's ability to work or participate in school events.</p> <p>Many studies used short-term evaluations with measurements taken quickly post-intervention.</p> <p>Some components, such as night-time driving restrictions, had a positive effect. However, it is difficult to know which components are most effective because it is unknown whether the effectiveness of one component is independent of other factors or is only effective in the presence of another component.</p>

		<p><b>Publication types searched:</b> Peer-review academic journals and conference proceedings. Searches were not restricted by language, publication status, or date (up to May 2009 for most of the search but up to September, 2009 in the TRANSPORT database).</p> <p><b>Quality assessment criteria:</b> To examine the quality of the studies, measurement errors, presence of control groups, statistical methods used, discussion of confounders, and regression to the mean were assessed.</p> <p>The quality of the GDL systems was assessed using the Classification of Licensing Systems from the Insurance Institute for Highway Safety. The grading system is as follows:</p> <p>Good: Mandatory learner's permit period of at least 6 months and optimal restriction on the initial licensing level.</p> <p>Fair: Optimal restrictions lasting until 17 years of age with regards to the learner permit holding period or any mandatory learner permit holding period and any night-driving or passenger restriction that lasts until 16.5 years of age.</p>		
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Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Washington, Cole &amp; Herbel (2011)</p> <p>International</p>	<p>Highlight conclusions from previous reviews of advanced driver training programs and examine gaps in the literature</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Reviews and studies of post-licence advanced training programs for novice drivers</p> <p>Studies were split for analysis into early studies (pre-1990), when advanced mastery skills were the focus of advanced driver training, and post-1990, when the focus changed in Europe to providing insight into drivers' inherent physical and mental limitations and awareness about the limitations of motor vehicles. These newer programs aim to increase skills and decrease self-perceived skills like overconfidence. They have addressed hazard perception, self-monitoring, impact of risky attitudes, and motivations on driving by novices.</p> <p><b>Publication types searched:</b> Included articles and reports from 1974 to 2009.</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>Consistent and strong evidence from the mid to late 1990s that the older type of advanced driver training was ineffective and decreased road safety. Reviews of studies from Europe and the US conducted pre-1990 showed overwhelming evidence that teaching skills such as braking at high speeds decreases road safety by increasing driver confidence. Attendees of these programs reported that they engaged in more aggressive driving and that they perceived that their skills were better, which was not the outcomes sought from these programs. The increase in confidence could have made drivers less risk adverse. The US continues to use this earlier form of advanced driver training.</p> <p>The few studies post-1990 in Europe suggest that the new focus of advanced driver training may be effective. The evidence is consistent in showing that these training programs have marginal to significant benefits for reducing crashes. Estimated effectiveness of the post-1990 programs: 5%-13% on crash rates. The new focus is on higher-level skills for living and self-control rather than low-level skills such as speed control, direction, and vehicle positioning.</p>	<p>Evaluations of the post-1990 advanced driver training programs have not used the best study designs. For example, they have not controlled for confounders, generally have small samples, and do not control for exposure before or after the advanced driver training. There are limitations found in earlier advanced driver training studies too.</p>

Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Helman, Grayson, &amp; Parkes (2010)</p> <p>International</p>	<p>To examine the effectiveness of driver training, driver education, and graduated driver licensing (GDL) systems in reducing crashes in new drivers</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> None stated but referenced mostly other literature reviews about pre-licensing and post-licensing driver programs</p> <p><b>Publication types searched:</b> Not discussed but review articles and individual studies published between 1978 and 2009 were included</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>Driver training has little impact on crash risk among new drivers. Training is important but cannot be expected to affect crash risk. Rather, evidence suggests that it is most important to include on-road driving experience pre- and post-licence and that GDL systems should be used. Also, cognitive training approaches should be considered.</p> <p>Driver training that addresses cognitive skills, such as hazard perception or 'reading the road', show promise in decreasing crash risk among new drivers. Unlike other programs, there is a theoretical plausible rationale for the training to be effective within a broader training program. Future research is needed to address how to create the most effective hazard perception training modules.</p> <p>Evidence is overwhelming in showing that GDL systems are effective in reducing crash risk during the probationary licensing period for all ages of teenagers and for all types of crashes but most notably among the youngest of the new drivers. Evidence on the effectiveness of GDL systems in reducing crash risk at the open licence level is inconclusive.</p> <p>Evidence is emerging that the effectiveness of a GDL system depends on the components that it includes. Components that have shown to be effective in reducing crash risk include: extension of the learner stage, supervised driving in the learning stage, restriction of the number of passengers in the car with the learner driver, and night-time driving restrictions. In a meta-analysis, the effectiveness of driver education with a GDL system was mixed, but there were methodological issues with the analysis.</p>	<p>Driving training and education programs tend to be too short and limited in their decrease crash risk. They do not typically teach in a way that overcomes factors that influence the way that people drive. The inability to group people by licensing stage and the lack of control for exposure are important limitations noted in a meta-analysis of studies that evaluated GDL systems. For evaluation of these systems, the maturity levels of participants and the differences in their exposure to risky situations pre- to post-licensing needs to be addressed.</p> <p>Programs focus on technical driving skills, not driving 'style', defined as the way that drivers choose to drive their vehicles. However, many behaviours that lead to crashes are related to driving style rather than driving skills. These include speeding, tailgating, risky overtaking behaviour, violation of traffic laws, using distractions such as smartphones, and insufficient sleep. Including such factors along with the technical skills would address all levels of the Goals for Driver Education matrix.</p> <p>Based on the premise that driving requires a set of cognitive skills, it is an error to think that pre-licensing training will have benefits post-licence. There is a mismatch in context between pre- and post-licensing. The mismatch is in knowledge needed to deal with different situations, such as different manoeuvres, driving situations of varying difficulties (such as day versus night driving), and social situations (instructor in the car, peers in the car).</p> <p>Studies have not shown whether driver training or education programs can indirectly affect crashes, such as through changes in larger community</p>

			<p>Gaining experience in driving post-licence is the most important factor in reducing crash risk of new drivers. The first 6 months or first 1000 miles from licensing are associated with the greatest reduction in crash risk.</p> <p>Some evidence indicates that driver training must provide same driving situations pre-licensing as post-licensing, so there is no mismatch in context.</p>	<p>attitudes that lead to the community be more accepting of ways to address poor driving behaviour.</p>
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Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>Lonerero &amp; Mayhew (2010)</p> <p>International</p>	<p>To provide a richer understanding of driver training and driver education evaluation and consider how pre-licence driver training and education can be improved</p>	<p><b>Study design:</b> Narrative Review</p> <p><b>Inclusion criteria:</b> Previous driver training and education reviews and studies</p> <p><b>Publication types searched:</b> Included articles, reports and reviews from 1974 to 2009</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>There is no clear evidence to indicate that driver training or education for novice drivers improves their safety. Few studies have shown positive results, and positive results have either been ignored by reviewers or have not been followed-up by researchers.</p> <p>There is one systematic review that reviewed only randomised controlled trial (RCT) studies. Other reviewers, however, have not limited their reviews to RCTs due to inherent methodological issues with these designs for evaluating the effectiveness of pre-licence driver training (e.g., difficulty in creating an appropriate control group). Only one meta-analysis has been conducted, which is the most definitive study given that it combines the results from previous studies, to overcome methodological issues of each. The findings did not show that driver training or education reduces crash risk over the first few years of driving.</p> <p>Overall, experimental studies have found no significant effects of driver training on reporting of road crashes, but two studies found positive effects (some analyses of the DeKalb County, US data and a separate California, US study). Two large ecological studies found positive effects of driver training or education on being involved in a crash, but one earlier study found no effect.</p> <p>More recent studies have used better designs and statistical methods, including adjusting for some confounders, but they also suffer from methodological issues. Overall, findings do not show that driving training or education is positively affecting crash rates.</p>	<p>Evaluations of driver training and education suffer from problems of scope, study design, and sampling issues.</p> <p>Early studies did not consider pre-existing differences between intervention and control groups, and therefore the findings are not credible. Later studies addressed this selection bias by using randomised controlled trials. However, even the best studies (RCTs have had methodological issues that have resulted in their findings not being definitive. RCTs have often had difficulty creating an appropriate comparison group without running into ethical issues, as seen in the DeKalb County study.</p> <p>Few evaluations have been conducted and these have focused on short-term, direct-safety outcomes. Few have looked at intermediate outcomes, like changes in knowledge, skills attitudes, and intentions, that would be expected to change from taking driver training or education.</p> <p>Some studies recruited small samples, resulting in a lack of power to detect statistically significant effects because large numbers of crashes are required to detect a difference in crash rates between those who have and those who have not taken an education/training program.</p> <p>Studies have not considered that driver training or education is at the beginning of the learning process and that other experiences can have a greater influence on safety.</p> <p>Few driving training or education programs have an underlying theory. Theory can be defined as</p>

			<p>Some recent studies suggest that some types of driver training or education can make learner drivers overconfident. Therefore, the training is offsetting any benefits.</p> <p>Most recent thinking is that driver training or education should occur incrementally rather than in one program.</p>	<p>the logical process of the steps in which a program is meant to impact an outcome.</p> <p>Few formative evaluations have been conducted. These are evaluations to monitor content and implementation and make changes as needed to make sure intermediate outcomes can be achieved.</p> <p>Few behaviour change interventions work well at improving road safety if they are offered as stand-alone programs. Rather, coordinated interventions seem to work better.</p> <p>Most studies have used total crashes as the outcome. National samples are required to look at serious crashes (those involving major injury) given the outcome is rare. These types of crashes are likely of most interest but are likely to have different factors predicting them than other types of crashes.</p>
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Author & Scope of Review	Aim	Study Design & Method	Main Results	Limitations Identified in the Studies Reviewed
<p>McKenna (2010)</p> <p>International</p>	<p>To examine why driver training and driver education programs may be ineffective</p>	<p><b>Study design:</b> Narrative description of the limitations of driver training and education programs</p> <p><b>Inclusion criteria:</b> Not discussed</p> <p><b>Publication types searched:</b> Not discussed but the report included previous reviews and individual studies published between 1974 and 2010</p> <p><b>Quality assessment criteria:</b> Not discussed</p>	<p>There is no evidence that driver training or education reduces crash risk. Some studies are showing that driver training increases crash risk in teenagers.</p> <p>If the outcome is injury or fatality, generally the program is deemed to be ineffective. If effectiveness is based on increasing knowledge, it is usually found to be successful.</p>	<p><b>Intervention frameworks:</b> Few driver training or education programs are based on theory or evidence, or they try to impact the wrong outcomes. Few are evaluated. Evidence from the education literature that acquiring knowledge is sufficient to induce change is not supported because drivers are often aware of the risks. For drivers who are not aware of the risks and who acquire knowledge from a program, the acquired knowledge does not typically lead to changes in behaviour.</p> <p><b>Intervention dose from larger education literature:</b> Programs are often too short (e.g. too few sessions, sessions too short, spacing between sessions is too short) to have an impact on the outcome in the long-term.</p> <p><b>Risk as value:</b> From the larger literature, it is known that sensation seeking peaks during the teenage years. Interventions may not be able to overcome that attraction to risky or pleasurable behaviours.</p> <p><b>Social norms:</b> Suggesting that a risky behaviour is the norm can encourage people to engage in that risky behaviour.</p> <p><b>Exposure to risk:</b> Undertaking driver training or education programs without engaging in sufficient time in practicing those skills can lead to increased exposure to risk because drivers may have the knowledge of driving skills, but may yet be able to use those skills instinctively or effectively if they have not practiced them enough.</p> <p><b>Outcomes of programs:</b> There can be differences in the type of data used to measure</p>

				<p>crashes, such as self-reported information versus police or hospital data. There can be other factors that lead to the crash beyond the behaviour of the person of interest.</p> <p>If an outcome is rare, like a serious crash, large sample sizes are required to find an effect, but most studies do not have the large sample sizes required to detect an effect on the outcome.</p> <p>If evaluation is not valued, due to economic conditions, weak designs may be used or the evaluation may not occur.</p> <p>Programs must be evaluated against their aims. Aims must be worded more specifically to allow for evaluation against them.</p>
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*Table 2.*

*Details of recent individual studies of driver training (most recent first)*



Authors & Scope of Research	Aim	Study Design & Sample	Measures	Main Results	Limitations
<p>Usami, Persia, &amp; Iurato (2016)</p> <p>Italy</p>	<p>Examined the effects of post-licence advanced driver training on number and type of driving violations</p>	<p><b>Study design:</b> Intervention study of advanced driver training (ADT) courses offered 2011-2012 and that included theory and practice on-track</p> <p><b>Recruitment:</b> Data were obtained from three datasets: a dataset of all drivers participating in the evaluation study (over 13,000), a dataset of 10,000 randomly selected drivers extracted from a national database of licensed drivers, and a database of 10,000 randomly selected drivers who committed a driving offence between 2010 and 2012 extracted from a national database of licensed drivers.</p> <p><b>Final sample</b> Analysis 1: Treatment=6,932 Control 8,469 Analysis 2: Treatment=491 Control 2=9.216</p>	<p><b>Outcome:</b> Number and types of driving offence citations</p> <p><b>Predictor:</b> Attendance at an ADT (treatment/control).</p> <p><b>Confounders:</b> Age and gender were measured but not included in analysis</p> <p><b>Analysis:</b> Wilcoxon signed-rank test to examine difference pre-test (before taking an ADT course) to post-test (after taking an ADT course) and survival analysis. The researchers conducted 3 analyses:</p> <ol style="list-style-type: none"> <li>1. Comparison between drivers who participated in ADT and drivers who did not</li> <li>2. Comparison between drivers who committed a driving offence with citation before participating in ADT and drivers who did not participate in ADT, but received a citation for a driving offence.</li> <li>3. Comparison between drivers who committed a driving offence before participating in ADT and drivers who did not participate in ADT but received similar numbers of citations for driving offences to drivers in the treatment group.</li> <li>4. Comparison between drivers who had committed a violation within 6 months after taking an ADT and drivers who had committed a violation in the</li> </ol>	<p>First analysis: Significant reduction pre-test to post-test in the number of violations in the treatment group (people who had taken an ADT) (<math>p=0.002</math>) but not in the control group. In the treatment group there was a reduction in the number of violations per 100 drivers examined except for an increase in the number of speeding violations (no statistical testing provided). The control group had a similar pattern.</p> <p>Second and third analysis: Borderline significant increase pre-test to post-test in the number of violations in the treatment group (<math>p=0.06</math>) that was not seen in the control group. The treatment group had an increase in the number of violations per 100 drivers whereas in the control group, there was a decrease in the number of violations for all violations except speeding, for which there was a slight increase for the second analysis but not the third (no statistical testing provided).</p> <p>Across groups, speeding was the main reason for a violation (50% of violations). Pre-test and post-test, the people in the treatment groups had more of each type of violation examined than people in the control groups. The researchers indicated that this difference was likely due to the treatment group being composed of professional drivers or frequent drivers.</p>	<p><b>Limitations identified by the researchers:</b> There were differences in age and gender between treatment and control groups.</p> <p><b>Other limitations:</b> Self-reported data from questionnaires.</p> <p>The study did not use a multivariable analysis approach. Therefore, analysis did not take into account various factors that could have influenced the number of driving offences cited.</p> <p>Although age and gender were recorded, they were not included in the analysis. However, differences between treatment and control group are apparent from the demographic data reported. Notably there were a much higher percentage of men and fewer people aged 22-44 years in the treatment group vs the control group included in the first analysis.</p>

		<p>Analysis 3: Treatment=491 Control 3=3,686</p> <p><b>Response rate:</b> Not applicable</p>	<p>same period but had not taken an ADT course. Analysis examined the probability of a violation occurring during the first year after the first violation using a hazard function.</p>	<p>The probability of getting a violation during the 12 months after the first violation was lower for people who had attended an ADT compared to those who had not.</p>	
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Authors & Scope of Research	Aim	Study Design & Sample	Measures	Main Results	Limitations
<p>Akaateba, Amoh-Gyimah, &amp; Amponsah (2015)</p> <p>Kumasi, Ghana</p>	<p>To examine the influence of driver training, driving experience and the form of driver training on frequency of traffic violations</p>	<p><b>Study design:</b> Cross-sectional survey</p> <p><b>Recruitment:</b> Data were collected over 1 week in the Kumasi metropolis from drivers of parked cars at local bus terminals, taxi stations, workplaces, universities and other locations. Interview-administered and self-administered questionnaires were used, depending if the participant was literate or not.</p> <p><b>Final sample:</b> N=285 ♂=253 ♀=32</p> <p>47.4% aged 31-40 years.</p> <p>About 13% were self-taught drivers.</p> <p><b>Response rate:</b> Unknown</p>	<p><b>Outcome:</b> Frequency of 10 driving offences.</p> <p><b>Predictors:</b> Highest attained education level, driving experience (years of driving), form of driver training (e.g., driving school, family and friends).</p> <p><b>Confounders:</b> Age and gender</p> <p><b>Analysis:</b> One-Way ANOVA and Bonferroni Post Hoc.</p>	<p>Respondents with formal driver training from schools reported on average the most driving offences. However, for most offences, there were no differences observed in the outcome based on driver training. The exceptions were that respondents with formal training had a higher frequency of not complying with traffic light signals (<math>p=0.02</math>) and getting off the road to bypass a traffic jam (<math>p=0.03</math>) compared to those whose training came from other sources. Training through apprenticeship was associated with higher frequency of speeding compared to training from other sources (<math>p=0.01</math>).</p> <p>Respondents with up to a primary level of education had the highest average frequency of offences. Having an education up to a primary level was associated with more frequent speeding and overtaking offences compared to those with higher levels of education (<math>p&lt;0.01</math>). Having a tertiary high education was associated with reporting the lowest frequency of offences for using a mobile phone while driving (<math>p=0.04</math>) but having the highest frequency of offences for stopping at undesignated areas to pick up passengers (<math>p=0.04</math>).</p> <p>Respondents with over 15 years driving experience reported the highest mean frequency of driving offences. They reported a higher</p>	<p><b>Limitations identified by the researchers:</b> Driver training in Ghana is mainly classroom based, with minimal practice training. Taking formal driver training leads to earlier licensure. The results could therefore reflect these aspects of the driver training in Ghana.</p> <p>People in Ghana tend to report in social desirable ways, and therefore respondents were likely to under-report their offences.</p> <p><b>Other limitations:</b> Cross-sectional, self-report data.</p> <p>Despite the inclusion of information about demographics characteristics, the study did not account of all of them or other important factors in the analysis.</p> <p>The researchers did not ask participants about the quality of training they received.</p> <p>In the questionnaire item that asks about the type of driver training taken, respondent could only select one option, which would not have been appropriate for respondents who had participated in more than one type of driver training.</p>

				<p>frequency of using a mobile phone while driving (<math>p&lt;0.01</math>), failing to comply with a traffic light signal (<math>p&lt;0.01</math>), getting off the road to bypass a traffic jam (<math>p=0.02</math>), not stopping at a pedestrian crossing when pedestrians were waiting to cross (<math>p=0.03</math>), and speeding (<math>p=0.01</math>). However, this group had the lowest frequency for not wearing a seatbelt (<math>p&lt;0.01</math>).</p> <p>Driving under the influence of alcohol, failing to comply with traffic light signals, overtaking when prohibited, getting off the road to bypass a traffic jam, and not stopping at pedestrian crossings when pedestrians were waiting to cross were the most common types of driving offences committed.</p>	
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## SECTION 3: REVIEW OF THE LITERATURE ON MOTOR SPORT PARTICIPATION AND ROAD SAFETY

Motor sport is broadly defined as a competitive racing sport that uses high-powered motor vehicles to compete within a closed-circuit track. Popular types of motor sport include touring car racing, rallying, autocross, stock car racing, drag racing, and kart racing. Motor sport drivers can compete in standard racing or time trial formats. Standard racing involves competing simultaneously with other drivers with the objective of crossing the finish line before the other drivers. Conversely, time-trials are conducted individually with the objective of covering a set distance in the quickest time. Motor sport drivers need be able to navigate through high-risk driving situations, outrace other drivers, and manoeuvre around a track as rapidly as possible to be victorious.

Although motor sport is popular among Australians and North Americans, there is evidence to suggest that motor sport can have negative effects on individual driver behaviours and overall on-road safety (Tranter & Lowes, 2005). In particular, motor sport drivers were shown to be negative exemplars of safe on-road driving behaviours in an early study (Williams & O'Neill, 1974) that has influenced thinking about motor sport drivers to this day. The following section will summarise the methodologies, findings and limitations of studies that examined predictors of motor sport involvement as well as outcomes associated with motor sport participation. The table at the end of this section provides further details about each study described in this review. In this chapter, we first discuss the earliest published studies and then the more recently published studies.

### *3.1 Motor sport, driving violations, and road collisions (William & O'Neill, 1974)*

There has been interest in researching the effect of motor sport involvement on on-road driving behaviours and road crashes since the 1970's. Williams and O'Neill (1974) investigated the cross-sectional association between motor sport involvement and both on-road driving offences and road crashes in North America. For their sample, they obtained membership data of motor sport drivers who held national competition licences from the Sport Car Club of America in Florida, New York, and Texas. This club held motor sport races for people with special licences that qualified them to complete in these races. A comparison group was created by matching each motor sport driver to one or more non-motor sport drivers identified in state motor vehicle records. Matching was done based on age, race and sex in Florida; on age, race, sex and licence type in New York; and on age, sex, and geographic location in Texas. The researchers also obtained on-road driving records, including records of crashes and driving violations, of the motor sport drivers and non-motor sport drivers from state records. The final sample consisted of 1,500 people (447 motor sport drivers, 1053 non-motor sport drivers).

Motor sport drivers had more crashes than non-motor sport drivers in all three states. The results were statistically significant for Florida ( $p=0.02$ ) and New York ( $p=0.001$ ) but not for Texas ( $p>0.10$ ) (Williams & O'Neill, 1974). In all three states motor sport drivers had significantly more speeding offences than did

non-motor sport drivers ( $p < 0.001$ ). However, in all three states there was no significant differences between groups in other moving violations ( $p > 0.10$ ), and non-moving violations were only significantly higher in motor sport drivers in New York ( $p = 0.002$ ). These findings suggest that being a motor sport driver may be associated with developing some unsafe on-road driving behaviours. Noteworthy is the limited number of potential confounders including in analysis (e.g., driving attitudes could not be examined and limited details on driving exposure were captured), and the possibility that the two groups being compared could have differed in ways not accounted for by the matching.

### *3.2 Illegal street-racing, sensation seeking tendencies, and risky driving behaviours (Warn et al., 2004)*

Warn et al. (2004) surveyed 158 men under 25 years of age in New Zealand about their sensation-seeking tendencies, risky driving behaviours, involvement in motor sport, involvement in illegal street racing, risk perceptions, and attitudes towards speeding. Involvement in motor sport or in illegal street-racing included interest in the activity as a spectator or participation as a driver or a passenger. Men under 25 years of age were studied because they were considered the demographic most likely to be involved in illegal street racing. The survey was administered to university first-year students, motor vehicle engineering students, and high-school students.

Involvement in motor sport was associated with an increased likelihood of reporting risky driving behaviour (Warn et al., 2004). The mechanism by which motor sport involvement increased this likelihood was mostly through the effect of motor sport involvement on attitudes towards speeding. Participants who were involved in motor sport were more accepting of speeding than those who were not involved in motor sport, and an acceptance of speeding increased the likelihood of reporting risky driving behaviour. A high sensation-seeking tendency was also associated with risky driving behaviours both directly and through increasing the likelihood of being involved in motor sport. Furthermore, involvement in motor sport and high sensation-seeking tendencies were associated with involvement in illegal street racing. These findings suggest that young males who are involved in motor sport or illegal street-racing are more likely than those who are not to engage in risky driving behaviours, mainly because it changes their attitudes towards speeding.

Notably, because the study only recruited young males, the results are not generalisable to women or older adults. Moreover, the analysis did not account for demographic characteristics (e.g. socio-economic status, location of residence), driving attitudes, driving exposure or driver training, which could affect driving behaviour. Motor sport spectators were not examined separately from motor sport drivers/passengers, and therefore, the association between level of involvement with motor sport and negative driving outcomes is not known from this study.

### ***3.3 Motor sport, driving attitudes, and driving behaviours in mature drivers (Tranter & Warn, 2008)***

Tranter and Warn (2008) surveyed mature-aged drivers (aged 25 years or over) with at least 2 years of driving experience, to investigate the cross-sectional relationship between being a motor sport fan, attitudes and driving offences. "Motor sport fan" was defined for participants as being a "motor racing fan" or enjoying "watching motor racing". The survey inquired about attitudes towards speeding, sensation-seeking tendencies, driving offences (e.g., not wearing a seatbelt, driving while having a blood alcohol concentration above the legal limit), driving experience, driving frequency, and demographic characteristics. Copies of the survey were distributed to a random sample of 5,000 households in Queanbeyan, New South Wales. A total of 524 (10.5%) surveys were returned. After the exclusion of those who did not meet the eligibility criteria, data from 478 respondents (men=277, women=201) were available for analysis.

Being younger, having high sensation seeking tendencies, and having either no post-secondary education or a trades-related certificate increased the likelihood of being a motor sport fan. After controlling for age, education level and sensation seeking tendencies, there was no direct association between being a motor sport fan and reporting speeding on public roads or other driving offenses although there was an indirect effect on speeding violations through attitudes towards speeding. In other words, motor sport fans were more likely than non-motor sport fans to show positive attitudes towards going over the speed limit, and having these positive attitudes was associated with reporting more speeding violations. The only factor that was directly associated with speeding and other offences was younger age.

These findings suggest that those with an interest in motor sport are more likely than those who are not to believe that speeding is acceptable, and this acceptance of speeding is associated with speeding offenses. Of note is that the survey did not inquire about motor sport driving specifically, and therefore, it is not known whether the relationships found in the study would differ between motor sport fans and motor sport drivers or passengers. Also, there was a limited number of potential confounders (age, education level and sensation seeking tendencies) included in the modelling. Driving exposure was not included.

### ***3.4 Motor sport and adolescents/young adults with childhood attention-deficit hyperactivity disorder (Wymbs et al., 2013)***

Wymbs et al. (2013) investigated the relationship between childhood attention-deficit hyperactivity disorder (ADHD) and motor sport participation in US men. The researchers recruited from a pool of 516 eligible candidates who had been diagnosed with the DSM-III-R or DSM-IV (Diagnostic and Statistical Manual of Mental Disorders) criteria for ADHD in childhood and had received treatment from the Attention Deficit Disorder Clinic at the Western Psychiatric Institute and Clinic in Pittsburgh, Pennsylvania, between 1987 and 1996. Of the 516, 364 agreed to participate in a follow-up study between 1999 and 2003. Data for this study was collected during the first follow-up interview. Exclusion of those who did not

meet the study's eligibility (had to be aged 16-25 years, driving age, to be included), resulted in a sample of 221 young men with ADHD being included. Females were excluded because there were too few identified as being involved in motor sport (n=2).

For a comparison group, 139 men who did not meet the DSM-III-R criteria for ADHD were recruited from the general population in Pittsburgh between 1999 and 2001.

Participants completed a survey for which they were asked about their participation in motor sport (i.e., in auto racing, four wheeling, motorcycle trail biking or ATV driving), impulsive tendencies, conduct disorder/anti-social personality diagnoses, alcohol consumption, driving offences, road accidents, and demographic characteristics.

Compared with the young men who rarely participated in motor sport, those who frequently participated in motor sport were more likely to have been involved in a road accident, to have received a citation for a driving offence, to have been involved in a road accident after consuming alcohol, and to have received a citation for alcohol consumption while driving (Wymbs et al., 2013). Among the young men with ADHD, those who frequently participated in motor sport were more likely to have been involved in a road accident and to have received a citation for driving offences than those who rarely participated in motor sport. Among those without an ADHD diagnosis, those who frequently participated in motor sport were more likely to have received a citation for a driving offence. Otherwise, risky driving behaviours did not significantly differ between those who frequently and those who rarely participated in motor sport.

These findings suggest that particularly for young men with ADHD, being involved in motor sport could inspire them to engage in at least some risky driving behaviours, thereby putting themselves and others at risk of being involved in a road accident. There was some risk of unsafe driving behaviour among those without ADHD, but the association was found to occur more strongly among those with a history of ADHD.

It should be noted that the focus on men with a certain diagnosis limits the generalisability of the findings of this study to other populations. Also, because the group with the diagnosis and the group without a diagnosis were recruited from different settings, there could be differences in the two groups that were not accounted for in the analysis. Also notably, for the measure of motor sport participation study participants were asked to describe their frequency of participation in four types of motor sport, with those reporting that they "used to do it regularly" or that they "do it now, very often" considered to be motor sport participants. More detailed information about motor sport participation than examined is likely to be needed to better understand associations between motor sport and negative driving outcomes. Last, the confounders that were included in analysis were limited to demographic characteristics: age, living with parents, household income and education.



### ***3.5 Motor sport, risky driving behaviours, and driving offences (Yildirim-Yenier et al., 2015)***

Yildirim-Yenier et al. (2015) surveyed members and visitors of Canadian car clubs or motor racing websites to learn about the relationship between risky driving behaviours, driving offences, and road collisions in Canada. Their online survey included questions about attitude towards illegal street racing, road collisions in the past 5 years, driving offences in the previous year, driving frequency, driver's licence held, and demographic characteristics. After respondents who were not eligible or had missing data were excluded, the final sample consisted of 366 respondents (men=341, women=25).

Having a positive attitude towards street-racing and stunt driving was associated with reporting speeding behaviour and aggressive driving behaviour, such as honking the horn or swearing out of frustration, and reporting either type of risky driving behaviour was associated with reporting a citation for a driving offence (Yildirim-Yenier et al., 2015). However, engaging in risky driving behaviours was not associated with being involved in a road collision (Yildirim-Yenier et al., 2015). These findings suggest that individuals who are supportive of street-racing and stunt driving are less likely to be compliant with road rules and are more likely to engage in risky driving behaviours than those who are not. Of note was the over-representation of males, the grouping of everyone with an interest in motor sport together (e.g., no differentiation between spectators and drivers), and the limited number of potential confounders (age, gender and driving frequency) included in the modelling.

### ***3.6 Motor sport, sensation seeking tendencies, attitudes towards speeding, and driving offences (Yildirim-Yenier et al., 2016)***

Using data from the same dataset as the previous study, Yildirim-Yenier et al. (2016) examined the relationships among sensation seeking tendencies, competitive attitudes towards driving, attitudes towards speed limits, and speeding offences. They also tested whether or not these relationships differed between motor sport spectators and motor sport drivers. After excluding respondents who were not eligible or had missing data, the final sample included 408 participants (men=381, women=27). Of these, 45 were not involved in motor sport, 136 were spectators only, and 224 were motor sport drivers or passengers.

Being older and having high sensation-seeking tendencies were characteristics associated with motor sport involvement (Yildirim-Yenier et al., 2016). For both motor sport spectators and drivers/passengers, sensation-seeking tendencies and a competitive driving attitude were associated with reporting speeding offences. For motor sport drivers or passengers, having a negative attitude toward speed limits was also associated with reporting speeding offences. The researchers suggested that because motor sport involvement is costly, older people, being more likely to have the necessary financial resources, are more likely to be actively involved in motor sport than younger people. They also suggested that individuals who have high sensation-seeking tendencies and competitive driving attitudes may feel road rules are too restrictive. Therefore, such individuals may frequently not comply with road rules, in order to enhance

their driving experience by engaging in risky driving behaviours such as speeding. As with other studies of motor sport, in this study the sample was predominately men. Although the researchers identified age as a significant factor associated with motor sport involvement, there was a limited number of potential confounders (age, gender, education and driving frequency) included in the modelling. This study does not appear to control for other potentially-important factors, such as socio-economic status or motor sport experience.

### *3.7 Summary*

Previous researchers have consistently found that motor sport involvement and high sensation-seeking tendencies are associated with risky on-road driving behaviours and driving offences, especially speeding. The previous studies have also consistently showed that men are much more likely to be interested in or involved in motor sport than women.

However, the association between motor sport involvement and road crashes remains unclear. With only six studies that have investigated the association between motor sport involvement and on-road safety and not all of them examining crashes, there is currently not sufficient evidence to conclude that these associations exist. Most of these studies shared similar types of limitations. One issue is the use of self-reported data about driving offence and road crashes, but it should be noted that for collection of data from a large sample, gathering self-reported data is often the most feasible way to collect the data and to then be able to link it with behaviours, attitudes and previous experiences of individuals. Important issues with the data collection have been the large amounts of missing data in self-reported data and limited adjustments for potential confounding factors in the analysis. Some important factors relevant to motor sport that were not typically controlled for in previous studies include the frequency of motor sport involvement and level of motor sport experience and knowledge. Only a few of the studies captured driving exposure. Furthermore, motor sport licensing is required to become an official motor sport driver, yet none of the studies explored specialised motor sport driver training. Specialised driver training may be necessary for learning driving skills important for competing in motor sport. However, it is unknown whether or not those driver-skills specific for competitive motor sport would affect driver behaviours, on-road safety, driving offences, and road crashes. Gaining a more comprehensive understanding of the relationship between driver training and motor sport involvement will be an important step in understanding which factors increase or decrease the risk of crashes on public roads.

*Table 3*

*Details of articles included in the review of the motor sport literature*

Authors & Scope of Research	Aim	Study Design & Sample	Measures	Main Results	Limitations
<p>Williams &amp; O'Neill (1974)</p> <p>Florida, New York, and Texas, US</p>	<p>To explore whether motor sport drivers have skills and training that lead to reduced crash experiences</p>	<p><b>Study design:</b> Case-control</p> <p>Review of all reported crashes and driving offences listed on the driving records of licensed motor sport drivers and a comparison group of non-motor sport drivers</p> <p><b>Context:</b> Names and addresses of national competition licence holders in Florida, New York, and Texas was obtained from the Sports Car Club of America in 1971.</p> <p>A control group of non-motor sport drivers was made by matching each motor sport driver on the basis of data collected by state motor vehicle records.</p> <p><b>Final sample:</b> N=1500 Motor sport drivers=447 Controls=1053</p>	<p><b>Outcomes:</b> Number of reported crashes and driving offences (speeding, movement offences, non-movement offences) from 1966-1972 (Florida), 1965-1972 (New York), 1967-1972 (Texas).</p> <p><b>Predictors:</b> Motor sport driver status (motor sport driver/non-motor sport driver)</p> <p><b>Confounder:</b> Distance driven in previous year in a subgroup of the New York sample</p> <p><b>Matching:</b> Florida: 1 motor sport driver matched to one non-motor sport driver based on age, sex, race Texas: 1 motor sport driver matched to 3 non-motor sport drivers based on age, sex, and geographical location New York: 1 motor sport driver matched to 3 non-motor sport drivers based age, sex, and licence type</p> <p><b>Analysis:</b> Conditional binomial test</p> <p><b>Definition of motor sport driver:</b> Being listed as having a national competition licence with the Sport Car Club of America in 1971</p>	<p>In all three states, motor sport drivers had more crashes, on average, than non-motor sport drivers. The results were statistically significant in Florida (<math>p=0.02</math>) and New York (<math>p=0.001</math>).</p> <p>In all three states, motor sport drivers reported statistically significantly (<math>p&lt;0.001</math>) more speeding offences than non-race drivers.</p> <p>Motor sport drivers reported more movement offences than non-motor sport drivers, but the difference was not statistically significant (<math>p&gt;0.10</math>) in any of the three states.</p> <p>Motor sport drivers reported more non-movement offences than non-motor sport drivers. The difference was only statistically significant in New York (<math>p=0.002</math>).</p> <p>In New York, the distance driven in the previous year did not explain motor sport drivers' increased number of crashes and driving offences when compared to non-motor sport drivers of the same age and sex.</p>	<p><b>Limitations noted by the researchers:</b> Information on motor vehicle registrations was not complete.</p> <p>The researchers suggested that motor sport drivers in New York drove more miles in the previous year than non-motor sport drivers of the same age and sex. However, the available information on the distance driven per year was too limited to draw any conclusions. Future studies should take into account the distance driven in a given period of time.</p> <p><b>Other limitations:</b> Over-representation of men.</p> <p>Outcome (offences) were mostly measured before the predictor (motor sport driver status).</p> <p>Limited adjustments for potential confounders including no adjustments for attitudes towards driving and limited data available to examine exposure to driving. Groups could have differed in ways not captured by the variables used to conduct the matching.</p>

		<p>Average age of the motor sport drivers: 36 in Florida 35 in New York 35 in Texas</p> <p>Only 4 motor sport drivers were women.</p> <p><b>Response rate:</b> Not applicable</p>			
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Authors & Scope of Research	Aim	Study Design & Sample	Measures	Main Results	Limitations
<p>Warn, Tranter &amp; Kingham (2004)</p> <p>Christchurch, New Zealand</p>	<p>To investigate the relationship between interest in motor sport, illegal street-racing, sensation seeking, and risky driving behaviours in young male drivers</p>	<p><b>Study design:</b> Cross-sectional survey</p> <p><b>Recruitment:</b> A survey was distributed to a population of secondary students, first year university students, and polytech motor vehicle engineering students.</p> <p><b>Final sample:</b> N=158</p> <p>Restricted to males &lt;25 years of age</p> <p>Median age =18 years</p> <p>Median time a licence has been held = 3 years</p> <p><b>Response rate:</b> Not provided</p>	<p><b>Outcomes and predictors:</b> Sensation seeking tendencies, risky driving behaviours, involvement in motor sport, involvement in street-racing, risk perception, attitudes towards speeding.</p> <p><b>Analysis:</b> Two separate path analyses were conducted. The first analysis tested if sensation seeking tendencies, involvement in motor sport, risk perception, and attitudes towards speeding predicted risky driving behaviours. The second analysis tested if these same factors predicted involvement in street-racing.</p> <p><b>Definition of involvement in motor sport:</b> 7-item scale that measured number of motor sport events watched on TV and in person in previous year, being a driver or rider in a motor sport event ever, attendance at a drag racing event ever, attendance at a local raceway ever, interest in motor sport as a child, current interest in motor sport.</p> <p><b>Survey items based on:</b> Brief Sensation Seeking Scale Driver Behaviour Questionnaire</p>	<p>Involvement in motor sport increased the likelihood of risky driving behaviours both directly and indirectly through attitudes towards speeding. This means that participants who were involved in motor sport were more likely to have positive attitudes towards speeding, and these positive attitudes increased the likelihood of engaging in risk driving behaviours.</p> <p>Having sensation seeking tendencies was directly associated with risky driving behaviours and indirectly through involvement in motor sport.</p> <p>Involvement in motor sport and having sensation seeking tendencies were directly associated with involvement in street-racing. Involvement in motor sport had a strong direct effect on the likelihood of being involved in street-racing, regardless of a participant's sensation seeking tendencies.</p>	<p><b>Limitations noted by the researchers:</b> The sample only included young men.</p> <p><b>Other limitations:</b> Cross-sectional, self-report data.</p> <p>Some survey items asked about driving behaviours. However, respondents who were in secondary school may not have had a driver's licence. If they had not driven on the road before, they may not have been able to accurately respond to those questions.</p> <p>Motor sport spectators were not examined separately from motor sport participants (drivers or passengers).</p> <p>Limited number of confounders was included in analyses. The influences of demographic characteristics and driving exposure were not examined.</p>

Authors & Scope of Research	Aim	Study Design & Sample	Measures	Main Results	Limitations
<p>Tranter &amp; Warn (2008)</p> <p>Queanbeyan, New South Wales, Australia</p>	<p>To examine the relationship between the level of interest in motor sport and the speeding behaviours and attitudes of motor sport drivers</p>	<p><b>Study design:</b> Cross-sectional survey</p> <p><b>Recruitment:</b> A household survey was distributed to a random sample of households.</p> <p><b>Final sample:</b> N=478 ♂ non-fans=111 ♂ fans=166 ♀ non-fans=134 ♀ fans=67</p> <p>Respondents were eligible if they were aged ≤25 years and had &gt;2 years of driving experience.</p> <p><b>Response rate:</b> 10.5%</p>	<p><b>Outcomes and predictors:</b> Level of interest in motor racing, attitudes towards speeding, sensation-seeking tendencies, self-reported speeding offences, other driving offences.</p> <p><b>Confounders:</b> Age and education level.</p> <p><b>Analysis:</b> Path analysis was conducted to test whether being a motor sport fan increased the likelihood of engaging in risky driving behaviours after adjusting for confounders. Separate analysis conducted for men and women.</p> <p><b>Definition of a motor sport fan:</b> Agreed that “I am a motor racing fan” or that “I enjoy watching motor racing.”</p> <p><b>Survey items based on:</b> Driver Behaviour Questionnaire Brief Sensation Seeking Scale</p>	<p>The only factor that was directly associated with speeding and other offences was younger age.</p> <p>There was no direct association between being a motor sport fan and reporting speeding on public roads or other driving offenses although there was an indirect effect on speeding violations through attitudes towards speeding. This means that motor sport fans were more likelihood than non-motor sport fans to show positive attitudes towards going over the speed limit, and this positive attitude was associated with having more speeding violations.</p> <p>Being younger, having high sensation seeking tendencies, and having either no post-secondary education or a trades-related certificate increased the likelihood of being a motor sport fan.</p>	<p><b>Limitations noted by the researchers:</b> The researchers did not state any limitations of their study.</p> <p><b>Other limitations:</b> Cross-sectional, self-report data.</p> <p>Broad definition of motor sport fan. Thus, it is not possible to differentiate between motor sport spectators versus drivers or their passengers.</p> <p>Limited number of potential confounders examined. These did not include driving exposure.</p>

Authors & Scope of Research	Aim	Study Design & Sample	Measures	Main Results	Limitations
<p>Wymbs, Molina, Belendiuk, Pedersen, Walther, Cheong, McGinley, Marshal, Gnagy &amp; Pelham (2013)</p> <p>Pennsylvania, US</p>	<p>To examine whether adolescents and young adults with childhood ADHD are more likely than those without childhood ADHD to report frequent engagement in motor sport</p>	<p><b>Study design:</b> Case-control</p> <p><b>Recruitment:</b> Cases were young adults or adolescents who had been diagnosed with ADHD in childhood and treated at the Western Psychiatric Institute and Clinic in Pittsburgh from 1987 to 1996 and who participated in a follow-up study between 1999 and 2003.</p> <p>Controls were recruited from the community, 1999 to 2001, in Pittsburgh.</p> <p>Recruited participants completed a survey online and on hardcopy.</p> <p><b>Final sample:</b> N=360 males Cases=221 Controls=139 Aged 16-25 years</p>	<p><b>Outcomes and predictors:</b> Involvement in motor sport, persistent impulsivity, a comorbid conduct disorder or antisocial personality disorder diagnoses, alcohol consumption, self-reported road accidents and driving offence citations.</p> <p><b>Confounders:</b> Age, living with parents, household income, education level.</p> <p><b>Analysis:</b> Path analysis tested whether persistent impulsivity, comorbid conduct disorder or antisocial personality disorder, and heavy alcohol use mediated the association between childhood ADHD diagnosis and frequent involvement in motor sport.</p> <p><b>Definition of motor sport involvement:</b> 4-item survey adapted from Donovan (1993)'s thrill-seeking scale. Items asked about auto racing, four wheeling, motorcycle trail biking and ATV driving. Participants were classified as "frequent motorsporters" if they reported they "used to do it regularly" or "do it now, very often" for 1+ of the 4 motor sports listed.</p> <p><b>Survey items based on:</b> Eysenck Impulsivity Scale Young Adult Driving Questionnaire</p>	<p>Adolescents and young adults with an ADHD diagnosis were 3 times more likely than controls to report frequent participation in one or more motor sport activities. Participants who frequently participated in motor sport were more likely to have been in a road accident, to have received a citation for a driving offence, to have been in a road accident after consuming alcohol, and to have received a citation for driving offences after consuming alcohol than participants who rarely participated in motor sport.</p> <p>Among participants with an ADHD diagnosis, those who frequently participated in motor sport were more likely to have been in a road accident, to have received a citation for a driving offence, including after consuming alcohol, than those who rarely participated in motor sport.</p> <p>Among participants without an ADHD diagnosis, those who frequently participated in motor sport were more likely to have received a citation for a driving offence. Otherwise, risky driving behaviours did not significantly differ between those who frequently and those who rarely participated in motor sport.</p> <p>Impulsivity was not directly associated with frequent participation in motor sport.</p>	<p><b>Limitations noted by the researchers:</b> The sample included only males. Females were excluded because only 2 reported motor sport participation.</p> <p>The researchers noted that people with ADHD tend to under-report their symptoms and impairments, and it is therefore possible that they would also under-report their road accidents, offences and drinking behaviour. Also, the researchers note that the people in the study had received treatment for their ADHD as children, and the results could have been different for those with ADHD who had not received such treatment.</p> <p><b>Other limitations:</b> Cross-sectional, self-report data.</p> <p>The study focused on a very specific population of people. The outcomes are unlikely to be representative of those that would be seen in the general population.</p> <p>Assessment of participation in motor sport was limited as the items only assessed involvement in four types of motor sport and were broadly defined. Other aspects of involvement were not measured. Limited number of potential confounders examined. These did not include attitudinal variables or driving exposure.</p>



Authors & Scope of Research	Aim	Study Design & Sample	Measures	Main Results	Limitations
<p>Yildirim-Yenier, Vingilis, Wiesenthal, Mann, &amp; Seeley (2015)</p> <p>Ontario, Canada</p>	<p>To examine the relationships among high-risk driving attitudes, risky driving behaviour, and collisions and driving offense citations, in car and racing enthusiasts</p>	<p><b>Study design:</b> Cross-sectional online survey</p> <p><b>Recruitment:</b> Participants were members and visitors aged 16+ years of car club and racing websites in southern Ontario. Invitations to potential participants were posted on the websites.</p> <p><b>Final sample:</b> N=366 ♂=341 ♀=25</p> <p><b>Response rate:</b> 26.1%</p>	<p><b>Outcomes and predictors:</b> Attitudes towards new penalties and new offences for Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation, general attitudes towards street racing and stunt driving, risky driving behaviours, self-reported road collisions and driving offence citations.</p> <p><b>Confounders:</b> Age, gender, and driving frequency</p> <p><b>Analysis:</b> Factor analysis and structural equation modelling.</p> <p><b>Definition of “car and racing enthusiasts”:</b> Member or a visitor to a car club or racing website</p> <p><b>Survey items based on:</b> Driver Behaviour Questionnaire Self-Report Driver Aggression Questionnaire</p>	<p>Having negative attitudes toward new offenses of stunt driving under new legislation and positive attitudes toward street racing and stunt driving were associated with reporting speeding behaviour (<math>p \leq 0.001</math>), which was associated with reporting driving offence citations (<math>p \leq 0.05</math>).</p> <p>Having positive attitudes toward street racing and stunt driving was also associated with reporting aggressive driving behaviour, such as honking horn or swearing out of frustration (<math>p \leq 0.01</math>), which was associated with reporting driving offence citations (<math>p \leq 0.01</math>).</p>	<p><b>Limitations noted by the researchers:</b> There was an over-representation of men.</p> <p><b>Other limitations:</b> Cross-sectional, self-report data.</p> <p>Motor sport spectators were not differentiated from motor sport participants (drivers or passengers).</p> <p>Limited number of potential confounders examined.</p>

Authors & Scope of Research	Aim	Study Design & Sample	Measures	Main Results	Limitations
<p>Yildirim-Yenier, Vingilis, Wiesenthal, Mann, &amp; Seeley (2016)</p> <p>Ontario, Canada</p>	<p>To examine the relationship between motor sport involvement with age, education, thrill seeking, speeding attitudes, and driving violations</p>	<p><b>Study design:</b> Cross-sectional online survey</p> <p><b>Recruitment:</b> Participants were members and visitors aged 16+ years of car club and racing websites in southern Ontario. Invitations to potential participants were posted on the websites.</p> <p><b>Participants:</b> N=408 ♂=381 ♀=27</p> <p>Non-motor sport ♂=45 ♀=3</p> <p>Motor sport spectator ♂=123 ♀=13</p> <p>Motor sport driver ♂=213 ♀=11</p> <p><b>Response rate:</b> 26.1%.</p>	<p><b>Outcomes and predictors:</b> Involvement in motor sport, driving offences, attitudes towards speed limits, competitive driving attitudes, sensation seeking tendencies</p> <p><b>Confounders:</b> Age, gender, education level, and driving frequency</p> <p><b>Analysis:</b> Path analysis was used to examine the associations among variables. Separate analyses for spectator only and driver participants were also conducted.</p> <p><b>Definition of motor sport involvement:</b> Motor sport drivers reported that they had “ever been a driver (or passenger) in an official racing event. Motor sport spectators reported that they had “ever attended an official racing event as a spectator”.</p> <p><b>Survey items based on:</b> Driver Behaviour Questionnaire Self-Report Driver Aggression Questionnaire Driver Thrill Seeking Scale</p>	<p>Being older was positively associated with involvement in motor sport.</p> <p>Having high sensation seeking tendencies was positively associated with involvement in motor sport, competitive driving attitudes, and reporting speeding offences.</p> <p>Involvement in motor sport directly predicted having competitive driving attitudes, which was positively associated with reporting speeding offences.</p> <p>For both motor sport spectators and drivers, having high sensation seeking tendencies was associated with reporting speeding offences, and having competitive attitudes towards driving, which itself was associated with reporting speeding offences.</p> <p>Also, having high sensation seeking tendencies was associated with having negative attitudes towards speed limits, and among motor sport drivers/passengers, having these negative attitudes was associated with reporting speeding offenses.</p>	<p><b>Limitations noted by the researchers:</b> This study targeted only people who were interested in cars and racing.</p> <p>There was uncertainty about how representative the sample was of the car and racing enthusiast populations.</p> <p>Men were over-represented; some under-representation of people aged 55+ years.</p> <p>The study did not assess income of participants. Older people are more likely to earn higher incomes and to have the financial resources to participate in motor sports than younger people. Therefore, the researchers encouraged future research to account for income and expenses spent on motor sport.</p> <p><b>Other limitations:</b> Cross-sectional, self-report data.</p> <p>Limited number of potential confounders examined.</p>

## SECTION 4: CONCLUSIONS

The aim of this report was to review previous studies and reviews that evaluated the effectiveness of pre- and post-licence driver training and graduated driver licensing systems in improving on-road safety as well as studies that examined links between motor sport involvement and road safety. Summaries of the findings in the literature are discussed below.

### *4.1 Driver training and graduated driver licensing systems*

Although research on pre- and post-licence driver training is abundant, there is limited to no evidence to show that technical skills acquired from driver training has a direct effect on reducing road crash risk. Rather, evidence shows that the combination of acquired technical driving skills, frequent engagement in driving practice, and desires to develop and engage in safe driving behaviours is more important in reducing road crash risk than acquired technical driving skills alone. Graduated driver licensing systems with components that delay time to full licensure and impose driving restrictions on learner and probationary licence drivers have been shown to be effective in reducing road crash risk in young drivers. Post-licence driver training that specialises in teaching technical driving skills has been shown to be counterproductive to improving on-road safety, but there is some limited evidence that training that focuses on teaching higher-order cognitive skills promotes safe driving behaviours. These findings suggest that driver training that teaches cognitive skills, encourages mastery of driving skills, and promotes safe driving behaviours are more effective at reducing crash risk than driver training that only teaches technical skills. Previous reviewers of these studies, however, have reported that evaluations of driver training often have methodological issues that weaken the validity of findings or there has not been enough robust evidence to draw reliable conclusions. Methodological issues include poor sampling, inappropriate control groups, short evaluation timeframes, reporting bias, and failure to control for important confounding factors in the analyses. More rigorous research methods will be needed to determine the effectiveness of driver training in reducing crash risk, especially to examine outcomes in the years ahead after completing driver training.

### *4.2 Motor sport involvement*

Evidence from the scientific literature indicates that motor sport involvement and high sensation-seeking tendencies are positively associated with engaging in risky on-road driving behaviours and reporting of driving offences, especially speeding. Research has also consistently shown that men are more likely than women to be interested in motor sport. However, there are too few studies to date that have examined the association between motor sport involvement and on-road safety to draw reliable conclusions about these associations. In most of these studies large amounts of

missing data have been noted. Furthermore, most studies have not controlled for important confounding factors, such as exposure (time spent driving or distance driven on public roads), demographic characteristics of the population beyond age and gender (e.g., socio-economic status), attitudes about driving, and specifics about motor sport involvement, such as frequency of motor sport involvement, level of motor sport experience and knowledge, and participation in specialised motor sport driver training. Only a few studies have used complex statistical modelling (e.g., path analysis) to examine associations between motor sport and other factors and crash risk. Therefore, future research that addresses these methodological concerns is needed to better understand the association between motor sport participation and increased road crash risk after accounting for other important influences on crash risk.

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