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Reducing Young Drivers' Crash Risk: Are We There Yet?

An Ecological Systems-Based Review of the Last Decade of Research

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Abstract

The involvement of young novice drivers in road crashes and violations has remained a significant transport and public health issue worldwide. Despite extensive evidence that multiple individual, social, and environmental factors contribute to risk while driving, crashes among young novice drivers have decreased only marginally. There is a need to define clear indicators of risk as well as develop effective interventions.

The current study reviews the literature on young novice drivers, including empirical studies, systematic reviews, and crash reports published over the past ten years to provide a synthesis of risk and protective factors across multiple domains, from individual characteristics, to social influences, to behavioural and social interventions, to the car and road environment. Adopting an ecological systems perspective, we discuss links between these domains to clarify the strongest indicators of risk for young novice drivers as compared to experienced drivers, and we collate the available evidence on social and environmental factors that can improve young drivers' behaviour so to reduce the rate of their road crashes.

Among the factors discussed, the incomplete maturation of cognitive skills crucial to safe driving (visual scanning, hazard anticipation, handling of in-vehicle distractions) and the higher susceptibility to social influences (especially peers and parents) emerged as the strongest determinants of discrepancies in performance between young novice and experienced drivers. Growing awareness of the complex array of factors intervening synergistically in young drivers' risk, as well as technological advancements have led to the design of interventions with some level of effectiveness, however, further research and more robust programmes adopting ecological and holistic approaches are needed to fully address the young driver problem.

Keywords: young driver; novice; risk; ecological systems; development.

Highlights:

- We review the last decade of research on young drivers' crash risk
- Individual, social, and environmental risk/protective factors are discussed
- An ecological framework is proposed to understand synergies between factors
- Positive learning and social experiences can reduce young drivers' risk
- Future interventions should consider young drivers in the contexts of their development

1. Introduction

Although reductions in young novice drivers' crash rates have been reported in the literature, for example in the U.S. (Ferguson, Teoh, & McCartt, 2007), this demographic group continues to be over-represented in car crashes and road fatalities worldwide, especially if male (Al-Aamri, Padmadas, Zhang, & Al-Maniri, 2017; T. Brown, George, Rickwood, & Frost, 2016; Curry, Pfeiffer, Durbin, & Elliott, 2015; Elvik, 2010; S. E. Lee, Simons-Morton, Klauer, Ouimet, & Dingus, 2011; Sheridan, Howell, Mckeown, & Bedford, 2011; Shope & Bingham, 2008; Spoerri, Egger, & Von Elm, 2011; Toroyan & Peden, 2007). Extensive literature has demonstrated that multiple internal and external factors contribute to crash risk for young novice drivers, and a number of contributions have attempted to synthesise intervening factors (L. J. Bates, Davey, Watson, King, & Armstrong, 2014; Shope & Bingham, 2008). However, many studies have focused on specific determinants of crash risk or prevention rather than exploring synergies between factors, which reflects the difficulty of addressing such a multifaceted topic. Using a more holistic approach, recent publications have adapted ecological perspectives to consider the complex interaction of risk and protective factors associated with crashes or injuries (Buckley, Chapman, & Sheehan, 2014; Scott-Parker, Goode, & Salmon, 2015; Scott-Parker, Goode, Salmon, & Senserrick, 2016). Ecological systems theory was first developed by Bronfenbrenner (1979) and maintains that human development depends on the synergistic interplay of different systems of individual and socio-environmental influences across different systems: 1) the individual and their cognitions, attitudes, and personalities; 2) the micro-system of proximal social and environmental influences; 3) the macro-system of the cultural and geographical context.

Applying ecological systems theory to young drivers' crash risk is useful for a number of reasons. Firstly, it enables to categorise factors of development based on how immediate and direct their impact on the development is (i.e., it distinguishes proximal and distal factors). Secondly, it stimulates to investigate interconnections between factors: Individual circumstances (e.g., experience or attitudes) can affect young drivers' performance in different social or environmental circumstances, but on the other hand, social and environmental factors (e.g., parents, training, or a safe car and road environment) can moderate the effect of individual characteristics on crash risk. Furthermore, applying ecological systems theory to young drivers has the advantage of taking into account developmental circumstances that may influence their risk (Johnson & Jones, 2011). Teenagers and young adults experience considerable physical, mental, and social changes

that, together with inexperience behind the wheel, can impact negatively on driving performance (Glendon, 2011; Scott-Parker, 2017). Parts of the brain that are crucial to safe driving, particularly the prefrontal cortex which is involved in attention and decision-making, may not be fully developed up to the age of 25, limiting a young motorist's ability to deal with complex road situations (Glendon, 2011; Romer, Lee, McDonald, & Winston, 2014; Underwood, 2007). Furthermore, brain and emotional development can limit the level of psychosocial maturation and behavioural control displayed by young individuals, making them more prone to unsafe driving behaviours which exacerbate the risk of road crashes. Speeding, drink-driving, distracted driving, not wearing seat belts, and aggressive driving have been indicated as the most common causes of road crashes in young adulthood (Begg, Brookland, & Connor, 2017; Bingham, 2014; Russo, Kay, Savolainen, & Gates, 2014; Sarma, Carey, Kervick, & Bimpeh, 2013; Scott-Parker, Watson, King, & Hyde, 2014a; Weiss, Kaplan, & Prato, 2014; Zhang & Chan, 2016). Because developmental processes can affect driving performance and behaviour, comparing young novice and experienced motorists can help to identify determinants of risk that specifically apply to young novice drivers. However, the development that young adults are undergoing is also more positively associated with mental fluidity, enabling them to improve their driving performance and behaviours if exposed to positive learning and social experiences (Glendon, 2011; Keating & Halpern-Felsher, 2008). Thus, identifying programmes and interventions that have been effective in reducing young drivers' risk across the individual, social, and environmental domains is useful to clarify which factors best enhance the learning process. Ecological perspectives have been proposed in relation to young peoples' risk of injury (Johnson & Jones, 2011) and in terms of specific driving-related issues such as distractibility (Buckley et al., 2014). However, to our knowledge, there are no overviews of recent research on young drivers' crash risk that adopt ecological systems theory. By adopting Bronfenbrenner's model, and building upon previously developed frameworks (L. J. Bates et al., 2014; Buckley et al., 2014; Scott-Parker, Goode, et al., 2015; Shope & Bingham, 2008), the present review provides an overview of the past ten years of evidence on factors of young novice drivers' crash risk as well as, crucially, the links between factors. The key unique contribution of adopting an ecological systems approach is that the many levels of factors, as well as the interactions between factors, can be more clearly understood and examined. There is a wealth of research on young driver crash risk, making it difficult to clearly visualise and structure the many intervening factors, for both researchers in the field and those who may be new to the area (e.g., policy makers, insurance providers). The ecological systems model has proven

useful for understanding development and we feel it is well placed to aid our understanding of young driver crash risk.

The aim of this review is to: 1) Identify the most important indicators of crash risk in young novice drivers as compared to experienced drivers, considering individual, social, and environmental circumstances; 2) Highlight the most effective preventive factors for young drivers; 3) Note gaps in current knowledge that will need to be addressed in future research.

2. Search Method

The review aimed to synthesise the evidence on risk and protective factors of young drivers' crashes published after a previous contribution (Shope & Bingham, 2008) that provided a comprehensive account intervening factors. For this reason, our search focused on papers published between 2007 and 2017, and for which the full-text was available in English language. The search included empirical studies (qualitative and quantitative), systematic reviews, meta-analyses, doctoral dissertations, and government or police records on crashes. Searches were conducted on PubMed and PsycInfo. Search words included ("young driver" OR "novice driver") AND ("risky driving" OR "crash*" OR "accident*") AND ("age" OT "experience*") present in the title or abstract. Specific driving-related journals (Transportation Research Part F: Psychology and Behaviour; Accident Analysis and Prevention; Traffic Injury Prevention) were also hand-searched for the period 2007-2017. Google scholar was hand searched for government or police records. The search took place between June and November 2017. A total of 370 abstracts were screened by both authors for inclusion, with 98 titles being removed as duplicates. After full-text inspection, a further 76 papers were excluded because they did not compare drivers based on age and/or experience or did not describe an intervention. A total of 196 papers were deemed eligible for inclusion in the review.

3. Framework

In the following sections, factors that contribute to increase or reduce young drivers' crash risk are described under the following categories: individual characteristics, social influences (parents and peers, training), car and road environmental circumstances, and the broader socio-cultural and geographical context. Such categorisation is based on frameworks of factors of young drivers' crash risk previously proposed in the literature (L. J. Bates et al., 2014; Shope & Bingham, 2008), and structured to be in line with ecological systems theory

(Bronfenbrenner, 1979), as shown in Figure 1. We begin with the individual domain (the central circle in the figure) by considering driving-related cognitive skills, attitudes, personality characteristics, emotions, and socioeconomic circumstances that can increase or decrease young novice drivers' risk. Secondly, we discuss the micro-system of proximal social factors (parents, peers, driving experience, training, and interventions) and environmental influences (car and road environment) that can moderate individual characteristics and affect young drivers' risk most immediately and directly. We then synthesise the available evidence on the broad socio-cultural context (macro-system) including cultural attitudes, law enforcements, and safety campaigns, that can have a more indirect (i.e., "distal") influence on young drivers' risk.

In the Discussion (section 8), we highlight how an ecological perspective is useful to clarify links between factors across different systems, at the level of the meso-and exo-system (see Figure 1). The meso-system includes interconnections between individual and micro-level social and environmental factors, and in the case of driving refers, for instance, to the influence that parents can have on the effects of young drivers' training, or to the distracting effects of peer passengers on certain roads and at certain times of the day. The exo-system is instead the level were proximal and distal factors influence each other: for example, law enforcements can limit dangerous in-car circumstances, but on the other hand social groups can influence a young driver's attitudes towards road rules. We argue that identifying such links and applying them to existing interventions is key to reducing young drivers' risk. Lastly, we note changes in the knowledge about young drivers' risk occurred in the past ten years, and we suggest directions for future research on the topic.

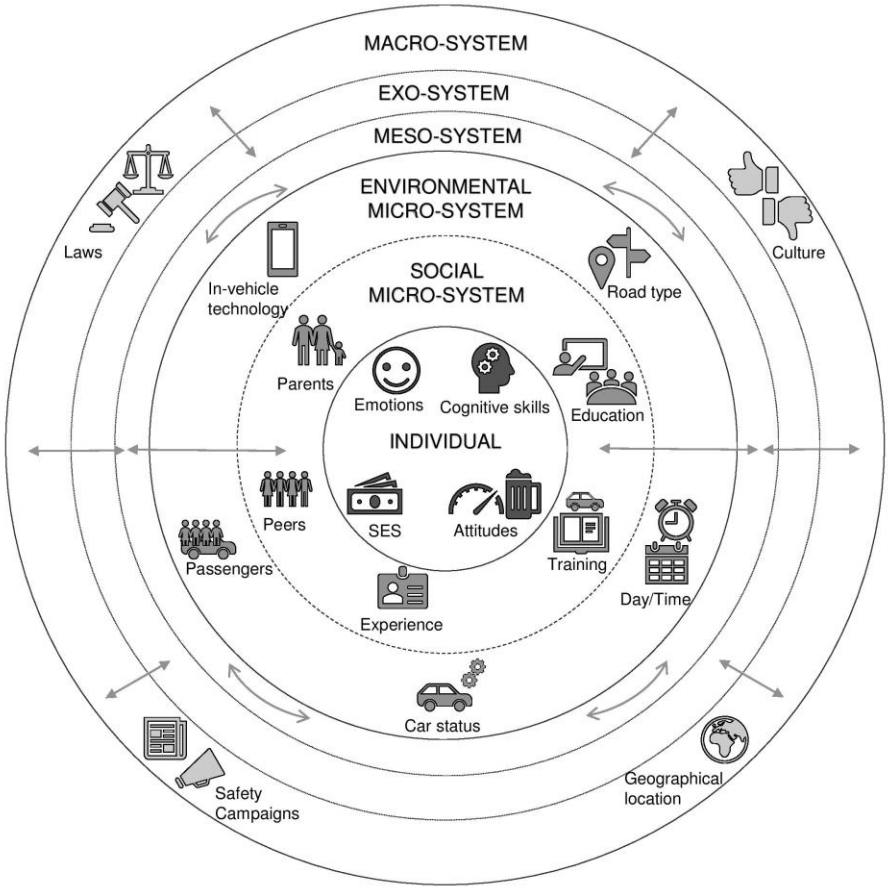


Figure 1: Framework of individual, social, and environmental factors intervening in young novice drivers' risk using an ecological systems model (Bronfenbrenner, 1979). Arrows indicate links between factors within and between systems.

4. Individual Factors

4.1 Driving-Related Cognitive skills

Skills such as visual search, hazard perception, inhibition of distractions, and decision-making, which are related to executive function, are crucial to effectively control a vehicle and pay attention to what is happening on the road. The incomplete development of brain areas involved in these skills up to the age of 25, together with lack of experience behind the wheel, make young individuals who use a car for the first time less effective drivers than older experienced motorists (Glendon, 2011). For instance, a study in which participants aged 17 to 30 years old completed an attentional task while in a driving simulator found that selective attention improved with age and was significantly associated with a decreased risk of collisions (McManus, Cox, Vance, & Stavrinos, 2015). Another study found lower cognitive impulsiveness, higher sensitivity to situational hazard-related cues, and more situation-congruent actions in an experienced than a young novice group of drivers (Xu, Li, & Jiang, 2014). Controlling for both age and experience in drivers aged 18-22 years old, a study using neuroimaging in a simulated driving environment showed that prefrontal cortex activity associated with inhibitory control (i.e., the ability to manage mental workload) was higher in older (21-22 years old) than younger drivers (18-19 years old) only in the experienced group (with more than 10,000 miles driven), whereas the novice group (less than 5,000 miles driven) performed worse overall, and no age-related differences emerged (Foy, Runham, & Chapman, 2016).

These age- or experience- related differences in executive functions have an important role in determining young novice drivers' crash risk because they can negatively impact hazard perception as well as susceptibility to distractors. This has been demonstrated by a considerable number of studies showing that novice drivers tend to scan the road more narrowly than experienced drivers (Alberti, Shahar, & Crundall, 2014; Chan, Pradhan, Pollatsek, Knodler, & Fisher, 2010; Konstantopoulos, Chapman, & Crundall, 2010; Underwood, 2007), and are less effective in anticipating, detecting, or responding to hazards (Borowsky & Oron-Gilad, 2013; Chan et al., 2010; Crundall, 2016; Imtiaz & Stanley, 2015; Jackson, Chapman, & Crundall, 2009; S. Lee et al., 2008; Nugter, 2017; Parmet, Borowsky, Yona, & Oron-Gilad, 2014; Smith, Horswill, Chambers, & Wetton, 2009; Ventsislavova et al., 2016), especially if the hazards are not clearly visible (Crundall et al., 2012; Madigan, 2013). Hazard perception is such a crucial ability to driving that in some regions it is routinely tested as part of the licensing process (e.g., Queensland, Australia; U.K.), and a

recent study on over 5,800 young novice drivers found that those who failed a hazard perception test as learners were 25% more at risk of being involved in a road crash in the following year (Horswill, Hill, & Wetton, 2015).

Individual differences in the association between executive functions and young drivers' performance have been noted based on personality and attitudes, with studies reporting for example that young drivers with high working memory capacity can display higher sensation seeking and as a consequence higher engagement in risky driving behaviours (Walshe, Ward McIntosh, Romer, & Winston, 2017). Nonetheless, the available evidence indicates that younger drivers tend to experience deficiencies in driving-related cognitive skills which may impair driving performance. Notably, these skills are the individual factors most amenable to improvements through experience and training, as it will be outlined in the subsequent section 5.1 "Experience, Training and Interventions".

4.2 Personal Characteristics

Incomplete brain maturation and inexperience can cause young novice drivers to overestimate their driving skills more than experienced drivers (De Craen, Twisk, Hagenzieker, Elffers, & Brookhuis, 2011; Mynttinen et al., 2009), with a negative impact on the ability to adapt one's driving performance to changing road circumstances (de Craen, Twisk, Hagenzieker, Elffers, & Brookhuis, 2008; de Craen, Twisk, Hagenzieker, Helffers, & Brookhuis, 2007). On the other hand, young inexperienced motorists tend to underestimate the perceived risks associated with driving, for example in relation to using a mobile phone while on the road (Cazzulino, Burke, Muller, Arbogast, & Upperman, 2014). In a study where young (aged 18-34) and older adults (aged 55-82) used the phone during a simulated drive, both age groups' performance decreased significantly, however, young participants were significantly less aware than experienced participants of the magnitude of the negative impact of the secondary task on driving, especially if male (Horrey, Lesch, & Garabet, 2008). This combination of overestimating skills while simultaneously underestimating risk is an important contributor to young drivers' engagement in risky behaviours (Sarma et al., 2013). Interestingly, despite having higher risk perception is associated with lower engagement in risky driving in young drivers (Mirman, Albert, Jacobsohn, & Winston, 2012), that might not necessarily be sufficient to deter young drivers from engaging in unsafe driving (Atchley, Atwood, & Boulton, 2011). Self-perceptions such as high self-efficacy for driving and multi-tasking, as well as high perceived behavioural control, can in fact lead to higher engagement

in risky or distracted driving in young drivers in spite of risk perceptions (Gupta, Burns, & Boyd, 2016; Hill et al., 2015).

Perceptions also interact with personality traits to influence driving attitudes and behaviours (Harbeck & Glendon, 2013; Machin & Sankey, 2008; Mirman et al., 2012). For example, an Australian study with drivers aged under 25 found that participants with low sensation seeking and high risk perceptions showed lower rates of drink-driving and driving while fatigued, together with higher use of seat belts; however moderating effects of risk perceptions did not emerge for participants high in sensation seeking (Hatfield, Fernandes, & Job, 2014). In a recent review of the literature, Scott-Parker and colleagues (2017) reported a positive association between rewards sensitivity and risky driving behaviour across 11 international papers, and noticed an age-related trend in rewards sensitivity, peaking in adolescence and decreasing with older age, as suggested by Steinberg (2010). Some studies have noticed differential correlations between personality characteristics and risky driving behaviours based on drivers' age and experience (Bachoo, Bhagwanjee, & Govender, 2013; T. G. Brown et al., 2017; Cestac, Paran, & Delhomme, 2011; Constantinou, Panayiotou, Konstantinou, Loutsiou-Ladd, & Kapardis, 2011; Endriulaitienė, Žardeckaitė-matulaitienė, & Šeibokaitė, 2013; Sarma et al., 2013). However, the results are inconsistent across studies, as some have indicated a stronger association between risk-accepting personality traits (e.g., sensation seeking, impulsivity) and risky driving in people younger than 25 years old (Bachoo et al., 2013; Cestac et al., 2011; Sarma et al., 2013), whereas others have found the opposite pattern (Endriulaitienė et al., 2013) or age-specific correlations based on the type of risky behaviour investigated (T. G. Brown et al., 2017). In addition, the influence of personality traits on driving attitudes and behaviours can vary across gender groups (Berdoulat, Vavassori, & Sastre, 2013; Miller & Taubman - Ben-Ari, 2010) and across different social and environmental circumstances (Gauld, Lewis, White, & Watson, 2016; McDonald & Sommers, 2015; Taubman – Ben-Ari, Kaplan, Lotan, & Prato, 2016); thus, more research is needed in this area to delineate the role of personality factors, both alone and in conjunction with other variables such as risk perception.

Emotional states can influence driving performance as well. In a recent experimental study, drivers aged 18-21 completed a simulated drive while visually exposed to words that elicited either a relaxed positive emotion ("calm"), an arousing positive emotion ("exciting"), a negative emotion ("sad"), or a neutral word with no relation to emotions ("hat"). Both arousing positive emotions and negative emotions were linked with faster and less safe

driving than relaxed positive states (Eherenfreund-Hager, Taubman – Ben-Ari, Toledo, & Farah, 2017). Similar results were found in a study with drivers aged 27 and older (Zimasa, Jamson, & Henson, 2017), suggesting that the impact of emotions on driving performance might be less dependent on the person's age. However, a recent review of studies demonstrated that brain and social changes experienced in young age might make young drivers more susceptible than older individuals to their inner states (Scott-Parker, 2017). Similarly, a recent meta-analysis found that younger drivers tend to display anger while driving more frequently and intensely than older drivers, and this is significantly associated with aggressive driving (Zhang & Chan, 2016). However, different social and environmental conditions can trigger specific emotional states (Scott-Parker, 2017), supporting the idea that an ecological approach is useful to better understand determinants of risk in young drivers.

Lastly, individual socioeconomic circumstances, such as education or employment, also play a role in crash risk and severity of injury in young car drivers, with greater risk for those in more disadvantaged circumstances (H. Y. Chen, Ivers, et al., 2010; H. Y. Chen, Senserrick, et al., 2010). In a nationally representative sample of young Swedish drivers involved in road traffic crashes, those from manual worker families had 80 times higher risk of injury than those from families with higher socioeconomic status (Hasselberg & Laflamme, 2008). It is notable, however, that the socioeconomic status of a driver may have an indirect influence on crash risk because it is associated with other mediating factors, for example the lower quality of the car that can be afforded by a young driver (Williams, Leaf, Simons-Morton, & Hartos, 2006), as well as social and cultural attitudes which can be more accepting of risky driving in disadvantaged areas (H. Y. Chen, Ivers, et al., 2010; Rakauskas, Ward, & Gerberich, 2009). These factors will be discussed in the sections 6.1 (Car Type and Conditions) and 7.1 (Cultural Norms). Some studies that have looked at socioeconomic status and road crashes have indicated no significant differences among age groups (Males, 2009), suggesting that this effect is not unique to young driver, however it is a factor worth considering in an ecological approach to young driver risk.

Developmental changes in cognitive and affective processes can make teenagers and young adults less effective in dealing with complex driving situations than older individuals, as well as cause less realistic perceptions of driving risks and skills. While differences in cognitive skills (e.g., hazard perception) between drivers of different age and/or experience have been extensively investigated in the literature, studies on personal characteristics appear to have mainly focused on individual differences within young groups. For this reason, it is

hard to conclude whether, for instance, sensation seeking is a stronger indicator of risky driving behaviour in younger than older drivers. Nonetheless, some evidence indicates that driving risk, particularly the level of engagement in risky driving behaviours, is increased in younger than older drivers because of their particular stage of development, and that promoting safe attitudes towards driving might moderate the negative impact of personal characteristics that are less amenable to change (e.g. personality traits). As will be described in the following section 5.1, designing training and interventions that encourage safer driving behaviours together with promoting positive social influences can compensate for individual characteristics that put young drivers at risk of crashes.

5. Social Micro-System

5.1 Experience, Training, and Interventions

Lack of experience in young drivers is an important risk factor for unsafe driving and crashes (McDonald et al., 2013; Winston, McDonald, Kandadai, Seacrist, & Winston, 2014), and the first six months after licensure appear to be the riskiest time for young novice drivers (Li, Guo, Klauer, & Simons-Morton, 2017; Taubman-Ben-Ari & Lotan, 2011). Among young drivers, the youngest (16-17 years old) are the most at risk in the first stages after licensure (Engström, Gregersen, Granström, & Nyberg, 2008), but in fact they are the group who benefits the most from driving frequently and in different road scenarios (Curry, Metzger, Williams, & Tefft, 2017; Curry, Pfeiffer, et al., 2015; McCartt, Mayhew, Braitman, Ferguson, & Simpson, 2009). Thus, gaining early driving experience is a major protective factor for the reduction of crash risk in young novice drivers, and this is mainly because it enables to improve high-level driving-related cognitive skills. Positive associations have in fact been found between mileage covered and hazard detection in young novice drivers (Kinnear, Kelly, Stradling, & Thomson, 2013). Studies have noted that six months after licensure 17 year-old novice drivers experience significant improvements in in eye glances, expanding from the road ahead to rear-view and opposite mirror-window, reaching similar levels of performance to those of experienced drivers (Olsen, Lee, & Simons-Morton, 2007). Similarly, O'Brien *et al* (2016) found significant decreases in eye glances off the road while engaging in a secondary task in novice drivers 12 months after licensure.

Importantly, gaining driving experience in safe circumstances (i.e., supervised, limiting night-time driving or presence of passengers) can significantly decrease the risk of road crashes in novice drivers, especially among the youngest (Glendon, 2014; McCartt,

Teoh, Fields, Braitman, & Hellinga, 2010; Zhu, Cummings, Chu, Coben, & Li, 2013). The introduction of Graduate Driving Licensing (GDL) systems in the U.S., for instance, has led to a 8-14% decrease in fatal crashes as well as substantial reductions in road violations among 16-17 years old drivers (DePesa et al., 2017; Fell, Jones, Romano, & Voas, 2011), and these benefits have been noted also in other countries that have introduced GDL (Russell, Vandermeer, & Hartling, 2011).

As well as experience, an important protective factor for young drivers is the level of training that they receive. While vehicle-handling training is useful in improving procedural skills, it is less effective than cognitive training programmes (e.g., focusing on hazard perception or road awareness) in promoting safe driving and reducing negative driving outcomes (Beanland, Goode, Salmon, & Lenné, 2013; Isler, Starkey, & Sheppard, 2011; Madigan, 2013; McDonald et al., 2017; Meir et al., 2014; Underwood, 2007). An experimental study comparing the effects of high-level cognitive skills training with vehicle-handling training and a control group in individuals aged 15-18 years-old found significant improvements in terms of hazard perception, safe attitudes towards driving, and perceptions of risks for the cognitive training only (Isler et al., 2011). Driving-related cognitive training has also been shown to improve novice drivers' visual scanning, hazard perception, and road awareness to match that of more experienced drivers (Divekar et al., 2016; Madigan, 2013; Stahl, Donmez, & Jamieson, 2016; Underwood, 2007), with the duration of training varying across studies from few weeks to four months.

Despite the benefits of cognitive training in improving driving skills, recent research has shown that very young drivers continue to experience difficulties even after training in particularly demanding road situations such as cross-flow turns (McDonald, Kandadai, et al., 2015). This is an important limitation, and it highlights the need to design training programmes that enable novice drivers to experience novel complex driving situations safely (Simons-Morton & Ehsani, 2016). In addition, a recent review of hazard anticipation training pointed out that the majority of studies evaluated the effects of the intervention only in the short-term (immediately or few days after training), recommending the use of long-term follow-ups to better understand the effectiveness of training programmes (McDonald, Goodwin, Pradhan, Romoser, & Williams, 2015). This is another major limitation of research in this area as it is currently difficult to estimate the long-term effectiveness of intervention programmes.

Training interventions can improve risk and skills perceptions as well. An Israeli study provided a 4-5 hours driving training programmes to young and older participants (age range: 18-64) to improve their ability to recognise, avoid, and handle risks in demanding driving situations, and found an overall increased risk perception at the end of the training (Rosenbloom, Shahar, Elharar, & Danino, 2008); however, younger male participants showed the smallest improvements, suggesting the need to better target these programmes to specific populations.

Educational programmes, knowledge-based training, and behavioural interventions have also shown to benefit young driving groups by raising awareness on risky behaviours and promoting safer attitudes. As attitudes have been shown to moderate the influence of maladaptive personality characteristics, which are less amenable to change (Mackenzie, Watling, & Leal, 2015), awareness-based interventions are crucial to promote safe driving. Some evidence has shown that early educational interventions can be effective in increasing knowledge on safe driving. A pre-learner educational programmes provided to Irish students aged 14-17 years old indicated significant improvements in driving-related knowledge, risk perception and, to a certain extent, attitudes towards risky driving, with effects remaining up to 9-12 months after the intervention (Ryan, 2013). In the U.S., an outreach project aimed at reducing distracted driving using an interactive teaching methodology with over 1,000 teenagers (14-18 years old) was effective in improving the participants' perspectives on the risks associated with distracted driving as well as their ability to correctly identify different types of distracted driving, although the authors assessed the effects only two weeks after the intervention (Hurwitz et al., 2016). Similarly, a high-school peer-generated safety campaign to limit texting while driving, for instance, led to a 14% decrease in self-reported texting in the car (Unni et al., 2017), and a college community programme to enforce laws against drink-driving among teenagers and young adults (under 25) produced substantial reductions in alcohol abuse while driving, observed via night-time roadside surveys before and during the programme (McCartt, Hellinga, & Wells, 2009). In addition, a peer-to-peer intervention used to promote seat belt use among teenagers in 11 high schools in the U.S. was linked to a 12% increase in observed seat belt use between two and four months after the intervention (Goldzweig et al., 2013). Given the evidence from a recent meta-analysis that seat belt use can decrease front seat fatalities by 60% and rear seat fatalities by 40% (Høye, 2016), early interventions are crucial to address young drivers' risk.

Behavioural interventions have also proven effective in changing young drivers' attitudes towards risky driving. A meta-analysis of programmes to address drink-driving, for example, indicated that brief interventions (under five hours of contact) providing young people (average age: 17) with information about the effects of alcohol on driving, discussing legal considerations around drinking and driving, and providing guidance for harm reduction led to small but significant reductions in self-reported drink-driving at 6-12 months post-intervention, with stronger effects for adolescent participants (Steinka-Fry, Tanner-Smith, & Hennessy, 2015; Tanner-Smith & Risser, 2016). Other interventions have instead focused on providing feedback on driving performance. In a study both young novice and older experienced drivers received a simulation-based feedback training to raise awareness of the detrimental effects of dual tasking on driving performance, and while safer attitudes towards mobile phone use while driving were noted following the training independent of driver's experience, the benefits lasted longer for the experienced than the novice group (Wang et al., 2010). Research on speeding has indicated some level of effectiveness for interventions that combine performance feedback with incentives or rewards as opposed to those using feedback only (Bolderdijk, Knockaert, Steg, & Verhoef, 2011; Kervick, 2016; Mullen, Maxwell, & Bédard, 2015). However, a study in which young drivers were rewarded to use a smartphone monitoring application providing feedback on driving performance found that once participants received their incentives, they stopped using the application (Lotan, Musicant, & Grimberg, 2014), demonstrating the potential limitation of using extrinsic motivational methods.

While this evidence indicates advancements in training and intervention programmes over the past ten years, important limitations include the use of self-reported measures of behaviour or intention, and short-term follow-ups of intervention effects. It would be interesting, for instance, to understand whether the benefits of pre-learner educational programmes are maintained when the participants obtain their license; in addition, the potential effects of these interventions on crash rates are unclear. Furthermore, several studies have noted that designing multi-dimensional interventions which consider several potential intervening factors of young drivers' risk (e.g., individual attitudes but also parents' involvement and behaviour) might be more effective than targeted programmes in promoting safe driving behaviour (Buckley et al., 2014; Steinka-Fry et al., 2015). In line with this consideration, the evidence on the benefits of GDL suggests that promoting driving in safe

social and environmental circumstances is key to reduce crash risk, further supporting the importance of considering factors across multiple systems.

5.2 Family and Peers

Young people are more susceptible to social influences than older individuals because of their need to build a sense of identity and belonging to a group (J. P. Allen & Brown, 2008). Parents and peers - the closest sources of social contact – can significantly influence the engagement in risky driving in young people through their behaviours and attitudes (Carter, Bingham, Zakrajsek, Shope, & Sayer, 2014; Leadbeater, Foran, & Grove-White, 2008; Reniers et al., 2017; Scott-Parker, Watson, King, & Hyde, 2014b; Taubman-Ben-Ari & Katz-Ben-Ami, 2012; Taubman - Ben-Ari, Kaplan, Lotan, & Prato, 2015; Watters & Beck, 2015).

5.2.1 Family

Parents' driving behaviour and attitudes, as well as the parent-child relationship, influence young drivers' performance greatly (Gil, Taubman – Ben-Ari, & Toledo, 2016; Schmidt, Morrongiello, & Colwell, 2014; Scott-Parker, Watson, King, & Hyde, 2015). An Israeli study found that the parent's driving style predicted the child's driving style one year later (Miller & Taubman - Ben-Ari, 2010). In a series of studies involving young male drivers (aged 17-21 years old) and their families, the same research group found a higher rate of risky driving events for participants whose parents were less committed to safety, less conformed to authority, more aggressive and perceived as low-monitoring (Taubman-Ben-Ari & Katz-Ben-Ami, 2012; Taubman - Ben-Ari et al., 2015; Taubman - Ben-Ari, Musicant, Lotan, & Farah, 2014). Furthermore, a higher risk of drink-driving or distracted driving has been noted in young drivers if they perceive their parents as engaging in those types of behavior (Bingham, Zakrajsek, Almani, Shope, & Sayer, 2015; M. J. Chen, Grube, Nygaard, & Miller, 2008).

Promoting parental involvement in the learning phase of driving, particularly in terms of supervised driving practice, has been noted as an important protective factor for safe driving in young adulthood as well as a determinant of time needed to reach full licensure (Ehsani, Ionides, Klauer, Perlus, & Gee, 2016). However, it is important to note that not all forms of parental involvement are equally effective. An experimental study found that the mere presence of an adult passenger in the car did not translate into safer driving for a young

motorist, whereas an adult passenger providing suggestions on how to drive safely led young drivers to reduce speeding, with effects transferring to situations of lone driving (Chung, Choe, Lee, Lee, & Sohn, 2014). In addition, a study that monitored the type of instructions given by 50 parents to young drivers in the car for four months during the learner licensing phase (via cameras and audio recording) found that instructions about car handling were very frequent, while in contrast directions related to hazard perception or other high-level driving skills were limited, illustrating the need to guide parents on how to best support young novice drivers (Goodwin, Foss, Margolis, & Harrell, 2014).

A recent review (Curry, Peek-Asa, Hamann, & Mirman, 2015) compared interventions to promote the involvement of parents in the learning process of young drivers under 21, and noted that programmes with active (i.e. direct involvement of parents) rather than passive components (e.g. providing informational material), as wells as those providing feedback and tools to monitor driving performance (e.g. via in-vehicle monitoring systems), were more effective in improving parents' supervision and in reducing risky driving behaviours. However, the effects of the interventions on crash reduction were unclear and longitudinal investigations were limited, indicating a clear need for improvements to design and implementation of these studies. Nonetheless, important considerations emerge from existing interventions. Given the strong influence of emotional and cognitive states on young drivers' behaviour, programmes that focus on increasing restrictions may cause resistance in a young person, and thus be less effective than interventions which foster a positive family climate. In line with this, Mirman et al. (2017) found that young drivers in intermediate licensing phases progressed faster to full licensure if their parents had positive perceptions of their driving skills and allowed them to drive in a diverse range of environments, further highlighting important interactions between social factors (parents' role and attitudes), individual circumstances (young driver's perceptions) and the environmental context of learning. Furthermore, providing guidance to parents on how to be vigilant of their children's driving behaviours can promote safer driving (Shimshoni et al., 2015), however, tackling the parents' own driving behaviour is an important aspect to take into account, as it can hinder the benefits of driving interventions (Taubman – Ben-Ari, Lotan, & Prato, 2017). In this sense, parents themselves exist in their own complex ecological systems, thus understanding which internal and external factors can promote their involvement in the learning process can help them to be better driving instructors and role models. To date, it is unclear at what age of young driver parents' influence becomes less strong, but the discussed research appears to

indicate that early learning stages before and after licensure are a crucial period for parents to be actively supportive and setting a good example, thus one might expect the effects of parent-child interventions to be maximised in that time window. Lastly, promoting the benefits of in-car or phone telematics to monitor safe driving with both parents and wider social circles rather than with young drivers only can significantly enhance their uptake (Guttman & Gesser-Edelsburg, 2011; Kervick, Hogan, O'Hora, & Sarma, 2015) and potentially reduce the selection biases encountered in interventions that use monitoring technologies.

5.2.2 Peers

Some studies have indicated that young drivers, contrary to older drivers, are more inclined to engage in risky driving behaviours in the presence of passengers (Braitman, Chaudhary, & McCartt, 2014; Donmez & Liu, 2015; Orsi, Marchetti, Montomoli, & Morandi, 2013; Williams, Ferguson, & McCartt, 2007). Several international crash reports indicate that driving with passengers, especially if peers, doubles the risk of a crash for young drivers (Curry, Mirman, Kallan, Winston, & Durbin, 2012; Donnelly-Swift & Kelly, 2015; Fell, Todd, & Voas, 2011; McEvoy, Stevenson, & Woodward, 2007; Ouimet et al., 2015; Tefft, Williams, & Grabowski, 2013). Passengers' negative influence is especially strong if they are peers rather than adults (H. Y. Chen, Senserrick, et al., 2010; Simons-Morton et al., 2011), if they are risk-accepting, and exert social pressure (Bingham et al., 2016). Peers' pressure can be exerted actively in the car, either by verbally or physically encouraging risky driving behaviours (direct pressure) or by persuading the driver (indirect pressure), for example through storytelling, or it can be shared passively based on the social norms accepted by the peer group (Centifanti, Modecki, Maclellan, & Gowling, 2016). Active direct and indirect pressure have been shown to have stronger negative impact on young drivers' speeding than passive pressure (Gheorghiu, Delhomme, & Felonneau, 2015), suggesting a big influence of in-vehicle social circumstances. Experimental studies have found that driving with a risk-accepting rather than a risk-averse peer passenger can double a young driver's risk of incurring in road violations (Simons-Morton, Bingham, et al., 2014) and increase driving speed (Shepherd, Lane, Tapscott, & Gentile, 2011). In addition, Shepherd and colleagues (2011) found that the effect of peers' influence varied based on the type of communication, showing that peer passengers who exert normative influence (i.e., persuading to modify driving speed) have the strongest negative impact on young drivers (i.e., significantly

increase risky driving), whereas passengers who use informational influence (i.e., giving advice on why speeding is good or bad) have the most positive impact.

Social norms shared by the peer group can significantly influence risky driving as well. In both experimental and qualitative studies with young novice drivers, peers' positive attitudes towards risky driving have been linked to higher speeding and unsafe driving behaviours, and conversely, participants whose friends punished risky driving or perceived it as unpopular were more committed to safe driving (Scott-Parker, Watson, et al., 2015; Taubman - Ben-Ari et al., 2015, 2014). In addition, different components of peer relationships can affect the engagement in risky driving differently depending on the young driver's age, with aspects of leisure (i.e., spending leisure time together) linked to speeding and distracted driving for younger male drivers (Guggenheim & Taubman – Ben-Ari, 2015).

Another reason why peers increase young drivers' risk is that they can act a source of distraction while in the car (Ehsani et al., 2015; Heck & Carlos, 2008). In experimental studies, having peer passengers led young drivers (under 25) to commit more driving errors caused by distraction (e.g., reduced lane-keeping) (Ross, Jongen, Brijs, Brijs, & Wets, 2016), and caused a narrower visual scanning of the road (Pradhan et al., 2014). In a naturalistic study on distracted driving that used in-vehicle recording for 6 months, young drivers (16-18 years old) carrying multiple passengers in conditions of loud conversation and horseplay were twice as likely to look away from the road longer than a second, and six times more at risk of a serious road event (Foss & Goodwin, 2014). Considering the limited ability of a young adult to deal with secondary tasks in the car because of the lack of automaticity in driving, these results support regulations that limit the number of passengers allowed for novice drivers (Fell, Todd, et al., 2011). It is important to note, however, that studies comparing peers' effects on drivers of different age and/or experience are limited; thus, while it is known that younger people are particularly susceptible to social pressure, it is less clear to what extent peers' pressure and distracting effects are a cause of crashes more specifically for young drivers than for all drivers in general.

Considering potential protective factors, studies have found that high inhibitory control enables a young driver to be less susceptible to peers' pressure, and less likely to engage in risky driving (Cascio et al., 2015; Jongen, Brijs, Brijs, & Wets, 2013; Mirman & Curry, 2016), which suggests that training cognitive skills can not only improve driving performance, but also moderate social influences (Lambert, Simons-Morton, Cain, Weisz, & Cox, 2014). Some interventions have focused on encouraging young people to be safer

passengers, by promoting risk perception and fostering values on safe driving (Buckley & Davidson, 2013). However, while a previous review noted some advancements in passenger-related safety interventions prior to 2007 (Williams et al., 2007), more recent evidence on these types of interventions is currently very limited. In one study, a school-based injury prevention programme was successful in reducing passenger-related risk taking and increasing intentions to intervene in friends' risky driving at 6-months follow-up (Chapman, Buckley, & Sheehan, 2012). Interestingly, a training intervention for young drivers and their passengers focused on promoting peer communication and collaborative safe driving demonstrated short-term improvements (1-2 weeks) in following distance, hazard perception, and safe in-vehicle communication in a simulated drive (Lenné, Liu, Salmon, Holden, & Moss, 2011). Focusing on communication skills might represent a viable pathway to turn peer passengers into resources to reduce driving risk, on one hand by promoting safer social norms (Geber, Baumann, & Klimmt, 2017), and on the other hand by training them to provide guidance for directions, detect road risks and reduce the distracting potential of in-vehicle technology (McDonald & Sommers, 2016). However, the few studies available on peer interventions share design limitations with behavioural and educational interventions discussed above, namely, the short-term follow-ups of effects, and the use of self-reported outcome measures. In line with the ecological framework proposed in this paper, Williams and colleagues (2007) suggested that, in order to maximise their effectiveness, peer-focused interventions need more complex designs which integrate protective factors at multiple ecological levels: on one hand involving parents (micro social system) can improve young drivers' awareness of the increased risk for a young driver carrying passengers; on the other, reinforcing laws and restrictions (macro system) can help to create safer attitudes towards driving.

6. Environmental Micro-System: Car and Road Environment

6.1 In-vehicle technology

Interacting with technology while driving is a distracting activity. Limited evidence exists for distracting effects of technological systems embedded in the car, such as the radio (Brodsky & Slor, 2013) or driving monitoring systems (Kervick, 2016). Conversely, several studies have explored the effects of using a mobile phone while driving, as both calling and texting can significantly decrease driving performance and increase the risk of a crash (Caird, Willness, Steel, & Scialfa, 2008; Collet, Guillot, & Petit, 2010). This is in line with a

systematic review of research on distracted driving which found that studies examining mobile phone use were 16% more likely than those exploring other sources of distraction to find a detrimental association between engaging in a secondary task and driving performance (Ferdinand & Menachemi, 2014). In a naturalistic study monitoring teenage drivers, Simons-Morton and colleagues (2014) noted that glancing off the road to pay attention to a secondary task for longer than two seconds was associated with three times higher risk of crashes and near-crashes, and such risk increased to five times more when engaging with a wireless secondary task (i.e., talking on the phone or texting). Texting in particular increases both motor and cognitive load (due to holding a device and manipulating it), leading to significantly longer glances off the road, an increase in missed lane changes, and considerably higher variability in lane position and following distances (Hosking, Young, & Regan, 2009).

Distracted driving related to mobile phone use is a problem impacting not only young drivers, but the wider population in general (Overton, Rives, Hecht, Shafi, & Gandhi, 2015), as noted in some studies that have found similar crash risk in younger and older drivers linked to using a mobile phone (Donmez & Liu, 2015; McEvoy et al., 2007). On the other hand, however, experimental studies have shown that young novice drivers are more negatively affected by secondary tasks than experienced drivers (H. Lee et al., 2015). In a study where both novice and experienced drivers engaged in a hands-free phone conversation while driving, both groups experienced decreases in performance, however, novice participants showed lower situational awareness and committed a higher number of driving infractions (Kass, Cole, & Stanny, 2007). Another study found that novice drivers had an increased risk of crashes and near-crashes when engaging in multiple in-vehicle activities including dialling a cell phone, reaching for the phone or other objects, texting, eating, or looking at objects on the roadside, whereas experienced drivers' risk increased significantly in association with dialling only (Klauer et al., 2014). These results are in line with the idea that young motorists' lack of automaticity in driving due to little experience, together with limited self-regulatory behaviour due to cognitive development, can cause a cognitive workload when engaging with sources of distraction in the car that can lead to incorrect or insufficient allocation of attention to the road, and as a consequence increase the risk of road crashes (J. D. Lee, 2007). Reports of crashes have in fact shown that, together with carrying passengers, using a mobile phone while driving can increase young drivers' risk of severe crashes up to four times (Neyens & Boyle, 2008). In a report of American crashes in the

period 2003-2008, younger drivers (under 25) who talked on a cell phone while driving had a significantly higher risk of severe crash injuries than those aged 25 and over (Donmez & Liu, 2015). Another report of fatal crashes in the U.S. in 2011 indicated that 21% of drivers aged 15-19 years old involved in distraction-related crashes had been using a mobile phone at the time of the crash (Kahn, Cisneros, Lotfipour, Imani, & Chakravarthy, 2015).

Surprisingly, a recent study exploring the effects of texting on lane excursions (i.e., deviation from the centre of the lane) in different age groups found that, although texting had in general a negative impact on driving performance across all ages, the youngest group (aged 18-24) was the least negatively affected (Rumschlag et al., 2015). A possible reason for this result could be young drivers' higher frequency of mobile phone use while driving (Braitman & McCartt, 2010; Brusque & Alauzet, 2008; Gras et al., 2007). However, a study found no significant differences in the frequency of mobile phone use while driving between young drivers and their parents (Mirman, Durbin, Lee, & Seifert, 2017). Interestingly, despite having increased significantly in the last decade, the amount of time using mobile phones is not necessarily predictive of crashes (Farmer, Klauer, McClafferty, & Guo, 2015), possibly because an increased used of mobile phones has changed how drivers allocate their attention to different tasks, or because drivers have learned to use compensatory strategies to reduce the impact of distraction (e.g., reducing speed) (Saifuzzaman, Haque, Zheng, & Washington, 2015).

While it is clear that using a mobile-phone while driving can increase the risk of crashes, the discussed evidence is inconclusive in relation to whether this risk is different for drivers of varying age and/or experience. While rapid changes in mobile phone use could explain the inconsistencies found across studies, recent reviews have highlighted important methodological limitations in the literature on driving-related multi-tasking, including the lack of a standardised operationalisation of secondary tasks or multi-tasking, lack of clarity on the mechanisms that lead to a crash during distracted driving, as well as the lack of cross-national and longitudinal studies (Keseru & Macharis, 2017; Klauer, Ehsani, McGehee, & Manser, 2015). Addressing these limitations in future research is thus key to clarify the contribution of in-vehicle technology to young drivers' crash risk. These aspects highlight the need for more robust research on multi-tasking while driving which compares young and novice drivers.

6.2 Car type and conditions

While in-car distracting conditions are the most impactful environmental factor of crashes among novice drivers, the car state and/or type can affect risk as well. Young drivers, especially those who are not financially independent or with lower socioeconomic status, are more likely to use smaller, older and less safe cars than adult drivers (Brookland & Begg, 2011; Eichelberger, Teoh, & McCartt, 2015; Hellinga, McCartt, & Haire, 2007; Keall & Newstead, 2013b), and poorer car conditions can lead to a higher risk of fatal crashes and injuries. Furthermore, vehicle power can affect young drivers' crash risk as well. A study on crashes in Australia and New Zealand found that drivers under 24 had a 69% increase in the risk of being involved in a crash if driving a high-performance car (Keall & Newstead, 2013a). Whether optimal car conditions/types exist specifically for young drivers remains to be established, and financial costs may make this factor more challenging to address than modifiable behavioural or social factors. Nonetheless, raising young drivers' awareness of the risks linked with poor car conditions or high vehicle power, may be a useful intervention strategy, though to date no such intervention studies have been published.

6.3 Road Circumstances

The road system and the day/time of driving can also affect the risk of a crash for all drivers (Alian, Baker, & Wood, 2016a; Twisk, Commandeur, Bos, Shope, & Kok, 2015). Some studies have found that young drivers, especially if male, are more likely than older drivers to be involved in crashes occurring on rural roads at night-time (Alian, Baker, & Wood, 2016b; Bedford, McKeown, O'Farrell, & Howell, 2009; Hasselberg & Laflamme, 2009; Houwing & Twisk, 2015; Konstantopoulos et al., 2010). A report from the UK indicated that the highest proportion of fatalities associated with road traffic collisions occurred on rural roads, often involving drivers aged 20-25 year-old (Lachowycz & Brown, 2007). An Australian prospective study found that young rural drivers had overall lower risk of crashes than urban drivers, however, they were more at risk of incurring in a single vehicle crash, mainly due to speeding on curved roads (H. Y. Chen et al., 2009). The same researchers found that Australian young drivers' fatal crashes had decreased between 1997 and 2007 by 5%, but the highest decreases were among urban rather than rural drivers (H. Y. Chen, Senserrick, et al., 2010). One reason for the higher risk of crashes on rural roads is the lower level of traffic and road complexity (i.e., higher visibility), which can induce the driver to feel more in control and thus more inclined to distraction, as emerged for example in a Greek study using a driving simulator with drivers aged 18-28 (Yannis, Laiou, Papantoniou,

& Christoforou, 2014). These biases might not necessarily vary across age (Cox, Beanland, & Filtness, 2017), however, considering the limited driving skills of a young novice driver and the negative impact of social pressure, limiting access to rural roads especially at night-time during the weekend could significantly reduce crashes (Kervick, 2016). On the other hand, conditions of high clutter (e.g., urban busy roads) can as well impact negatively on driving performance if the driver is engaged in a secondary task (Oviedo-Trespalacios, Haque, King, & Washington, 2017), indicating that road conditions might not determine crash risk directly, but in interaction with individual conditions, for example alcohol use (Pour-Rouholamin, Zhou, & Zhou, 2017), and in-vehicle circumstances, such as mobile phone use or the presence of passengers.

Considering potential interventions, a recent study used a computer-based educational tool with high school students living in rural areas to raise awareness of the specific risks associated with driving on rural roads (Kumfer, Liu, Wu, Wei, & Sama, 2017), and reported significant improvements (higher awareness of rural road safety issues), as assessed immediately after the intervention. Addressing environmental circumstances has the potential to improve existing interventions, however no other studies using this type of intervention were found in the recent literature.

7. Macro-System: Socio-Cultural Context

7.1 Cultural Norms

The wider social context in which young people grow up can indirectly influence their driving performance through shared cultural norms which can be more or less permissive of risky driving (Nævestad & Bjørnskau, 2012), although their impact on the individual can be moderated by proximal social influence such as parents and peers. For instance, a recent study compared determinants of driving styles between Israeli and Australian young drivers (Skvirsky, Taubman, -Ari, Greenbury, & Prato, 2017), and found that the influence of parents and peers was equally strong in both samples.

Nonetheless, a few studies have conducted cross-cultural comparisons and noted some macro-level differences. One study found that, compared to other countries, Australian young drivers did not show strong associations between sensation seeking and drink driving, possible because alcohol use associated with driving might be perceived as less appealing in Australia rather than in other countries (Hatfield et al., 2014). Similarly, a cross-national study found a higher rate of risky driving in adolescent and young Colombian drivers than in

those from Australia or New Zealand, probably due to more permissive licensing enforcements (Scott-Parker & Oviedo-Trespalacios, 2017).

Although not focused on young drivers only, a cross-national study noted culture-based differences in risk perception and driving behaviour between Norway, Russia, India, Ghana, Tanzania, Uganda, Turkey and Iran: Specifically, personal attitudes and behaviours were found to be more influential than situational factors of safe driving in cultures which had individualistic (i.e., prioritising the self and being independent rather than conform to a group mentality) than collectivistic views (i.e., prioritising the needs of a group or a community over those of the individual) (Nordfjærna, Şimşekoğlub, & Rundmo, 2014). Another study comparing hazard perception in Malaysian and British drivers noted a higher threshold of danger for Malaysian drivers (despite no cross-cultural differences in visual strategies were found), potentially due to a more dangerous road environment in Malaysia (Lim, Sheppard, & Crundall, 2013). These findings are indicative of a potential role of both culture and law enforcements in safe driving, however, to the best of our knowledge there are no cross-national studies comparing novice and experienced drivers across different areas, limiting the possibility to conclude on whether cultural influences might change based on drivers' age or experience.

Some cultural differences can also be found based on the level of urbanity or rurality of the place of residence, although the results of available studies on young drivers appear to be inconsistent. An Australian qualitative study found that young rural dwellers relied heavily on cars to move around because of geographical isolation, tended to begin driving at a very early age (before minimum age of licensure) and reported a lack of opportunities for professional tuition, which influenced their increased acceptance of speeding and a lower adherence to road rules - all aspects that put them more at risk of crashes while on the road (Knight, Iverson, & Harris, 2012, 2013). On the other hand, by surveying teens living in or outside towns in a rural U.S. region, Ramirez and colleagues (2013) found that, although attitudes towards general driving safety did not differ between the two groups, participants living in towns had poorer safety attitudes towards rural roadway hazards, potentially due to lower exposure to and knowledge about rural roads.

While attitudes towards safe driving appear to vary across cultures, it is difficult to conclude whether the broad cultural context might have a specific impact on young novice drivers as opposed to the rest of the driving population, and thus more studies are needed that explore the impact of cultural norms on drivers of different age and experience.

7.2 Road Rules and Enforcement

Laws and restrictions related to road safety vary across countries and states, and areas where stricter rules are in place have seen reductions in crashes and road fatalities over the years. An example is the introduction of GDL which, as noted in section 5.1, has proven effective in reducing young drivers' crash risk (Zhu et al., 2013) as well as improving compliance with road rules (DePesa et al., 2017). Rules aimed at reducing risky driving behaviours have also been investigated. For instance, setting a minimum legal age for alcohol consumptions has been associated with reductions in drink-driving among younger people (McCartt, Hellinga, & Kirley, 2010). Some studies have investigated the effects of regulations for mobile phone use while driving and noted that strict law enforcements to limit mobile phone use while driving can significantly reduce crashes. For instance, a large study comparing the effect of laws tackling distracted driving across several U.S. states found that young drivers living in areas with universal texting bans (i.e., applied to all ages) together with complete cell phone bans applied to young drivers were less likely to report texting while driving (Rudisill & Zhu, 2015) when compared to those in states where those bans had not been implemented. Laws that target texting specifically have also shown to be more effective in reducing texting while driving among high school students than laws banning all types of phone use in the car (Qiao & Bell, 2016). However, a recent review of 11 international studies found that the evidence for a lower prevalence of young drivers' crashes following cell phone restrictions was inconclusive, especially in relation to comparisons of effects on novice and experienced drivers (Ehsani et al., 2016). While having laws in place is important to promote a safer driving culture, the implementation and enforcement of rules depends greatly on social acceptance and norms, as shown for example in a study in Northern Ireland where GDL is in the process of being introduced and young drivers' attitudes towards it appear to be influenced by the attitudes of family and peers (Christie, Steinbach, Green, Mullan, & Prior, 2017). Similarly, studies on young Australian provisional drivers noted that compliance with road rules was more dependent on informal deterrence given by parents than on formal deterrence or experiencing enforcement (S. Allen, Murphy, & Bates, 2017; L. Bates, Darvell, & Watson, 2017). As suggested by Scott-Parker and colleagues (2016), concerted actions by key players at multiple levels are needed to enforce road rules and drive compliance, including families, local communities, and governments. This supports the idea that understanding interactions between individual, micro- and macro-level factors at the exo-

system level is important in determining compliance and should be examined in future research.

7.3 Safety Campaigns

Safety campaigns and advertisements are often designed in the form of threat appeals to raise awareness of road and driving risks. Although threat appeals are effective in eliciting fear, a meta-analysis of experimental studies found that these effects do not necessarily translate into safer driving behaviours (Carey, McDermott, & Sarma, 2013). This is in line with the recent finding that young drivers' intentions to drive safely may not necessarily match their actual driving behaviour after viewing safety ads (Plant, Irwin, & Chekaluk, 2017). Some studies have shown that the communication strategy used in an appeal, as well as the driver's experience, can moderate its impact on driving. A study conducted in Israel found that implicit rather than explicit threats (showing the video of a group of friends driving in a car with one of them not wearing a seat belt, and omitting vs. including the clip of the crash) were more effective in improving hazard perception in novice rather than experienced drivers (Hoffman & Rosenbloom, 2016).

Implicit threats have also been shown to be more effective on young drivers when appeals use stereotypes. An Australian experimental study (Skorich et al., 2013) with provisional license drivers (Mean age = 18) manipulated stereotype threat by asking participants to either identify themselves as provisional license drivers (implicit categorisation condition) or to identify themselves and read a serious of negative facts associated with provisional license drivers (explicit stereotype condition); in a third control group no stereotypes related to the driving status were elicited. The results showed that those who had received an implicit stereotype threat (i.e., who had categorised themselves as provisional license drivers but not told explicitly that they were an at risk driving group) had improvements in a hazard perception task from baseline (i.e., before receiving the threat), while those who had received an explicit threat were actually worse, possibly because of a negative impact of the explicit threat on self-esteem, supporting the argument that implicit threats are more effective on young drivers than explicit ones. In line with these findings, research conducted with Irish male drivers aged 18-24 (Carey & Sarma, 2016) found that road safety ads eliciting fear together with sense of efficacy (i.e., showing a collision and including questions on-screen inviting the viewer to engage with the content of the ad) were more effective in reducing speeding in a simulated drive than appeals using fear only (i.e.,

showing a collision without the questions); however, inducing a state of anger in the participants impacted negatively on the positive effects of the ads. Different effects of educational campaigns have also been noted based on the users' gender and the types of motivational orientations addressed (Gauld, Lewis, White, Fleiter, & Watson, 2017). These findings point out the importance of considering personal characteristics (i.e., age, emotional states) and driving experience to design safety campaigns that are effective specifically for young drivers. Importantly, given the emotional valence of threat appeals, integrating them with positive or empowering messages appears to be an important element to promote safer driving in young people. Social aspects are also to be taken into account: as noted in section 5.1, school-run campaigns with a peer-to-peer format appear to be particularly effective in improving driving behaviour or attitudes. However, once again using short-term follow-ups to test campaigns effects and the lack of data on potential links with crash rates limit our understanding of the role of safety campaigns for reducing young drivers' risk.

8. Discussion

The present review provided an overview of recent evidence on the individual, social, and environmental factors that put young novice drivers at risk of road crashes and explored factors that can promote safe driving (particularly in terms of interventions and training programmes) in light of ecological systems theory. Here we summarise the most important risk and protective factors and their links, as well as advancements and gaps in the literature.

8.1 Risk and protective factors and their links

Considering individual-level indicators of crash risk, clear disadvantages for young inexperienced drivers (as compared to experienced drivers) have emerged in terms of driving-related cognitive skills due to lack of experience and developmental processes. Thanks to advancements in neuroimaging and virtual reality, experimental studies have shown that untrained high-level cognitive skills such as hazard perception and inhibitory control are strong predictors of a less effective management of complex road situations as well as a higher susceptibility to in-car distractions, including passengers and mobile phones. While lower cognitive performance behind the wheel can increase crash risk directly, other individual characteristics, including skills and risk perceptions, personality, and emotional states can cause a higher engagement in risky driving behaviours which in turn leads to higher risk of crashes. Such characteristics appear however to be strongly influenced by social and environmental circumstances. Important risk factors for young novice drivers in the social domain include risk-accepting peers, and/or parents who engage themselves in

risky driving or who are not involved in the learning process, as they can promote unsafe attitudes towards driving as well as risky driving behaviours, and thus affect the effectiveness of interventions or regulations. In addition, increasing use of in-vehicle monitoring systems, and thus of investigations in naturalistic settings, has identified carrying peer passengers and interacting with technological devices while driving (especially if mobile phones) as strong environmental predictors of distracted driving and thus of road crashes.

On the other hand, positive learning and social influences can help young drivers to acquire driving experience safely and more effectively. There is growing consensus that cognitive training programmes, together with safe and gradually more complex driving experiences (i.e., GDL), can help young novice drivers to learn to master the complex task that is driving (Glendon, 2014). In addition, behavioural and educational interventions that have been developed over the past ten years, for instance those raising awareness on driving risks in interactive ways, or those that involve parents and peers in the learning process, have shown some level of effectiveness in promoting safer driving among young groups, especially if provided at a pre-learner stage. Incorporating incentives and rewards into interventions, especially those providing feedback on driving performance, can add to the effectiveness of the programmes. More broadly, promoting a culture of safe driving through strict law enforcements or safety campaigns is also important to reduce young drivers' risks, but these factors have been investigated to a lesser extent and appear to have a more indirect impact on risk mediated by social norms and attitudes shared within peer groups and families.

Some studies have investigated the complex interactions between factors across different systems, highlighting how crashes seldom have one unique cause: for instance, a review of police records of crashes linked to alcohol abuse in the U.S. noted that drivers aged 16-19 years old were more likely than drivers aged 45-65 to be involved in alcohol-related crashes in the presence of passengers and when driving at night-time during the weekend (Bingham, Shope, Parow, & Raghunathan, 2009). Here we see the interaction of individual and micro-level social/environmental factors (what we define in our framework as meso-system) that put a young driver to a heightened risk of crashes. Furthermore, many of the reviewed studies on perceptions and attitudes towards driving safely suggest an important mediating role of micro-level social and environmental circumstances (e.g., presence of passengers and the road context), once again supporting the importance of identifying links between factors at the meso-system level to better understand what increases or reduces young drivers' risk. Considering the exo-system (i.e., links between individual, micro- and

macro-level factors), studies have shown that the acceptance or enforcement of driving rules or monitoring systems by young drivers can be promoted by involving peers and parents (Christie et al., 2017; Kervick et al., 2015), and that compliance might vary depending on the geographical location of residence (Knight et al., 2013). Similarly, the effectiveness of safety campaigns can be increased by taking into account the drivers' emotional states or motivational orientations (Carey & Sarma, 2016). While this evidence is encouraging and highlights increasing attempts to identify synergies between factors, the future section will discuss a number of gaps in the literature that need to be addressed by future research.

8.2 Future directions

Despite the advancements in knowledge provided by the recent evidence, some important limitations need to be addressed. Firstly, comparisons of driving performance based on age or experience have been conducted extensively for some domains (i.e., cognitive skills), but need further investigation for other aspects (e.g., perceptions and attitudes, peers' norms and roles as passengers, mobile phone use, or cultural norms). It is intuitive that developmental changes put young novice drivers at a higher risk of unsafe driving than experienced ones, however, the available literature fails to clearly quantify the magnitude of differences in risk for several factors; in some cases (e.g., mobile phone use while driving), it appears to suggest no stronger negative impact for young novice drivers. Even though several studies have demonstrated that age and experience have a distinct impact on driving performance, these two factors appear to be used interchangeably across many studies, which limits our understanding of their differential influence and calls for future studies to conceptualise and investigate age and experience as two distinct factors. Along this, a better understanding of risk for young drivers related to factors such as mobile-phone use will be achieved through a reduction in methodological heterogeneity across studies, including the use of standardised definitions of factors or mechanisms of risk (e.g., multi-tasking while driving).

Considering protective factors such as training and interventions, reaching conclusions on their effectiveness is limited by the short-term follow-ups employed, the lack of longitudinal investigations, and the tendency to use self-reported intentions or attitudes rather than testing direct effects on crash reduction. Importantly, while an increasing number of studies over the past ten years has begun to consider clusters of internal and external

factors that may contribute to reduce young drivers' risk (Gil et al., 2016), these findings are yet to be translated into multi-faceted interventions that take into account multiple levels of influences (individual, micro- and macro-level) targeted to young novice individuals (Buckley et al., 2014; Scott-Parker, Goode, et al., 2015; Scott-Parker et al., 2016; Steinka-Fry et al., 2015; Williams et al., 2007). In order to address these limitations, an ecological perspective is needed to better clarify the interplay of factors across multiple levels. The framework proposed in the present review was built with the aim to highlight the most important risk and protective factors of young drivers' crashes that have emerged in the past ten years of research, and to synthesise these factors into an ecological framework to guide future studies in investigating their links. This review is not without limitations. While we used a number of information sources, this work is not a systematic review of all the relevant literature. In addition, our search strategy did not include terms such as "teen drivers" or "provisional drivers", although studies with these words were captured by our search. Nonetheless, we aimed to provide an overview of what recent studies have contributed to our understanding of young drivers' crash risk based on well-established frameworks and models of development, and found that the structure of our framework appropriately represented the content of the included papers. Importantly, our framework enabled us to highlight current gaps in research and point out how a more holistic and ecological approach that focuses on clusters of factors has the potential to maximise the efforts undertaken to tackle the young driver problem. This, together with an investigation of the benefits of existing interventions over a longer time, can better inform future preventive programmes and make them more cost-effective.

9. Conclusion

Research on young novice drivers has demonstrated that training driving-related cognitive skills and promoting positive social influences can reduce the risk of crashes. The available evidence is extensive, and the last decade has seen substantial progress in addressing the young driver problem. However, our understanding of the overlap and interactions between factors is limited. Adopting an ecological perspective is crucial to clarify how developmental processes make young novice drivers more at risk than experienced drivers of crashes directly (lack of experience) or indirectly (attitudes and behaviours), and to identify social and environmental circumstances that can help to reduce risk. While we are not there yet, there is an increasing acknowledgment of the importance of

investigating clusters of factors, and this, together with improved methodologies and advances in technologies will surely allow us to progress even further over the next ten years.

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