European Commission

Novice Drivers 2015

European Road Safety Observatory
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Transport

CONTENTS

1 Overview

Traffic crashes are the single greatest killer of 15 to 24 year olds in the EU, and, although data are not always available, the situation appears to be no better in other, non-EU countries. This focuses on young and novice drivers in the 18-24 age group, addressing the magnitude and nature of the problem and discussing effective countermeasures.

Magnitude of the problem

In every crash and fatality statistic, 16-24 year old drivers are greatly over-represented, with 2 to 3 times higher risks than those of more experienced drivers. They pose a greater risk to themselves, their passengers and to other road users than other drivers do. In young driver crashes, for each young driver killed, about 1,3 others also die (e.g. passengers and other users). Young driver crashes differ from those involving more experienced drivers, in fact they typically occur at night, are single vehicle crashes (with no other vehicles involved), and occur as a result of 'loss of control' and high speeds. Even alcohol consumption in low quantities has a greater impact on young people than on experienced drivers.

Underlying factors contributing to this risk

Young drivers' high crash rates primarily result from immaturity, lack of experience, impairment, and lifestyles associated with their age and their gender. Young men in particular are often over-confident about their driving skills.

Immaturity

Biological research shows that at the age of 18, areas of the human brain which are responsible for the integration of information and impulse control, are still developing. Youngsters are still maturing not only in physiological terms, but also in social terms. One example is getting away from parental influence and gaining more independence. As part of this process peers become increasingly important, particularly in lifestyle related choices.

Exposure

Young drivers drive more frequently during high-risk hours and in high-risk situations. Examples are night-time driving, speeding, carrying passengers and a less frequent use of seat belts and driving older cars with fewer safety features.

Lack of driving experience

Learning to drive demands a lot of practice before expert levels are reached. In comparison, while vehicle handling skills are relatively easy to master in a few hours, skills such as anticipation of potentially hazardous traffic situations require years of practice. The driving task is partly determined by the demands of the road environment, such as road design, the presence and manoeuvres of other road users and traffic rules. However, the complexity of the driving task is very much under the driver's control also, because of personal choices of driving speeds, following distances and position. These choices may lead to either small or large safety margins and are based on self-estimates of ability to handle these traffic situations. In making these choices, inexperienced drivers in particular need to aim at large safety margins in order to compensate for their lack of experience. In reality however, young inexperienced drivers tend to choose safety margins which are too small. This phenomenon is largely a consequence of the fact that this age group, and the young male in particular, tends to overestimate its skills and to underestimate the complexity of the traffic situation.

Impairment

In addition to their social and biological immaturity and their lack of driving experience, young novice drivers are often impaired while driving. This impairment results from alcohol and drug use, fatigue and distraction. Compared to experienced drivers, alcohol leads to greater deterioration in the young driver's task performance. Illicit drug use is on the increase in this age group with its inherent increase in crash risk. The combined use of different drugs and alcohol leads to extremely high crash risks. Youngsters are also strongly affected by loss of sleep, the task duration and the biological clock, when driving during normal sleeping hours. These three factors lead to increased fatigue, which can be recognized as a loss of energy, a reduced tendency to react and reluctance to continue with the task, ultimately resulting in falling asleep at the wheel. Distraction as a cause of driving error is more prominent in novices than in experienced drivers. Furthermore, youngsters are frequently distracted, for instance by passengers or mobile phone use, which lessens attention to the traffic situation.

Effective countermeasures

Specific measures are needed to counteract and eliminate the harmful effects of immaturity and inexperience. Measures that raise the overall safety level of the road traffic system such as adequate enforcement (alcohol, speed and seat belts), safe roads and safe cars, will also increase the safety levels of inexperienced and young drivers. Specific, effective measures for novice drivers are also called for such as those which increase the amount of driving experience before solo driving and reduce exposure to high-risk situations in the first phases of solo driving. Pre-license experience can be increased by supervised driving (apprenticeships). Protection during the first stages of solo driving can be provided by measures such as low alcohol limits, restrictions on night time driving and driving with peer passengers. These measures will only be effective when compliance rates are high, so strictly enforced safety standards and rules are necessary. To facilitate their acceptance, information campaigns are needed to increase awareness of road safety problems in society and amongst youngsters and their parents in particular.

Potential improvements

Potential improvements can be found in driver standards and in the application of technologies to control access to the traffic system and to monitor actual driving behavior. For improvements in driver instruction the focus should shift from vehicle control and traffic participation to higher order skills such as hazard perception. A complex area in relation to training is how to recognize personal skill limitations and to 'manage' safety margins in accordance with them. With respect to technology, the application of electronic car keys that hold information about the privileges of the driver, alcolocks and event data recorders, may reduce the exposure of young drivers to high-risk conditions.

2 Magnitude and nature of the problem

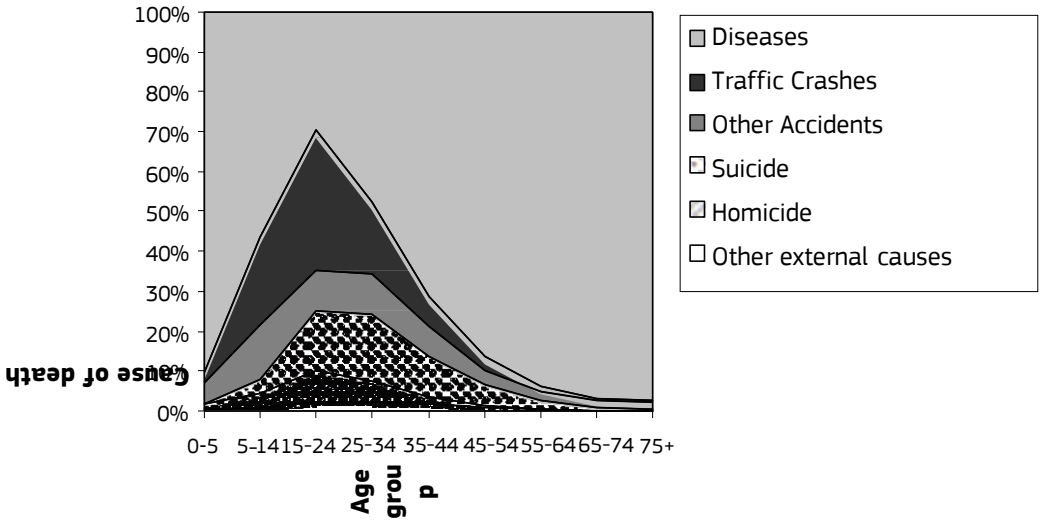
This section looks at the scope of young driver road safety risk. It discusses the key characteristics of the problem, focusing on age, experience, the types of crashes in which novice drivers are over-represented and the factors which contribute to this.

2.1 The magnitude

In most countries, novice drivers under the age of 25 account for the largest share of road traffic crashes and fatalities. As a share of all driver fatalities within the EU, the proportion of fatalities for young drivers ranges from 18% in Denmark to 32% in Germany. In contrast, the share of

this age group in the total population ranges from 8% in Denmark to 13% in Ireland. Road traffic is the largest source of premature morbidity due to unintentional injuries among adolescents in developed countries (Sleet, et al., 2010) and traffic crashes are the single greatest killer of those aged 15 to 24 in OECD countries, accounting for 35% of all deaths, or approximately 25.000 people annually, as is presented in Figure 1.

Figure 1: The proportional distribution of causes of death in OECD countries for different age groups

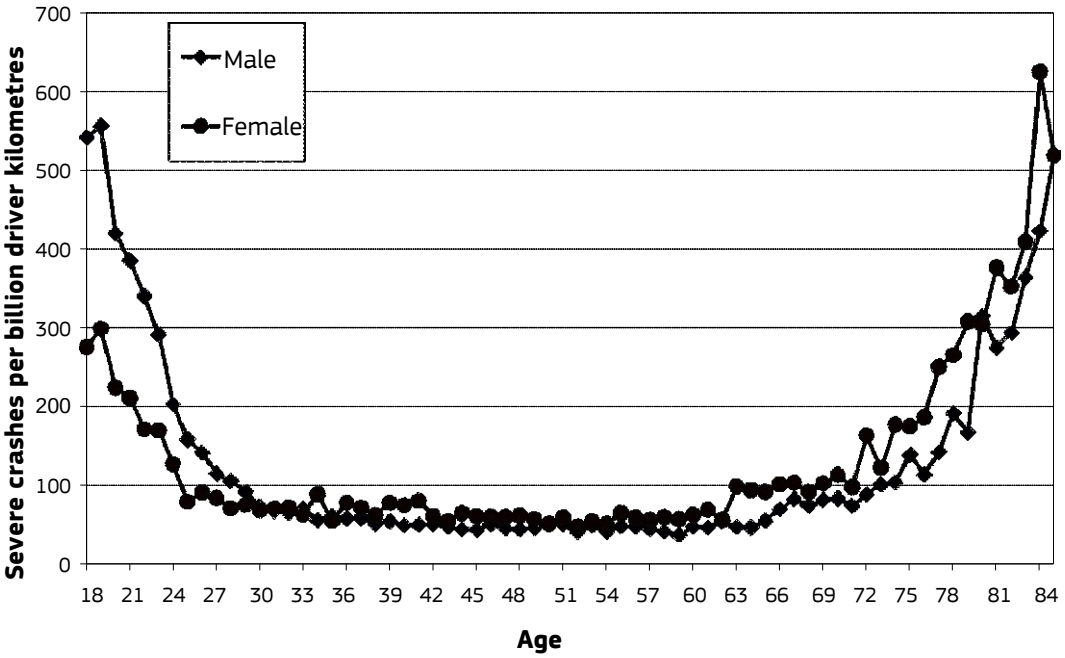


Source: World Health Organization, Mortality Database

2.2 Age and experience

Young male drivers are more over-represented in severe crashes than young female drivers, also when controlled for exposure (annual mileage). As an example, Figure 2 shows the average crash rate (number of severe crashes per billion driver kilometers) over the years 2004-2009 per years of age for licensed female and male drivers in the Netherlands.

Figure 2: Average number of severe crashes per billion driver kilometres of male and female drivers by age over the period 2004-2009.

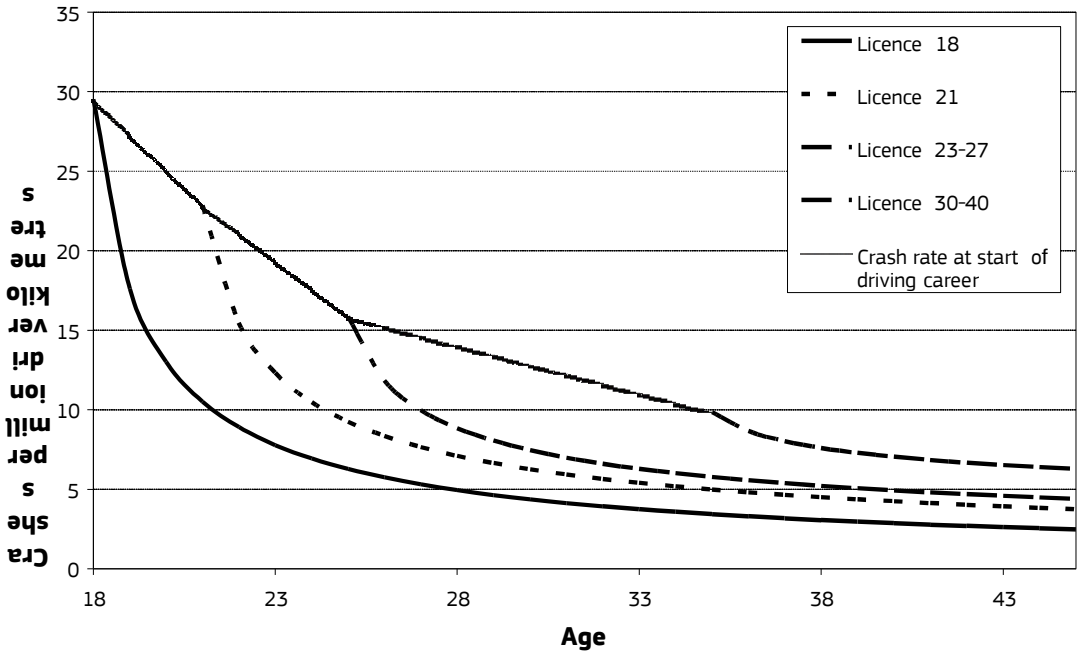


Source: Ministry of Infrastructure and Environment, Statistics Netherlands

The licensing age in the Netherlands as well as in most European countries is 18 years. The figure shows that the crash rate (severe crashes per billion driver kilometers) is the highest directly after licensing (18-19 years of age) and is particularly high for youngest male drivers. The crash rate declines rapidly in the first years after licensing, but after the age of 30, the decline is modest. The crash rate rises again after the age of 60. This rise in crash rate is at first very modest, but after the age of 75 the rise in crash rate is quite steep. This U-shape is not unique for the Netherlands. Elvik et al. (2009) were able to compare crash rates by gender and age for the State of Victoria in Australia, the United States, Sweden, Norway, Denmark and the Netherlands. The authors conclude that the function of crash rate by gender and age were remarkably similar in all the mentioned countries. All had a U-shape. Young male drivers had a higher crash rate than young female drivers and after the age of about 30, women had a slightly higher crash rate than men.

However, not everyone starts to drive after having reached the age limit. Figure 3 shows the trend lines of the self-reported crash rates (self-reported crashes in the past year and self-reported mileages) after licensing for drivers that start to drive at age 18, age 21, age 23-27 and age 30-40 in the Netherlands.

Figure 3: Crash rate of novice drivers after licensing of drivers that commenced driving early in life and drivers that commenced driving late in life. Only the trend lines are represented



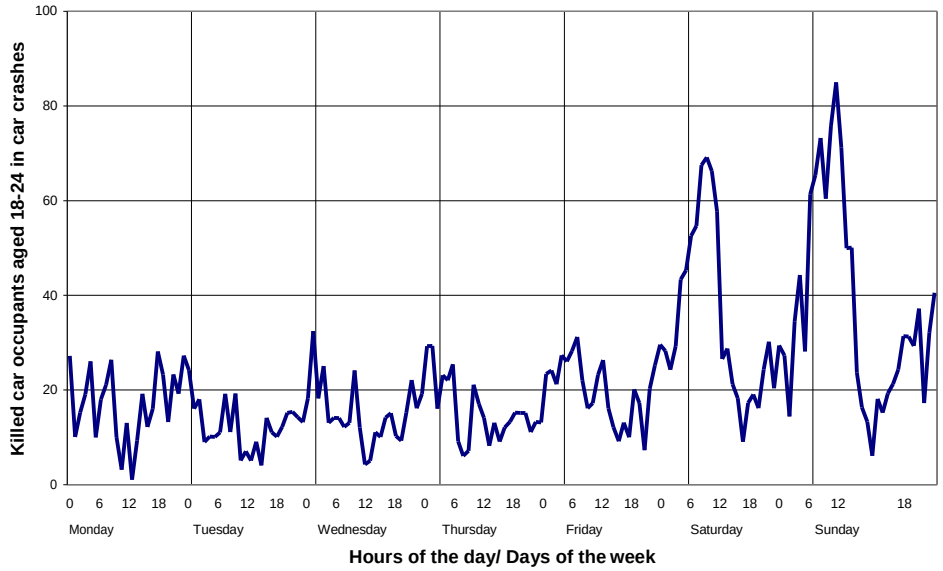
Source: Vlakveld, 2005

Figure 3 suggests that the decline in crash rate is caused both by people growing older (maturation, transition from adolescence to adulthood) as well as the accumulating driving experience. Considering the age affect, represented by the line that connects the crash rates at the start of the driving career on the different ages, approximately 40% of the reduction of crash rate is caused by age and approximately 60% is caused by experience. However, people are free to choose when to start with their driving career. There was no random assignment. It is possible that people that decide to start their driving career later are more cautious. This may be the cause of their relatively low crash rate at the very beginning of their driving career and not so much the fact that they are more mature. More attempts have been made to distinguish the age effect from the experience effect with similar results (a somewhat stronger effect of experience than of age), see for an overview McCartt (2009).

2.3 Typical young novice driver crashes

The types of crashes in which young drivers are involved differ from the types of crashes in which older, more experienced drivers are involved. Young novice drivers have relatively more single-vehicle crashes (mostly due to loss of control) and head-on collisions. Young novice drivers are also over-represented in crashes on intersections. They share this over-representation of crashes on intersections with drivers of 70 years of age and older (Clarke, 2006). With regard to the day of the week and the time of the day young novice drivers are in particularly over-represented in crashes in weekend nights after midnight, see Figure 4.

Figure 4: 18-24 year old car occupants killed in car crashes in Member States of the European Union in 2008, except Germany



Source: CARE (EU road accident database)

Several attempts have been made to understand why young novice drivers have such a high crash rate and are over-represented in the previously mentioned types of crashes on the basis of police crash reports. However, the results are inconclusive. Some of these studies conclude that crashes involving young novice drivers are mainly caused by inexperience such as lack of hazard perception, unintended driving too fast for the circumstances and distraction (McKnight, 2003; Curry, 2001) and other studies conclude after having analyzed the police reports that most of the crashes involving young novice drivers are caused by deliberate risk taking (the age factor) such as intended speeding and drink driving (Clarke, 2006, 2005). However, police reports are probably an insufficiently reliable source to decide if crashes are the result of intentional risk-taking or, for instance, of insufficient hazard anticipation skills. A recent in-depth analysis of young drivers' crashes in Florida has produced interesting results (Hassan et al., 2013): aggressive violations and in-vehicle distractions are the significant factors affecting young drivers' involvement in at-fault crashes or traffic violations at the age of 16-17, attitudes towards speeding and in-vehicle distractions at the age of 18-24. Running late and racing with other cars are the two most frequently quoted reasons for speeding. Attitudes towards speeding and distraction seem so to be the two main issues for driver education at this period of life.

In Australia, a recent survey (Scott-Parker et al., 2014) has given a precise picture of self-reported risky behaviors by young novice drivers: exceeding speed limits is done by 87% of the sample, driving when tired by 84%, drunk driving by 19% of males and 12% of females, drugged driving by 6% of males and 1% of females, and risky driving behaviors are inter-correlated.

Logically, there is a prediction of crash involvement by traffic rules violations of young novice drivers as shown by a recent Turkish work (Alver et al., 2014): among two thousands young drivers, 24% stated that they were involved in at least one crash within the last 3 years; this crash rate increases to 38% for those who received at least one citation/violation in the last 3 years and peaks to 47% for those who were fined for seat-belt violations in the last 3 years.

In the same vein, a recent Australian work (Scott-Parker et al., 2013) has revisited the concept of the "problem young driver" within the context of the "young driver problem": all young drivers do not share the same risk and the high risk sub-group of young drivers were characterized by

more pre-license driving, unsupervised learner driving, speeding, driving errors, risky driving exposure, crash involvement and offence detection during the probation period; "problem young drivers" had some insight into their high risk-driving since they report significantly greater intentions to bend road rules in future driving. Tailored interventions should target this high risk group within the context of broad countermeasures applied to the whole young drivers population such as graduated driver licensing, crash involvement could be used to identify drivers as a pre-intervention screening measure.

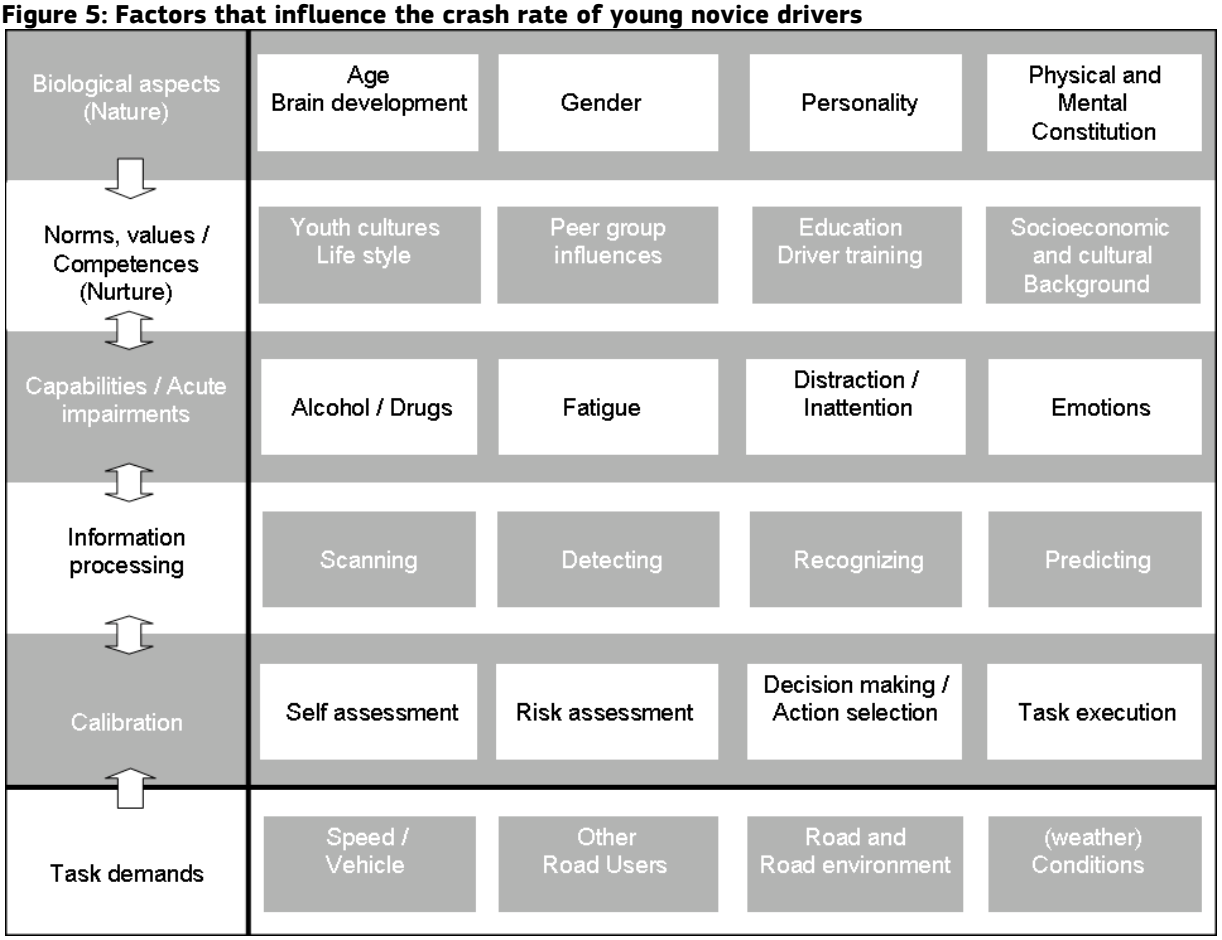
A re-conceptualization of the reckless driving behavior of young drivers has been proposed recently, based on factorial analyses (Mc Nally et al., 2014); these analyses of self-reported driving data revealed four conceptually distinct categories of reckless driving behaviors, those that increase crash risk due to: distractions or deficit in perception, attention or reaction time (labeled "distracted"); driving under the influence of alcohol or drugs (labeled "substance use"); placing the vehicle in an unsafe environment beyond its design expectations (labeled "extreme"); speed and positioning of the vehicle relatively to other vehicles or objects (labeled "positioning"). The consequences of this four factors-structure are that interventions in one reckless driving domain may not be helpful in others.

The young novice driver problem is not a new problem and besides analyses of crash reports, hundreds of studies have been conducted in the past decades in order to comprehend why young novice drivers have such a high crash rate. For a structured and coherent presentation of the main findings of these studies a taxonomy has been developed that is presented in the next section.

2.4 Taxonomy of the young driver problem

In Figure 5 a systematic overview is presented of the determinants mentioned in the literature of the young novice driver problem.

Figure 5: Factors that influence the crash rate of young novice drivers



On the left side are the categories of the determinants. At the top are the biological factors, in particular those that are characteristic for adolescence and young adulthood.

Below this category are the social and cultural factors characteristic for the social environment of adolescents and young adults. Both the biological factors and the social and cultural factors are constituent not only for their behavior in traffic, but also for other activities in life.

The third category from the top concerns the transient factors that reduce instantaneous driving capabilities.

The fourth category and the fifth category are about what drivers actually do when they drive. These two categories are strongly interrelated. The fourth category is about visual search and the detection, recognition and prediction of a possible hazardous situation. In short, this category is about hazard perception and anticipation.

The fifth is about self-assessment; risk assessment decision making and the execution of actions. Driving is mainly a self-paced task and to a certain extent drives can determine how difficult and/or risky the driving task is. When for instance a driver starts to drive faster, the driving task will usually become more complex and risky. The balancing of task demands and her or his capabilities (not engaging in driving activities that exceed one's limitations) is called

calibration, self-regulation or behavioral adaptation. Safe drivers are not necessarily also the most skillful drivers. Safe drivers are most and for all drivers that know their own limitations, accept only low risks and act accordingly. Technically skillful drivers that overestimate their skills and underestimate the risks are not safe drivers. On the other hand, drivers with basic driving techniques (but not harmful driving techniques) who know their own limitations and accept only low risks can be safe drivers.

The sixth category is about the task demands and exposure to specific road and traffic situations. How difficult the driving task is, depends on the speed and the vehicle type being driven, the behavior of other road users in the vicinity of the driver, the road and the road environment (e.g. an intersection or a motorway) and the (weather) conditions (rain, fog, day and night).

The four factors to the right of each category in Figure 5 are factors that are the most important factors for that specific category. In order to keep the taxonomy concise, only four factors are mentioned for each category. There is not necessarily a direct link between a factor in a particular layer and the factor directly underneath or above this factor in another layer. In the remaining part of this chapter the key findings of studies about the young novice driver problem are presented along the hierarchical structure of this taxonomy.

2.5 Biological aspects

Age, risk-taking and brain development

Most drivers start to drive when they are still adolescents. Adolescence is the transitional stage in human development between childhood and adulthood and starts with the onset of puberty. Puberty is the period of development which endows an adolescent with reproductive competence i.e. elevated secretion of sex hormones (testosterone and estrogen) (Susman, 2009). Elevated levels of testosterone have been particularly associated with risk-taking in older male adolescents. In girls, elevated testosterone levels have been associated with the tendency to affiliate with deviant peers (Vermeesch, 2008). Although in various studies a relationship between testosterone and risk-taking has been found, there are also studies in which no relationship was found (Booth, 2003). Adolescence has been characterized as comprising a number of psychological phenomena that can stimulate risky driving behavior: the power of friends, the optimism bias and mood swings (Arnett, 2002). In the literature, novelty-seeking and sensation-seeking are also mentioned as characteristics of adolescence that influence risky driving behavior (Jonah, 1997). Adolescents form cliques (small, closely knit groups of friends) that are the basis for their leisure lives. Young people, and boys especially, are inclined to show risky driving behavior (e.g. show how fast they can drive or how quickly they can pass another car) to alleviate boredom and/or to impress friends. These friends can also encourage the driver to take risks away from parental influence. There is little evidence, however, that the optimism bias is more present in adolescents than in adults. A literature review about decision making, rationality and risk taking concluded that when asked to think about risky acts, adolescents are not more irrational or deficient in their reasoning about risks than adults (Reyna & Farley, 2006). The same review also concluded that there was no evidence that adolescents are more likely to believe in their own invulnerability and that adolescents on average are risk-averse when asked to reflect on risky acts. However, it was also concluded that the capacity to override risk-taking impulses, when in emotionally-charged situations, seems to be less developed in adolescents than in adults. An explanation why adolescents take more risks, but in general do not reason differently about risks when they have the time to think and are not aroused, may be found in the study of brain development.

Recent longitudinal studies on brain development in which brain scans were made at regular intervals, using Magnetic Resonance Imaging (MRI), show that brain anatomy continues to develop until well into the third decade of life. The Dorso-Lateral Prefrontal Cortex (DLPFC) is about the last region of the brain that gets fully matured (Giedd, 2004). The DLPFC is a region of the Pre-Frontal Cortex (PFC) and is involved in impulse control, judgment, planning and decision-making. The PFC that consists of various sub-areas such as the DLPFC is essential for what are called the executive functions. Executive functions refer to the regulation of planning and social behavior in situations when 'automatic' responses are inadequate such as when persons are planning tasks, weighing risks and other tasks related to decision making. The late maturation of the PFC and in particular the late maturation of the DLPFC have tentatively been associated with the high crash rate of young novice drivers (Isler, 2008).

Research indicates that risk-taking during adolescence is probably not solely the result of the late maturation of the PFC (Casey, Getz, and Galvan, 2008). Although sub-cortical areas do not seem to mature markedly during the second half of adolescence (the period in which adolescents start to drive), certain sub-cortical areas in adolescents show different activities (increased activity or decreased activity) compared to adults when participants of both groups have to perform tasks such as gambling tasks when situated in an MRI. Research in which participants have to perform tasks that do not require head movements while situated in an MRI, is called functional Magnetic Resonance Imaging (fMRI).

Risk-taking in adolescence is the result of the early development of the sub-cortical areas that play a role in the experience of negative emotions, feelings of anticipated pleasure, motivation, long-term memory storage and the direct regulation of emotion and the late development of areas in the PFC that control these sub cortical areas (Casey et al., 2008).

A literature review of studies applying MRI on the risk-taking of adolescents, postulated that risk-taking behavior of adolescents arises from three different decision-making biases: risk aversion, loss aversion and inter-temporal choice (Barbalat et al., 2010). Risk aversion means that when people have to choose between two rewarding options, they will usually prefer the more certain option even when the reward of that option is possibly lower than that of the more risky option. Although adolescents are also risk averse, they are less risk averse than adults. Loss averse means that people are generally more sensitive to the possibility of losing something than gaining something (Tversky, 1981). Barbalat et al. (2010) suggested that adolescents may be less loss averse than adults as they are less affected by anticipated punishment than adults. The third aspect mentioned by Barbalat et al. (2010), Inter-temporal choice, means that direct reward is preferred above long term reward. For example, a person might not wear a helmet following a visit to the hairdresser when riding on a moped, because a helmet might ruin the hairdo. Keating (2007) mentions the maturational gap caused by the difference in functional development of the socio-emotional circuits of the brain and the control circuits of the brain that is assumed by Casey et al. (2008) as a possible cause of the high crash rate of young drivers.

Gender

An in-depth analysis of fatal crashes in which young male and female drivers (aged 18-21) were the culpable party was conducted in Finland (Laapotti, 1998). Of the 413 fatal crashes included in that study, a young man was the driver in 338 cases and a young woman was the driver in 75. The percentage 'loss-of-control' crashes was about the same for young male and young female drivers (65,7% and 64,0% respectively). When a driver loses control the driver can run

off the road (and hit a tree) (a single-vehicle crash), but the driver can also hit another car or another type of vehicle or a pedestrian (car-car crash or car-other vehicle type crash). For young male drivers, a loss-of-control crash was usually a single-vehicle crash (in about 75% of the cases). For young female drivers a loss of control crash was usually a car-car or a car-other vehicle type crash (in about 65% of the cases). Typically, young male drivers' loss of control crashes took place in the evening, at night, and at high speed (in 83% of the cases). In about half of the cases the young male driver was under the influence of alcohol. The loss-of-control crashes involving young female drivers mostly occurred in daylight. In 40% of the cases the young female driver drove too fast and in 6% of the cases the young female driver was under the influence of alcohol. Young female drivers had significantly more loss-of-control crashes on slippery roads than young male drivers. The results suggest that for young male drivers, loss-of-control is more often the result of risk-taking behavior (speeding, driving while under the influence of alcohol) and for young female drivers more often the result of poor vehicle handling.

Differences in behavior between young females and young males may be caused by cultural differences (the way boys and girls are educated and socialized), by biological differences and by a combination of the two. There are some quantitative differences between the average adult brain of females and the average adult brain of males, but there is also considerable variance within each sex. The main conclusion is that the brains of girls mature faster than the brains of boys. Due to this and hormonal differences, young female drivers take more risks in traffic than middle-aged drivers but take less risks than young male drivers. Cultural differences are discussed in the lifestyle section.

Personality

Are young drivers with certain personality traits more crash-prone than young drivers with other personality traits? Studies on self-regulated behavior have examined driving behavior against whether individuals are (1) focused on ambition, are goal directed and have an enhanced sensitive for positive outcomes, or are (2) focused on responsibility and obligations and have enhanced sensitivity for negative outcomes. Hamstra et al. (2011) found that young drivers with high scores on the first scale and low scores on the second scale drove with higher speeds and accepted smaller gaps when turning left at an intersection than young drivers with high scores on the second scale and low scores on the first scale. Ulleberg (2001) found that there were two groups of young drivers (aged 18-23) that reported risk taking acts. The first high-risk group consisted mostly of young men with low levels of altruism and anxiety and high levels of sensation seeking and irresponsibility. These young drivers showed risky behavior not so much because they were angry with other road users, but because dangerous driving was considered to be thrilling and because they had less regard for the well-being of others. The second high-risk group also scored high on sensation seeking, but in contrast to the first group this group had high scores on aggression, anxiety and driving anger. These young drivers seemed to tolerate little from other road users and easily became angry. Both groups had high scores on sensation seeking. Jonah (1997) reviewed forty studies on the relationship between sensation seeking and risky driving. In the vast majority of these, a strong correlation was found between scores on sensation seeking and (self-reported) risky driving behavior. Seven studies reported significant differences between high and low scores on sensation seeking and crash involvement. More recently, a Spanish study (Gonzalez-Iglesias et al., 2014) on 274 young drivers has observed again this correlation between sensation seeking and drunk driving but has also observed a mediating role of social norms and of biased self-efficacy perceptions, that is the impact of sensation seeking varies according to these two factors, and it is easier to modify these factors than to change a personality trait. Another recent Australian work (Scott-Parker et al., 2013) has

produced a further exploration of the influences of sensation seeking propensity, reward sensitivity, depression and anxiety on the risky behavior of young novice drivers in a structural equation model: anxiety, sensation seeking propensity and reward sensitivity predict risky driving, but gender is a moderator as reward sensitivity predicts risky driving only for males. Finally, another interaction has been shown by a recent Australian work (Hatfield et al., 2014): normally, perceived risk decreases risky driving, but not for high sensation seekers, so emphasizing the riskiness of a particular road behavior may be of limited benefit for young sensation seekers.

Physical and mental constitution

Young people in general enjoy good health. Their visual acuity and reaction times are better than the visual acuity and reaction times of older people. Young people need less practice to acquire complex motor skills, including vehicle handling. The older the person starting to learn to drive, the more hours of driving instruction are required to pass the driving test (Maycock, 1997).

Although young people possess some physical advantages over older people, there is a mental disorder that has a higher prevalence in young people than in older people. This is Attention Deficit Hyperactivity Disorder (ADHD). In the Netherlands 7,8% of men and 1,8% of women between 18 and 24 years of age are diagnosed as having ADHD in some degree (Graaf, de, 2010). Inattention, hyperactivity and impulsivity are the main characteristics of ADHD. Neuropsychological findings suggest that these behaviors result from underlying deficits in executive functions such as deficits in response inhibition and delay aversion. The effect of ADHD on road safety has received much attention. According to a meta-analysis in which thirteen studies were included, the odds ratio for being involved in a car crash of young drivers diagnosed with ADHD was 1,88, 95% CI [1,42; 2,50] (Jerome, 2006). Drivers with ADHD are more often inattentive, adhere less to the rules of the road, show reduced inhibition and are more easily distracted than non-ADHD drivers (Barkley, 2007).

2.6 Norms, Values and Competences

Youth cultures/ lifestyle

A car is not only a means of getting from A to B. There are additional motives for driving and one study distinguished between four different psychosocial motives that were mentioned by young drivers in a focus group. These were: visibility ('See me driving like Michael Schumacher in this fast car'), status ('My friends will respect me now that I have a car' and 'I'm king of the road in my own car'), control ('It gives me a kick to be in control of this car when I drive fast') and mobility and freedom ('Now that I have a car I can go whenever and where ever I want' and 'I can enjoy myself with my friends in my car').

According to the Problem Behavior Theory (PBT) (Jessor, 1987) motives for in this case risky driving are also motives for other deviant behavior such as unsafe sex, smoking, alcohol consumption and illicit drug use (Møller, 2004). Although these activities are perceived as deviant behavior by society, they can be functional in the life of adolescents (e.g. explore roles, attitudes and values and becoming independent of parents).
PBT categorizes motives for reckless behavior in three systems:
(1) Perceived environment system. This includes for instance peer group pressure.
(2) Personality system (i.e. feelings and perceptions about the self that promotes tolerance of deviance)
(3) Behavioral system (other risky behavior than the risky behavior of study).

In PBT, risky driving behavior is considered as symptom of a syndrome. This syndrome is a problematic adolescent lifestyle. Research indicates that drink driving and involvement in alcohol-related crashes can be predicted by friends' support for drinking, susceptibility to peer pressure (perceived environment system) and tolerance of deviance (the personality system) (Shope, Raghunathan, and Patil, 2003). Also a preference for some types of leisure time activity has been found to be related to self-reported risky driving behavior (Møller, 2008, 2009). These activities could be characterized by low organization and high impulse such as playing PC-games, visiting fitness centers and partying with friends. More recently, this Danish author (Møller et al., 2013) has shown by following the same subjects that changes in lifestyle and driving style ("cruising") occur for the majority of male drivers between the age of 18 and 23 except for a small group.

One study asked 20 year old drivers in a questionnaire about their lifestyle, driving behavior and crash involvement. Four lifestyle profiles were identified with a crash rate that was 1,5 times the average crash rate and two lifestyle profiles with a lower crash rate than average (0,75 times the average crash rate) (Gregersen & Berg,1994):

- The first high-risk group (10% of respondents) was predominantly male, were rarely active in sport, liked to consume alcohol, were interested in cars and liked to drive for fun.

- The second high-risk group (5% of the respondents) and 62% of this group being male could be characterized as young urban professionals (yuppies). The young drivers in this group had a high annual mileage and although driving in the first place was considered as a means of transportation in this group (fast and comfortable), the type of car mattered to them (status). The way they were dressed and cultural activities also were important to them. As with the first group they liked to consume alcohol, but unlike the first group they did not drive for fun.

- The third high-risk group (2% of the respondents and mainly male) did not consume alcohol and were not much socially engaged, but had strong additional motives for driving (i.e. showing off, pleasure, sensation seeking). They also were interested in cars and drove often at night.

- The fourth and last high-risk group (4% of the respondents and 61% male) did not drive a lot, were not socially engaged, but when they drove additional motives were very important to them.
- The first low-risk group was large (23% of the respondents) and predominantly female. The young drivers in this group rarely drove, did not consume alcohol and scored a little higher than average on culture and social commitments. This group was not interested in driving and in cars. The second low-risk group (6% of the respondents and 68% female) was active in sport, did not consume alcohol and was not interested in clothes, movies and cars. For this group, driving had nothing special to offer. In contrast to the first low-risk group, however, they liked to drive to parties.

Family environment

Even if the family influences are usually more easily understood for children, numerous studies have shown now that the family environment still constitutes between 15 and 25 years-old a major source of risk or of protection at the period of life when the young driver starts his/her driving career. A literature review and a theoretical model of these influences have been proposed by Assailly (2007, 2011) showing the interactions between five main components of the family influences: the genetic factors, the affective relationships, the evolution of the family

structure with time, the traffic behaviors of the parents, the supervision of the lifestyles and behaviors. Several works have shown that there is an intergenerational reproduction of driving styles and accident involvement. For example, in a recent Israeli work (Taubman-Ben Ari et al., 2015), the parents' contribution to risky driving of male teen drivers is very important: the parents' (especially the fathers') sensation seeking, anxiety aggression and their risky driving events are positively associated with the risky driving of the young driver.

The family safety climate influences also the risky driving of young novice drivers but the effect is mediated by attitudes, focus over control and social norms, as shown in a recent Belgian work (Carpentier et al., 2014). Other recent results in this field are an Italian study (Smorti et al., 2014) which has shown that the maternal (but not the paternal) bond is associated to resistance to peer pressure about risky driving in adolescence, and a Lithuanian one (Strukcinskiene et al., 2014) showing the similarities between self-reported road safety behavior of teenage drivers and the road safety behavior of their parents (concerning speeding, driving while tired, using cell phone while driving and not fastening the seatbelt in the back seat).

Peer group influences

In adolescence, reckless behavior does not usually take place if a person is alone. The widely-held view is that, especially during adolescence, peers promote and reward (with praise and esteem) each other's reckless behavior. One explanation could be that reckless behavior promoted by friends fortifies the bond between them. Arnett (1992) however warns against causal interpretations. It could be that adolescents like everybody else choose their friends on the basis of common characteristics and this might include sensation seeking. If this is the case, reckless behavior is not so much the result of group dynamics, but the result of a common trait in members of the group.

Passengers can strongly influence driver behavior. They can distract the driver (e.g. by having a conversation with the driver) and they can also stimulate certain driver behavior. They can encourage the driver to take risks (e.g. 'Show us how fast this car is'), but they can also reduce the risk taking tendencies of the driver. The latter is the case when a passenger makes the driver feel that she or he is responsible for the life of the passenger. In various studies outside Europe it was found that crash rate increased in the presence of passengers (Chen, 2000; Doherty, 1998; Preusser, 1998). The more occupants in the car and the younger the age of the driver, the higher the crash rate was (Williams, 2003). However, in two studies carried out in Europe (Spain and Sweden) no increased crash rate was found when young drivers were in the presence of passengers (Engstrøm, 2008; Rueda-Domingo, 2004). The difference in these results could have been caused by the age of the novice driver. The licensing age in the United States, Canada, Australia and New Zealand is often 16 and in some states even younger. In most countries in Europe the licensing age is generally 18.

However, it is not only the driver age that matters but also the passenger(s) age and the gender of both the driver and the passenger(s). Chen et al. (2000) found a higher crash rate for both young male novice drivers and young female novice drivers only when the passenger was male. Simons-Morton, Lerner, and Singer (2005) observed cars that left parking lots. They identified the gender of the driver and passenger if present and assessed their ages. Young novice drivers of both sexes drove faster than the general traffic and followed other vehicles more closely. This effect was stronger for young drivers (of both sexes) in the presence of a male teenage passenger. When young novice male drivers drove in the presence of a female teenage passenger, headways were longer. Conversely, the presence of an adult passenger or even only

driving tips from the adult passenger before driving are associated with a more careful behavior (Chung et al., 2014) for young adult drivers' driving speed.

A problem with all studies about the effect of passengers on crash rates is reliable exposure data – the mileage of drivers with passengers in their cars. On the basis of an incomplete dataset – the data only provided mileages of drivers driven with members of their household as a passenger – Ouimet et al. (2010) assessed crash rates by age and sex of the driver and passenger. The highest crash rate was found for young male drivers (15 to 20 years of age) with young male passengers (16 to 20 years of age). This crash rate was 9.9 times the crash rate of young male drivers without a passenger, 95% CI [9,1; 10,8]. With a young female passenger (16 to 20 years of age) these young male drivers had a relative risk of 3,3, 95% CI [2,9; 3,7]. Young female drivers (15 to 20 years of age) driving with a young male passenger (16 to 20 years of age) had a crash rate that was 4.1 times their crash rate when they drove without a passenger, 95% CI [3,4; 4,9]. When young female drivers drove with a young female passenger (16 to 20 years of age) their relative risk was 4,4, 95% CI [3,8; 5,0]. When young drivers of both sexes drove with passengers over 35 years of age, their crash rate was considerably lower compared to their crash rate without a passenger. From these results it can be concluded that peers' pressure to take risks and/or distraction is present when young drivers drive with passengers of the same age. This is especially the case when young male drivers drive with young male passengers. Whereas passengers of the same age increase the crash rate of young drivers, older passengers (35 years and older) seem to have a protective effect on young drivers.

We need more works on this topic as the presence of passengers interact with other factors: a recent Dutch study (Houwing et al., 2015) has recorded observed exposure and alcohol use during weekend nights among young male drivers carrying passengers, as Netherlands is a late licensing country comparatively to North America, and concluded that multiple passengers were a protective factor, relatively to no passengers or a solo passenger. In the same way, an Israeli work (Guggenheim et al., 2015) has shown that a friendship can serve as an impetus for safe driving among young drivers, the effect of the relationship on driving depending on the type of friendship. And finally, a recent American work (Rhodes et al., 2015) has shown that there is an interaction between the effects of mood and passengers on risky driving among young male drivers: passengers increase the driving speed only in a happy mood.

In fact, the influence of peers as the parents' one is dependent of *descriptive norms* (how frequently the young person thinks that his parents or peers are committing a dangerous or careful behavior) and of *injunctive norms* (if the young person thinks that his dangerous or careful behavior is approved or disapproved by his parents or peers), this has been clearly shown in recent Australian (Scott-Parker et al., 2015) and French (Cestac et al., 2014) works. Another interesting finding observed in a recent Danish work (Moller et al., 2014) is that the peer influence on speeding evolves with age: the descriptive subjective norm, that is the perception of friends' speeding, is the most important predictor of speeding at 18 as well as at 28 years-old; however, at 18, young male drivers are socialized into increased speeding by peer pressure, but at 28, peer pressure mainly seems to maintain or justify speeding behavior, so preventive measure should use peer-based approach with the 18 years-old and a more individual approach with the 28 years-old.

Education in general and driver education

In this section a distinction is made between general education and driver education. In the first section the effect of general education on crash risk is discussed and in the second section the effect of driver education on crash risk is tackled.

a. General education

In a Swedish study a weak correlation between the level of education, school performance and crash rate was found (Murray, 1998). The lower the education level and the lower the school performance are, especially in science, the higher the crash rate. In the United States, Bingham, Shope and Tang (2005) found that less academically educated young drivers tended to experience slightly more driving problems, including drink driving. Considering the two mentioned studies it seems that the level of general education may have a small impact on the crash rate of young drivers with higher levels of general education having a slightly lower crash rate.

b. Traditional driver education

Contrary to popular belief, evaluation studies and meta-analyses have shown that formal basic driver training in order to pass the driving test does not result in a lower crash rate after licensing than informal training (learning to drive by self-training and training by family members or friends) (Elvik, 2009; Christi, 2001; Senserrick, 2005). Traditional driver training in order to pass the driving test is about vehicle handling, applying the rules of the road and mastering basic traffic situations. In traditional driver training not much attention is paid to the factors mentioned in Figure 5 such as hazard perception, risk assessment, risk acceptance, self-assessment, the effects of fatigue and distraction, etc., that cause the high crash rate of young novice drivers. Furthermore, demonstrated performance of the skills learned such as manoeuvring, vehicle handling and mastering common traffic situations, skill performance may appear as if candidates are ready to acquire a license, but it is questionable if candidates undergoing the driving test are able to 'read' the road and anticipate possible forthcoming dangerous traffic situations.

Socio-economic and cultural background

There are few studies about the Socio-Economic Status (SES) of the family of young novice drivers and their crash risk. In a longitudinal study about lifestyle factors and crash rates in New Zealand, the SES of parents was not found to be an important predictor of crashes (Begg, Langley and Williams, 1999). However in an Australian study Chen et al. (2010) found that whereas the overall annual crash rate for young novice drivers (17 to 25 years of age) decreased significantly over time (from 1997 to 2007) it did not decrease significantly in rural areas with low SES. Drunk driving, speeding and non-use of seat belts in the young novice driver population remained high in these areas over time. Sweden is probably the only country in the world where the relationship between SES of the parents and the number of crashes of young novice drivers has been studied frequently (Murray, 1998; Hasselberg, 2003). All these Swedish studies indicated that the higher the SES of the parents of the young novice drivers is, the lower the number of severe crashes is. In one of the Swedish studies the country of origin of both the parents (second generation) and of the young novice drivers themselves (first generation) were studied in addition to these elements (Hasselberg, 2008). In contrast to SES, no relationship was found between country of origin and injury rate. This was true for the first generation from both other Western countries and non-Western countries and the second generation from both other Western countries and non-Western countries. A serious limitation of all the mentioned Swedish studies is that none of the results were controlled for exposure. It is very likely that the annual mileages are different in each group. And it is also very likely that the lower the SES of the parents, the less protection the cars, in which the young novice drivers drive, will offer.

More recently, the fatal crash involvement of young unlicensed drivers in the US has been associated to material deprivation (Hanna et al., 2012) by comparing the US regions.

2.7 Capabilities/Acute Impairments

Alcohol and drugs

Increasing crash rate with increasing BAC levels is substantially higher for young drivers than for middle-aged drivers (Peck, 2008; Preusser, 2002). The crash rate of drivers aged 21 or younger with a BAC level of 0,5 g/l (the legal limit in most countries) was more than twice the crash rate of drivers aged over 21 years with a BAC level of 0,5 g/l (Peck, 2008).

There are several possible explanations for the fact that alcohol has a greater deteriorating effect on young novice drivers than on older, more experienced drivers. Firstly, the tolerance for alcohol may be lower, because they are not yet accustomed to alcohol. Secondly, because various subtasks of the driving task are not yet executed fully automatically, the mental work load when driving is higher for young novice drivers than for more experienced drivers (Waard, de, 2002; Patten, 2006). As more mental work load is required for the performance of the basic driving task, young novice drivers have to allocate more of their limited attentional resources to these tasks. Alcohol impairs information processing and in this regard has a greater deteriorating effect on tasks that require much attention than on tasks that require little attention. Thirdly, young drivers may tend to show more risk-taking behavior under the influence of alcohol than older ones, more experienced drivers. Low quantities of alcohol can give a feeling of euphoria and decrease (social) inhibition. The brain of adolescents is not yet fully matured (see paragraph 2.3.1). This makes inhibition of impulses and the weighing up of risks more difficult for adolescents than for adults. Because of the effect of alcohol on the brain, executive functions may deteriorate more in adolescents than in adults and this may result in more risk-taking behavior by young novice driver than by older, more experienced drivers. See also Erso Alcohol web text.

Alcohol is not the only substance that affect driving capabilities. Illicit drugs such as cannabis, cocaine, opiates and stimulants (amphetamine and designer drugs such as ecstasy (MDMA)) can also have adverse effects in driving.

Cannabis. In laboratory studies and simulator studies the effect of delta-9-tetra- hydro cannabinol (THC) – the psychoactive component of cannabis – on driving performance has been clearly demonstrated. THC impairs tracking (steering), attention, reaction time, short-term memory, hand-eye coordination, decision making and concentration (Ramaekers, 2004). Despite these impairments until recently, there was no epidemiological proof for a heightened relative crash rate when driving under the influence of cannabis [see EMCDDA, 1999, for an overview]. Initially it was considered that although cannabis affects basic driving skills it does not affect calibration skills. Drivers know that they are under the influence of cannabis and compensate for impairments, for example, by driving more slowly and by avoiding risky traffic situations (Krüger, 1995). This may be partly the case, but in earlier epidemiological studies for an indication of driving under the influence of cannabis, drivers were tested on the presence of an inactive metabolite of THC in their urine. This metabolite of THC can be present days after THC has been active in the brain. In more recent epidemiological studies presence of the THC itself in blood was directly measured. From these studies it can be concluded that all doses of THC increase crash rates [see Drummer, 2009, for an overview]. Some effects of cannabis use may

not only be acute but also long-term: for example, a precocious age of onset (before 14) of cannabis use has been associated to driving under the influence of cannabis after 21 (Le Strat et al., 2015).

Cocaine, amphetamine and ecstasy make users more energetic and alert. The negative effects (mostly in a later phase) of amphetamine are: delirium, panic, paranoia, impulsive behavior and aggression. The negative effects of cocaine are headaches, panic attacks and nausea (Shinar, 2006). MDMA (ecstasy) causes mild hallucinogenic effects, increased tactile sensitivity and emphatic feelings. Brookhuis et al. (2004) found that MDMA had only modest effects on basic driving skills at an operational level. However, MDMA did affect the tendency of drivers to take risks. In a simulator drive, while crossing a priority road with oncoming traffic from left and right and while turning left with approaching traffic, participants under the influence of MDMA accepted smaller gaps than when they were sober. Some epidemiological evidence exists that amphetamine increases crash rate (Drummer, 2009), but for cocaine and MDMA clear evidence of an increased crash rate on the basis of epidemiological field studies is not available. There also is no epidemiological evidence that opiates increase crash rates.

In order to improve the limited existing knowledge about the effects of drugs on crash rate, the European project DRUID (Driving under the Influence of Drugs, Alcohol and Medicines) has run from 2006 to 2011 within the 6th Research Framework Program. The aims of DRUID[1] were to gain new insights with regard to the real degree of impairment caused by psychoactive substances and their actual impact on road safety, and to produce recommendations for harmonized EU regulations. 18 countries have participated. The major work contents of the scientific work packages were:

- Data on prevalence of psychoactive substances in the general driving population was collected in roadside surveys conducted in 13 European countries according to a uniform study design. For this purpose samples of body fluids of approximately 50.000 randomly selected drivers have been analysed.
- Risk estimates for driving under influence of psychoactive substances have been derived from the case-control study in which data of the roadside surveys was linked to the data of approximately 4.500 drivers seriously injured or killed in an accident.
- Characteristics of drivers tending to drive under the influence of psychoactive substances were identified.
- 13 driving tests were conducted according to a uniform study design to close knowledge gaps on the impact of major illicit drugs and medicines on driving performance.
- Oral fluid screening devices and checklists for identifying clinical signs of impairment have been evaluated.
- A cost-benefit analysis of increased anti-drug enforcement through traffic police was done.
- A four level classification and labeling system for medicines regarding their influence on driving performance was created.
- The most comprehensive database on European rehabilitation schemes and measures as well as on quality assurance measures for rehabilitation programs was established.

[1] all the reports and deliverables are available on the project web site : www.druid-project.eu

- A compilation of practices of driving license withdrawal in Europe and recommendations concerning best practice for withdrawal/ licensing strategies was made.
- Guidelines for health care professionals on prescribing and dispensing medicines were developed taking their impact on driving performance into account.
- Recommendations on how to disseminate the DRUID results to different target groups, i.e. general public, young drivers, patients, health care professionals, policy makers were produced.
- Recommendations for policy makers at European level have been derived from the results of all Work Packages.

Combined substance use. Despite the fact that no clear negative effects on road safety have been found to date for some illicit drugs, it has been demonstrated that combined substance use, especially the combination of alcohol and illicit drugs, leads to a substantially higher crash rate (Mathijssen, 2005). In contrast to drunk driving, the prevalence of illicit drug driving was the highest in the youngest age group of motorists (motorists between 18 and 24 years) in the Netherlands (Mathijssen, 2005).

Fatigue (See also Erso Fatigue web text)
Fatigue has been defined as a state of reduced mental alertness that impairs performance during a range of cognitive and psychomotor tasks including driving (Williamson, 1996). The words sleepiness and drowsiness are used as synonyms for the word fatigue, especially when reference is made to the neurobiological processes that regulate the circadian rhythm and the need to sleep (Dinges, 1995). Fatigue can be caused by time on task and the complexity of the task, but also by lack of sleep. Lack of sleep can be chronic when during a long period the daily quality of sleep is poor and/or the daily quantity is not enough. Lack of sleep is acute when task performance is impaired due to one bad and/or short night. Driver fatigue can also occur when a person drives at moments when she or he is normally asleep (e.g. night-time driving). During a 24-hour cycle the human body has greater need for sleep at some moments (especially between midnight and 4 a.m.) than on others. The 24-hour cycle of the body is called the circadian rhythm. Finally, drowsiness, but not fatigue can occur when the driving task is monotonous. This is called driving without attention or highway hypnoses. Driver fatigue can cause crashes because of deficits in attention, vigilance and information processing. When one falls asleep behind the wheel, failure to perform the driving task is complete.

A recent naturalistic driving study – '100-Car Naturalistic Driving study' – revealed that drowsiness was a contributing factor in 13% of the crashes and in 12% of near crashes (Dingus, 2008). In a naturalistic driving study participants drive in instrumented cars. Participants know that they are driving in instrumented vehicles, but these instruments (e.g. cameras) are not visible or hardly visible and are unobtrusive. In this type of study participants are not instructed to use the car in a particular way. It is the intention to observe driving behavior in daily life. In the '100-Car Naturalistic driving study', car performance and driver behavior were recorded in 100 instrumented cars over a year. It was possible to analyze what the driver did just prior to 82 crashes and 761 near-crashes and how the traffic situation developed in these situations.

In the '100-Car Naturalistic driving study' no distinction was made between young novice drivers and older, more experienced drivers with regard to drowsy driving. There are, however, indications that drowsy driving is more common among young drivers than among older drivers (Barr, 2011). Young drivers are also more involved in fatigue-related crashes than older drivers

(McCartt, 1996). Probably, fatigue deteriorates the performance of the driving task of young novice drivers more than it affects the driving task of older more experienced drivers. Smith et al. (2009) made young novice drivers (aged 17-24) and older, more experienced drivers (aged 28-36) complete a video-based hazard perception test at 03:00 a.m. (higher sleepiness) and at 10:00 a.m. (lower sleepiness). In this test, participants watched videos that were taken from the perspective of a driver. In these videos conflicts developed (e.g. a lead vehicle that brakes due to a blockage further ahead, or a car that pulls out from a row of parked cars when the driver of the video passes the parked cars). Participants had to press a button as soon as they detected the developing hazard. As in earlier studies in which this type of test was applied (McKenna, 1997, 1999) response latencies (the time between the first sign of a developing conflict and the time the button is pressed) were significantly longer for the young novice driver group than for the older, more experienced driver group (both in the lower sleepiness condition as in the higher sleepiness condition). However, the response latencies were about the same in the lower sleepiness condition and the higher sleepiness condition for the older, more experienced drivers, but were significantly longer in the higher sleepiness condition than in the lower sleepiness condition for young novice drivers.

Horne and Reyner (1995) found that drivers under 30 years of age (especially men) were particularly prone to sleep-related crashes in the very early hours of the morning. Typical sleep-related crashes are single vehicle crashes or head on collisions that are not alcohol or drug related, usually with no passengers in the car, in good road and weather conditions and in which the driver has taken no evasive action (e.g. braking) to avert the crash at the last moment (Schagen, van, 2003; Groeger, 2006). We can suppose that drowsy driving is more common in young drivers not only because they drive relatively more frequently late at night, but also because of their sleep patterns and the quality of their sleep. As teenagers grow older they go to bed later, but they have to wake up as early as before. Self-reported need for more sleep is the highest around 15 years of age, but is still relatively high at the age of 21. Sleep structure also changes markedly across adolescence and early adulthood, with among other changes a considerable reduction in the amount of slow wave sleep. According to Groeger (2006) this may be one of the causes that waking up not feeling refreshed is high between 16 and 23 years of age. The effect of sleep loss and changes in the quality of sleep may not only result in drowsy driving, but may also hamper learning to drive as newly acquired procedural skills require sleep in order to be consolidated (Walker, 2005).

Distraction/Inattention (See also Erso Driver distraction web text)
Lee, Young, and Regan (2008) mention 14 different sources of driver distraction. This can be an object (e.g. a billboard), a person (e.g. a passenger or a pedestrian on the pavement), an event (e.g. a low-flying airplane that is landing) or an activity of the driver (e.g. mobile phone use while driving). The source of distraction can be within the driver (e.g. when the driver is absorbed in thought or is daydreaming), inside the vehicle (e.g. a wasp in the car or crying children in the backseats) or outside the vehicle (e.g. a billboard or a remarkable pedestrian on the sidewalk). The driver can be compelled by the source and cannot ignore to pay attention to it (e.g. a crash in the opposing lane) or the driver voluntarily chooses to do something (e.g. calling up someone with his cell phone). In many definitions distraction is related to attention (e.g. 'distraction occurs when attention is withdrawn from the driving task'). Due to distraction, attention can be disturbed, diverted or misallocated. Finally the outcome of distraction can be described in terms of impaired behavior of the driver (e.g. delayed response or no response) or impaired capabilities of the driver (e.g. diminished situation awareness, diminished hazard anticipation, degraded decision making). The outcome can also be described in terms of car performance (e.g.

disruptions of speed and lane maintenance) or in terms of road safety (e.g. increased crash risk). An overview of the sources of distraction, location, intentionality, processes and outcomes is presented in the following list (Lee, 2008):

Source:
- Object,
- Person,
- Event,
- Activity.

Location of Source:
- Internal activity (daydreaming),
- Inside vehicle,
- Outside vehicle,
- Activity.

Intentionality:
- Compelled by source,
- Driver's choice.

Process:
- Disturbance of control,
- Diversion of attention,
- Misallocation of attention.

Outcome:
- Delayed response,
- Degraded longitudinal and lateral control,
- Diminished situation awareness,
- Degraded decision making,
- Increased crash risk.

Lee et al. (2008) proposed the following definition: "Driver distraction is a diversion of attention away from activities critical for safe driving toward a competing activity.

Note that this definition excludes drowsy driving or driving without awareness when the workload is low and the driving task is monotonous (see the section on Fatigue). According to this definition, distraction is about diverted attention and not about diminished attention (e.g. because of fatigue or highway hypnoses). Also note that the definition includes poorly timed driving activities such as turning on the wipers when immediate action is required to avert a crash. The competing activities in the definition can refer to interactions with equipment (both driving related and not driving related) in the vehicle, passengers, food, thoughts (of the driver her- or himself) while the traffic situation is safety critical or developing into a safety critical situation. Being captured by objects, persons and events outside the vehicle not related to the safety of the traffic situation is also a 'competing activity'.

One of the most remarkable results of the '100-Car Naturalistic driving study' (see the section on Fatigue) was that in nearly 80% of the crashes and 65% of the near-crashes, distraction was a contributing cause. However, distraction in this study also included drowsy driving and 'non-

specific eye glance away from the forward roadway'. These non-specific eye glances could be the result of internal distraction (e.g. when the driver is absorbed in her or his own thoughts), but could also be the effect of highway hypnoses. The first is included in the definition of distraction, but the latter not. When drowsy driving and non-specific eye glances are excluded, still in nearly 68% of the crashes and 35% of the near-crashes distraction was a contributing factor. The 100-Car Naturalistic driving study also showed that young drivers are more often distracted than older drivers. A possible explanation for the high involvement of young drivers in distraction-related crashes is that they more often engage in secondary tasks than older drivers, especially with cell phones and smart phones. A second explanation could be that as the basic tasks for operating the vehicle are not yet fully mastered and still require mental workload, the disruptive effect of secondary tasks is greater for novice drivers than for experienced drivers. A third possible explanation could be that novice drivers lack the skills to assess whether the traffic situation is safe enough to engage in secondary tasks or not. This latter possibility is closely related to the hazard anticipation.

Emotions

As in other aspects of daily life, drivers experience emotions when certain events take place in traffic. A driver may be angered by another driver who interrupts the achievement of personal goals or creates a hazardous situation. Drivers also experience fear as they become aware of the hazards in traffic, even when the risk is low (Taylor, 2007). These drivers exhibit driving anxiety, fear of driving or even driving phobia. On the other hand, drivers can experience joy and excitement when they drive fast and think that they still control the vehicle. Mesken (2006), after having reviewed studies about the effects of emotions on driver behavior and emotion theories, concluded that traffic situations can elicit emotions. Negative emotions, in particular, such as anger and hostility are related to risky driving and affect general task performance. In contrast to feelings and moods, emotions are related to a particular event or object (Mesken, 2006). According to Frijda (1986), cited in Mesken (2006), an important characteristic of emotions is that the events or objects that evoke emotions have personal relevance. When for instance, personal goals are interrupted by another, anger might be accompanied by action to do something about it (e.g. hit that person). This is termed action readiness; the tendency to act as a response to the emotion-evoking event. This action readiness can be so comprehensive that all other intentions (e.g. to drive safely) are overruled which is termed the control precedence of emotions.

Arnett, Offer and Fine (1997) distinguished state factors and trait factors of emotions. Trait anger for instance is the disposition of a person to experience anger. Some people become angry before others. State anger is the experience of the emotional state itself that is caused by a certain event. It could be that trait factors are stronger during adolescence and young adulthood than in childhood or adulthood.

Adolescence has long been characterized as a time of increased emotional state. Aristotle already described youth as 'passionate, irascible, and apt to be carried away by their impulses' (cited by Larson, 1989). If all adolescents and young adults experience more turmoil than they experience at other ages is questionable (Arnett, 1999). However, there is evidence that states such as sadness, anxiety, irritability and restlessness are more common in adolescence and in young adulthood that in all other stages of life [see Petersen, 1993 for a review of the literature]. The effect of this on driver behavior is not well known. There are studies in which a relationship between negative moods and risky driving were observed for drivers in general [see Mesken, (2006) for a review of the literature]. One study could be found that showed this relationship for

young drivers (Arnett, 1997), but no studies could be found that has examined if negative moods while driving resulted more often in risky driving behavior in young drivers than in older drivers. More recently, a South African study (Bachoo et al., 2013) on 306 post-graduate university students in Durban has shown that young drivers with higher anger, sensation seeking and impulsivity report more risky driving acts, using the Iversen scale of risky traffic behaviors (2004).

2.8 Information processing

Scanning

Scan patterns, eye movements and fixations of novice drivers and experienced drivers have been recorded with an eye tracker while participants were driving in real traffic (Crundall, 1998). The results of these studies are not conclusive. Mourant and Rockwell (1972) found that novice drivers tend to look less far in the distance and less often in the rear-view mirror. However, the fact that novice drivers tend to look closer to the front of the car could not be confirmed by Underwood and Crundall (1998) and Falkmer & Gregersen (2005). On the other hand in all studies carried out in real traffic was found that young novice drivers scan less broadly side to side as older, more experienced drivers do. Moreover Crundall and Underwood (1998) found that novice drivers do not adapt their scan patterns as well to the complexity of the roadway as experienced drivers.

Detection, recognition and prediction

The factors detection, recognition and prediction are strongly inter-related and are discussed together. They are all elements of hazard perception. Drivers are aware of hazards when they can detect them in an early stage of development, recognize them and predict how they may develop.

These three abilities are also present in the theory of 'situation awareness' (Endsley, 1995). Endsley (1995) describes situation awareness as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future'. Within the model of situation awareness there are three levels: perception (level 1), comprehension (level 2); and projection (level 3).

In hazard anticipation, Level 1 would be the ability to perceive a possible hazard. A driver actively searches for stimuli that could intervene with her or his goals. Perception means that stimuli in the environment draw the attention of the driver because they give her or him a vague notion that they have meaning (i.e. could intervene with her or his goals such as to arrive somewhere safely and in time) without exactly knowing what.

Level 2 in hazard anticipation would be the recognition of the situation. For the understanding of the present situation, the driver retrieves from memory knowledge such as rules of the road and past experiences in situations like this. For the understanding of the present situation the driver also assess the speed and direction of other road users in the scene.

Level 3 would be driver's prediction about the development of the recognized traffic situation. These predictions are also based on knowledge stored in memory and assessment of elements in the present situation (e.g. speed and direction of other vehicles in the scene).

Although 3 levels are distinguished in situation awareness, these levels are interrelated. Being aware of the situation is the same as having a holistic comprehension of the situation.

Hazard perception test

Hazard perception skills are most often measured with a hazard perception test that was developed by McKenna and Crick (1997). Participants watch video fragments that are taken from the perspective of a driver. In these video fragments hazards slowly materialize from time to time, but the video clips never end in a crash. As soon as a participant has detected a hazard a button is to be pressed and this response is measured. McKenna and Crick found that older, more experienced drivers had significantly better scores in this task than young novice drivers. This study has been replicated many times and similar results were found (McKenna, 2006; Sexton, 2000; Wallis, 2007). However in some studies of this task no differences were found between young novice drivers and older, more experienced drivers (Chapman, 1998; Underwood, 2000; Sagberg & Bjørnskau, 2006). However in three situations with more complicated latent hazards in their videos, Sagberg and Bjørnskau (2006) found that older, more experienced drivers responded significantly faster than young novice drivers after the first signs of a hazard had appeared on the screen. In a more advanced version of this type of testing, participants do not press a button, but point and click at the location of the developing hazard on the screen with their mouse (Smith, 2009) or press with one of their fingers on a touch screen (Wetton, 2010). The advantage of this method is that it reduces ambiguity about why participants press the button. When participants only have to press a button it remains unknown why they have pressed.

Jackson, Chapman and Crundall (2009) found that older, more experienced drivers were significantly better in predicting what could happen next than young novice drivers. This was only the case when participants made their predictions after the video had stopped and the screen had turned black. When the last image of the stopped video remained visible as a photograph on the screen, there was no significant difference in correct predictions between older, more experienced drivers and novice drivers.

Hazard anticipation is also tested in a driving simulator where participants are equipped with an eye tracker (Pradhan, 2005). Pradhan et al. (2005) found that 16-17 year old drivers with less than six months driving experiences usually failed to look in directions where another road user on a collision course could suddenly appear, due to a view obstructed by for instance bushes, or parked cars, or a lorry etc. and that 19-29 year old drivers failed to look in these directions. They also found that on their turn 60-75 year old experienced drivers more often made anticipatory eye glances in situations with these hidden latent hazards than did the 19-29 year old drivers. Similar results have been obtained more recently in Israel (Borowsky et al., 2013) about the effects of driving experience on hazard awareness and risk perception via real-time hazard identification and rating tasks: comparing young novice, experienced and taxi drivers with an eye tracker, it was observed that the young novice drivers were the less sensitive to hidden hazards.

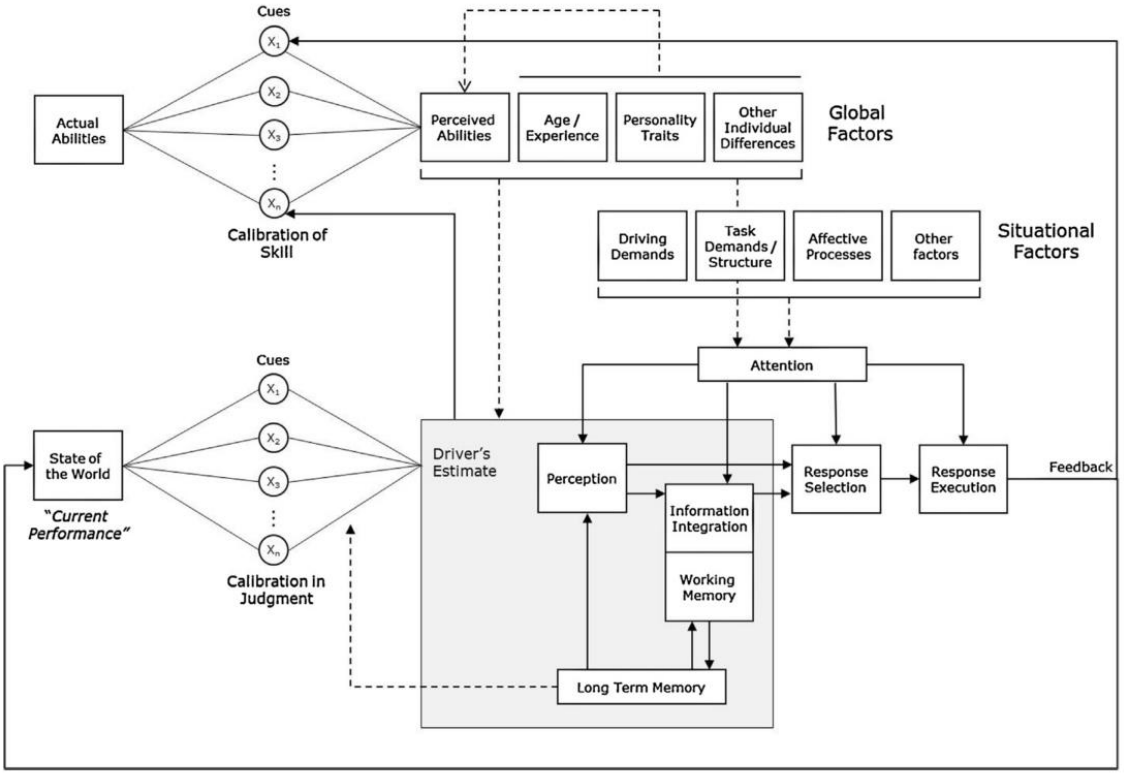
2.9 Calibration

Driving for the most part is a self-paced task where drivers proactively control the driving situation, based on expectations of how things will develop in the near future. To a certain extent drivers can determine how difficult and/or risky the driving task is. When for instance a driver begins to drive faster, the task will usually become more complex and riskier. Normally a driver does not want to exceed her or his own abilities and lose control over the situation (Fuller, 2000).

In order not to lose control, the driver balances the task demands against own capabilities. This balancing of capabilities and task demands based on self-assessment and risk assessment is called calibration (Fuller, 2007). A driver does not balance task demands/risks and capabilities, but balances perceived task demands and perceived risks. When both the perceived capabilities completely coincide with the real capabilities and the perceived task demands/risks completely coincide with the real task demands/risks, a driver is well calibrated. A driver can only calibrate properly when she or he is able to assess her or his own capabilities adequately, assess the risk adequately and only accept risks that do not exceed her or his own limitations. In the section above hazard perception was discussed, thus it's clear that a driver can detect, recognize and predict hazards. A driver that can detect, recognize and predict hazards not necessarily is a safe driver. A driver also has to calibrate, that is to say that she or he must feel the risks of the predicted hazards and must have the willingness to avert these hazards. There are indications that young novice drivers do not calibrate very well and that it takes years before their calibration skills improve (Craen, de, 2010).

More recently, a global theoretical framework of calibration has been proposed by Horrey et al. (2015), integrating calibration of skill and calibration of judgment in the driving task. This model includes aspects of information processing and lens modeling (how different information are selectively weighed and used), it aims at a global understanding of decision making in critical situations. The factors involved are summarized in figure 6 below:

Figure 6: Factors involved in calibration during driving



Source: in Horrey et al. (2015)

The application of the model to young novice drivers and the potentially adverse effects of their miscalibration suggests that insight training will be more adequate than skills training in the type of feedbacks sent to the young driver, in order to decrease overestimation of skill and underestimation of risk.

Self-assessment

As already mentioned if adolescents and young adults have the time to reflect on their own capabilities they are not more unrealistic about their weaknesses and their capabilities than older persons (Reyna, 2006). For example, a recent Turkish study (Amado et al., 2014) has shown that overestimation of one's driving abilities and over-positive appraisal of driving behavior is common among drivers of all ages, using naturalistic and systematic observations, comparing one's self-evaluation with an expert evaluation. This overestimation is stronger among drivers scoring high on the violations and errors scales of the DBQ (Driving Behavior Questionnaire) which shows clearly the risk factor of this wrong self-evaluation and the need for realistic feedbacks during training or rehabilitation.

In fact, to observe if young novice drivers overestimate their driving skills more than experienced drivers, or less, depends on the measurement mode chosen (de Craen et al., 2011): when young novice drivers are asked to compare themselves to the average and peer driver, they are not more overoptimistic than experienced drivers, but when they are asked to compare their self-assessment with their actual behaviors, they tend to overestimate their skills.

However, how young people act is not always in accordance with their rather adequate awareness of their own limitations when they have time to think about these limitations (see the earlier section on age, risk taking and brain development). Why they reflect on their

capabilities like adults and still take risks that an adult most of the times would not take, has probably to do with brain development (see the section on age, risk taking and brain development).

Risk assessment and risk acceptance

Kelly et al. (2010) assumed that novice drivers and experienced drivers do not differ so much in their analytical assessment of how risky traffic situations are if they have time to analyse the situation, but differ with respect to the risk felt in these traffic situations (the emotional aspect of hazard anticipation). In order to test this they asked participants to classify photographs that were taken from the driver's perspective as (1) safe, (2) potentially hazardous (containing latent hazards) and (3) hazardous situations (containing imminent hazards). Novice drivers and experienced drivers did not differ significantly in their ability to sort photographs as hazardous, potentially hazardous and safe. Whereas both groups recognized latent hazards equally well on photographs, the experienced drivers more intensely felt the risk involved in these situations.

3 Exposure

Excess and inappropriate speed

Young, novice drivers tend to drive in circumstances that would increase the risk for any driver. Why they tend to do this has been described in the previous sections. In this section some facts about their exposure to risks are presented. Apart for the first months after licensing, young novice drivers tend to drive too fast (Clarke, 2004). While they may not generally exceed the speed limits in these first months, they tend to drive too fast for the circumstances (e.g. too fast in a bend) (McKnight, 2003).

Driving at night and with passengers of a similar age

They often drive at night and more often with passengers of the same age. If they own a car, it is, on average, an older and smaller car than those owned by drivers in other age groups (Cammisa, 1999). Ferguson (2003) found that the older and the smaller cars in which young novices drove, the higher the risk was of crash injury. This study was conducted in the USA, but similar results have been found in Germany and Australia (Schepers, 1996; Watson, 2009). Finally, recent studies about self-reported seat belt use and age no longer show substantially higher percentages for young drivers that do not use seat belts than for middle-aged drivers (SARTRE3, 2004; Zandvliet, 2009). Young people living in rural areas are more at risk of driving under the influence of alcohol or drugs and of riding with a driver under the influence of alcohol or drugs, as less collective transport is available there, as shown by a recent Spanish study (Font-Ribera et al., 2013).

System-induced exposure

A recent Dutch work (Twisk et al., 2015) has applied the "Safe System Approach" in order to quantify the influence of safe roads systems and legal licensing age on road mortality among young adolescents: in this approach, the crash involvement of young drivers is not only dependent of their risky behaviors but also of the system-induced exposure of the country in which they live (age of licensing, mileage, type of vehicles, legal regulations, etc.): for example, late licensing in some countries do not reduce crash rate because of dangerous alternative travel modes (mopeds, bicycles).

4 Countermeasures

Introduction

A variety of measures is available which specifically target increased crash risk among novice drivers, including changes in their exposure to driving. Due to its multi-faceted nature, there is no single solution to this problem. Therefore, a package of countermeasures is required in order to combat it. Furthermore, as countries widely differ in culture, history, motorization and overall traffic safety levels, the strategies employed may need local tailoring.

This section provides with an overview of the countermeasures used in different countries that can have an important impact on reducing young novice driver risk. These countermeasures are associated with age of access, driver training and testing, enforcement and communication.

Introductory issues related to these countermeasures include questions of whether:

- Should countermeasures focus on young drivers only or should the measures be directed at all novice drivers?
- How should effectiveness be assessed? Are measures that are effective because they reduce the crash rate also 'acceptable' countermeasures?
- What is the contribution of general safety measures to young driver safety?
- What is the potential contribution of non-safety policy measures?

4.1 Novice versus young drivers

A central issue in the process of selecting countermeasures is the question of whether countermeasures should target only young drivers or all novice drivers. As all young drivers are initially novice drivers, it is most effective to target the combined factors of age and inexperience-related phenomena. Moreover, in most industrialized countries, novice drivers tend to be fairly young. At the same time, many countermeasures are equally applicable to all novice drivers, whatever their age.

4.2 Exposure control versus safe travelling

Countermeasure effectiveness can be assessed as well as targeted for several different potential success criteria:

- Safe behavior e.g. wearing a seat belt (an intermediate criterion/outcome)
- Crashes (an absolute or final criterion/outcome)
- Fatalities (a final fatality criterion/outcome)
- Crashes and fatalities per distance driven (a risk criterion/outcome).

The 'absolute number or final criterion/outcome' aims solely to increase safety and may entail measures that reduce travel, or even block access to the traffic system as drivers by increasing the age at which novice drivers can gain their license. In contrast, the 'risk criterion' states that safety should be expressed as a decrease in fatalities/crashes per distance driven. These two different perspectives result in different assessments of the outcome of measures, as well as in preferred measures. They also show that individual measures are effective in two distinct ways:

- by reducing exposure to risky travel (by means of reducing mobility under risky conditions),
- by improving the general safety level of the traffic system, including novice driver performance, resulting in more safety per kilometer driven.

4.3 The contribution of general safety measures

It is important to recognize that young drivers benefit from general traffic safety measures such as adequate traffic regulations (like low BAC), good quality enforcement of rules and regulations, safe roads, injury protection systems etc.. Table 1 gives a survey of general measures that are particularly effective for young drivers.

Table 1: Survey of generic measures beneficial to specific road safety issues, by type of effect (Unfilled circles= indirect effect/filled circles = direct effect)

The strategic approach

Road safety issues	Classes of initiatives						
	Improved enforcement	Public education	Lower speeds	Safer roads	Occupant protection	Safer modes of travel	Planning a safer system
Drunk driving	⊠	⊠		⊠	⊠	⊠	
Speeding	⊠	⊠		⊠	⊠	⊠	
Restraint non-use	⊠	⊠		⊠	⊠	⊠	
Driver fatigue		⊠		⊠	⊠		
Young drivers	⊠	⊠	⊠	⊠	⊠	⊠	⊠
Older drivers	⊠		⊠	⊠	⊠	⊠	⊠
Motorcycles	⊠	⊠	⊠	⊠	⊠	⊠	
Bicycles	⊠	⊠	⊠	⊠	⊠	⊠	⊠
Pedestrians	⊠	⊠	⊠	⊠	⊠	??	⊠
Heavy vehicles				⊠	⊠		
Drugs				⊠	⊠	⊠	

Source: Western Australia Road Safety Council and Government (2002)

4.4 Contribution of other policies

Other policies, such as an effective public transport system with reduced fares for young users can have an important impact in changing young novice drivers' patterns, mileage and risks. Other examples of how general policies may affect young driver safety are the geographical location of youngsters' meeting points like discos and socially safe transport. This kind of policy may encourage youngsters to drive or even drink and drive. Similarly, such policies may also reduce exposure. In the Netherlands for example, the introduction of a free public transport pass for students has systematically and enduringly reduced mileage in the age group 18-24 years, and subsequently reduced their crash rate.

4.5 The need for early education

Although youngsters are newcomers as drivers, they are not new to the roads. They already have extensive experience in other traffic roles (e.g. moped use, pedestrians, cycling). Moreover they have observed the way their parents drive and have been confronted with many driving violations of other road users. Studies in the field of developmental psychology have demonstrated that safety-related attitudes are formed at a very young age (Waylen, 2008). This implies that safety-related education should not only be directed at youngsters preparing to take their driving test, but, perhaps even more importantly, be directed at children in primary and secondary school.

4.6 Age of access

The choice of a minimum age for solo driving can be difficult, as it may be conditioned by different local, social, or cultural circumstances. A higher driving age is likely to save lives by preventing young and inexperienced drivers from solo driving until they are older. It has been shown that first year fatalities rise as the age of first time solo driving decreases.

At the same time, these measures can limit access to work and social and educational opportunities. Therefore, the need for mobility at a given age should be balanced against the cost of this mobility, in terms of human life and health, as well as economic impact. Such an analysis should be based on as complete and reliable data as possible.

Particularly in countries where people are allowed to drive from their mid-teens, any government seeking to reduce young driver-related deaths should consider the option of raising the minimum legal age. Furthermore, learning periods following the minimum driving age and protective measures following licensing for solo driving can do much to reduce the age-related aspects of risk.

If a higher access age is chosen for car driving, this may motivate young people to choose even less safe modes of transport, such as motorcycles. Ideally, young people should not be allowed to ride a two-wheeled motor vehicle at an earlier age than for solo car driving, but in some conditions this may restrict their mobility too severely. In terms of policy development, these potentially adverse effects of delayed licensing need to be carefully weighed against the expected safety gains.

4.7 Licensing regimes

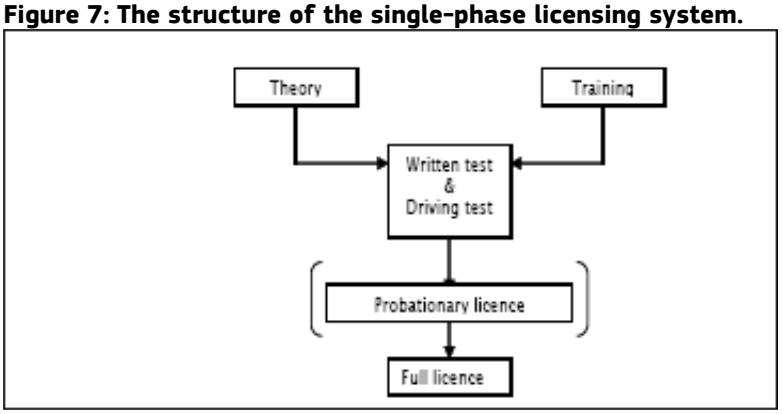
The primary aim of licensing systems is to exclude individuals with insufficient driving ability and competence. Licensing systems are based on laws and regulations referring to the requirements for being licensed (e.g. age, driving aptitude), the quality of licenses (e.g. restrictions), the administrative procedures for licensing (e.g. licensing, withdrawal) and fitness to drive. Systems differ more or less regarding the items that are tested, the formal procedures and the institutions within the system.

Although in each country the licensing system is unique in terms of content and organization, in general two distinct categories of licensing systems can be distinguished: (a) traditional and probationary licensing systems and (b) graduated licensing systems (GDL).

4.7.1 Traditional and probationary licensing systems

In this system, a driver is fully licensed after passing the driver test, and no special conditions apply to the novice driver (Figure 7). Today most countries using a 'single-phase licensing system' have also introduced a probationary license. Consequently, the novice driver does not become a fully licensed driver until he or she has completed a probationary period, which could include demerit points and restrictions such as zero BAC.

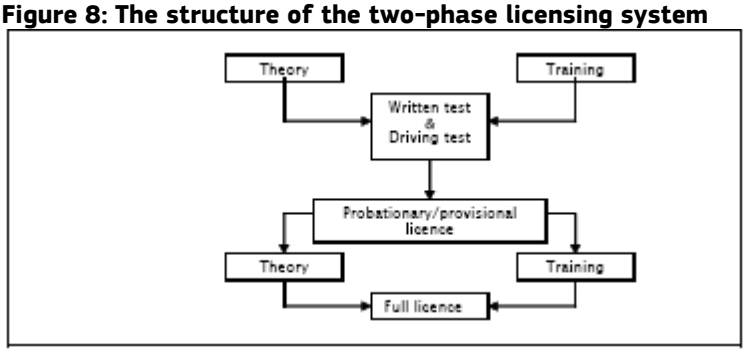
Figure 7: The structure of the single-phase licensing system.



Source: Adapted from Engström et al., 2003 p. 100

A variation to this is the 'two-phase system' (Figure 8), in which candidates get a provisional license after having completed the first phase, allowing them to drive solo. Only after completing the second phase of theory and training, but without further testing, the full license is acquired.

Figure 8: The structure of the two-phase licensing system



Source: Adapted from Engström et al., 2003

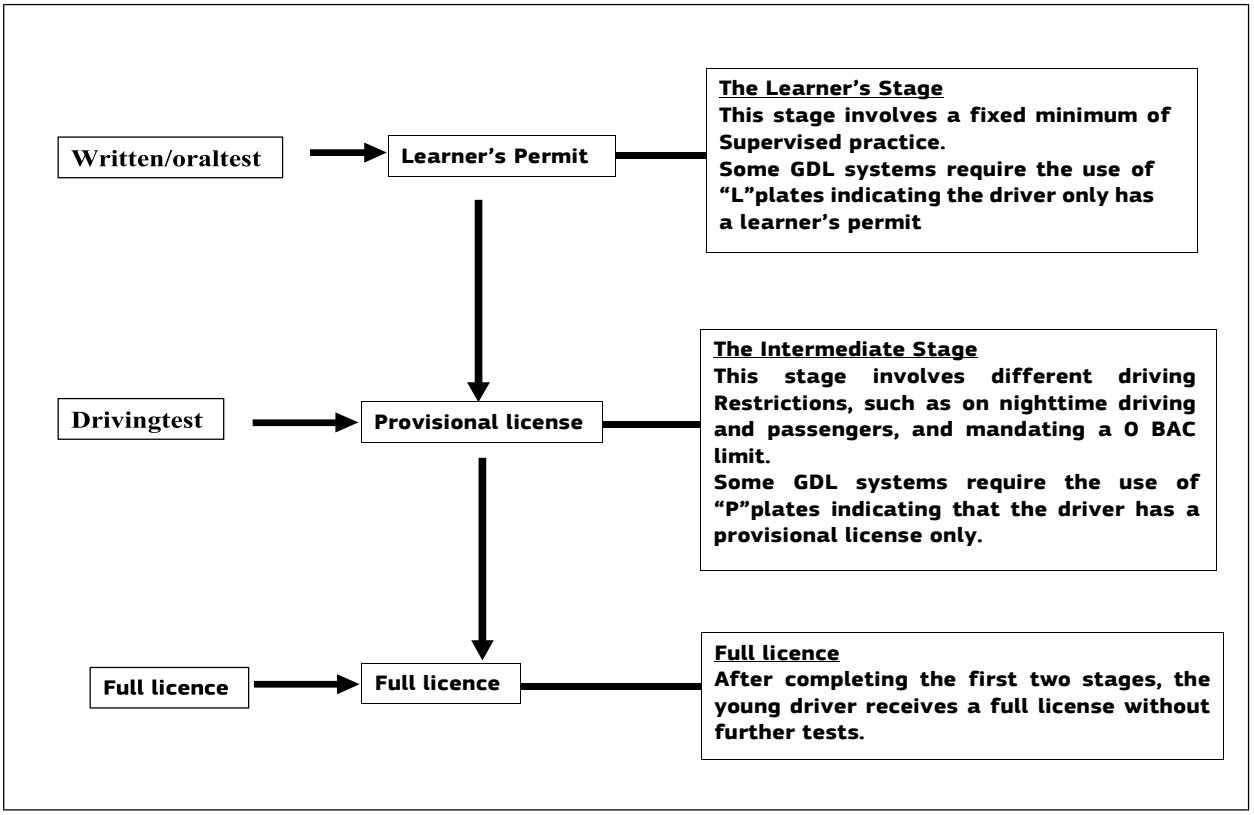
4.7.2 Graduated licensing

The basic principle of graduated licensing (GDL) is to allow learner drivers to acquire driving experience under low-risk conditions. When a young driver drives with a middle-aged passenger, for instance, the crash rate is low (Ouimet, 2010). A graduated driving license aims to provide novice drivers with driving experience in such a way that they encounter as little danger as possible. As skills improve, they are gradually allowed to gain more experience in more dangerous situations. At the same time, the graduated license attempts to increase the motivation to drive safely by only lifting limitations if no offences have been committed and/or the novice driver has not been involved in any crashes.

A graduated license usually comprises three stages. The first stage is the 'learner' stage' in which only supervised driving is allowed. The supervisor and learner must usually keep a logbook of the operations that the learner has carried out, together with an assessment of how well they were done. Usually a parent is the supervisor. The learner's stage is followed by the 'intermediate stage'. Nearly all types of graduated license have a test before moving on to the intermediate phase. During the intermediate stage the learner may drive independently, but only under circumstances in which the risk of a crash is small. In this stage even the smallest amount of alcohol is usually prohibited when driving. Often driving in the dark and driving with passengers in the same age group are also forbidden. The intermediate period can be lengthened if an offence has been committed and/or a crash has been caused. Another test sometimes follows the intermediate stage; this test focuses on the higher order skills like hazard perception. The intermediate stage is followed by a phase that can be called the 'beginner's license'. This phase

entails stricter rules during the first years after obtaining a driving license than for experienced motorists (e.g. lower alcohol limit or a heavier demerit point system). It is also possible to demote the learner to the intermediate phase after having committed a traffic offence.

Figure 9: The structure of graduated licensing



Source: Engström et al., 2003

Most evaluations of the graduated driving license conducted to date, have reported significant reductions in crashes and fatalities. However, they show great variation, some reporting effects as large between 10 to 60% (Hedlund, 2005; Senserrick & Whelan, 2003; Hedlund, Shults & Compton, 2003; Hartling et al., 2004). A recent work (Masten et al., 2013) has analysed which components calibration of the graduated driver licensing program were associated with the reductions in fatal crash involvement; these were: a minimum learner permit holding period of 9/12 months and a passenger restriction allowing only one teen for 6 months or longer.

It should be borne in mind though, that the graduated driving license is only implemented in the USA, Australia and New Zealand. The evaluation studies have shown positive improvements compared to their 'old' licensing systems. These systems however were less 'advanced' compared to the European licensing systems. This implies that the magnitude of the effect of graduated driving license in Europe may be smaller.

As the licensing age in most European countries is 18, it is more difficult to realize a full GDL-program. However, Austria has realized a full GDL-system and more and more countries in Europe have introduced a learner stage. In Germany, learners first have to pass the complete driving test at age 17 and if under 18 years of age can only drive while accompanied by a dedicated supervisor (usually a parent). Preliminary results show a 20% decrease in crash rate as a result of the introduction of a learner's stage in Germany (Willmes-Lenz, 2010).

4.8 Content of training: best practice

The fundamental goal of the education, training and licensing process should be to create drivers who are safe and not just technically competent by the time they are permitted to drive unsupervised and unaccompanied. Essential to this is a training process that engages novice drivers personally and emotionally, increasing their awareness of their own limitations and of the dangers inherent to driving. It is important to focus on the fundamental beliefs about driving, including assessment of the trainees own skills and motives for driving, as well as the basic skills needed for driving.

In order to provide an overview of what the licensing process should cover, the GDE Matrix (Goals for Driver Education) was initially developed in the context of the EU's GADGET project (Siegrist, 1999), and later frequently updated (Engström, 2003)]. This GDE can be seen as 'best practice', as it was developed on the basis of the knowledge of risk conditions and learning processes.

Table 2: Goals for Driver Education (GDE) Matrix

	Knowledge and skill	**Risk increa-sing aspects**	**Self assesment**
Goals for life and skills for living	**L**ifestyle, age, group, culture, social position etc, vs driving behaviour	**S**ensation seeking **R**isk acceptance **G**roup norms **P**eer pressure	**I**ntrospective com-petence **O**wn preconditions **I**mpulse control
Goals and context of driving	**M**odal choice **C**hoice oftime **R**ole of motives **R**oute planning	**A**lcohol, fatigue **L**ow friction **R**ush hours **Y**oung passengers	**O**wn motives in-fluencing choices **S**elf-critical thin-king
Driving in traffic	**T**raffic rules **C**o-operation **H**azard perception **A**utomatization	**D**isobeying rules **C**lose-following **L**ow friction **V**ulnerable r.u.	**C**alibration of dri-ving skills **O**wn driving style
Vehicle control	**C**ar functioning **P**rotection systems **V**ehicle control **P**hysical laws	**N**o seatbelts **B**reakdown of ve-hicle systems **W**orn-out tyres	**C**alibration of car-control skills

Source: Hatakka et al., 2002

It provides a hierarchical schema of the driver's task and addresses on four different levels:

Level 4: Goals for life and skills for living
This level refers to personal motives and tendencies that may influence attitudes, decision-making and behavior in driving and, consequently, crash involvement. Examples of such tendencies are a person's desire to experience thrills, or to impress others. The basic message is 'the way you drive as a reflection of who you are, or who you want to be'.

Level 3: Goals and context of driving
This level focuses on the goals behind driving and the context in which driving is performed. Examples include the type of car you want to drive, the trips you make, and the choice to drive under the influence of alcohol or not. Clearly, level four elements might affect decisions at the third level. In turn, choices made on the third level have an influence on situations that will occur in real traffic, the level of risk (level 2) and how well the driver will be able to handle specific traffic situations (level 1).

Level 2: Driving in traffic situations
This level is about mastering driving in specific traffic situations. The ability to adjust his or her driving to constant changes in traffic, as well as the ability to identify potential hazards and to act correctly in order to avoid them, are both included in this level.

Level 1: Vehicle control
This level focuses on the vehicle control skills. It includes the ability to control the vehicle, even in difficult situations, as well as the functioning, use and benefits of injury prevention systems such as seat belts.

These four levels are considered hierarchical, because the higher levels directly affect the lower ones. On the basis of expert opinion and literature reviews, the EU BASIC project concluded, that by focusing on the higher levels in the model in driver training, more inherently safe drivers could be produced (Hatakka, 2003). The current training systems primarily focus on levels 1 and 2.

These four levels make up the GDE Matrix in Table 2, which defines appropriate goals for driver education, when combined with three key training areas:
- Knowledge and skills. This area describes the basic skills and knowledge a driver needs for normal traffic situations.
- Risk increasing factors. The driver needs to be aware of risk increasing factors, such as the effect of fatigue, worn-out tires, alcohol, and peer pressure.
- Self-assessment. This domain deals with how accurately a driver assesses his own competencies. This is particularly relevant as this self-assessment will be the basis on which a person selects his driving speed and following distances (safety margins). Young drivers tend to overestimate their driving skills.

In 2006 Norway has based its training and testing system on the GDE. An evaluation study is expected in a few years. Several other EU countries are trying to apply the matrix, however one difficulty often found in many countries is that not all the driving trainers (and in fact only few) are able to apply the matrix in their work (because of lack of time and of initial training background).

4.9 Training Method

Two pre-license training methods can be distinguished:
- Formal pre-license training
- Informal pre-license training

4.9.1 Effects of formal training

Formal pre-license training is a training in which a candidate driver practices under the supervision of a qualified driving instructor, usually while simultaneously receiving instruction on how to drive and as a part of a structured training process.

Different reviews (Christ, 2001; Engström et al., 2003; Elvik & Vaa, 2004) conclude that formal pre-license driver training does not reduce novice driver crash rates. At the same time, formal training adds to the cost burden of the learner. This has been confirmed more recently by a study in New Zealand (Begg et al., 2014) which has shown that pre-licensed driving experience increase car crash involvement during the learner and restricted license stages of graduated driver

licensing. However, this result may also be explained by the characteristics of the young pre-licensed drivers (Begg et al., 2012): pre-license driving is higher among males, Maoris (i.e. indigenous Polynesian people of New Zealand), those living in rural areas, those living in areas of high deprivation, all demographic and behavioral characteristics that are associated with a higher crash risk, so pre-license would not be a suitable solution for them.

Recent surveys on the content of formal pre-licensed training have shown that current training systems primarily focus on the 'lower order' car driving skills, such as vehicle control and the execution of manoeuvres like overtaking and crossing intersections, while there is a lack of training at a more strategic level, like route finding, and self-assessment of driving skills. It has been hypothesized that including the 'higher levels' in driver training will improve its effectiveness but there is little evidence to date in support of that view.

In the EU-project HERMES an attempt was made to combine the GDE-Matrix with learner centered didactics. Instead of instructions, learners were stimulated by questions of a coach to reflect on the way they drove and how they could improve things by themselves. See for a video clip of this approach: http://www.alles-fuehrerschein.at/HERMES/index.php?page=player&v=Hermes_ENG_full&title=Complete%20Film. Whether driver education based on the GDE-matrix and the application of learner centered didactics result in a lower crash rate, is not known yet.

More recently, a German study (Weiss et al., 2013) has shown that computer-based learning is more efficient than traditional learning to improve hazard perception, quality of self-evaluation and calibration of the driving task by learner drivers. An Australian work (Prabhakharan et al. 2012) has shown how episodic training (a method dedicated to the higher levels of the GDE matrix) could reduce speeding by young drivers but that the effect was depending on the cognitive workload. This result is suggesting to compartmentalize driver training of novice drivers in order to reduce the cognitive load of trainees.

4.9.2 Effects of informal training (accompanied driving)

Informal pre-license training involves accompanied driving with an experienced driver in the passenger seat. This option is available in various countries: UK, Sweden, France, etc.

Informal driver training is voluntary in many licensing systems, although it is often encouraged by official regulations in order to increase the learner's driving experience prior to solo driving.

In formal training schemes, young drivers often only have about 25 to 40 hours of driving experience when they are licensed for solo driving. Research (Gregersen, 2000b; Sagberg, 2002) indicates that risks would be greatly reduced if all learner drivers were to acquire much higher levels of pre-license driving experience. However, on its own this measure may not be sufficient as was demonstrated in France, where a similar scheme aimed at increasing pre-license driving experience failed to be effective (Page, Quimet & Cunny, 2004). Outcomes of accompanied driving vary across the countries: for example, a recent evaluation in Israel (Toledo et al., 2012) of a new accompanied driving scheme with a guidance has observed lower crash records for the young people having participated in the program.

4.9.3 Quality of trainer/supervisor

Well-educated instructors possessing the necessary knowledge and teaching skills is vital for a well-functioning system. The EU project MERIT made an inventory of the standards in the EU

countries, and has proposed guidelines for further improvements. The quality of the instructor may contribute to the success or failure of potentially effective training programs (Craen de et al., 2005). In addition, to get good results with an informal pre-licensing system, it is essential that those accompanying the learner (e.g. parents) must be prepared to provide appropriate direction and influence. Some countries have published guidelines for that purpose. Evaluations of the effects of these guidelines have not been made. A follow-up of the MERIT-project was the HERMES-project (see section 4.9.1).

4.9.4 Are advanced vehicle skills counterproductive at this stage?

Courses which focus on advanced vehicle control skills such as skidding are not advisable for novice driver training, since this may lead to over-confidence in skills in dangerous conditions, which may previously have been avoided (Advanced, 2002). For instance skid control is a skill that should be extensively practiced, and regularly applied which cannot be achieved in a one day course. However, training in higher order skills such as hazard anticipation, can reduce crash risk (McKenna, 2005; Fisher, 2006; Wang, 2010). For example, such training in higher order skills has been evaluated recently in New Zealand (Isler et al., 2011) comparatively to training in vehicle handling skills with a randomized trial: better outcomes are observed concerning visual search, hazard perception, and safer attitudes to close following and to dangerous overtaking, decrease of overconfidence. Another recent example is an innovative technique coming from aviation training, the repair of faulty scripts (Prabhakharan et al., 2012), which has reduced speeding among young drivers.

4.10 The Driver Test

In addition to the importance of good training, well-qualified instructors and the availability of teaching resources, a well-functioning licensing system needs a high quality testing system. First of all, the design and content of the test should enable a check on whether the stated training objectives have been reached. Secondly, a well-designed test provides direction and content for the training process. If certain objectives are not covered in the test, and are not tested in other ways, it is unlikely that these topics will be dealt with in the training process. Therefore test and training need to reinforce each other. Discrepancies lead to a malfunction of the whole system.

4.10.1 Content

In many countries, the driving test consists of a theory and a practical test. Tests are used to decide whether the learner has achieved the defined training objectives, so they need to be of high quality. Some countries have a separate hazard perception test.

Theory test

In a theory test the candidate needs to demonstrate a good and thorough understanding of the traffic systems and the rules that apply. Although it can be assumed that this understanding will probably improve the quality of a driver's decisions, the relative contribution of this test to overall safety has not yet been studied, and hence no conclusions can be drawn about its effectiveness.

Practical test

When comparing the practical tests in different countries, two different ways of establishing the content of the test can be distinguished: in some countries, such as Norway and Great Britain, standardized test routes are used in order to guarantee that the test includes certain elements. In other countries, like Sweden, the examiner decides on the test route for the practical test, but ensures that all relevant traffic situations are present in the route. The EU project TEST (Test,

2005) showed that the test procedure differed significantly between countries and that not all elements required by the European Driving License Directive are tested. As yet no assessments of the quality and effects of different tests are available.

Hazard perception testing

Young novice drivers are poor in detecting and assessing hazards. Therefore, several countries have introduced hazard perception tests as a compulsory element of driver testing, to test the ability to foresee and react to hazards. This kind of test is still under development and several other countries now consider implementing this type of test. There are indications that the incorporation of a hazard perception test in the driving test has a positive effect on road safety (Congdon, 1999; Wells, 2008). More recently, an Australian work (Horswill et al., 2015) has shown that a video-based hazard perception test used for driver licensing can predict crash involvement of novice drivers in Queensland: drivers having failed the test were more likely to be involved in an active crash after licensing.

Hazard perception training

In order to improve the young novice drivers' abilities in hazard perception, it may not be sufficient to test hazard perception but also to train it. A recent Australian work (Wetton et al., 2013) has shown that "what happens next" exercises and self-generated commentaries are useful addition to hazard perception training for novice drivers if used in combination.

4.10.2 Quality of tests

Reliability

Any driving test needs to be reliable. Reliability refers to the degree to which test scores are free from errors of measurement. If the test is reliable, then the same candidate, when tested twice, should have approximately the same score both times. The European project TEST (Test, 2005) concluded that a low reliability is undesirable because it is likely to be seen as unfair, and thus to randomly penalize some candidates and pass others. Moreover, an unreliable test is inefficient and costly, since it will result in unnecessary failures and subsequent retests, and is likely to be held in general disrepute.

Validity

Validity is also an important characteristic in any driving test. It refers to the extent to which the test measures competence and propensity to be a safe driver. In other words, how effectively does the test discriminate between those drivers that will be safe and those who will be unsafe in future? As yet, studies on this subject are not available. A test can be judged to have a good content validity if it (a) covers all aspects of driving known or judged to be relevant to its objective (e.g. safety) and (b) induces adequate training and practice in all of these aspects even if they do not feature in the test itself.

Legitimacy

Aside from these more methodological issues, an additional point can be made about the importance of the legitimacy of the licensing process in the eyes of the public. Changes to the system should be convincingly related to safety and mobility in order to prevent public concerns about changes only being aimed at generating financial benefits for the licensing authority. In line with this, it is of vital importance to assure that the licensing process is free of any possible corruption.

4.11 Specific post license measures for novice drivers

Crash figures show that it is of the utmost importance to convince youngsters to drive safely, not to intentionally violate traffic rules, and to reduce exposure. Instruments to achieve this are:

- Advanced training: to improve driver attitudes
- Protective measures: to reduced exposure to high-risk conditions
- In-car monitors that reward safe driving and or discourage risky driving

Given that drivers' safety-related attitudes are formed well before the driving age, measures should also focus on children at a much younger age than 16-18.

4.11.1 Advanced training

The amount of experience gained during formal pre-license driver training is limited. Also, the types of situation encountered during training are likely to be rather limited compared to the conditions regularly faced by drivers, such as driving in heavy traffic, late at night and driving for long periods.

For these reasons, some countries have post license training as a compulsory part of a two-phase licensing system. Some other countries offer it as a voluntary option.

Advanced post-license training has been shown to influence behavior and attitude, but evaluation studies studying the effects on crash risk are not conclusive (NovEV, 2002). In a recent study in Germany no effect was found of a voluntary advanced training program (Sindern, 2010). In Belgium, a post-license education program called "On the road" has recently been evaluated (Brijs et al., 2014), aiming to target the higher levels of the GDE matrix, awareness and insight. The evaluation took place twice, immediate post-test and at a 2 months follow-up. It was concluded that the program had little effects on speeding intentions and on risk detection but improved risk-related knowledge; thus it is considered a good starting point but the methods still need to be improved.

4.11.2 Protective measures

The necessity to reduce risk when it is likely to be the highest (immediately following gaining a license) can be achieved by way of protective measures. These measures create conditions which manage exposure to risk in the first years of driving. Protective measures limit the complexity of the driving task, and protect the novice driver from dangers resulting from poor self-regulation and self-control, in the period in which higher order skills are still 'under construction'. Licensing systems throughout the world are implementing different combinations of these measures. The measures applied most frequently are:

- Zero alcohol limits
- Restrictions on night time driving
- The presence of peers as passengers

<u>Zero alcohol limits</u>

Alcohol consumption, even in small amounts, increases driver fatality risk. This effect is particularly strong for young novice drivers. Hingson et al. (1994) showed that for young drivers, starting from a Blood Alcohol Level (BAC) of 0,8 g/l, only lowering from 0,8 g/l to 0 or 0,2 g/l was effective, and that lowering BAC levels to 0,4 or 0,6 g/l did not produce significant reductions in alcohol-related fatalities. In both graduated driving license and probationary systems, a

maximum BAC level of 0 to 0,2 g/l, linked to serious repercussions or high demerit point loss as a result of contraventions, could contribute much towards lowering young driver risk.

Many countries have already, or are about to introduce lower BAC levels for novice drivers, and there is an ongoing debate on whether the best level would be 0,2 or 0 g/l alcohol. The primary philosophy behind the 0 g/l alcohol limit is the consistency with the message which emphasizes that any amount of alcohol will increase crash risk. The choice for 0,2 g/l alcohol limit is based on the relative low risk below the 0,2 g/l limit, the possibility of false positive results in tests and the withdrawal of enforcement capacity form the high-risk categories (above 0,2 g/l) leading to a potential increase in alcohol related crashes. These arguments would in principle suggest 0,2 g/l as the more effective measure.

Night time restrictions

Young drivers have a particularly high crash risk during night hours. Thus, restrictions on night-time driving are often included in graduated driving license systems, of which they are considered to be one of the most beneficial elements in lowering crash involvement and severe crashes during solo driving. However, the benefits of this countermeasure need to be weighed against the social equity issues of mobility and access.

Presence of peers as passengers

Driving with other young people in the vehicle increases young drivers' crash risks. Thus, limits on driving with similarly aged passengers are widely used in the intermediate stage of the graduated driving license. Again, social equity and access to the benefits associated with mobility is an issue. With this in mind, in almost all systems where this restriction is used, it does not apply to family members.

4.11.3 In-car data recorders that monitor driving behaviour

Data recorders can be installed in the cars of novice drivers that monitor their driving behavior. In an experiment in the Netherlands, these were used to reward safe driving. Young novice drivers participating in the study could earn a 50 Euro discount on their car insurance if the data recorder registered that they did not speed. The effect was that speeding decreased by 14% (Bolderdijk, 2011). In Israel, in an experiment, a data recorder was installed that warned the young novice driver that he or she showed reckless driving behavior and automatically a text message was sent to the parents of the young novice driver, informing them that their son or daughter drove unsafely (Prato, 2010; Guttman, 2011). The effects on crash rate are not yet known. A recent Israeli study (Gesser-Edelsburg et al., 2013) has given interesting results about the social acceptability by teenagers of in-vehicle driver monitoring technologies, as a successful implementation of this promising action needs to be accepted by young people: if they attribute positive functions to the technology as an "objective" indicator which so would be acceptable for both themselves and their parents in order to evaluate their driving, this "virtual" accompaniment has also negative connotations like the traditional "actual" accompaniment by parents, in terms of invasion of privacy, restriction of independence, extension of the supervision that may introduce tensions and frictions in the relationship, especially as young people do not always consider their parents as good role models concerning driving!

4.12 Enforcement

4.12.1 Police strategies

Compliance is vital in order for protective measures to have an effect. This requires effective enforcement. However, targeting on young people can lead to serious suggestions of discrimination and in many countries it may not be possible from a legal point of view. This implies that initiatives aimed at all drivers are particularly relevant for young drivers, who are most likely to commit many violations and to have a high crash risk.

New developments in the field of information technology systems may, in future, assist in focusing enforcement on certain high-risk groups.

Special attention should be paid to unlicensed driving. The more regulated and demanding the licensing process becomes, the more tempted novices will be to drop out of the licensing process and to drive without a license.

4.12.2 Targeted violations

Speed

Speed enforcement, both by the police and by automatic systems, is essential for ensuring young driver safety to prevent excess speed. However, ensuring appropriate speed choice requires the use of electronic devices, like data recorders, that make continuous monitoring of driver behavior possible. Also, a stringent demerit points system or restrictions regarding alcohol, night driving, and carrying passengers mitigate the effects of speed.

Drink driving

Clearly, enforcement plays a key role in preventing drinking and driving. Random and targeted breath testing (RBT), where drivers are selected purely on the basis of chance, during periods when and at locations where high alcohol use is expected, is an effective policing technique. RBT increases the potential offenders' perception of the possibility of being caught, which affects their drinking and/or driving behavior. Police enforcement in this field can be targeted at specific problem areas where higher proportions of impaired individuals can be expected among the driving population, such as close to discotheques, music halls or leisure-time areas. In this sense, it should be noted that patterns of youth drinking may differ from those of older people. Although social tolerance on drink driving has decreased over time, the effectiveness of RBT requires intense enforcement activity on the road and accompanying media coverage.

Drugged driving

One basic problem in dealing with drug-related road safety risk is that, in roadside testing, drugs are less easily detected than alcohol, as the technology both for detecting them, as well as for determining their level of presence, is not yet as precise as it is for alcohol. This may induce some people to opt for drugs rather than alcohol.

Clearly, enforcement of drugged driving would be enhanced by improved roadside testing technology, as well as by appropriate legislation. More detail on the issues of risk and roadside testing is available from the EU's DRUID project (www.druid-project.eu) and the literature review by Lenne et al. (2004).

More recently, four German screening devices (Oral Twist, Envite Smart Clip MultiDrug, Envite Smart Clip MultiDrug THC, Securetep DrugWipe) have been tested in South Africa (Matzopoulos et al., 2013). This study showed that these devices improve the screening for amphetamines and

cocaine compared to routine drunk-driving spot detection operating procedures. The time of use do not exceed 5 minutes and they decrease the confirmation of evidence load.

4.12.3 Point systems

One disincentive for risky driving is the threat of losing one's license or having to pay more to renew it. This is often enforced through demerit points assigned to drivers caught breaking rules. The frequent violation of traffic rules committed by novice drivers is punished more severely than that committed by more experienced drivers. Evaluation studies show mixed results on the effects of demerit point systems, in particular regarding their lasting effect.

Experiences with 'general' demerit systems for all drivers have demonstrated that, after an initial positive effect, the impact decreases over time to zero in conditions where police enforcement is low. This indicates that demerit point systems are only effective if the chance of the police detecting a violation is high. In addition, the fact that license revocation as a part of point system may lead to an increase in unlicensed driving also needs to be counteracted in order for demerit point systems not to lose credibility. Recently, a European collaborative project called BESTPOINT (2012) has produced a handbook stating the conditions for getting the best out of a demerit point system.

4.12.4 Publicity campaigns

Publicity campaigns aim to persuade young people to drive safely. When combined with other measures their overall effect was estimated by the European project GADGET (1999) to reduce the number of crashes by 8,5% during the campaign period. During the period following the campaigns, the overall effect nearly doubled, to 14,8%. Other combined measures included police enforcement, rewards, legislation, and educational programs. These programs can be directed at youngsters and/or their parents or guardians. However, most programs target youngsters; not many programs focus on the role of parents (Delaney et al, 2004; Mulvihill et al., 2005).

4.12.5 Parents

Parents need to play an active role in moderating high-risk among young, novice solo drivers. Many programs and instructional materials have been developed to help parents to teach adolescents to drive, but few educational materials are available to encourage and teach parents how to deal with young driver risks.

Parental management (monitoring and restriction) is undoubtedly an important influence on teen driving and safety when imposed, but unfortunately, parents do not perceive teen driving as highly risky and establish few restrictions on teens once they have gained their license. Therefore, the first step should be to increase problem awareness. A review of literature on the effectiveness of parents-based interventions concerning drunk driving (improving supervision and communication) has recently been produced (Assailly, 2014).

4.12.6 Young people

Persuasive information campaigns should be employed in combination with other countermeasures, such as enforcement and education, as a means of positively changing attitudes towards safe driving. It is especially necessary for these campaigns to make a thorough analysis of target groups and the appropriate message for them, and specifically target young males. It is also necessary to ensure ongoing evaluation and improvement of these campaigns.

4.13 ITS

Technology based interventions are still under development and can be very useful. In some cases, the use of new technologies may involve public acceptability issues as well as to the legal implications of reducing driver control over aspects of vehicle functioning. On the other hand, though, they provide an efficient means of restricting very young drivers, as it would enable parents to impose that technology for use of the 'family car'. It is also important that new drivers learn how to use these technologies, as well as to develop skills for situations in which the technologies do not function or are not available.

As these measures are very new, some are in the test phase, others only exist on the drawing boards, few studies have been made of the safety benefits and disadvantages of these measures. Promising ITS applications for young drivers are:

- Smart cards
- Alcolocks
- Seat belt systems
- Driving data storage unit (see section 4.11.3)
- Electronic stability control (ESC)
- Advanced driver assistance systems (ADAS)
- Intelligent speed adaptation

Smart cards

Smart cards hold information about the driver and, used in conjunction with the ignition key, prevent the car from starting if the driver is not authorized to drive it. They could also be used as a tool to select which drivers are allowed to drive under specific conditions (for instance, they could prevent novice drivers from driving at certain hours of the day).

Alcolocks

Alcohol is one of the important risk factors for young drivers. A system which could prevent youngsters from using a car while under the influence of alcohol could improve safety. An alcolock is a device that checks the concentration of alcohol in the driver's breath before and during driving. If the alcohol level is higher than a pre-set level, the system will render the car impossible to start and drive. So in theory, such an application for young drivers may save lives. As yet, evaluation studies have only been applied to programs using alcolocks for repeat alcohol offenders. No programs are known that have targeted young drivers.

Seat belt systems
Given the role of non-seat belt use in fatal and serious casualties among young, novice drivers, systems that warn the driver to put on a seatbelt, or prevent the engine from starting until the seat belt is fastened, also play an important role in reducing risk.

Driving data storage unit
Also named event data recorders or black-boxes, they can be used to register information about the driver's performance, the vehicle, and traffic situations, in order to provide feedback to the driver or others, such as employers, parents, traffic authorities or insurance companies. Black-boxes, especially in combination with incentives (for instance, insurance based ones) and punishment, may have great potential (see section 4.11.3).

Electronic stability control (ESC)
This system uses sensors to detect a vehicle's deviations from the driver's intended path, and then applies breaking or power reduction to individual wheels to bring the vehicle back under control. It also assists in slowing down the vehicle in loss-of-control situations (OECD, 2006).

The OECD indicates that ESC can be effective in reducing single-vehicle, loss-of-control crashes that result in serious injuries or fatalities by more than 30%. As this type of crash is so prominent in young drivers, such a system might prove valuable as long as it does not lead to 'more' risk taking. Such counter effective patterns have been observed related to the introduction of similar systems, encouraging drivers to use smaller safety margins (behavioral adaptation). ESC might have similar effects on young, in particular male drivers. Therefore, careful piloting and subsequent monitoring should be part of any implementation program.

Intelligent speed adaptation
The potential value of different types of driver assistance technologies in helping drivers to comply with speed limits is large. (See Erso eSafety and Speeding and Speed Enforcement web texts). Given the propensity of young drivers for high speed, this area would seem to have good potential, perhaps forming part of a graduated driver licensing provision, although the specific benefits for these age groups has not yet been identified.

Advanced driver assistance systems (ADAS)
This is a broad category of systems aimed at supporting the driver in his driving task. The effects of many of these systems are still being studied (see also Erso web text on Older drivers). The available information shows that none of these studies have differentiated between user groups, and as a result we do not know what these systems will contribute to young driver safety. This is a serious omission, as young drivers are a high-risk group, likely to test the limits of any ADAS system.

5 Implementation process

Implementing measures in the field of road safety and in particular with respect to young drivers, is a complex process. For detailed information on the organization of these processes see web text on Road Safety Management where some aspects closely related to the young driver issues are discussed: e.g. prioritising measures, costs and benefits, and public support.

5.1 Prioritizing measures

The multi-faceted nature of the young novice driver problem requires a broad spectrum of measures to prevent serious and fatal crash injury. Still, within this broad spectrum it is necessary and possible to prioritise these measures on the basis of availability and effectiveness. That is, focus on those measures which are known to be effective in a broad range of situations and across countries. This, in contrast to measures that have been shown to be effective in small scale pilots only, or are believed to be effective on the basis of expert knowledge. Priority casualty reduction measures include:

- Implementing general Safe System safety measures such as legislation and enforcement on seat belts, speed and alcohol. Improve, roads in particular roadsides, speed management, vehicle crash protection and better post-crash care.
- Introduce supervised practice before licensing and add protective measures during the first stages of solo driving.
- Improve driver testing and driver training (which can improve attitudes) using the GDE matrix.

5.2 The role of cost-benefit analyses

To overcome resistance to change, which will also be caused by questions of cost, objective data and facts are needed that show economic savings generated by these measures to be higher than their costs.

Table 3 shows the socio-economic costs of young driver fatalities in OECD countries. The costs include medical costs, production loss, settlement costs and loss of quality of life (also referred to as 'human costs' or 'human losses'). For most European countries a standard European value is used (corrected for differences in purchasing power), as proposed by the ECMT. In addition, country specific values have been used for non-European countries. The calculations indicate that the total costs of young driver fatalities in the countries mentioned are about 20 billion Euros (price level 2004). A large part of these costs, about 14 billion Euros, are human losses. The other costs (medical costs, gross production loss and settlement costs) are about 6 billion Euros. Note that victims of young driver crashes killed along with the young drivers are not incorporated into the calculations in Table 3, nor are the costs of injuries. Thus, obviously, the full costs of young drivers' crashes will be much higher (OECD, 2006).

Table 3: the costs associated with traffic fatalities per country

	Number of young driver fatalities	Cost per fatality including human losses (million Euros, 2004)	Total costs including human losses (million euros, 2004)	Total costs excluding human losses (million Euros, 2004)
Australia(1)	195	1,16	227	179
Canada(1)	262	1,37	360	-
NZ(1)	51	1,66	85	0
USA(1)	3.999	358	14.333	3.715
Iceland(2)	3	2,19	6	2
Austria(3)	110	1,78	196	72
Belgium(3)	154	1,83	281	104
Denmark(3)	35	1,86	65	24
Finland(3)	43	1,70	73	27
France(3)	645	1,80	1.159	429
Germany(3)	750	1,82	1.362	504
Greece(3)	105	1,65	173	64
UK(3)	330	1,85	611	226
Ireland(3)	31	1,93	60	22
Netherlands(3)	74	1,96	145	54
Norway(3)	25	2,04	51	19
Portugal(3)	80	1,72	137	51
Spain(3)	322	1,83	591	219
Sweden(3)	40	1,77	71	26
Switzerland(3)	49	1,85	90	33
Total			20.065	5.903

Source: SWOV,
(1) Source of calculations: Sælensminde (2003)
(2) Source of calculations: Calculations by SWOV
(3) Source of calculations: ECMT(1998)

These calculations can be used to carry out cost-benefit analyses, in which the costs of measures are compared to the savings that will result from the measures.

5.3 Public acceptance

Road safety improvements greatly benefit society, by reducing injuries, loss of life and other general economic costs, associated with police, medical care, and emergency services. But at an individual level these benefits are not always recognised, as countermeasures may be perceived as interfering with civil liberties. This is particularly true for young drivers: as their driving license is their passport to adulthood, the gateway to independence and an opportunity to enlarge the social circle. Most of the measures proposed here and particularly the most effective ones complicate their access to a driving license and reduce the young drivers' mobility in the first stages of solo driving. In addition, these countermeasures may also be perceived as unfair as they do not only affect bad drivers, but every young novice driver irrespective of his previous driving record. These types of general measures often meet with more resistance than those targeted on 'problem' drivers only. Finally, the predictable bad reception of these types of measures by citizens makes politicians reluctant to introduce them.

Even though all these difficulties exist, it should not be forgotten that other important measures on road safety, such as the use of seatbelts or helmets, or the limits on alcohol were also badly

received by the public at first. Nowadays, they have become standard practice in most countries, and in particular the alcohol policies are supported by the majority of the population (SARTRE 3, 2004). This means that initial resistance should not discourage the implementation of these measures, as acceptance will grow over time.

Despite the fact that measures will meet with initial resistance, a lot can be done to ease the implementation process. In gaining acceptance the following aspects are important to consider:

- The cooperation of relevant actors. Many earn their living in the driver testing industry and car insurance companies. Care should be taken to involve them in the process.
- Parents: They care about their children, but are badly informed about the actual risk. Inform and involve them.
- Young drivers-to-be. They have to accept effective, new countermeasures given that road crash injury represents their main threat to life. Their problem awareness is low and they need to be informed.

A good example of how to generate the public debate in this field is the initiative of some Australian states (Vic Roads, 2005; Western Australia, 2005).

5.4 A strategic approach to implementing countermeasures

Countermeasures need to be implemented in a strategic manner that shows results both immediately and over the longer term. In doing so, particular attention should be paid to the key elements that underlie and increase risk. Furthermore, there are important differences between the various countermeasures in terms of their impact, their costs, and the timelines within which they can be implemented, which will condition the options for action. In particular, those that require new legislation will take considerable time to implement.

The following is a suggested step by step implementation of countermeasures:

Increase public awareness of the problem. This could involve undertaking information campaigns, based on well-researched information, sensitising the public to the nature of the risk and encouraging changes in attitudes and behavior. Also, political leaders could highlight the problem in speeches and other interventions. This countermeasure may be undertaken immediately. In itself, it is not expected to yield high reductions in risk, but it is a prerequisite for achieving greater public understanding of the problem and encouraging acceptance of other countermeasures. Furthermore, the combination of other countermeasures, particularly enforcement, with communication can bring about changes in attitudes towards safety risk over the longer term. There are obvious costs involved, although these are likely to be uncontroversial, given the importance of the message and the fact that the public is accustomed to seeing information campaigns from public authorities.

Consider the road safety effects, especially for young drivers, of public policy decisions that are not directly related to road safety. These include, among others, such issues as the availability and cost of public transport, the costs of operating a vehicle, the availability of parking at schools and other areas frequented by young people, and the locations of bars and discos. The immediate impact may not be expected to be particularly large, although over time it could have important cumulative effects. This is an area where action could begin immediately, although more time

would be required to formalize such practice. Resistance is to be particularly expected in instances where decisions limit the options of individuals and businesses.

Implement overall road safety improvements that address young driver risk. This includes ensuring the existence of appropriate legislation and rigorous enforcement of road safety law, focusing on areas where young driver risk is especially high: speeding, alcohol, drugs and seat belt use. It is an area where immediate action can be taken, based on existing laws and regulations, and short-term gains are to be expected. There will be important costs, in the form of resources used for enforcement, as well as in the implementation of high standards of safety in vehicles and infrastructure. Effective communication will thus be required to gain public support. However, public resistance may be expected, particularly to enforcement.

Introduce high levels of pre-licensing accompanied practice. This is potentially one of the most effective countermeasures. However, it may require new legislation, meaning that it cannot be implemented in the short term. Costs are relatively low, both to administrations and the public, and primarily consist of demands on the time of young, novice drivers and those who accompany them. While young people themselves may be expected to voice opposition, consultation with the community, including co-operation with relevant community groups, may well reveal a widespread demand for action to reduce young driver risks. In countries where licensing begins at 18 years-old, resistance will be less if the accompanied practice is allowed to begin before that age.

Implement protective restrictions during initial solo driving. This countermeasure holds considerable potential. It should include BAC levels of no more than 0,2 g/l. and limited driving at night and/or with passengers should also be considered. Again, legislation is probably required, although the minimal BAC restrictions could possibly be implemented under existing drink-driving laws. The effective enforcement discussed under the second point is a key pre-requisite to such measures. There will also be additional administrative costs associated with changes to the licensing system. Considerable resistance to these measures can be expected from the young drivers themselves, although an effective communication strategy may reveal substantial support for such measures among society in general.

Provide effective disincentives to inappropriate driving behavior. Enforcement of road safety law and special licensing measures will only be effective if they are backed up with concrete repercussions for non-compliance. Novice drivers should be subject to probationary periods during which inappropriate behavior could result in loss of driving privileges or obligatory retraining. This could be reinforced by way of special demerit point scales. Such countermeasures may require new legislation, but would not add important additional costs to those associated with enforcement, as discussed above. While they may be subject to considerable resistance from young drivers, they are not expected to be unpopular with society as a whole. Additional disincentives to unsafe driving by young drivers could be provided through vehicle insurance. Road safety administrations and insurance companies could examine means of co-operating in this area.

Improve driver training and testing, including a stronger focus on self-awareness and understanding the circumstances that lead to safer driving. Such changes will require considerable prior analysis, and probably legislative action, meaning that they will require time for implementation. While this measure is important, it is not likely to have the same impact as countermeasures that effectively limit exposure to risk and increase experience prior to solo

driving, such as those noted in Points 3 and 4. Initially, there will be new costs associated with changes to the licensing system, and resistance may be expected from the driver instruction industry in particular.

Understand the benefits of technological solutions for monitoring and enforcement, and for assisting the novice driver with the driving task, and selectively implement these where they prove to be effective. This is a longer term initiative, particularly as it will involve research and development. While the potential is high, the actual gains to be achieved from new technologies are unknown. These solutions will initially generate new costs for implementing technology in vehicles, which could cause resistance from drivers and vehicle manufacturers. Concerns regarding the legal side effects of new technologies will also need to be addressed, particularly if they are perceived to relinquish the driver of full responsibility for operating the vehicle.

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Notes

1. Country abbreviations

	Belgium	BE		Italy	IT		Romania	RO
	Bulgaria	BG		Cyprus	CY		Slovenia	SI
	Czech Republic	CZ		Latvia	LV		Slovakia	SK
	Denmark	DK		Lithuania	LT		Finland	FI
	Germany	DE		Luxembourg	LU		Sweden	SE
	Estonia	EE		Hungary	HU		United Kingdom	UK
	Ireland	IE		Malta	MT			
	Greece	EL		Netherlands	NL		Iceland	IS
	Spain	ES		Austria	AT		Liechtenstein	LI
	France	FR		Poland	PL		Norway	NO
	Croatia	HR		Portugal	PT		Switzerland	CH

2. This 2015 edition of Traffic Safety Synthesis on Novice Drivers updates the previous versions produced within the EU co-funded research projects SafetyNet (2008) and DaCoTA (2012). This Synthesis on Novice Drivers was originally written in 2008 by Divera Twisk, SWOV and then updated in 2012 by Willem Vlakveld, SWOV and in 2015 by Jean-Pascal Assailly, IFSTTAR.

3. All Traffic Safety Syntheses of the European Road Safety Observatory have been peer reviewed by the Scientific Editorial Board composed by: George Yannis, NTUA (chair), Robert Bauer, KFV, Christophe Nicodème, ERF, Klaus Machata, KFV, Eleonora Papadimitriou, NTUA, Pete Thomas, Un.Loughborough.

4. Disclaimer

5. Please refer to this Report as follows:

European Commission, Novice Drivers, European Commission, Directorate General for Transport, September 2015.


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