Driving skills, education and in-vehicle technology

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Abstract: Using an interview with former rally driver and advanced driving trainer, Rauno Aaltonen, as its impetus, this study explores developments in in-vehicle technology and the challenges such systems create for ergonomics and driver training.

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1 Introduction

Global investment in the development of in-vehicle systems and telematics has contributed to the reduction of accidents and fatalities, especially in young and inexperienced drivers. Farmer and Lund's (2006) analysis shows that without improved vehicle design, thousands of lives would have been lost. Despite this, vehicle accidents

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remain a major public health issue, with almost 1.3 million people fatally injured in traffic accidents worldwide (Peden et al., 2004). Additionally, of the 50 million who are injured, approximately half are seriously injured, causing additional emotional and financial distress (OECD, 2008).

Road traffic injuries are the leading cause of death among people aged 15–44 years in high-income countries (Krug et al., 2000). In the European Union (EU), more than 42,000 road users are killed and 3.5 million are injured each year (Hobbs et al., 2001). 18 – 25-year olds account for 19% of road deaths in the EU, representing 10% of the population (DGET, 2009). Young people in this group also account for 27% of the total of car drivers killed. In 2001, the EU set a target of reducing car fatalities by 50% between 2000 and 2010 (European Commission, 2001). Despite national (e.g., Vision Zero in Sweden) and international programmes (e.g., Vehicle to Vehicle and Vehicle to Infrastructure programmes), it is unlikely that this target has been reached. Although Intelligent Transport Systems (ITS) are expected to lead to increased road safety and a reduction in accidents and fatalities, early results from an analysis of advanced driver support systems, for example, have not been as unequivocal as expected (Malone and Eijkelenbergh, 2004). Despite the development of ITS to support drivers in their motoring, a recent survey in ‘What Car’ magazine reported that 79% of drivers believed driving standards had fallen, as opposed to just 9% who thought they had risen.

In the following sections, an interview with Rauno Aaltonen – a former European Rally Champion, now trainer of expert drivers – is used to provide the background to a review of developments in ITS and driver education, and to consider whether these systems are leading to the ‘detrimental’ changes in driver behaviour predicted by Janssen et al. (1995). The article concludes by arguing for greater investment in human factors research and the importance of maintaining and checking on the sufficiency and balance of manoeuvring skills and identifies potential shortfalls in (lifelong) driver training in the light of increased automation.

Looking at the effects of in-vehicle technology, this time on all drivers, Janssen et al. (1995) predicted that automation of the driving task would lead drivers into riskier behaviour; bring about decreases in general alertness and skill levels; produce less, but more severe accidents; create a different types of risks; increase driver diversity by reducing barriers to use; and require all road users to cope with long periods of transition as systems were introduced into vehicles and on the road network.

Ten years later, this may be evidenced in Broughton and Buckle (2005)’s conclusion that declining driving standards may contribute to the increased severity of injuries to car occupants with a higher incidence of loss of control and excessive speed in fatal and serious car accidents than had previously been identified. This may also be reflected in the increasing proportion of car occupants killed or seriously injured when their cars overturn (although changes to the car fleet such as the increasing proportion of 4 x 4s and people carriers may be contributory factors).

2 Young and inexperienced drivers

Any road transport system is a complex one, in which three elements - the road, vehicle and the user interact. It is a dynamic system. Changes in the driving population, road environment, vehicle design, government legislation and educational campaigns (such as speed restrictions, seat belt and drink driving legislation) can mean that it is difficult to determine whether driving is improving over time, whether skills have (or need to change), or the underlying factors responsible for these AUTHOR PLEASE NOTE THAT THE MEANING OF THE PHRASE "whether driving is improving over time, whether skills have (or need to change), or the underlying factors responsible" IS UNCLEAR. PLEASE REPHRASE FOR CLARITY. For example, despite a threefold increase in the number of cars in the UK, deaths on the road have more than halved since 1966. This may mean that drivers are becoming more skilled, or that cars and the road environment are safer.

The urge to drive and own a car is a dominant one in many cultures (an issue that may need to be addressed in future traffic education programmes). In the UK, over 780,000 people pass their driving test each year. Recent revisions to the test in the UK require learner drivers to display proficiency and awareness of the vehicle, with both theoretical understanding and practical skills being assessed. This has made it harder to gain a driving licence with the pass rate falling from 52% in 1990/91 to 43% in 2003/04. It is expected that a learner driver, at the time of passing the driving test in the UK, should possess good control skills – which can be added to with practice. However, many countries have different driver training programmes, requiring drivers to engage in pre - and post-test training (and reflection on driving), operate driver restrictions (e.g., on times and number of passengers) and seek to develop high-order skills and those related to traffic awareness and manoeuvring skills (DGET, 2009). Those EU Member states having widespread road safety culture and a long experience in training (such as the UK, Netherlands, Sweden, Germany, Finland, France, Spain, Denmark and Luxembourg) have the best accident records.

Focussing attention on the skills of young drivers, a recent AA poll of 2000 new (UK) drivers showed that one year after passing their test:

- 34% had forgotten how to parallel park
- 31% had difficulty understanding road signs
- 28% had forgotten how to reverse park
- 24% had difficulty in clutch control
- 20% forgot to check mirrors and signalling.

Leach (2009) reported a RoSPA survey in which three-quarters of employers who responded said their young workers were driving in situations that were not covered by the current learner driver training and testing process, for example at night or in icy conditions. Additionally, more than two-thirds of employers interviewed said that their young employees were driving vehicles for work that were larger than a car, and in which they had not been trained or tested. Developing safer driver attitudes, driving in different conditions, enhanced hazard perception and motorway driving were the top issues employers would like to include in a post-test qualification. This points to the fact that although skills may be high when drivers pass their test, the actual context in which they drive may reduce driving ability.

These figures are not surprising. After the test, major changes occur in cognitive skills associated with driving. Driving becomes more automatic. However, automaticity does not necessarily bring about safer driving. Young drivers learn how the traffic system works, where to look for information, what to attend to and how other drivers behave (Summala, 2000). They may start to feel safer, more comfortable, confident and in control if they drive without experiencing negative incidents and if they are cushioned by in-vehicle decision support systems.

As a self-paced task (Näätänen and Summala, 1976), driving skills can drop off if they are not used or not seen as being essential. For example, Duncan et al. (1991) reported on the decline in the use of mirrors and signalling; other authors have noted a reduction in the safety-oriented aspects of driving (e.g., Brown and Groeger, 1988; Lajunen and Summala, 1995). This may explain some of the findings.

As well as not maintaining their driving and safety skills, drivers also have a tendency to overestimate these skills when compared to others (e.g., Delhomme, 1991; McKenna, 1993; Walton, 1999). This overinflation leads to a biased risk assessment which in turn leads to higher levels of risk assessment (Deery, 1999; Groeger and Brown, 1989). Sumer et al.'s (2006) study of Turkish drivers demonstrated that

> "exaggerated self-assessment of driving ability was associated with risky driving and/or risk taking on the road which results in overconfidence, optimism bias or self bias."

If drivers perceive themselves to be better than they are, they may take more risks and drive more unsafely. Sumer et al. also found that those reporting low levels of driving and safety skills also reported the highest hostile aggression and revenge feelings.

Young drivers are recognised to be most at risk of having a traffic accident. Hopkin (2008) undertook a comparative study of drivers aged 17–19 and 20–24 with those aged 25–59 and 60–79, using the Department of Transport's accident data for 2000 to 2006. She found a number of ways in which the accident circumstances of younger drivers differed. They had older cars (with less Euro NCAP-rated crash protection), had more casualties in the car and were involved in more single-vehicle accidents. The accidents occurred more frequently at night and at weekends, on wet roads (in fine weather, rain, fog or mist) and on minor roads in rural areas with a 60 mph speed limit particularly on bends. They entailed more skidding, in some cases overturning and leaving the road, and in many cases, hitting a roadside object or entering a ditch. These were summarised by Hopkin as relating to:

- inexperience and poor judgement in more difficult driving conditions (poor weather, poor visibility, minor rural roads)
- inadequate control of the car (single-vehicle accidents, skidding, overturning, leaving the road)
- lifestyle factors (social driving particularly at night and at weekends, when factors such as alcohol and peer pressure affect where and how young people drive)
- economic factors that result in young drivers being more likely to have cheaper, older cars that offer less protection.

Whereas poor control skills are likely to be influential in causing accidents, wider cultural issues play an important part in setting the context for an accident. This is being addressed by a more holistic approach to driver education.

3 Driver training and education

Hopkin (2008) in her recommendations suggested measures to reduce the incidence and severity of accidents among young people including road safety education to raise awareness of responsibility (see also Woodcock et al., 2001), more training on different road terrains and weather conditions and on factors that lead to loss of control and improvements to vehicle safety (see the following section). Of these issues, this article is more concerned with factors contributing to a loss of control, or that can be attributed to shortcomings in driver training.

These recommendations align to current thinking on driver education. This is regarded as a lifelong study, commencing in primary schools. Traffic education not only concerns learning the rules of the road but is part of the wider process of becoming a responsible person. It is argued that a more holistic approach to self-responsibility in traffic education might help young people deal with other risky aspects of their lives, such as moped accidents and substance abuse.

The Goals for Driver Education (GADGET) EU-funded project (Hatakka et al. in GADGET, 1999) has developed a holistic approach to driver training based on Keskinen's (1996) hierarchical matrix, which goes beyond skills training. The four levels, from the top down, are:

- *Level 4. Goals for life and skills for living*. The inclusion of this level is based on research showing that lifestyles, social background, gender, age and other individual preconditions have an influence on attitudes, driving behaviour and accident involvement.
- *Level 3. Goals and context of driving*. This focuses on why, where, when and with whom the driving is carried out; e.g., the choice of transport type, the time of day of the journey, car occupants.
- *Level 2. Driving in traffic situations*. This relates to understanding driving conditions and being able to handle the car appropriately e.g., at junctions, when overtaking.
- *Level 1. Vehicle control*. The bottom level emphasises the vehicle, its construction and how it is manoeuvred. Knowing how to start, change gears, etc. well enough to be able to use the car in traffic belongs to this level as well as more complex tasks.

Each level is associated with knowledge and skills, risk-increasing factors and self-evaluation (self-assessment skills). At Level 1 (the main subject of this article), knowledge and skills might relate to car control, vehicle properties, friction, etc.; risk-increasing factors are connected with car control, vehicle properties, friction; self-evaluation may relate to strengths and weaknesses in relation to basic driving skills and car control (especially in hazardous situations) etc. (Peraaho et al., 2003). By providing education in the higher level skills, young drivers may avoid risky situations and act with greater degrees of responsibility.

To summarise, it appears that fatalities and accidents are reducing with the introduction of new vehicle technology (see below), better driver training and legislation; yet, public perception is that driver behaviour is worsening and that certain groups of drivers still remain unequipped to drive cars in certain conditions. The focus of the new education programmes lies in higher level skills. It is argued that just providing drivers with better control skills may lead drivers into riskier situations because they think they can control the situation. Peraaho et al. (2003) acknowledge that manoeuvring skills are important and should be taught well, but that they should not be taught in isolation of the higher level skills. Attempts to improve safety by improving skills alone have actually failed to decrease accidents, for example, on vehicle handling on slippery road (Christensen and Glad, 1996; Katila et al., 1996), or when (imagined) increases in skill are used to satisfy needs to maintain high speeds (Gregersen, 1996). A motivation to drive safely needs to come first.

The next section provides a case study of how advanced driving skills are taught by Rauno Aaltonen, and summarises an interview in which he comments on changing driving skills.

4 Rally driving and the Aaltonen advanced driver training

4.1 Rally driving

Rally drivers can be thought of as experts in vehicle control and manoeuvring, as such they may be able to offer insights into how to control vehicles which could inform educational policy and practice. Based on his experiences as a competitive and expert driver, Rauno Aaltonen teaches advanced driving techniques in the UK and Finland. Barker, himself a rally driver, took part in these courses, after which he interviewed Aaltonen about whether he had noticed any changes in driving ability during his career. The UK course, conducted on sandy soil, was designed to improve driving technique in snow, emphasising the development of slide control and increasing speed on loose surfaces. The course at Lake Tahko in Finland was aimed at improving general car control using a low-friction surface, i.e., the frozen lake. The course Aaltonen has evolved aligns with many of the GADGET recommendations, including theory, practice, evaluation and reflection on action.

Discussion of rally driving has tended to concentrate on its history, race coverage and profiles of the leading racers rather than on a systematic analysis of rallying skills and their potential to inform educational developments . Rally cars are used to test out in-car safety features (for example, active torque dynamics and engine downsizing, Tempest, 2005). A more systematic analysis of these highly skilled drivers, their training and rally car modifications might be useful in producing a refined set of skills needed by today's motorists and the design of future vehicles.

Rallying provides an extreme example of on- and off-road driving, requiring teams competing against the clock on a series of about 25, 5–37 mile stages run over three days, across a variety of terrains and weather conditions. Multitasking, listening to instructions, understanding, anticipation and quick reactions are key to effective, safe rally driving. The stages are linked by public roads where local traffic laws must be obeyed. Each day contains about 250 miles of driving, a third of which are driven competitively.

Although World Rally Cars originate from four-seater road cars available to the general public, they are modified with high-tension steel, carbon fibre and latest in-vehicle technology. They have 2.0-litre turbocharged engines that produce over 300 horsepower, six-speed gearboxes and four-wheel drive. Safety measures include a protective roll cage, and a chassis two to three times more rigid than a normal road car. Limited aerodynamic modifications to improve performance are permissible.

Rally drivers possess a wealth of driving experience gained across difficult conditions. They are required to multi task, listen, understand, anticipate and respond to instructions while driving as quickly as possible on a wide variety of terrains – mud, asphalt, grit, snow – in a wide range of weather conditions. Specialist driving techniques include left foot braking, speed control by varying slip angle.

4.2 Experiences at the school

Rauno Aaltonen was motocross champion of Finland before turning to rallying and was European Rally Champion in 1965. From 1970, he became involved in driver training using the techniques he had developed during his rallying career to educate road drivers of high-performance cars. In his 35 years of driver training, he has developed a set of theories and practices that represent his thinking on driving dynamics as applicable to the current generation of drivers. Running driving courses on frozen Lake Tahko is the preferred method of educating drivers in the Aaltonen technique. This commences with a series of tutorials on driving dynamics, before driving on the 400 mm-thin ice of the lake. These include recommendations about the driver position, the control of the car and 'action learning' (Pedler, 1997). The basic skill set (some of which is outlined below) maps on to the lower levels of the GDE matrix.

4.2.1 Driver position

In order to be in control, the driver must be sitting in a relaxed neutral position, able to fully depress the car's pedals, turn the steering wheel through a full circle and see the car's extremities, especially all four corners. To achieve this ideal driving position, the seat may have to be adjusted both laterally and vertically and any moveable controls suitably placed. Aaltonen firmly advocates that the driver's back should be hard up against the seat but that the head should not be constantly resting against the headrest.

4.2.2 Control of the car

Once accurately seated, the driver is ready to take control. The steering wheel should be handled in a way that allows full movement of the steering with constant fine control. Aaltonen advocates holding the wheel just above the lateral spokes on each side with thumbs hooked over the padded spokes on a modern wheel. For older classic cars without padded spokes the thumbs are kept outboard away from the spokes to avoid injury from movement of the sharp spoke edges on a rough road. By holding the wheel firmly with the hand away from the corner apex and then lifting the wheel rim rather than pulling down on it, a much stronger steering force is generated allowing better control. The other hand stays in its position relative to the car, allowing the wheel to spin between thumb and forefinger. In this way, large steering angles can be quickly applied with a maximum of control.

Aaltonen also promotes the use of the left foot on the brake pedal in certain circumstances. In a front wheel drive car, braking with the left foot allows the car to be steered more effectively on a slippery surface, as sudden braking on entry to the corner while momentarily lifting the throttle pedal will cause the rear end of the car to lose grip and so slide outwards, pointing the car into the corner. This is an advanced technique, but not difficult with practise. In a competition situation, left foot braking also allows a quicker throttle response as the right foot is permanently on or over the accelerator and so time is not lost in transferring the right foot from brake to the throttle.

Positioning of the car to achieve cornering is also covered for both front and rear wheel drive cars using the throttle and brake to position the car perfectly to take right- and left-hand bends. Aaltonen also describes the forces on a sliding wheel explaining why traction can be lost or gained by use of steering and throttle.

4.2.3 Action learning through car control exercises

These techniques can be best applied in a moving car on a low-friction surface. The large expanse of relatively thick ice at Lake Tahko provides a suitable venue for putting the Aaltonen Technique to the test. Drivers are sent out onto a prepared section of ice in firstly rear wheel drive cars and then front wheel drive cars. Currently, BMW 3 series and Ford Focus vehicles are used. Even average drivers learn the difference in control techniques needed for the two types of vehicle and are able to pilot the cars successfully around a slalom course. The Aaltonen school do not use four wheel drive cars for tutoring because of their unpredictability on low-friction surfaces.

Other car control exercises such as sliding a rear wheel drive car around a 50 m diameter circle keeping the car at 30° to the direction of travel, and performing a reverse flick or *J* turn in a front wheel drive car are also part of the training diet. The aim with all of these activities is to develop coordination of control functions and a sense of car balance at all times.

Once safe car control is achieved, drivers are put onto a short ice circuit, giving them the opportunity to drive right - and left-hand bends of varying severity in a continuous loop. As confidence builds, so does speed and at the end of the session time, trials are held over five laps to see which drivers can pilot their car fastest over the course.

Although it is difficult for drivers used to high-grip asphalt surfaces to apply this after two days, the confidence that builds from being able to control a car at speed on ice is beneficial to normal road driving. Aaltonen states that a trained driver is a safer driver and the confidence of knowing how to handle a car once its starts to slide reduces the likelihood of panic and consequent accidents in everyday driving. For Barker, this meant that he learned how to control the car better in a skid and to be confident in provoking a deliberate skid as a way of slowing the car and negotiating corners on a low-grip surface. Such techniques could be used to increase safety in an extreme situation. It may be argued that all drivers would benefit from such training if the surfaces, vehicles and trainers were available, and that this in itself would contribute to increased road safety regardless of technological innovation.

4.3 Interview on trends in driving ability

The interview with Aaltonen focused on his perception of the changes in driving ability over the last 38 years. The following points have been summarised from the interview.

4.3.1 Reduction in braking ability

Aaltonen implies that the reaction times from recognising the need to brake to actual effecting that change by pressing the brake pedal are longer than they used to be

> "I've been now in driver training since 1970, soon 40 years, and there's been a remarkable change in the physical ability of car drivers to control the car. Their ability to move the steering wheel, their ability … the brain might say 'brake' and the leg is not able to move the foot quickly enough from the accelerator to the brake pedal and provide enough braking force. It is very clear and this is where the motor cars have very very much stronger power brakes than they used to have."

4.3.2 Steering ability

The widespread incorporation of power-assisted steering has had a noticeable effect on the strength, understanding and speed of response of young drivers in using the steering action to avoid obstacles or suddenly change direction of the car.

> "In Finland 20 years ago I never trained (people to do) counter-steering* because every Finn was able to do it, it was natural. It is the same as if you take seven year old kids in a little go kart and make them a run. You do not (have to) tell them … what to do and within 10 minutes they are all able to counter steer the kart, every one. They do not keep spinning they know what to do. Now you take a 25 year old young man, put him here on the ice track and the tail of the car swings away, he is not able to control it.
>
> When he was seven years old he was able to do it. Now he has not continued driving karts. Now the modern life and way of thinking has changed his mind and his ability to use his arms and hands. Today I have a major problem in teaching people counter steering. I do not put very much weight on it any more because I know it's a hopeless situation, people do not learn it."

*countersteering is the automatic application of steering lock opposite to the direction in which a car or kart is cornering in order to control a slide

4.3.3 Car control

Aaltonen also observes that young drivers are losing the ability to control their cars because of the controlled assistance provided by brakes and power steering. This is a worrying trend with road safety in mind.

> "Today there are electronic devices (fitted to cars) that make life easier. But it is the same … as in anything you do, everything is automatic. And you are not any more able to dictate what is being done. The level of output quality goes down, you can only be mediocre you cannot any more be top. We are today in that moment. Everything is forbidden, no wheelspin, braking ABS, the stopping distance is longer because it's an average slip for the wheels. On a soft surface you must lock up the wheels, on ice you must have very little wheelslip. But today it's standardised so the average is OK. And I see no other possibility; it's the only way as the drivers are getting so bad. And for those drivers who are good … it's distressing!"

Not a very positive outlook from one of Europe's most experienced advanced driving trainers. However as anyone who has watched children learn to control a virtual or real vehicle, learning car control is not a problem in the very young.

4.3.4 Responsibility

In addition, Aaltonen raised concern about the cultural and political climate that promotes such a hands-off attitude to driver responsibility.

> "It's not the correct way for the big public (to drive without electronic control of their car's performance) because they are not able to decide things anymore. I'm sorry to say that, I am very pessimistic about this. And it has nothing to do with the cars, it has to do with the communities today. Because today all people, especially the younger ones think that they have no responsibility over their lives. This is the thinking today which is globally getting stronger and stronger, which I think is silly. Because not everything can be controlled by the authorities and this is the same for the cars. I do not think that we should in the lower level cars, I do not think we should have a switch which would switch off the electronics. Drivers are not able to decide when it's suitable and when not."

An example of this can be seen with regard to speed limits, which force drivers to behave in ways that might not always seem appropriate. Self-discipline and decisions are being taken out of the loop. This may mean that drivers will not be able to make those judgements themselves when they are required to. Reducing speed limits to compensate for poor driving ability in over-performance vehicles is a step in the wrong direction.

4.3.5 Conclusions from the interviews

The issues raised by Aaltonen indicate that the potential performance of modern cars has outstripped drivers' abilities to control and manage the car safely. This may be problematic if such systems fail or are not available in all cars – as happens with gradual introductions of technology. The training in advanced techniques importantly makes drivers aware of their limitations (i.e., risk aware) and the skills they are missing in relation to driving dynamics and knowledge of how the car performs.

Looking back over 30 years, Aaltonen believes that driver ability is decreasing. As vehicle technology develops, fewer drivers will be able to cope with the unexpected dynamic behaviour in their vehicles, which may result in accidents. An ideal balance needs to be formed between vehicle and driver responsibility, as ultimately the human needs to be responsibly in charge of each vehicle on the public road. Vehicle safety legislators, human factors specialists, designers and developers need to debate this balance to achieve the best possible outcome and ensure that it is addressed in lifelong training.

Learners and new drivers may not get the chance to practice safe driving skills because they move straight into an overpopulated road environment, with cars that are too overpowered or have too many safety features. This means they do not get the feel for the car and the car dynamics, which may mean that when they get into difficulties (for whatever reason) and over (or wrongly estimate) their abilities, they will not be able to control the car.

There is a potentially serious gap in current models of driver training. This relates to the training received when a driver changes cars, or purchases new in vehicle technology. In the UK, when people purchase a new (or second–hand) car, little or no training is given on how to use the vehicle or its functionality. This may mean that the only experience the new purchaser has of the car and its controls will be in a very short test drive with the car salesman before the sale is agreed. At this point, the new owner drives the car straight into the traffic environment, without understanding the car dynamics, the location/ operation of primary controls or how unfamiliar in vehicle technologies might work. Although the need or lifelong driver education is recognised, this important transfer stage is being overlooked. An overview of the new systems that current and future drivers are going to have to understand is provided in the next section.

5 In-vehicle systems

Nagai (2007) characterised the first century of automotive driving as being one of autonomy of the human driver. The driver was almost exclusively responsible for navigation, speed, guidance, control and negotiating the car through the traffic environment. With the rapid and increasing power of sensor and in-vehicle computer technology, this has changed.

In the 1960s, Huelke and Gikas (1968) analysed 104 fatal car accidents and correlated vehicle characteristics with the sources of death and injury. This laid the foundations for passive safety, resulting in the redesign of steering wheels, steering columns, instrument panels, door latches, and seat belts. The agility, traction and performance of cars have been improved, but we do not know whether more recent improvements in the human-machine interface have led to reductions in accidents or safer driving. Many of the technological innovations have not yet had time to be subject to the same level or rigour of testing.

Author: Please check if the highlighted year is ok.

There are many ways of classifying in-vehicle systems, the European Automobile Manufacturers' Association safety model distinguishes between primary, secondary and tertiary safety features. To these, a new category can be added – integrated safety (for further discussion see Broughton et al., 2009).

- *Tertiary safety features* reduce the consequences of injury by making it easier and/or quicker for the casualty to receive medical treatment.
- *Primary safety features* help avoid an accident or its severity, eg braking and braking stability, handling, lighting and conspicuity, field of view, vehicle loading and ergonomics. Future developments include adaptive front headlamp systems that adapt to the manoeuvre or type of driving to provide the correct illumination in the right areas at all times; daytime running lights; increased minimum brake standards for all vehicle types; alcohol interlocks that prevent drivers from being able to start an equipped vehicle if they are over the alcohol limit. In the UK, it is estimated that 17% of all road deaths occurred when someone involved was driving while over the legal limit for alcohol (Department for Transport, 2006).
- *Secondary safety features* are designed to avoid or reduce the severity of injuries. These include structural crashworthiness, occupant protection and restraints such as mandatory use of seat belts. Future developments will relate to improved front impact protection in relation to the ability of the car either to protect its own occupants or to interact with other vehicles to increase the protection offered to the occupants of other vehicles; side and impact protection; rollover protection; frontal design of HGVs. AUTHOR PLEASE PROVIDE EXPANSION FOR HGVs.
- With increasing technological maturity and interoperability, *integrated systems* blur the boundaries between primary- and secondary-level features. For example, the

vehicle can monitor the likelihood of a collision, use primary safety systems to avoid or reduce its severity, and alert the secondary systems to protect. These also overlap with I TS (see below). Technologies developing in this area include lane departure warnings, in which in-vehicle sensors communicate with lane markings to detect when a vehicle is drifting out of lane (e.g., because the driver is distracted or falling asleep) and produce an audible or vibration warning on the side the vehicle is moving into. ECORYS (2006) estimates that the risk of a collision is reduced by approximately 12.5% (25% reduction in risk for 50% of all accidents) by this technology; lane change assist; forward collision warning; brake assist plus, Collision Mitigation Braking System (CMBS). Here if the driver is not able to avoid the collision, heavy brakes will automatically be applied. Grover et al. (2008) estimated that first-generation systems would reduce the number of fatalities occurring in front to rear shunt collisions with other vehicles by between 25% and 75%; Pre-crash adaptation/optimisation of restraints, so that when a collision is likely restraints and other occupant protection measures can be pre-armed.

Other future developments include intelligent speed adaptation (where the speed limit of the road is transmitted to the vehicle), pop-up bonnets (to reduce the severity of injury to pedestrians hitting the bonnet in crashes), variations of CMBS for different accident types and road environments, adaptive restraints that recognise the characteristics of the occupants, and adaptive structures that transform the vehicle structure in anticipation of a collision.

5.1 *Intelligent transport systems*

According to Linder et al.

> "ITS is generally road based, vehicle based, vehicle to road based or vehicle to vehicle based technologies supporting the driver and/or the management of traffic in a transport system." (Linder et al., 2007)

They can be divided into In-vehicle Information and Communication Systems (IVIS) or Advanced Driver Assistance Systems (ADAS), each of which in turn can be divided into active and passive systems, in which active systems adapt to the situation, anticipate needs, take initiative and provide explanations.

Given the emphasis of this article, the development of ADAS has a crucial bearing on driver skills because they support the primary driving tasks. They

> "warn the driver, provide feedback on driver actions, increase comfort and reduce the workload by actively stabilising or manoeuvring the car. They are assisting (compared to replacing) due to the fact that responsibility remains always with the driver." (PreVENT, 2007)

Linder et al. (2007) classified ITS related to vehicle safety as follows:

- Driver monitoring – drowsiness, distraction and other impairments
- Driver assistance – night vision, steering assistance, adaptive headlights, overtaking monitoring
- Vehicle control – lateral control, roll avoidance, speed control, hill descent control, stability control

- Crash avoidance/mitigation – obstacle detection, emergency braking, blindspot detection
- Injury mitigation – adaptive airbags, whiplash mitigation, belt tensioning
- Pedestrian protection – impact mitigation, pedestrian detection
- Post-crash systems.

These systems are producing, or are expected to produce, reductions in accidents and fatalities. Systems related to longitudinal vehicle control, affecting speed and rear end collisions, are the most mature technologies and offer significant benefits (Carsten et al., 2008). An examination of the benefits of these systems has been explored by Elvik (2009), Malone and Eijkelenbergh (2004) and Linden et al. (2007) and the eIMPACT project (Wilmink et al., 2008; Kulmala et al., 2008). As many of the systems are still in development, and methods to assess their effectiveness are likewise still emerging.

An example of the expected cost–benefits has been provided by the eIMPACT project, which selected systems that would come to market by 2020, were cooperative or stand alone, and covered different types of functionality. With full system penetration in the EU, they predict the following changes to injuries and fatalities.

Author: Please cite Table 1 in text.

Table 1 eIMPACT estimates of reduction in injuries and fatalities for the EU at 100% penetration

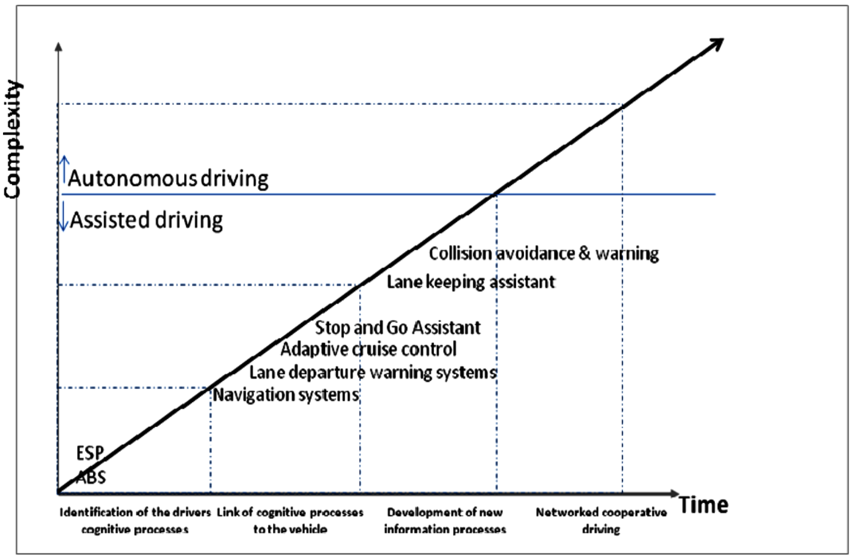
System	*Change in injuries* %	*Change in fatalities* %
Electronic Stability Control (ESC)	–6.6	–16.6
Full Speed Range ACC (FSR)	–3.9	–1.4
Emergency Braking (EBR)	–7.3	–7.0
Pre-Crash Protection of Vulnerable Road Users (PCV)	–1.9	–1.8
Lane Change Assistant (Warning) (LCA)	–4.8	–2.2
Lane Keeping Support (LKS)	–8.9	–15.2
NightVisionWarn (NIW)	–2.0	–2.9
Driver Drowsiness Monitoring and Warning (DDM)	–3.6	–5.0
eCall (one-way communication) (ECA)	+0.1	–5.8
Intersection Safety (INS)	–7.3	–3.9
Wireless Local Danger Warning (WLD)	–2.8	–4.5
SpeedAlert (SPE)	–6.2	–8.7

Source: Taken from Broughton et al. (2009)

The eIMPACT team concluded that few systems are achieving their full potential. Each percentage reduction represents approximately 230 fatalities. For example, *'in the case of ESC, in the 2020 high scenario, 3,250 fatalities would be avoided at the penetration rate of 75%'. No single system will achieve 'zero fatalities'.*

Author: Please cite Figure 1 in text.

Figure 1 Roadmap towards autonomous driving (see online version for colours)



Achieving target reductions in traffic accidents and fatalities requires interoperability, road telematics, improvements of vehicle design and uptake of next-generation vehicles and integrated systems (a roadmap of telematics issues is given in the EADIS web site). Future developments will lead to greater integration, perhaps as envisioned in the development of the 'cognitive car', which conceives of *"the vehicle as a technological system which can perceive itself and its environment, as well as collect and structure information in an autonomous way"* (Heide and Henning, 2006). Certainly, ITS developments are moving towards this. Combining figures in Heide and Henning (2006) with these from RWTH Aachen (2004) and Henning and Happe (2005), the following emerges.

6 Conclusions and discussion

Undoubtedly future autonomous vehicles will outperform drivers in some respects (eg., sensitivity of sensors, maintained attention). However, technological systems are never without flaws. Heide and Henning (2006) suggest that drivers may *"become dependent on the cognitive competencies of their vehicles and will not be able any longer to act adequately in a crisis situation, in case the supporting systems fail"*.

Without being unduly pessimistic, the approach of technologists and automotive engineers needs to be tempered with a degree of realism. Lessons can be drawn from automation in the aviation industry (Stanton and Marsden, 1996) and the appraisal of Janssen et al. (1995).

Systems do fail. They are not maintained. People do not read instruction manuals, may not be given training and forget how to operate complicated technology. Cars may be driven with different levels of ADAS and IVIS, which may confuse drivers in (critical) situations or when they first encounter them. Interoperability and contextual factors may mean that technology does not work in the manner expected, and technology is not always tested with representative end users (especially when widening diversity is an issue) or in the context of use prior to exploitation (Woodcock and Taylor, 2009).

According to anecdotal evidence, police officers, when carrying out traffic controls, often notice that drivers are often not familiar with the practical functions or equipment of their cars. In the Eurotest 2005 survey of approximately 3000 drivers across the EU, only half the drivers surveyed were familiar with in-vehicle technologies providing active and passive safety. The development of workable systems requires a substantial investment in HMI, prior to the widespread investment and introduction of such systems. In the worst case, drivers could be overloaded with information, they could avoid vital warning signs, or not know how to drive correctly when a system fails. Additionally, there is a problem with the introduction of such systems, and how they filter down through the car market.

Evidence suggests that drivers may have difficulty in regaining control of cars or driving appropriately when in-vehicle systems fail (e.g., Stanton et al., 1997). The effectiveness of such systems rely on drivers having the knowledge and skill to use them correctly in an emergency situation, not to adapt their behaviour in a negative way during normal driving and to be meaningfully engaged (as opposed to passively monitoring the task). For example, adaptive headlights may mean that drivers feel they are able to drive faster at night on rural roads. Stanton and Pinto (2000), for example, have shown in a simulator study how drivers responded to a vision enhancement system. They increased their speed. It was only when a 'system failure' was introduced that they reduced their speed because they were no longer confident in the system.

Stanton and Glendon (1996) argued that person-centred approaches are likely to be more successful than technical solutions alone. However, to develop these requires considerably more investment than the onslaught of technology allows. Stanton and Pinto conclude (2000, p.1369),

> "Only by anticipating the likely effects of driving technology on the driver, and conducting empirical research in simulated environments can an understanding be gained on how to make transportation systems safer."

Therefore, basic human factors research needs to be conducted into how driving tasks are changing with the inclusion of new systems and what this means for the human operator (e.g., the effects of information under/overload, and new attention demands) (see Lenior et al. (2006) for a discussion of issues in relation to driver support systems, and Rajaonah et al., (2008) for the relationship between trust, perceived workload, risk and automation). Such research needs to be undertaken to provide an understanding of human–machine interaction that can feed into the design of new vehicle environments, and underpin driver/traffic education programmes.

ITS will not create skilled drivers, who are able to think and act responsibly. A complementary approach needs to consider how best to train future and existing drivers, so that they can drive safely and appropriately. At the moment in-vehicle systems assist the driver, they leave him in control of some of the tasks. However, a paradigm shift is occurring, where the function of the driver is changing. This needs to be recognised and adequate provision made in training and education, in tandem with in-vehicle and transport developments. Training needs to relate to current and future vehicles and the transition stages in between, where drivers may find themselves in cars with more or less support systems, and in places and times when in-vehicle systems are not available. With the driver moving into a more supervisory role may come decreases in situational awareness, alertness and the easy transition into safe driving mode when systems fail. If the necessary skills are not practised, then task performance will be lowered at times when it is most needed, resulting in a higher probability of accidents. The European Seventh Framework Programme (FP7) (eSafety Forum, 2006, p.27) commented

> "[T]here is still a great need to investigate the behaviour of the user in the real traffic environment when being equipped with new ICT systems for safety and efficiency as compared to the user's behaviour without the ICT systems. The short and long term effect of the use of such systems is also of great importance to assess as a justification of the systems."

Technology is not new in cars. Aaltonen may be witnessing a decline in driving skills as a result of the widespread integration of technology. New skills will be required of drivers. However, there will continue to be an argument for the necessity of vehicle control skills in the future. The question that needs to be answered is: How can they be maintained through this period of transition, where not all cars or drivers are familiar with new technologies? Advocating a systems approach demands that the human is considered an integral part of the system. In providing technological solutions to reducing the risk and potential for human error, are we creating an underclass of drivers who are becoming increasingly dependent on technology to assist them, and make decisions for them? Ergonomists are alert to the dangers of automation (e.g., Reason, 1990 and Sanders and McCormack, 1993), which creates situations in which the human can become a passive monitor of systems, and is unable to take direct (or corrective) action when required.

New drivers entering the traffic environment need the four levels of skills outlined in GADGET. However, they also need a new skill set that will allow them to drive safely when they are exposed to different levels of in-vehicle technology. Aaltonen's course enables drivers of high-performance cars to gain better skills on different road surfaces. Beneficial as such courses may be, they are too expensive for those most in need of it. Similar courses may need to be developed to ensure correct use of in-vehicle systems.

In summary, the following recommendations are made, that

- Ergonomics research and usability trials be prioritised in technologically oriented projects (not just automotive ones). Too often usability trials, which by their very nature rely on 'operational systems', are reduced in scope or squeezed out of projects when technological barriers occur and projects run late. While acknowledging that sometimes this may occur, where there is a human interaction element, and products are near to market, a requirement of funding should be the auditable conduct of field operational trials – or separate funding is awarded solely for usability studies.
- Current training in vehicle control is continually evaluated and developed in the light of experiences of expert drivers, developments in ADAS and IVIS, and ergonomic research.
- Key stages in lifelong driver education are better understood. Research has focussed on developmental issues of the driver, not on technological issues or periods of transition (i.e., from one car or system to another).

References

Broughton, J. and Buckle, G. (2005) *Monitoring Progress Toward the 2010 Casualty Reduction Target*, TRL Ltd, Report No. 643, Crowthorne, Berkshire.

Broughton, J., Johnson, B., Knight, I., Lawton, B., Lynam, D., Whitfield, P., Carsten, O. and Allsop, R. (2009) *Road Safety Strategy Beyond 2010: A Scoping Study*, Road Safety Research Report No. 105, Department for Transport, London.

Brown, I.D. and Groeger, J.A. (1988) 'Risk perception and decision taking during the transition between novice and experienced driver status', *Ergonomics*, Vol. 31, pp.585–597.

Christensen, P. and Glad, A. (1996) *Mandatory Course of Driving on Slippery Roads for Driver of Heavy Vehicles*, The effect on accidents. TÖI 334/1996, Transportökonomisk institutt, Oslo.

Carsten, O.M.J., Fowkes, M., Lai, F., Chorlton, K., Jamson, S., Tate, F. and Simpkin, B. (2008) *Intelligent Speed Adaptation*, Department for Transport, London, www.dft.gov.uk/pgr/roads/vehicles/intelligentspeedadaptation/fullreport.pdf (accessed on 1 April 2009).

Deery, H.A. (1999) 'Hazard and risk perception among young novice drivers', *Journal of Safety Research*, Vol. 30, pp.225–236.

Delhomme, P. (1991) 'Comparing one's driving with others'; assessment of abilities and frequencies of offences. Evidence for a superior conformity of self bias', *Accident Analysis and Prevention*, Vol. 23, No. 6, pp.493–508.

Department for Transport (2006) *Road Casualties Great Britain: 2005*, The Stationery Office, London.

Directorate General for Education and Transport (DGET) (2009) *Driver Training and Traffic Safety Education*, *A Consultation Paper*, Prepared by the Unit Responsible for Road Safety Policy, Brussels, 22-04-09.

Duncan, J., Williams, P. and Brown, I. (1991) 'Components of driving skill: experience does not mean expertise', *Ergonomics*, Vol. 34, No. 7, pp.919–937.

EADIS (2009) *Vehicle Telematics Knowledge Map*, European Automotive Digital Innovation Studio, http://homepages.ipact.nl/~jverlinden/eadis/docs/Telematics_map_presentation3june2008.pdf, accessed 1/12/09. AUTHOR PLEASE CITE THIS REFERENCE IN TEXT.

Elvik, R. (2009) 'The trade-off between efficiency and equity in road safety policy', *Safety Science*, Vol. 47, pp.817–825.

ECORYS (2006) *Cost-benefit Assessment and Prioritisation of Vehicle Safety Technologies*, Framework Contract TREN 56/A1/2004, European Commission, Brussels.

eIMPACT project (2008) *Assessing the Impacts of Intelligent Vehicle Safety Systems*, http://www.eimpact.info/index.html and http://www.movea.se/IVSS_eIMPACT%20projektrapport.pdf accessed 1/12/09 AUTHOR PLEASE CITE THIS REFERENCE IN TEXT.

eSafety Forum (2006) *Strategic Research Agenda: ICT for Mobility. eSafety Forum*, Working Group RTD, European Commission, Information Society and Media, Brussels.

European Commission (2001) *European Transport Policy for 2010; Time to Decide*, White Paper, Office for Official Publications of the European Communities.

Farmer, C.M. and Lund, A.K. (2006) 'Trends over time in the risk of driver death; what if vehicle designs had not improved?', *Traffic Injury Prevention*, Vol. 7, No. 4, pp.335–342.

GADGET (1999) *Driver Training, Testing and Licensing - Towards Theory-Based Management of Young Drivers' Injury Risk in Road Traffic EU-Project Final Report*, Schweizerische Beratungsstelle für Unfallverhütung BfU, Berne.

Gregersen, N.P. (1996) 'Young drivers' overestimation of their own skill – an experiment on the relation between training strategy and skill', *Accident Analysis and Prevention*, Vol. 28, pp.243–250.

Groeger, J.A. and Brown, I.D. (1989) 'Assessing one's own and others' driving ability; influence of sex, age and experience', *Accident Analysis and Prevention*, Vol. 21, pp.155–168.

Grover, C., Knight, I., Okoro, F., Simmons, I., Couper, G., Massie P. and Smith, B. (2008) *Automated Emergency Braking Systems (AEBS): Technical Requirements, Costs and Benefits*, TRL project report PPR 227, TRL Limited, Crowthorne.

Hatakka, M., Keskinen, E., Gregersen, N.P., Glad, A. and Hernetkoski, K. (2002) 'From control of the vehicle to personal Self-Control; broadening the perspectives to driver education', *Transportation Research Part F*, pp.201–215. AUTHOR PLEASE SUPPLY VOLUME NUMBER.

Heide, A. and Henning, K. (2006) 'The 'cognitive car': a roadmap for research issues in the automotive sector', *Annual Reviews in Control*, Vol. 30, pp.197–203.

Henning, K. and Happe, J. (2005) *A Roadmap for Driving Assistance Systems*, in Heide and Henning (2006). AUTHOR PLEASE SUPPLY FULL DETAILS.

Hobbs, A., Cesari, D., Janssen, E., Kullgren, A., Langwieder, K., Otte, D., Da Siva, P.F. Thomas, P. and Turbell, T. (2001) *Priorities for EU Motor Vehicle Design*, ETSC, ISBN 90-76024-12-X.

Hopkin, J. (2008) *Young drivers – Where and When are They Unsafe: Analysis of Road Accidents in Great Britain 2000 – 2006*, http://www.iam.org.uk/Resources/Institute%20Of%20Advanced %20Motorists/Documents/IAM%20MT/JHFinalwithIAMTlogo15Augustt2.pdf. Research for the IAM Trust. Accessed 26th May 2009.

Huelke, D.F. and Gikas, P.W. (1968) 'Causes of deaths in automobile accidents', *JAMA*, 25 March, Vol. 203, No. 13, pp.1100–1107.

Janssen, W., Wierda, M. and van der Horst, R. (1995) 'Automation and the future of driver behaviour', *Safety Science*, Vol. 19, pp.237–244.

Katila, A., Keskinen, E. and Hatakka, M. (1996) 'Conflicting goals of skid training', *Accident Analysis and Prevention*, Vol. 28, pp.785–789.

Keskinen, E. (1996) *Why Do Young Drivers Have More Accidents? Junge Fahrer Und Fahrerinnen. Referate Der Ersten Interdiziplinären Fachkonferenz*, 12–14 December, 1994 in Köln (in English) Berichte der Bundesanstalt für Strassenwesen. Mensch und Sicherheit, Heft M 52.

Krug, E.G., Sharma, G.K. and Lozano, R. (2000) 'The global burden of injuries', *American Journal of Public Health*, Vol. 90, No. 4, pp.523–526.

Kulmala, R., Rämä, P. and Sihola, N, (2008) 'Safety impacts of co-operative systems', *Proceedings of the 21st ICTCT Workshop*, Session VI Road Safety Assessment. AUTHOR PLEASE SUPPLY LOCATION.

Lajunen, T. and Summala, H. (1995) 'Driving experience, personality, and skill and safety –motive dimensions in drivers' self assessments', *Personality and Individual Differences*, Vol. 19, pp.307–318.

Leach, B. (2009) http://www.telegraph.co.uk/finance/newsbysector/transport/5146018/Driving-test-does-not-prepare-young-people-for accessed 26th May 2009 and http://www.telegraph.co.uk/motoring/5345959/Half-of-drivers-would-fail-their-test-if-they-had-to-take-it-again.html accessed 26th May 2009.

Lenior, D., Janssen, W., Neerincx, M. and Schreibers, K. (2006) 'Human factors enginnering for smart transport; Decision support for car drivers and train traffic controllers', *Applied Ergonomics*, Vol. 37, pp.479–490.

Linder, A., Kircher, A., Vadeby, A. and Nygårdhs, S. (2007) *Intelligent Transport Systems (ITS) in Passenger Cars and Methods for Assessment of Traffic Safety Impact: A Literature Review*, VTI rapport 604a, www.vti.se/publications AUTHOR PLEASE CHECK IF THE HIGHLIGHTED AUTHOR NAME IS 'Linden' OR 'Linder'.

Malone, K.M. and Eijkelenbergh, P. (2004) *A Quick Scan of Quantified Effects of Advanced Driver Support Systems: ADASE II Extension*, AVV Transport Research Center, Rijkswaterstaat, TNO Inro number 04-7N-192-74070.

McKenna, F.P. (1993) 'It won't happen to me: Unrealistic optimism or illusion of control?', *British Journal of Psychology*, Vol. 84, pp.39–50.

Näätänen, R. and Summala, H. (1976) *Road User Behaviour and Traffic Accidents*, North-Holland/American Elsevier, Amsterdam and New York.

Nagai, M. (2007) 'The perspectives of research for enhancing active safety based on advanced control technology', *Vehicle System Dynamics*, Vol. 45, No. 5, pp.413–431.

OECD (2008) *Towards Zero – Ambitious Road Safety Targets and the Safe Systems Approach*, OECD, Paris.

Peden, M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A., Jarawan, E. and Mathers, C. (2004) *World Report on Road Traffic Injury Prevention*, World Health Organisation, Geneva.

Pedler, M. (1997) *Action Learning in Practice*, Gower Publishing, Ltd. AUTHOR PLEASE SUPPLY LOCATION.

Peräaho, M., Keskinen, E. and Hatakka, M. (2003) *Driver Competence in a Hierarchical Perspective*, Implications for Driver Education, University of Turku. AUTHOR PLEASE CHECK IF THE HIGHLIGHTED AUTHOR NAME IS 'Peraaho' OR 'Peräaho' AND SUPPLY LOCATION.

PReVENT (2007) *Code of Practice for the Design and Evaluation of ADAS*, PR-11300-SPD-060811-v16-CoP.doc V1.6, quoted in Linder et al.

Rajaonah, B., Tricot, N., Anceaux, F. and Millot, P. (2008) 'The role of intervening variables in the driver – ACC cooperation', *International Journal of Human-Computer Studies*, Vol. 66, pp.185–197.

Reason, J.T. (1990) *Human Error*, Cambridge University Press, Cambridge.

RWTH Aachen (2004) *Cognitive Technological Systems, Scientific Concept of the DFG Research Centre at RWTH Aachen*. AUTHOR PLEASE SUPPLY FULL DETAILS.

Sanders, M.S. and McCormick, E.J. (1993) *Human Factors in Engineering and Design*, 7th ed., McGraw-Hill, New York. AUTHOR PLEASE CHECK IF THE HIGHLIGHTED AUTHOR NAME IS 'McCormack' OR 'McCormick'.

Stanton, N.A. and Glendon, A.I. (1996) 'Risk homeostasis and risk assessment', *Safety Science*, Vol. 22, pp.1–13.

Stanton, N.A. and Marsden, P. (1996) 'From fly by wire to drive by wire, safety implications of automation in vehicles', *Safety Science*, Vol. 24, No. 1, pp.35–49.

Stanton, N.A. and Pinto, M. (2000) 'Behavioural compensation by drivers of a simulator when using a vision enhancement system', *Ergonomics*, Vol. 43, No. 9, pp.1359–1370.

Stanton, N.A., Young, M. and McClauder, B. (1997) 'Driver by wire,: the case of driver workload and reclaiming control with adaptive cruise control', *Safety Science*, Vol. 27, Nos. 2–3, pp.149–159.

Sumer, N., Özkan, T. and Lajunen, T. (2006) 'Asymmetric relationship between driving and safety skills', *Accident Analysis and Prevention*, Vol. 38, pp.703–711.

Summala, H. (2000) 'Automatization, automation and modelling of driver's behaviour', *Recherche Transports Sécurité*, Vol. 66, pp.35–45.

Walton, D. (1999) 'Examining the self enhancement bias; professional truck drivers' perceptions of speed, safety, skill and consideration', *Transport Research F2*, pp.91–113. AUTHOR PLEASE SUPPLY VOLUME NUMBER.

Wilmink, I., Janssen, W., Jonkers, E., Malone, K., van Noort, M., Klunder, G., Rämä, P., Sihvola, N., Kulmala, R., Schirokoff, A., Lind, G., Benz, T., Peters, H. and Schönebeck, S. (2008) *Impact Assessment of Intelligent Vehicle Safety Systems*, Deliverable D4 of eIMPACT. TNO Built Environment and Geosciences, Delft.

Woodcock, A., Galer Flyte, M.D., Garner, S.D., Lenard, J., Welsh, R., Bradley, M., Humpherson, A. and Porter, S. (2001) *A Study into the In-Car Safety and Security of Women Drivers and their Passengers*, Final report for DETR, Contract No. PPAD 9/72/36.

Woodcock, A. and Taylor, J. (2009) 'The role of ergonomics in technology oriented projects: The intelligent zero emissions vehicle project', in Bust, P.D. (Ed.): *Contemporary Ergonomics*, Taylor & Francis, London, pp.111–121.