

Behavioural Research in Road Safety 2007 Seventeenth Seminar



March 2009

Behavioural Research in Road Safety 2007: Seventeenth Seminar

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In-depth analysis of road traffic collisions: reflections on twenty years of research

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Abstract

The Action Analysis Group at the University of Nottingham uses sequence analysis and a range of related techniques to study various psychological problems and processes. Past projects have looked at machine-learning techniques for data analysis, language change, human–computer interaction, and road accidents.

Road accident projects undertaken for the Department for Transport/Transport Research Laboratory (TRL) over the last 20 years have investigated, in depth, right-turning accidents, overtaking accidents, young driver accidents, motorcycle accidents, work-related road traffic accidents and in-car fatal accidents. Our research shows that police accident reports are ‘information-rich’ sources that can be a valuable tool for providing information about the causation of a variety of accidents. This paper describes our technique and main findings from each project, and also examines some procedural problems that have affected our work.

Introduction

The causality of real road accidents can be a difficult phenomenon to study. One possible solution to this is the use of methodology that investigates road accidents after they have occurred, rather than the more familiar psychological research that relies, for its method, on the examination of driver behaviour in controlled environments.

One such well-known approach involves the use of multi-disciplinary accident investigation (MDAI) teams that travel to the site of accidents soon after they occur in order to collect data. Research such as that of Sabey and Taylor (1980) is based on the work of MDAI teams. Findings were concerned with the proportional contributions

to road accidents of the user, the environment and the vehicle. It is from this work that the much-quoted figure of 95% was identified as the proportion of road accidents involving human error. Sabey and Taylor (1980) cited research carried out in the United States that produced much the same figure. They went on to assess driver errors behind this figure by examining the contribution of perceptual errors, lack of skill, manner of execution and various forms of impairment, such as alcohol.

However, in a review of the work of multi-disciplinary team research worldwide, Grayson and Hakkert (1987) pointed out several disadvantages to such a method. Operational costs are very high, and typically only a small number of accidents can be studied, unless research can be carried out over several years. Even with a long time-period, sometimes only small numbers of accidents can be studied effectively, as was noted, for example, by Larsen and Kines (2002). Although Sabey and Taylor (1980) did study over 2,000 accidents, such a figure is the exception rather than the rule. There can also be a bias towards injury accidents because of the notification procedure.

This last point is a criticism that cannot be levelled at more recent UK research. Hills and Cuerden (2005) conducted a large, well-organised project in the UK, phase 1 of which was completed recently. Phase 1 of this work sampled over 6,000 accidents from two areas of the UK. Nearly 85% of the accidents attended were categorised as 'slight' (as opposed to 'serious' or 'fatal'). The accidents sampled were also, by definition, of a heterogeneous nature.

A further criticism of MDAI work in general concerns the conclusions reached. Despite the vast amount of information collected in such work, 'definitive conclusions are very limited' (Grayson and Hakkert, 1987) and have been applied mainly to vehicle design and engineering efforts rather than human behaviour and road design. According to Grayson and Hakkert (1987), these limitations tend to disappear 'if an in-depth but not immediate response on-the-spot approach is taken'. They comment that it is also important that any in-depth technique is only really of use if applied to specific areas rather than a large heterogeneous sample of information.

Many studies have used in-depth techniques applied to secondary data sources, such as police reports, interviews and questionnaires. Fell (1976) was among the first to claim that an 'accident causal schema' could be constructed from such sources. Fell was of the opinion that in-depth work using police reports, while still having some limitations, could be used to improve the 'state of the art' in understanding accident causation.

Malaterre (1990) used police reports to break down and analyse accidents. Malaterre constructed four stages in his analysis:

- driving;
- accident;
- emergency; and
- collision.

Factors identified in his analysis stage were next used in synthesis: the building of prototype cases. Such an approach, Malaterre claimed, focused effectively on functions not correctly carried out by the driver, which are sometimes difficult to locate. Malaterre's sample was, however, quite small (115 cases) and was also heterogeneous. He ended by concluding that more precise analysis needed to be carried out by referring to complete police accident reports, with all their varieties of information.

It is often overlooked that local council initiatives into examining accident causation at specific locations ('blackspots') make much use of police reports to present a full picture of what happened. England (1981) describes the approach as very cost-effective when targeting engineering countermeasures, and points out that it has the additional benefit of checking the accuracy of summary statistical information that is held on accidents.

The in-depth technique itself has been used in areas outside accident causation for some time. Examination of in-depth case study techniques by Yin (1984) shows how they are primarily of use in producing analytic generalisations rather than more traditional statistical generalisations. They concentrate on an iterative type of explanation-building that often features chronologies, sequences and contingent event analysis.

Initial methods and findings

The first of this group's studies, into right-turning collisions, used sequence analysis in conjunction with rule-finding computer software. This approach concentrated on the relatively homogeneous class of right-turn accidents to produce new findings. The research is described more fully in Clarke *et al.* (1998a, 1998b).

A genetic algorithm (BEAGLE) and an ID3-based classifier were used to describe and distinguish three types of right-turning accident case, showing the distinctive features of real accidents and the misconceptions of drivers as to how they occur.

The genetic algorithm work, for example, showed that young 'Turners' (under 25) are especially associated with right-turn accidents:

- on minor roads **or** on main roads after dark; and
- riding two-wheelers on a dry road surface.

Further, the key risk factors that make for a more serious accident are:

- pulling over to an outside (passing) lane just prior to the turn **or** colliding with a two-wheeler or pedestrian; and
- failing to notice another road user when turning **off** a main road **or** failing to notice another road user **in poor weather** when turning **onto** a main road.

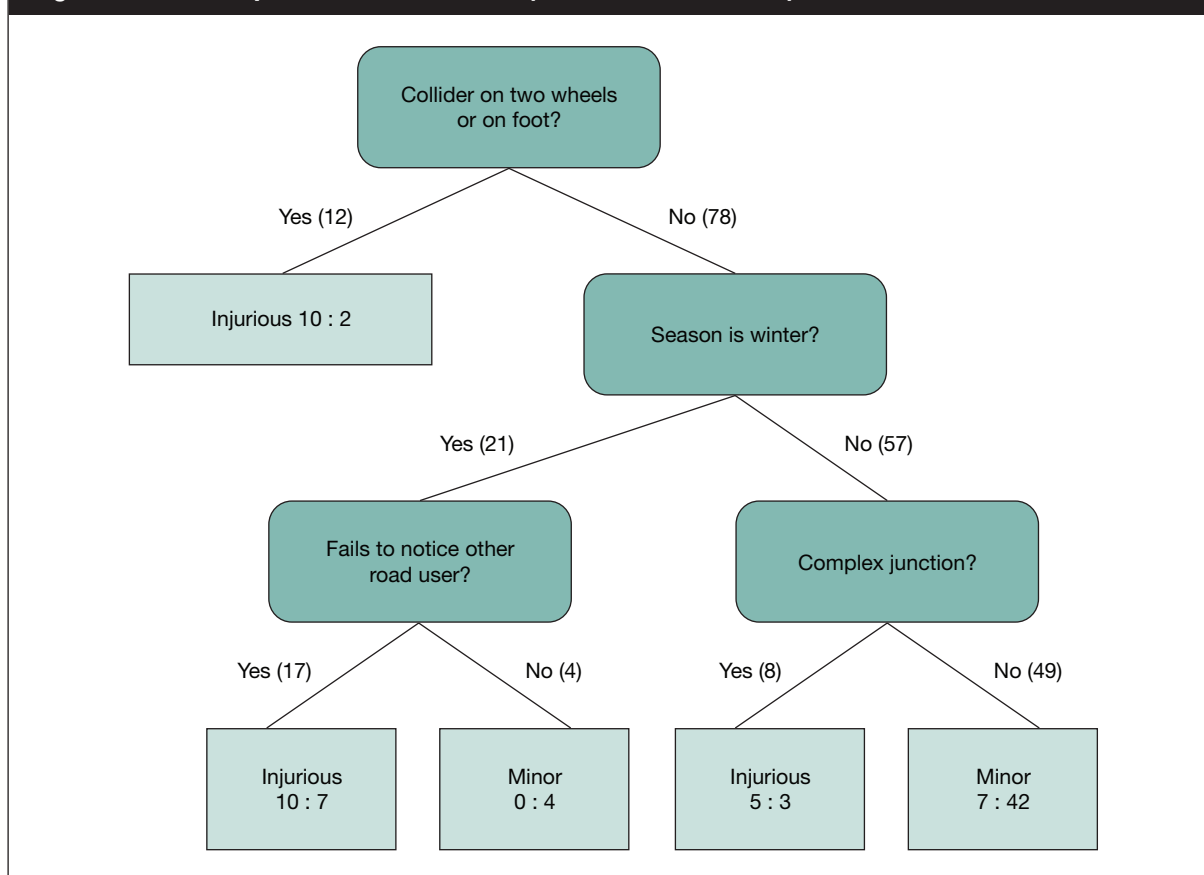
In this study there was no estimate of exposure or expectation from other data sets, but the problem of ‘over-fitting’ (i.e. describing anomalies in a particular set of cases which would not generalise to others) was avoided by a form of internal cross-validation using ‘training’ and ‘test’ sub-sets of cases.

The second strand to this method employed an AI machine-learning method based on Quinlan’s ‘ID3’ algorithm to create decision trees distinguishing the characteristics of:

- accidents that resulted in injury or in damage only;
- accidents of young male drivers; and
- accidents of the relatively more and less dangerous situations.

Different accident mechanisms were found for experienced and inexperienced drivers, and for turns onto and off major roads. Derived ‘rules’ were produced, for example classifying Right Turn ‘Onto’ accidents: Injury versus non-injury (Figure 1).

Figure 1 An example of a ‘derived rule’ (ID3-based classifier)



Later methods

In the earlier work described above it was felt that much of the information from the original police reports was being lost. The rich nature of an accident report that

made it understandable to a human observer had to be left out when the data were being prepared for computer analysis. Subsequent work investigating a variety of different accident types placed more emphasis on the interpretation of causal patterns by the human coders, but retained the powers of a computer database for the later stages of storing, sifting and aggregating explanatory models of individual cases. The later approach addressed relatively homogeneous classes of accident, and relied much more on the human interpretation of the full sequential nature of the accident story in each individual case.

Over the last few years, the research group has used the later method on the following classes of accident:

- overtaking;
- young drivers;
- motorcycles;
- work-related road traffic accidents (RTAs); and
- fatal ‘in car’ collisions.

In each case, the data were entered into a FileMaker Pro database that had been customised to handle the information and search parameters required for this project. Data were entered describing the relatively objective facts of each case: time of day, speed limit, class of road, etc. A ‘prose account’ was also entered for each case, giving a step-by-step description of the accident. These accounts gave a detailed summary of the available facts, including information from witnesses that appeared to be sufficiently reliable. A minimum set of possible explanations for each accident was recorded from a standard checklist adapted and developed throughout the individual studies. The ultimate aim of the database was to build a library of analysed fatal accidents stored as a series of case studies.

Results from the later work

Overtaking accidents

Over 400 cases that had occurred over a five-year period (1989–94) were examined in depth. Some main outcomes of the research are described below. The research is described more fully in Clarke *et al.* (1998c).

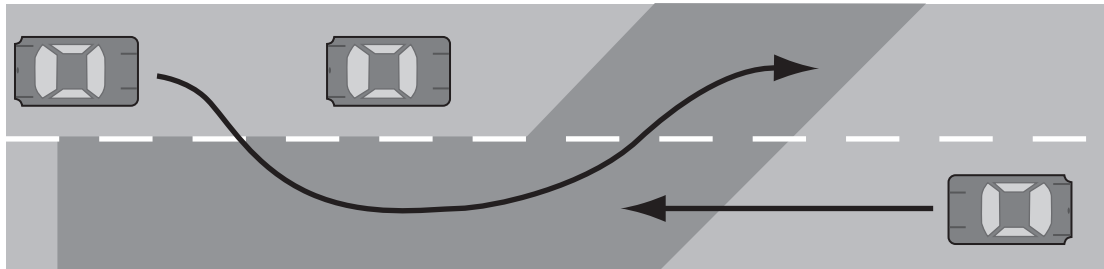
Firstly, a typology of overtaking accidents was produced after an initial pilot study:

- Type 1 – a vehicle collides with a vehicle it is overtaking as that vehicle turns right.
- Type 2 – a head-on collision with a vehicle travelling in the opposite direction.
- Type 3 – side swiping a vehicle which is being overtaken.

- Type 4 – hitting a vehicle either in front or behind when returning to a gap after overtaking.
- Type 5 – going out of control after returning to the nearside following an overtake.
- Type 5.1 – going out of control while carrying out the overtake.
- Type 6 – an overtaker collides with a vehicle making a turning or crossing movement at a junction.
- Type 7 – a vehicle overtaking on the nearside (undertaking) hits another.
- Type 8 – resulting from avoiding action following another driver's risky overtaking manoeuvre.
- Type 0 – unclassifiable/miscellaneous.

A key concept that was used in the overtaking work was the idea of the 'X area', i.e. the area of the road required to be free of other vehicles for a safe overtaking manoeuvre to occur. This is represented in the simplified diagram shown in Figure 2.

Figure 2 The 'X area' in an overtaking manoeuvre



A 'decision tree' approach was then used on the sample to show the most common overtaking decision pathways in relation to factors that included the X area. An example segment of a decision tree is shown in Figure 3.

Overall, it was found that the most common type of overtaking accident involves hitting traffic travelling in the same direction (i.e. type 1) rather than oncoming traffic, as in Figure 4.

Patterns of overtaking accidents for different driver groups were also examined and compared. Male drivers, for example, were found to overtake right-turners and attempt overtakes when they could not see all of the road ahead that was needed for the manoeuvre. Females, in contrast, were found to be involved in overtaking accidents by turning into/out of a junction into the path of an overtaking vehicle that they had not observed.

Figure 3 A segment of a decision tree

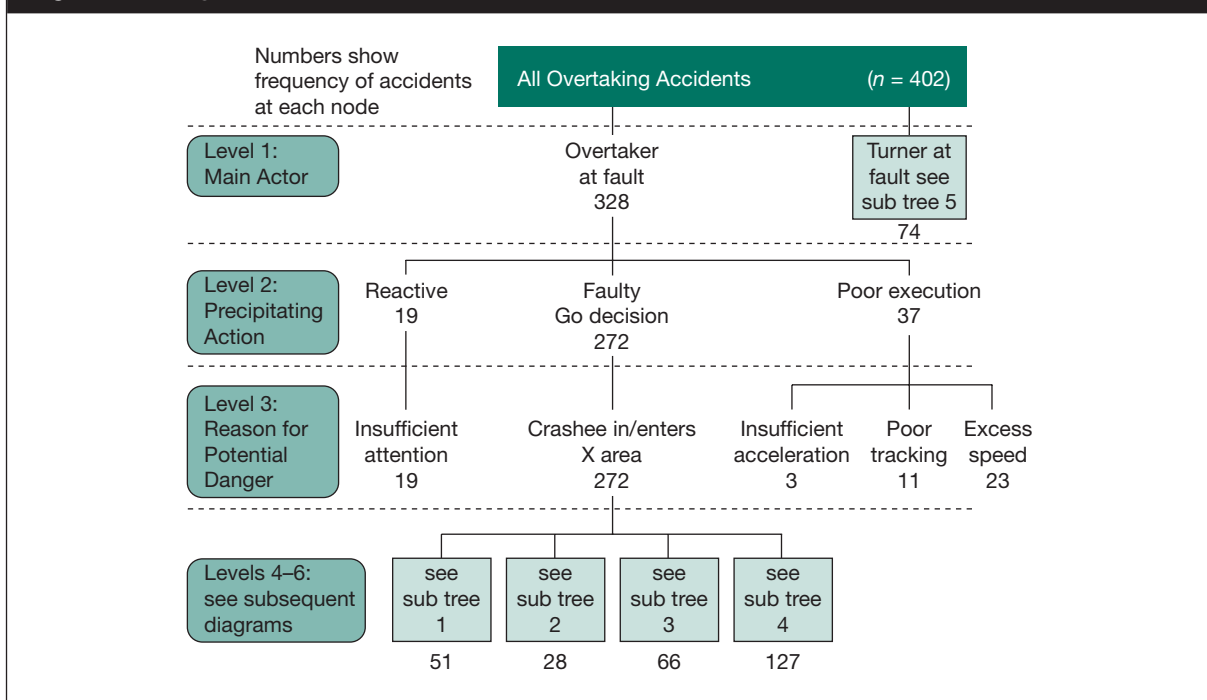
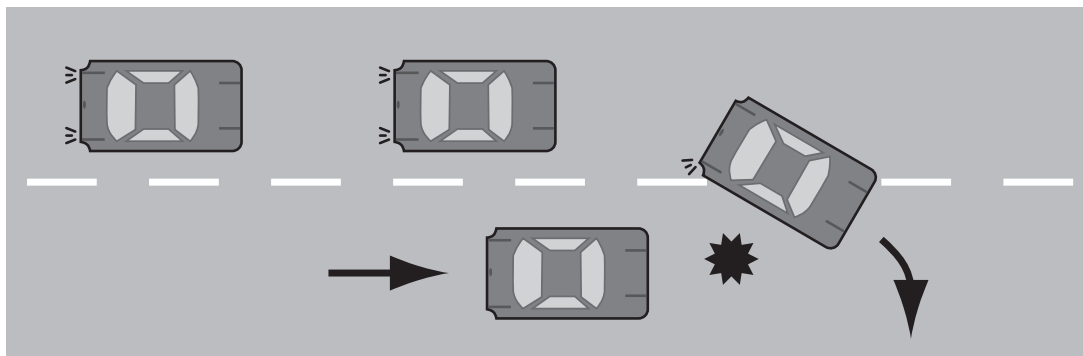


Figure 4 The most frequent type of overtaking accident – hitting a right-turner ahead



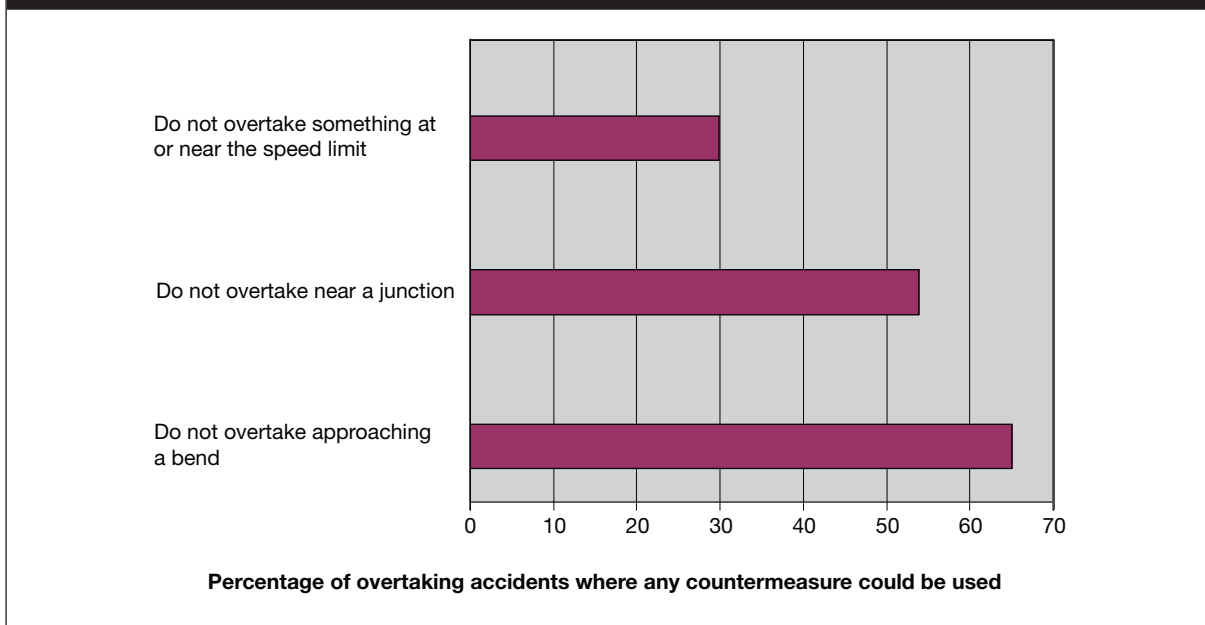
Novel accident causation patterns were discovered as a result of the in-depth analysis of a homogeneous class of accidents. Younger drivers, for instance, were found to be significantly over-involved in a type of overtaking accident characterised by loss of control either during or immediately after the manoeuvre.

Causal factors were linked directly with simple behavioural countermeasures in a systematic and quantifiable way. For most groups of drivers, three simple countermeasures could have made a substantial difference to the outcome of over 60% of their overtaking accidents, as shown in Table 1.

Table 1 Three top countermeasures in overtaking accidents

Countermeasure	Percentage of accidents where countermeasure could be used
Avoid overtaking a vehicle already travelling at or near the speed limit	29.8
Look specifically for signs of junctions ahead when about to overtake	29.8
Avoid overtaking when approaching a bend, even if the road appears clear	22.7

Such countermeasures can also be considered cumulatively, as shown in Figure 5.

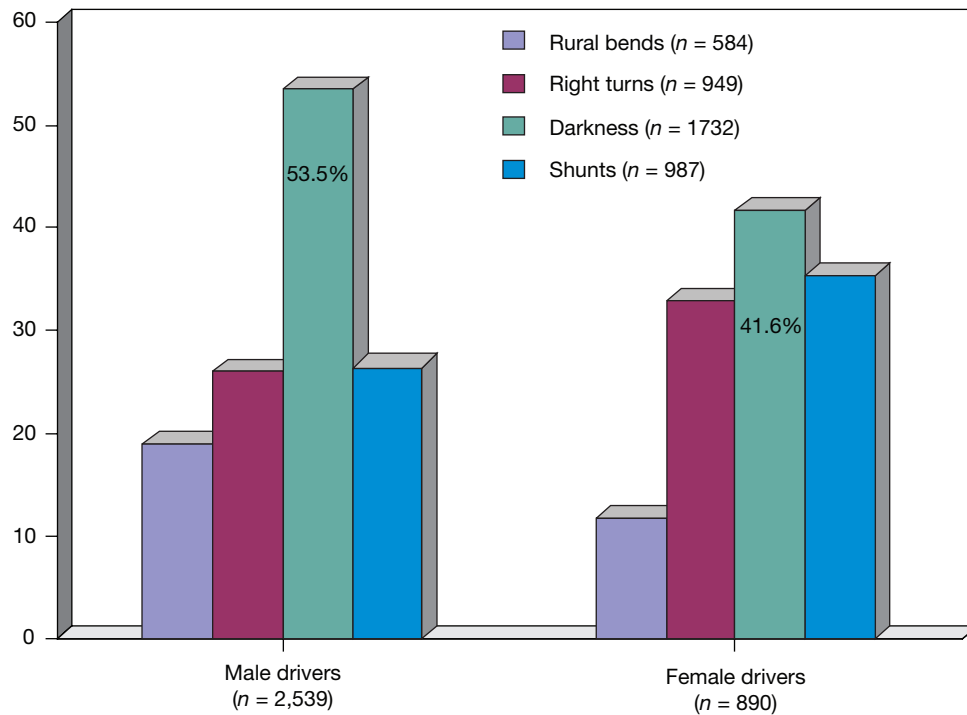
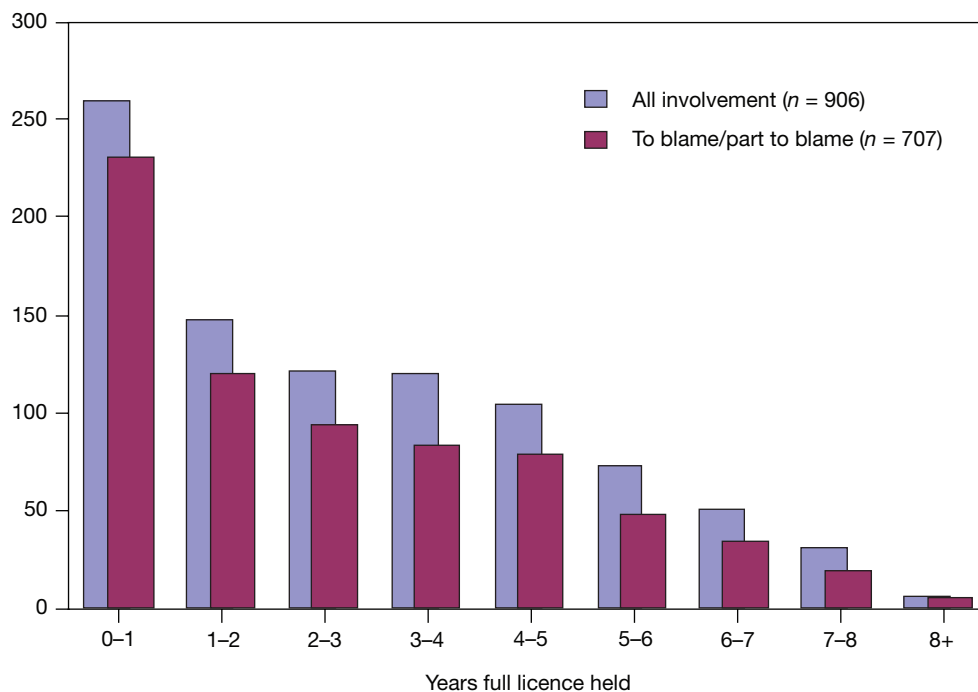
Figure 5 Three countermeasures that could affect the outcome of an overtaking accident, considered cumulatively

Young drivers

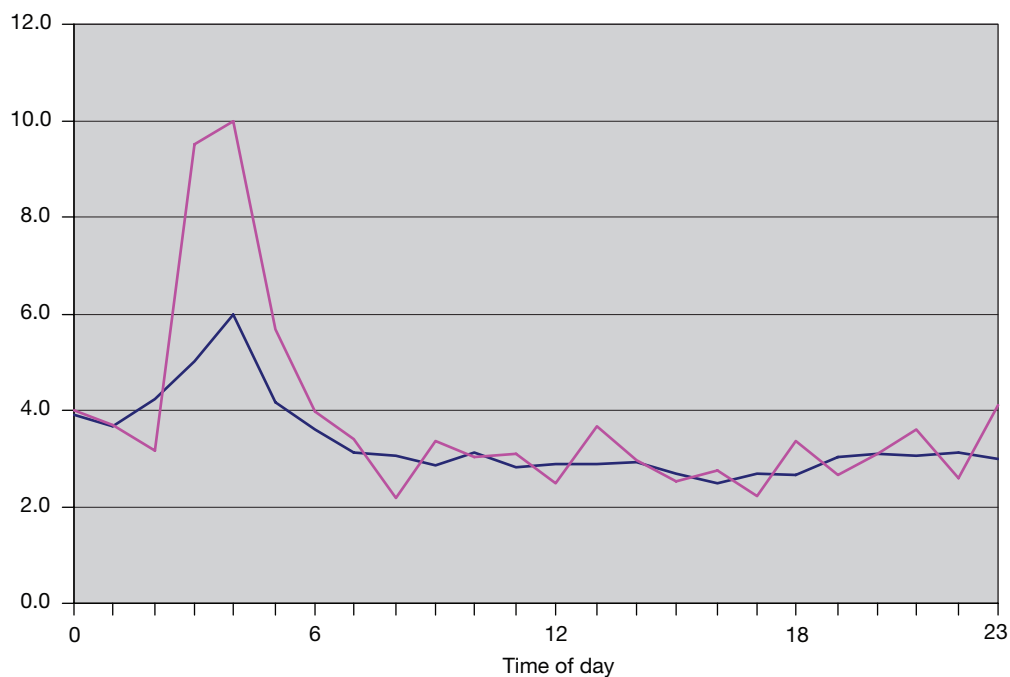
A sample of 3,437 accident cases was considered, including 1,296 in detail, from Midland police forces involving drivers aged 17–25, and covering the years 1994–96 inclusive. The research is described more fully in Clarke *et al.* (2002).

There appeared to be differences in the type of accident young drivers became involved in dependent on their gender, as shown in Figure 6.

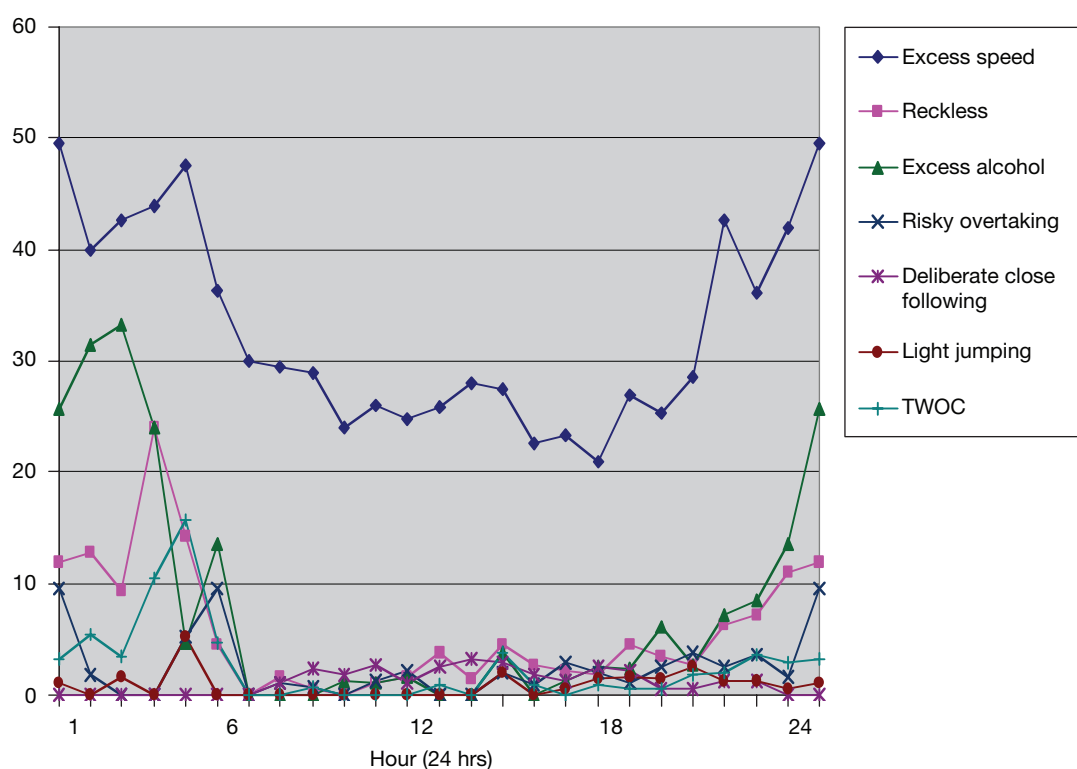
The more experience of driving that a young driver had (as measured by the years since their test pass, where these data were available), the less likely they appeared to be to blame in any accident in which they became involved, as shown in Figure 7.

Figure 6 Gender and accident type**Figure 7 Experience, accident frequency and blame**

When the ratios of blameworthiness (i.e. young divers to blame/not to blame) were examined by time of day, it was also shown that the ratios changed markedly in the early hours of the morning, as shown in Figure 8.

Figure 8 Ratios of all young drivers to blame/not to blame by time of day

One of the main general findings was that younger drivers tended to ‘attitudinal’ rather than skill-based deficits, particularly in their night-time accidents. This is shown in Figure 9.

Figure 9 Young driver ‘attitude-based’ errors in night-time accidents

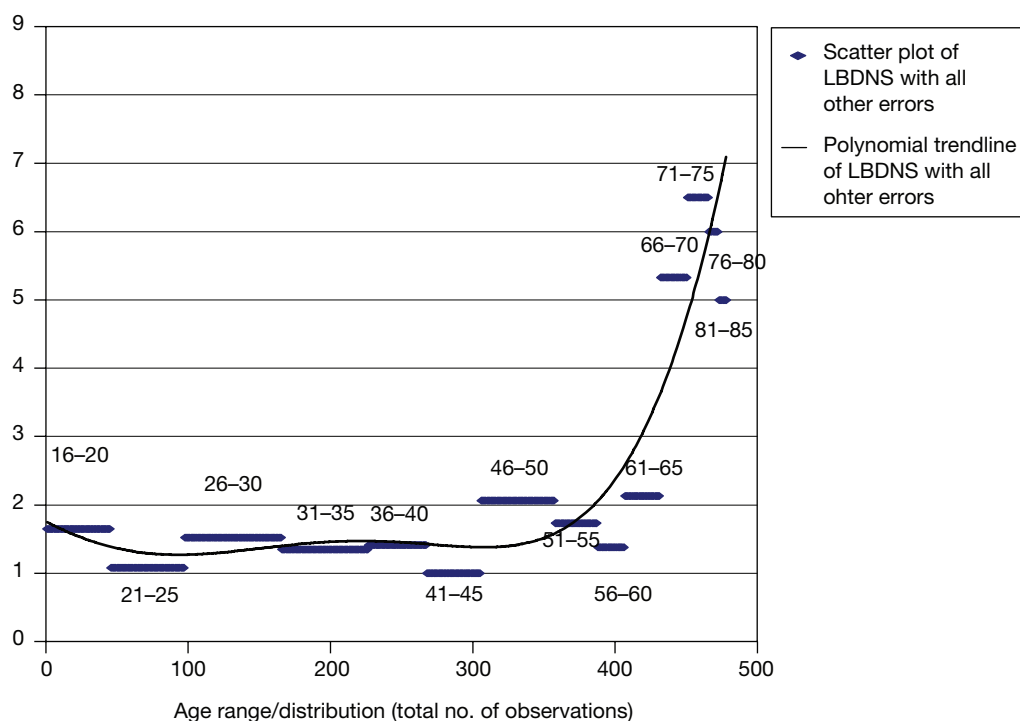
A similar plot, using factors that were related more to skills (such as a lack of effective observation, for example), produced a much flatter profile, with no noticeable peaks in the night-time.

Motorcycle accidents

A sample of 1,790 accident cases was considered, including 1,003 in detail, from Midland police forces involving motorcyclists of all ages, and covering the years 1997–2002 inclusive. The research is described more fully in Clarke *et al.* (2004).

Significant differences were discovered in the sample with respect to the types of accident involving motorcyclists (and their blameworthiness). There seemed to be a particular problem surrounding other road users' perception of motorcycles, particularly at junctions. Such accidents often seemed to involve older drivers with relatively high levels of driving experience who nonetheless seemed to have problems detecting approaching motorcycles. When ratios of LBDNS (i.e. 'looked but did not see') accidents against other types of 'at fault' accidents for involved drivers in the sample were examined, it was seen that the proportion of this visual error compared with other 'at-fault' errors rose with age. The change in ratio occurred at too great an age (65 years plus) to be related purely to driver skill factors, and suggested an age-related deficit. The scatter-plot in Figure 10 shows this, but ratio plots comparing LBDNS with other types of visual and non-visual error that have been produced from the data do not show any significant rise with age.

Figure 10 Scatter plot of ratios of driver at fault in LBDNS/all other errors



Motorcyclists themselves, on the other hand, seemed to have far more problems with other types of accident, such as those on bends and overtaking or 'filtering' accidents.

The main accidents suffered by motorcyclists are summarised in Table 2.

Table 2 Common factors in the two most frequent types of motorcycle accident

	Blame	Age	Severity	Weather	Speed limit	Location	Bike type	Day	Time	Purpose of journey
Right of way violation (ROWV)	Most are the fault of the other driver	Rider age not shown to be important. On average drivers 'at fault' tend to be 'older'	Unlikely to result in serious injury	Most occur in dry and fine weather	Most occur within a 30 mph limit	Mainly occur in urban settings	Not shown to be important	Most occur on a week day	Peak in accident rate during rush hours	Most occur while riders are commuting or riding on business
Bends/curves	Almost always the fault of the rider	Most likely to be younger riders	Most likely to result in serious injury	Most occur in dry and fine weather	Most occur within a 60 mph limit	Mainly occur in rural settings	Riders are most likely to be riding sports bikes	Half occur on a weekend, mainly Sundays	No noticeable peaks at busier times of day	Most occur while riding for leisure purposes

Work-related road traffic accidents

A sample of 2,111 accident cases was considered, including 1,009 in detail, from Midland police forces involving drivers/workers of all ages, and covering the years 1996–2004 inclusive. The research is described more fully in Clarke *et al.* (2005).

There were six main classes of accident-involved vehicle; these covered 88% of the sample. They were:

- company cars;
- vans/pickups;
- lorries (LGVs);
- buses (PCVs);
- taxis/minicabs; and
- emergency vehicles.

Sub-groups in the remaining 12% of the sample included people driving miscellaneous vehicle types and those working in, on or near the road.

The blameworthiness ratios (i.e. the ratio of drivers to blame/not to blame in accidents involving vehicles of the six types) are shown in Table 3.

Table 3 Blameworthiness ratios (in order of magnitude) for six types of work vehicle in road accidents

Vehicle type	Blameworthiness ratio
Lorry/LGV	2.46
Van/pickup	2.08
Company car	1.18
Emergency vehicle	0.90
Taxi/minicab	0.70
Bus/PSV	0.56
All work-related drivers	1.39

The drivers of company cars, vans/pickups and lorries (LGVs) all appeared to have a high ‘blameworthiness’ ratio in their accident involvement. Company car drivers showed excess speed as a causal factor, whereas van drivers showed more observational failures, and LGV drivers showed more fatigue and vehicle defects as factors.

The drivers of buses (PCVs), taxis/minicabs and emergency vehicles showed a low ‘blameworthiness’ ratio in their accident involvement. Their problems seemed to be primarily with the other drivers/parties with whom they share the road. While they made a variety of mistakes or errors, they were more likely to become the victim of another party’s mistake or error.

Workers on, in or near the road seemed to come to grief through the behaviour of drivers who sometimes seemed to be aggressively asserting their right of way over pedestrians with little regard to their safety.

Table 4 shows a summary of the common factors by vehicle class in work-related road traffic accidents.

Table 4 Summary of work-related road accidents by vehicle type

	Blame	Age/sex	Severity	Location – over-represented on ...	Over-represented contributory factors
Company cars	More to blame than not	Peak at 31–35 years, mostly male, some females	More fatalities than other vehicle types if driver to blame	Rural unclassified (60 mph limit)	Excess speed; poor observation; excess alcohol; slippery roads
Vans/pickups	More to blame than not	Peak at 21–25 years, mostly male, few females	No effect	Urban unclassified roads; rural B class roads; and rural unclassified roads (mixed limits)	Poor observation (restricted views and other drivers' signals)
LGV/lorry	More to blame than not	Peak at 26–30 years, nearly all male	More fatalities than other vehicle types, regardless of blame	Rural A roads (60 mph) and motorways (70 mph)	Poor observation; close following; fatigue; load problems; vehicle defects
PCV/bus	Other parties more to blame	Peak at 46–50 years, nearly all male	No effect	Urban roads, all classifications (30 and 40 mph)	Poor observation (at junctions); close following; failure to signal
Taxi/minicab	Other parties more to blame	Peak at 26–30 years, nearly all male	No effect	Urban roads, all classifications (30 and 40 mph)	Poor observation (U-turns and reversing); gap judgement
Emergency vehicle	Other parties more to blame	Peak at 26–30 years, nearly all male	More fatalities than other vehicle types, if driver to blame	Urban roads, all classifications (30 and 40 mph)	Excess speed; time pressure

Fatal 'in-car' casualties

A sample of 1,185 fatal vehicle occupant cases was considered, from 10 UK police forces, from the years 1994–2005 inclusive. The research is described more fully in Clarke *et al.* (2007).

Over 65% of the accidents examined involved driving at excessive speed, a driver in excess of the legal alcohol limit or the failure to wear a seat belt by a fatality, or some combination of these.

Young drivers have the great majority of their accidents by losing control on bends or curves, typically at night in rural areas and/or while driving for 'leisure' purposes. These accidents show high levels of deliberate speeding, alcohol involvement and recklessness. Figures 11 and 12 show the effect of driver age on accidents involving speed, bends and alcohol. (Both figures have overlaid 2nd order polynomial trend lines added.)

Figure 11 Youth, speed and bends in fatal collisions

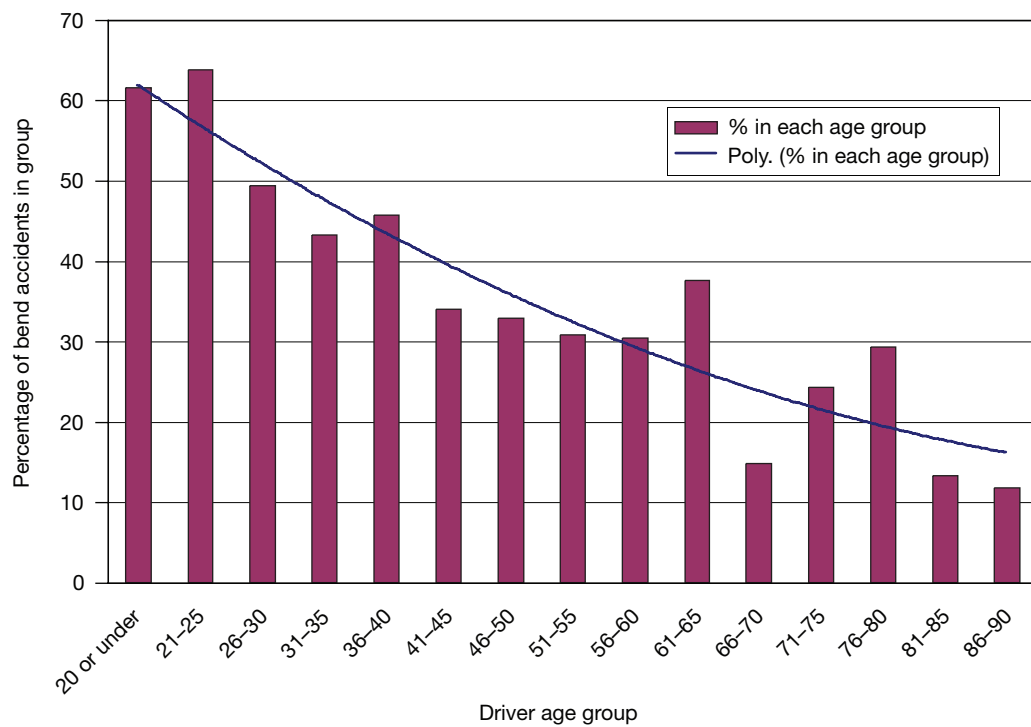
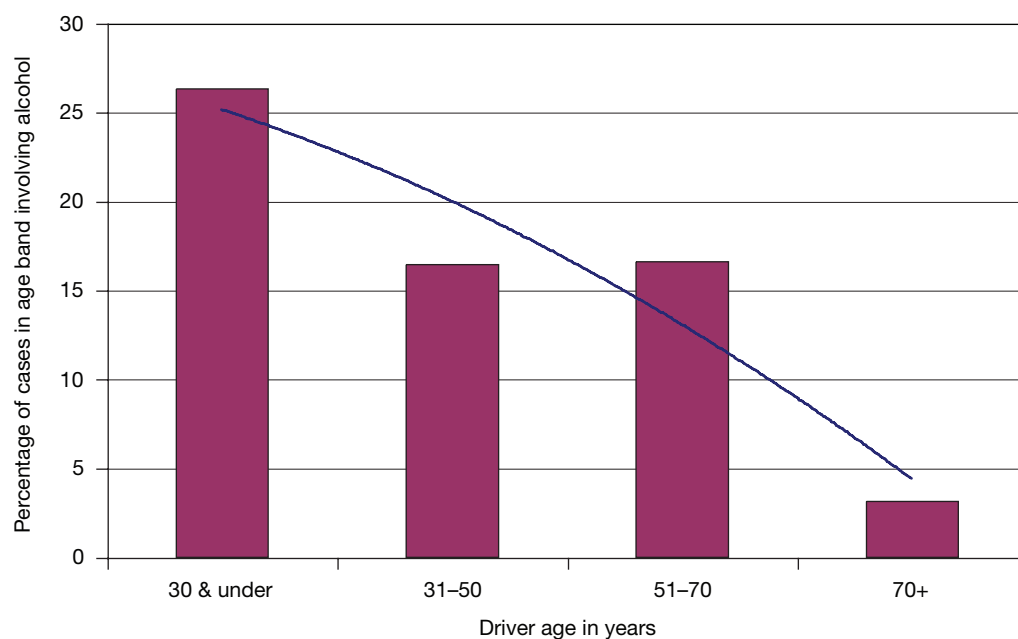
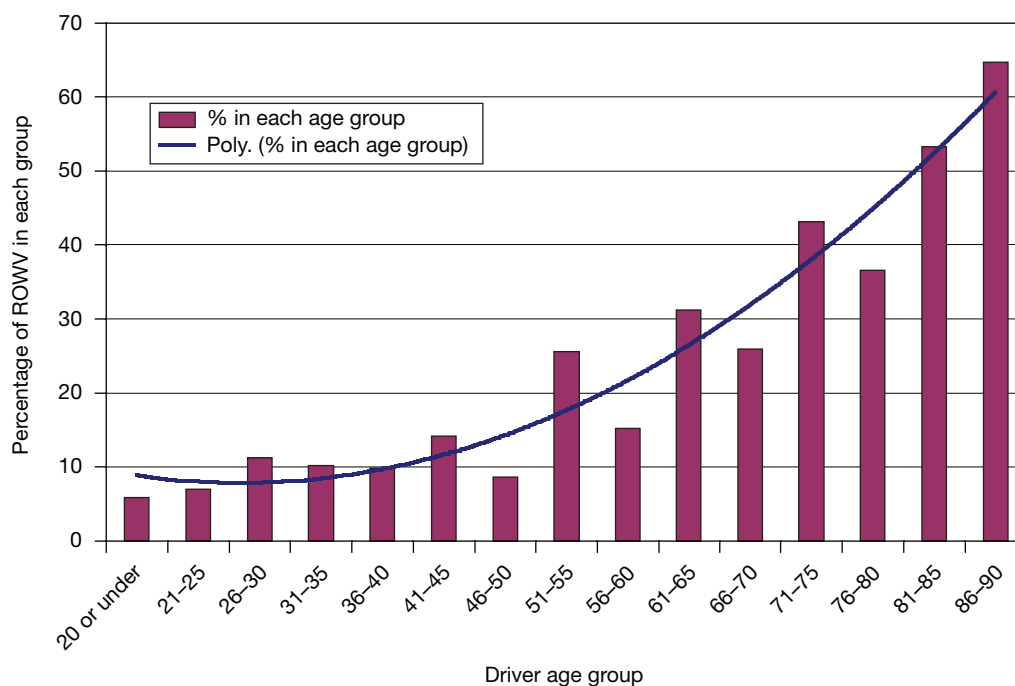


Figure 12 Youth and alcohol in fatal collisions



Older drivers had fewer accidents, but those fatalities they were involved in tended to involve misjudgement and perceptual errors in 'right of way' collisions, typically in the daytime on rural rather than urban roads. Blameworthy right of way errors were notably high for drivers aged over 65 years, as a proportion of total fatal accidents in that age group, as shown in Figure 13. This finding bore a remarkable similarity to earlier findings in our work on right-of-way collisions involving motorcycles.

Figure 13 Percentage of fatal right of way accidents by driver age band

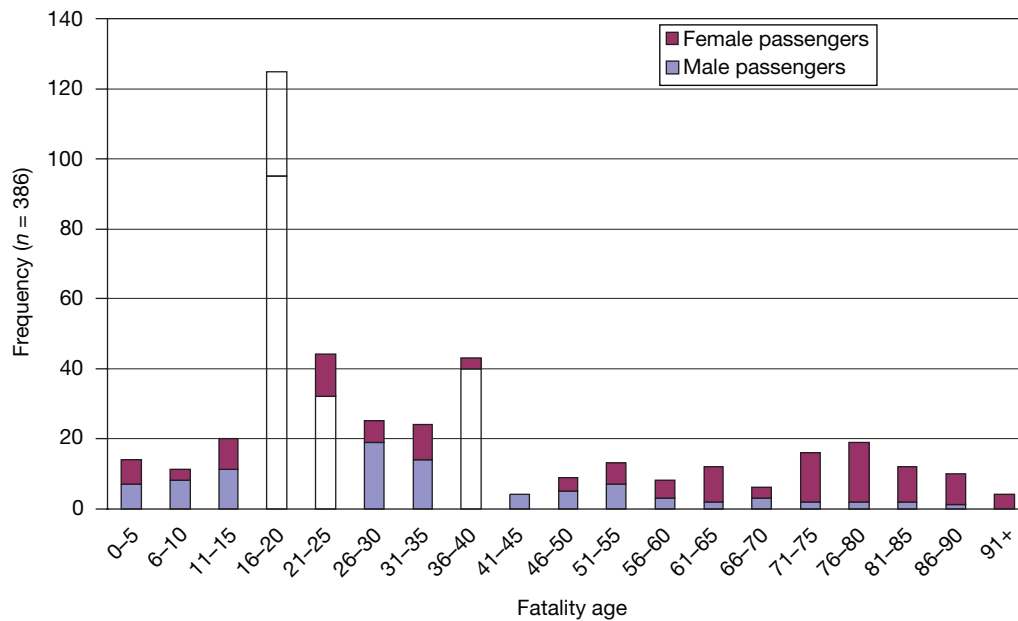


PASSENGERS IN FATAL COLLISIONS

- 75% of all cases involved the death of a driver.
- 33% of all cases involved the death of a passenger.
- 23% involved the death of a front-seat passenger.
- 12% involved the death of a rear passenger.
- 10% involved more than one fatality.
- In 26% of cases involving the death of any passenger, the driver of the same vehicle was also killed.

Figure 14 shows the distribution of passenger fatalities in the sample by age and sex.

The peak age/sex for passenger fatalities was 16–20-year-old males. Fifty-eight per cent of these casualties were not wearing seat belts. They were usually travelling with a slightly older driver (mean driver age for this subset was 21 years vs mean

Figure 14 Passenger fatalities by age and sex

passenger age of 18). The majority (68%) of this subset involved deliberate excessive speed by the driver concerned, and 36% involved deliberate recklessness, such as racing.

The drivers in this subset were almost always assessed as fully to blame for the accident; the driver was regarded as fully to blame in 95% of this subset vs 79% in the sample as a whole.

There was some evidence of a ‘commonality of behaviour’ between drivers and passengers, i.e. if a driver had been drinking/taking drugs/not wearing a seat belt it was likely that the passenger(s) had also been drinking/taking drugs/not wearing a seat belt. More than half of the group where the passenger was not wearing a seat belt also involved a driver not wearing one. The extent of this phenomenon is hard to quantify for actual levels of drink/drugs consumed, however, as it is rare to see a toxicology report on a passenger but reasonably common for a driver.

Discussion

The results section above has given a ‘thumbnail sketch’ of the main results from six major research projects carried out at the University of Nottingham over the last 20 years. Further details of each can be found by using the references cited in the text.

The work has examined the causal factors behind real accident cases, at a relatively inexpensive unit cost when compared with other research methodologies. This is not to say that the research has been without its problems. These problems have included the following:

1. Obtaining access to data – while some police forces have been very helpful in giving the Nottingham group access to data, this is regrettably not the case with all forces. Issues here are often related to the next problem.
2. The Data Protection Act – although we have never used personal data in any of our research, and never seek to identify any individual or their vehicle, the fact that we are given access to personal data in police files can lead to lengthy delays to the work process while data access protocols are agreed.
3. Obtaining continuity of research funding – this has been a perennial problem, and one which we are still experiencing (in common with the rest of the academic community).

Conclusions

The in-depth approach has been shown to be a highly effective research tool that can sometimes reveal somewhat counter-intuitive findings (e.g. that the most common type of overtaking accident does not involve hitting oncoming traffic). The research method has also proved valuable in driving analysis beyond the straight facts of statistics (e.g. as revealed by STATS19), and has revealed that a major road safety problem (especially, it would seem, with younger drivers) has its origin in driver attitudes, rather than failures of skill.

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2

On the Spot accident study – the characteristics of pedestrian accidents

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Executive summary

The UK's On the Spot (OTS) accident data collection project started in 2000 and continues to investigate 500 crashes per year. Investigations are undertaken minutes after the collision has occurred in order to gather all the perishable information. At the time of writing, over 3,200 crashes involving all road users and all injury severities have been examined. The OTS database provides a unique insight into the prevailing factors that have been seen to cause crashes and the associated human injuries and vehicle and infrastructure damage that have been witnessed by the crash investigation teams. This paper gives a brief overview of the project and highlights the structure and composition of the database.

The objective of the paper is to highlight that the OTS study has now collected enough in-depth data to offer the potential both to identify common crash characteristics and to address complex research questions concerning the causes and nature of road traffic accidents. To demonstrate this potential, new data are presented on the pre- and post-crash circumstances of a sample of 193 pedestrian crashes. Recent work highlighting the risk of pedestrian injury with respect to the car impact speed and a summary of the crash causation factors is included.

The information OTS provides can be used to begin to outline the potential effectiveness or scope of future crash prevention strategies and/or technologies.

Introduction

The OTS Accident Data Collection Study began in 2000 and continues to investigate over 500 crashes a year. As the investigation teams are on the scene within minutes of the accident occurring, they are able to collect perishable information and data on

the causation of each accident. This paper uses pedestrian accidents as an example of the level of analysis that can be achieved with the OTS study.

While the number of pedestrian injuries on the roads in the UK has been decreasing in recent years, in 2005 there were still over 33,000 pedestrian casualties, of which there were 671 deaths (Department for Transport, 2006). Pedestrian accidents represent 12% of the casualties and 21% of the fatalities on UK roads. It is believed that the accident figures for pedestrians are relatively accurate, as the drop in recorded accidents has been reflected by a drop in hospital admissions of pedestrians. Pedestrians are more likely to be severely injured than other road-user groups and so are more likely to go to hospital, which makes under-reporting less of a problem (Ward *et al.*, 2006).

The type and severity of injuries suffered by a pedestrian in an impact are related to the impact speed, type of vehicle, stiffness and shape of the vehicle front, age and size of the pedestrians, as well as the initial posture of the pedestrian relative to the front of the vehicle. Yang (2005) found that in 70% of crashes the driver braked before the pedestrian was hit, and that 95% of pedestrian impacts occurred at speeds below 60 km/h (37 mph). The importance of impact speed in pedestrian impacts has been reflected in physical, legal and publicity measures to reduce the speed of cars in urban areas, where the majority of pedestrian accidents occur (Davies, 1999).

The head and lower extremities are the most frequently-injured areas in a pedestrian impact because of the typical pedestrian kinematics when hit by a vehicle (Yang, 2005). When an adult is struck by the front of a car, the first contact is between the bumper and the leg, followed by contact between the bonnet edge and the thigh. The lower extremities are accelerated forwards because of the impact, while the upper body rotates and accelerates with respect to the car, with the head hitting the windscreen or the bonnet. The speed with which the head hits the car is usually 0.7–1.4 times the travelling speed of the vehicle.

Age is important in determining injury severity, with pedestrians above the age of 65 having a higher risk of serious injury or fatality (Dunbar *et al.*, 2004). Pedestrian age is also related to the risk of being involved in an accident. Several studies have shown that older people have an increased risk of being involved in pedestrian accidents because of changes to eyesight, hearing, visual attention, cognitive ability, as well as conditions such as arthritis. Different age groups also have different perceptions of the value of crossing the road, with older people less likely to cross in risky situations (Holland and Hill, 2007). But, while older people are more careful and allow larger time gaps to cross the road, they often do not compensate enough for their slower walking pace (Dunbar *et al.*, 2004; Oxley *et al.*, 2005).

There are also age-related behavioural reasons why peak injury rates occur among 12–14-year-olds (Tolmie *et al.*, 2006). Pedestrians of this age have a relatively careless approach to road crossing, often due to a perceived lack of caution of their peers. Risk-taking increases up to at least age 16, but above 14 years this increased risk-taking is counteracted by an increase in road crossing skill.

Differences in road crossing between men and women lead to a greater risk for male pedestrians. Holland and Hill (2007) found that these differences were associated with the perception of the risk of crossing, with women perceiving a higher risk than men.

In 2004, 42% of fatally-injured pedestrians had alcohol levels over 80 mg/100 ml, and 38% had over 100 mg/100 ml (Department for Transport, 2007). Oxley *et al.* (2006) showed that alcohol affects the ability to select gaps of appropriate length when crossing the road. Intoxicated pedestrians showed an increased lack of awareness of their impairment, had a tendency to make risky road crossings, and found it difficult to correctly interpret speed and distance information. Mobile-phone use while crossing has also been linked to distraction, which could reduce the safety of the pedestrian (Hatfield and Murphy, 2007).

Tyrrell *et al.* (2004) found that pedestrians can often overestimate their visibility to traffic, and also underestimate the benefit of conspicuity treatments such as light-coloured clothing or reflective vests.

While the above behavioural factors all relate to pedestrians, there are undoubtedly behavioural factors relating to drivers that make them more likely to have any type of accident, including a collision with a pedestrian. These include factors such as speeding, drink-driving, inattention, as well as age- or gender-related attitudes towards driving.

OTS methodology

The OTS Accident Data Collection Study has been developed to overcome a number of limitations encountered in earlier and current research. Most in-depth accident studies (such as the UK Co-operative Crash Injury Study (CCIS)) are entirely retrospective, in that investigations take place a matter of days after the incident and are therefore limited in scope to factors which are relatively permanent, such as vehicle deformation and occupant injuries. Retrospective crash studies provide a cost-effective methodology to investigate vehicle crashworthiness. However they do not, in general, record information relating to evidence existing at the crash site, such as the post-impact locations of vehicles, weather and road surface conditions, nor do they consider events leading up to the accident, such as the driving conditions encountered as the protagonists approached the crash site and their behaviour. It is these factors that give an insight into why the accident happened. The police, who do attend the scenes of accidents while such 'volatile' data are still available to be collected, tend to have other priorities, such as ensuring that the injured receive help, clearing the scene to restore the flow of traffic and ensuring that if anyone has broken the law they are dealt with appropriately. Some accident studies (such as the Heavy Vehicle Crash Injury Study) do record pre-crash information available from police files, but these are in the minority.

The philosophy of the OTS project was to put experienced accident researchers at the crash scene at the same time as the police and other emergency services. Thus, the study is still retrospective, in that the accident has already happened, but the timing is such that it should be possible to gather information on the environmental and behavioural conditions prevailing just before the crash. This provides valuable in-depth data on the causes as well as the consequences of crashes, and allows countermeasures to be developed in the fields of human behaviour and highway engineering as well as vehicle crashworthiness. The OTS study provides a significant enhancement to the data currently available from other studies.

The study involves two teams – from the Vehicle Safety Research Centre (VSRC) at Loughborough University and the Transport Research Laboratory (TRL) – working in close co-operation to produce a joint dataset. Work on the development of the study design and procedures began in 1998. Protocols were developed to be consistent with recent international activities. These include the EC proposals for the development of a Pan-European Accident Database based on recommendations from the Standardisation of Accident and Injury Registration Systems (STAIRS) project.

Funding for the project came from the Road Safety and the Transport Technology Systems Divisions at the Department for Transport, and from the Highways Agency (HA). Full data collection began in 2000, with a requirement to collect detailed information on 500 accidents per year. This was a large and complex activity, involving close collaboration between two geographically-remote research teams operating from TRL in Berkshire and VSRC in Nottinghamshire. Both teams developed the project using common protocols and liaison techniques with the emergency services, hospitals, HM Coroners and local authorities, and including routine technical links with the expertise available at the two institutes.

The study has seen a very close working relationship between the research teams and their respective local police in Nottinghamshire and Thames Valley. This link was strengthened by the inclusion of a serving police officer on each team, which provided a secure, direct and reliable link with the local police command and control systems, thus ensuring immediate crash notifications. Response vehicles, fitted with blue lights and driven by seconded police officers, were used to transport each research team safely to the scene. In this way it was possible to cover a larger area than in previous studies. The response technique ensured that the combination of a relatively large area and increased traffic densities on modern roads allowed larger samples of crashes to be investigated than were attained in some earlier studies. Given the attention to detail in establishing the necessary infrastructure, the well-designed sampling plan and conformity to common investigation protocols, the Department for Transport/HA OTS project provides an example of ‘best practice’ in this field.

It takes many years to establish useful databases and it is essential to have continuity to gain the best value from the database over the long term. The OTS project has two main strengths, compared with more conventional studies. The first is having access to volatile scene data, including transient highway factors and climatic conditions, which are particularly important for determining accident circumstances, especially when investigating vulnerable road-user accidents. The second is the ability to interview witnesses at the scene, thus gaining an insight into behavioural characteristics and how these may have been influenced by the transient factors referred to above.

Structure of the database

A large amount of data is collected by the OTS investigation teams for each accident, and this is collected in a database which protects data integrity and enables analysis. The database contains over 3,000 fields, and is structured in a way that enables successful analysis.

The OTS database is split into five main data levels: scene, approach, vehicle, human and injury.

- The scene level contains data which relates to the entire accident, and the collision scene. Data such as the date of the accident and the light conditions at the time of the accident are stored at the scene level. Accident causation factors are also recorded at a scene level.
- The approach level is immediately below the scene level, and contains information on the paths taken by the vehicles and pedestrians involved in the accident. This records environmental factors which could be different depending on the approach. For example, a right-hand bend for one approach would be a left-hand bend for a different approach.
- The vehicle level contains data on each vehicle involved in the accident. This is directly beneath the approach level. Vehicles will have a different approach if they, for example, collide head on, while they would have the same approach in a rear shunt. OTS records pedestrians as a 'vehicle' in their own right, so the vehicle level also includes information relating to pedestrians.
- The human level includes the occupants/riders of the vehicles involved, as well as more detail about pedestrians which was not included in the vehicle level. The human level includes data such as age, gender and whether their vision was obscured.
- Finally, the injury level contains details of each injury sustained by that human. This includes information on the type, severity and cause of the injury. More information on the methodology of OTS can be found in the DfT Road Safety Research Reports Nos 59 and 73 (Hill and Cuerden 2005; Cuerden *et al.* 2007).

Terminology

Police injury severity

The casualties' injury severity is classified by *Road Casualties Great Britain 2005* (RCGB 2005; Department for Transport, 2006) and by OTS according to the UK Government's definitions of fatal (killed), serious or slight.

'Fatal' injury includes only those where death occurs in less than 30 days as a result of the accident. Fatal does not include death from natural causes or suicide. Examples of 'serious' injury include fractures of bone, internal injury, severe general shock requiring hospital treatment or injuries to casualties who die 30 or more days after the accident from injuries sustained in that accident. Examples of 'slight' injuries include sprains, not necessarily requiring medical treatment, bruises, slight cuts and slight shock requiring roadside attention.

Abbreviated Injury Scale

The OTS casualties' injuries and characteristics (gender, age, height, weight, etc.) are obtained from police reports, questionnaires, hospital records or HM Coroner reports depending on the casualties' injury severity. The injuries sustained are coded using 'The Abbreviated Injury Scale (AIS) 1990 Revision' (AAAM 1990).

Each injury description is assigned a unique six-digit numerical code in addition to the AIS severity score. The first digit summarises the body region; the second digit identifies the type of anatomical structure; the third and fourth digits identify the specific anatomical structure or, in the case of injuries to the external region, the specific nature of the injury; the fifth and sixth digits identify the level of injury within a specific body region or anatomical structure. Finally, the digit to the right of the decimal point is the AIS severity score. This study specifically uses the AIS code for the body region injured and the AIS severity score.

The AIS severity score is a consensus-derived anatomically-based system that classifies individual injuries by body region on a six-point ordinal severity scale ranging from AIS 1 (minor) to AIS 6 (currently untreatable), shown in Table 1.

Table 1 Description of AIS scores

AIS score	Description
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum
9	Unknown

'MAIS' denotes the maximum AIS score of all injuries sustained by a particular occupant. It is a single number that attempts to describe the seriousness of the injuries suffered by that occupant. 'HAIS' denotes the highest AIS score of all injuries to a given body region sustained by an occupant. It is a single number that attempts to describe the seriousness of the injuries to a given body region suffered by that occupant.

The AIS system therefore allows injuries to be coded by their type and severity in terms of threat to life. In OTS, the injuries are then correlated with the associated vehicle damage to try to determine the ultimate cause of each individual injury.

Pedestrian accidents in OTS

Sample characteristics

Initial inspection of the OTS database showed that the details of 202 pedestrians were recorded. Of these, 193 had been struck by a moving vehicle, and it is these

pedestrians which form the dataset for this paper. The nine pedestrians who were not struck by a moving vehicle included two who caused an accident by being in the carriageway and thereby causing a vehicle to swerve, two who caused a vehicle to stop which was then hit from behind, two who distracted a driver so that an accident occurred, two who moved into a stationary vehicle, and one who was crossing with a pedestrian who was hit, but was not struck themselves.

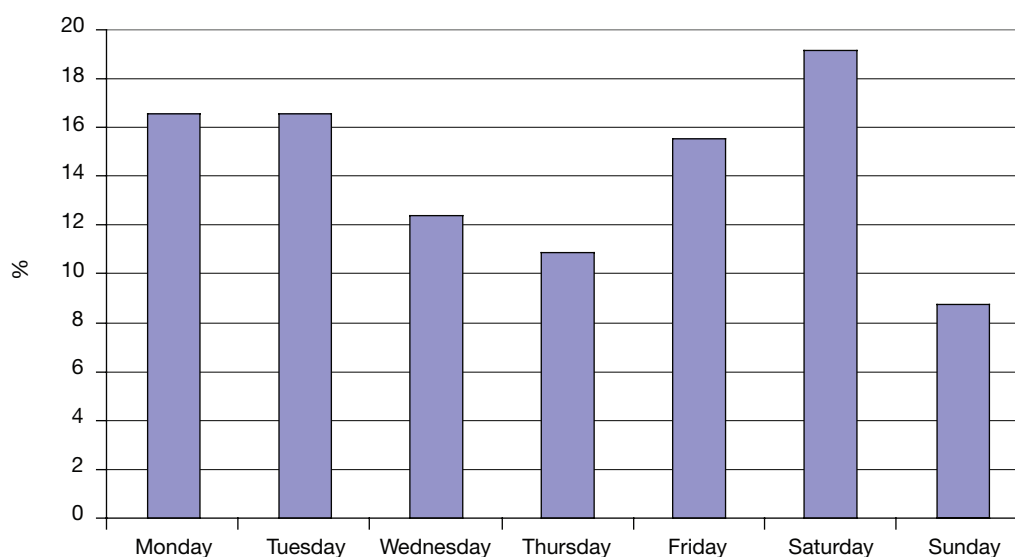
The peaks in accidents in the morning and evening reflect the morning and evening rush-hours. It can be seen in RCGB 2005 (Department for Transport, 2006) that there are more accidents in the evening rush-hour than in the morning, and OTS reflects this. It should be noted that RCGB includes only pedestrians who have been injured in an accident, while OTS includes pedestrians of all injury severities, including those who were not injured but were involved in an incident. This applies to all the comparisons made between OTS and RCGB in this paper. Only data from 2005 have been used, to give an idea of the general trends in the national data.

Table 2 shows how many accidents were located in an urban or a rural location. This information was known for 175 of the pedestrians. It is generally acknowledged that the majority of pedestrian accidents occur in urban environments because there is more exposure of pedestrians to traffic. From the RCGB 2005 data, 87.5% of pedestrian casualties occurred in urban areas compared with 12.5% in rural areas.

The gender of 184 of the pedestrians was known, and the distribution is shown in Table 3. The average ages for the males and females in the sample are very similar, and have a similar standard deviation. There are more male pedestrians in the sample than female, which again reflects data seen in RCGB 2005. In 2005, there were 19,338 (58.2%) male pedestrian casualties compared with 13,913 (41.8%) female casualties.

Figure 1 shows on which day of the week the accidents involving the 193 pedestrians occurred. Figure 2 shows the hour of the day when the accidents involving the 193 pedestrians occurred. Hour 00 runs from 00:00 to 00:59, hour 01 runs from 01:00 to 01:59, etc.

Figure 1 Day of the week for the pedestrian accidents in OTS



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Figure 2 Time of accident for the 193 pedestrians

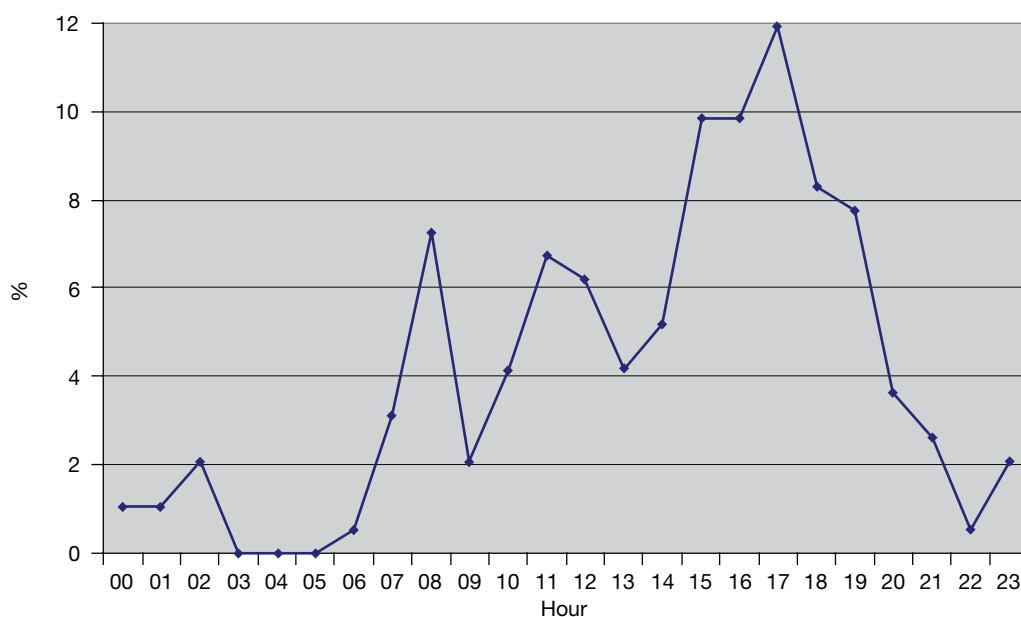


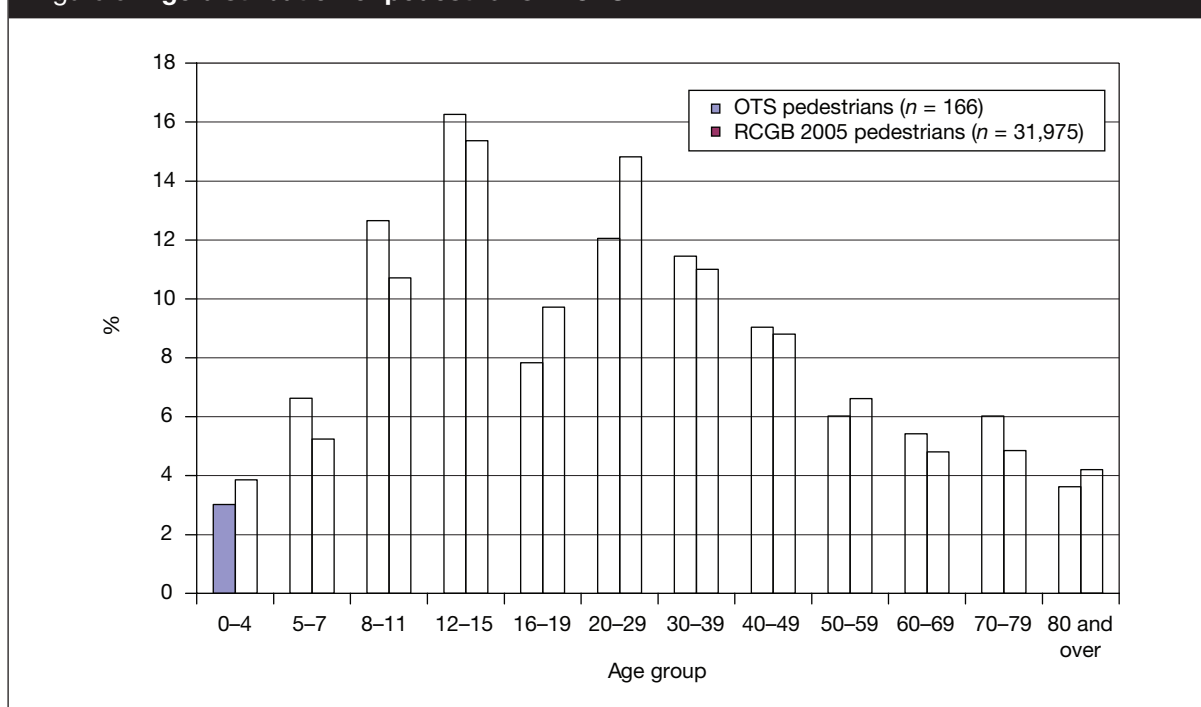
Table 2 Location of pedestrian accidents

Location	No. of pedestrians	% of known
Urban	155	88.6
Rural	20	11.4
Total	175	

Table 3 Gender and average age of pedestrians

Gender	No. of pedestrians	%	Average age	Standard deviation
Male	104	56.5	30.4	22.7
Female	80	43.5	30.1	23.5
Total	184			

Figure 3 shows the age distribution for the 166 pedestrians in OTS for whom age was known. The age ranges are chosen to match those used in RCGB 2005, and the national data for 2005 is also shown for comparison. It should be noted that the national data only includes pedestrians who were injured. The distribution of the ages of the pedestrians in OTS is similar to the national data for all ages. The largest difference is in the 20–29 age group.

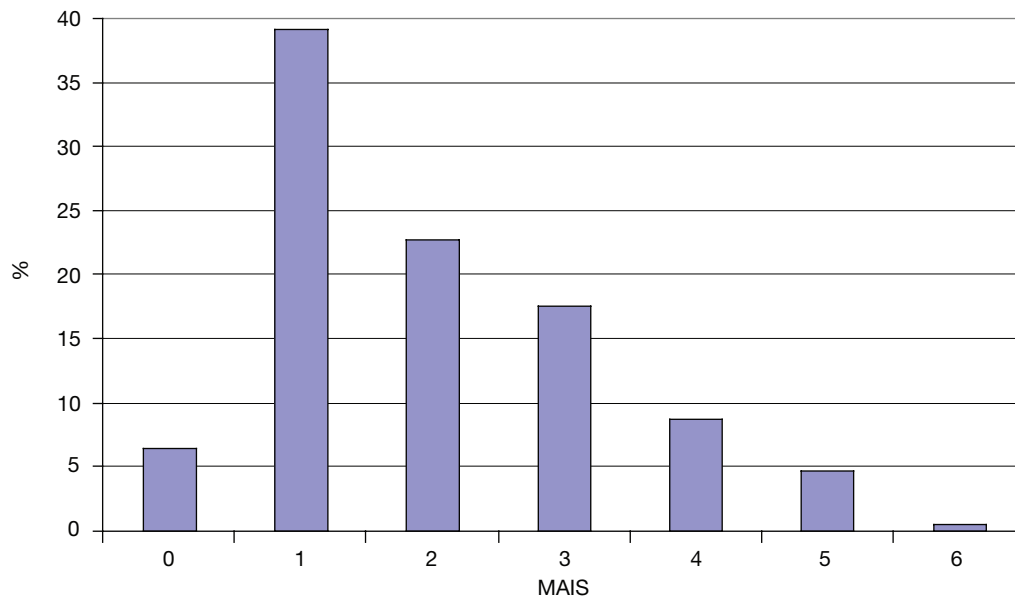
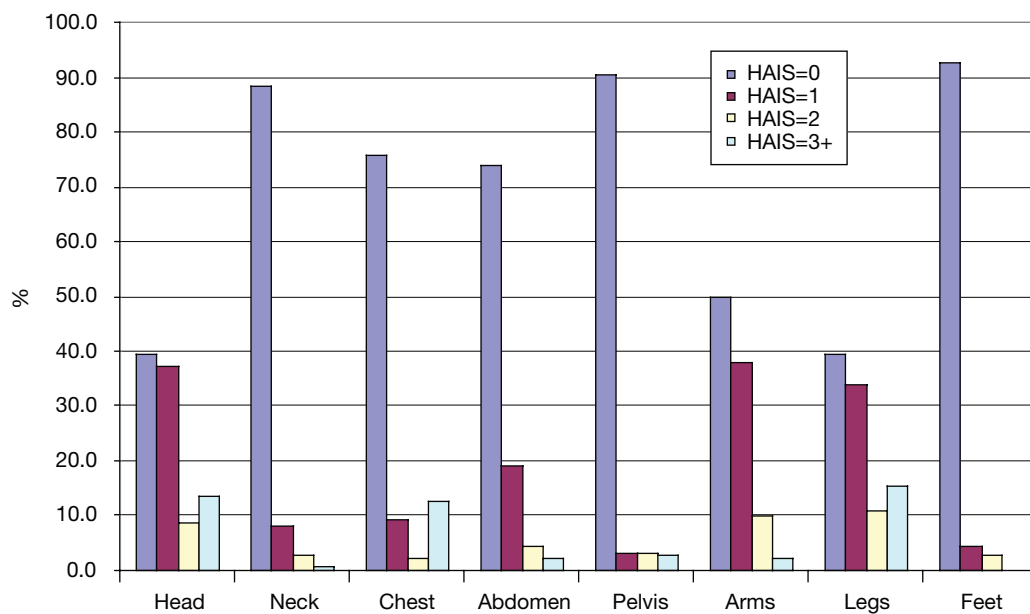
Figure 3 Age distribution of pedestrians in OTS

Pedestrian injuries

Figure 4 shows the MAIS distribution of the 171 pedestrians for whom MAIS was known.

There are very few pedestrians who were struck by a vehicle and did not suffer any injury, and, because of this, it would be expected that the OTS pedestrian dataset should show similar characteristics to the RCGB data. Of the pedestrians who did suffer an injury, relatively minor injuries were more frequent than more severe injuries.

Figure 5 shows the injuries sustained by the 182 pedestrians for whom the information was available. This is displayed using HAIS, which is the highest AIS in

Figure 4 MAIS distribution of pedestrians in OTS with known MAIS ($n = 171$)**Figure 5 Injury distribution of 182 pedestrians with known injuries**

that region of the body. The information is displayed as a percentage of the 182 pedestrians.

The head, arms and legs are the body regions most often injured in a pedestrian accident, with 50–60% of pedestrians sustaining injuries to at least one of these regions. The head and legs are the regions most likely to sustain a serious AIS 3+ injury, closely followed by the chest.

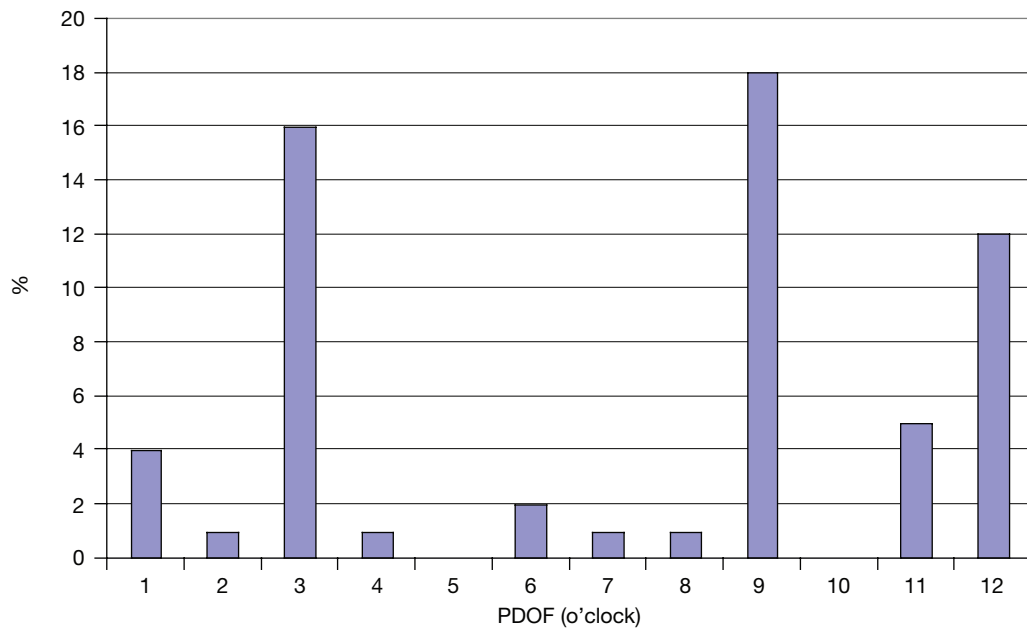
Figure 6 Principle direction of force (PDOF) on pedestrians ($n = 61$)

Figure 6 shows the principal direction of force experienced by the pedestrian. 12 o'clock is defined as being the front of the pedestrian, 3 o'clock the right of the pedestrian and 9 o'clock the left of the pedestrian.

The majority of strikes are to the side or the front of the pedestrian. This would depend on the configuration of the accident, which will be discussed later. A typical accident would involve a pedestrian running into the road without looking, which in the UK (where traffic comes from the right) would be likely to lead to an impact to the right side of the pedestrian.

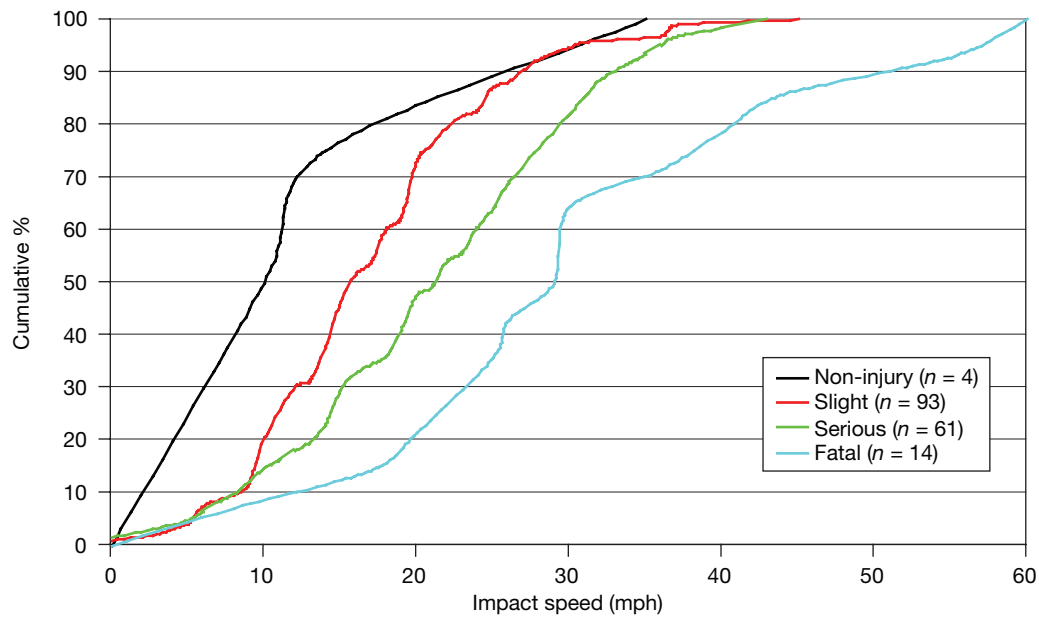
Table 4 shows the average impact speeds for pedestrians of different MAIS. There were 155 pedestrians where both the impact speed and the MAIS were known.

Table 4 MAIS and average impact speed

MAIS	No. of pedestrians	Average impact speed (mph)
0	9	13
1	62	16
2	36	21
3	27	25
4	14	27
5	7	28
Total	155	20

There is a clear relationship between the impact speed and the resulting MAIS of the pedestrian: as the impact speed increases, so does the MAIS of the pedestrian. Figure 7 shows the cumulative impact speed for the 172 pedestrians whose injury severity and impact speed were known.

Figure 7 Cumulative impact speed and pedestrian injury severity



There is a clear shift towards higher speeds for pedestrians with a greater injury severity. The 50th percentile impact speed for non-injured pedestrians is about 10 mph, for slight casualties it is 15 mph, for serious injury it is 20 mph and for fatal accidents it is approximately 29 mph. However, it should be noted that serious accidents can still occur at relatively low speeds, and slight accidents can occur at relatively high speeds.

OTS records the physical interactions between the pedestrian and the vehicle. Interactions were recorded for 157 of the 193 pedestrians, including interactions recorded as 'unknown'. The three most frequent interactions were 'glancing impact' (40 pedestrians), 'scooped up and came off bonnet' (26 pedestrians) and 'thrown straight forward' (15 pedestrians). Physical trauma suffered by the pedestrians caused by the vehicle is recorded for 140 of the 193 pedestrians. By far the most frequent is 'contact with vehicle only' (99 pedestrians). Accidents where the pedestrian was run over are relatively rare. It should be noted that as well as contact with the vehicle, contact with the ground has also been shown to cause serious injuries. Contact with the ground is not recorded in this field, which only considers trauma related to the vehicle.

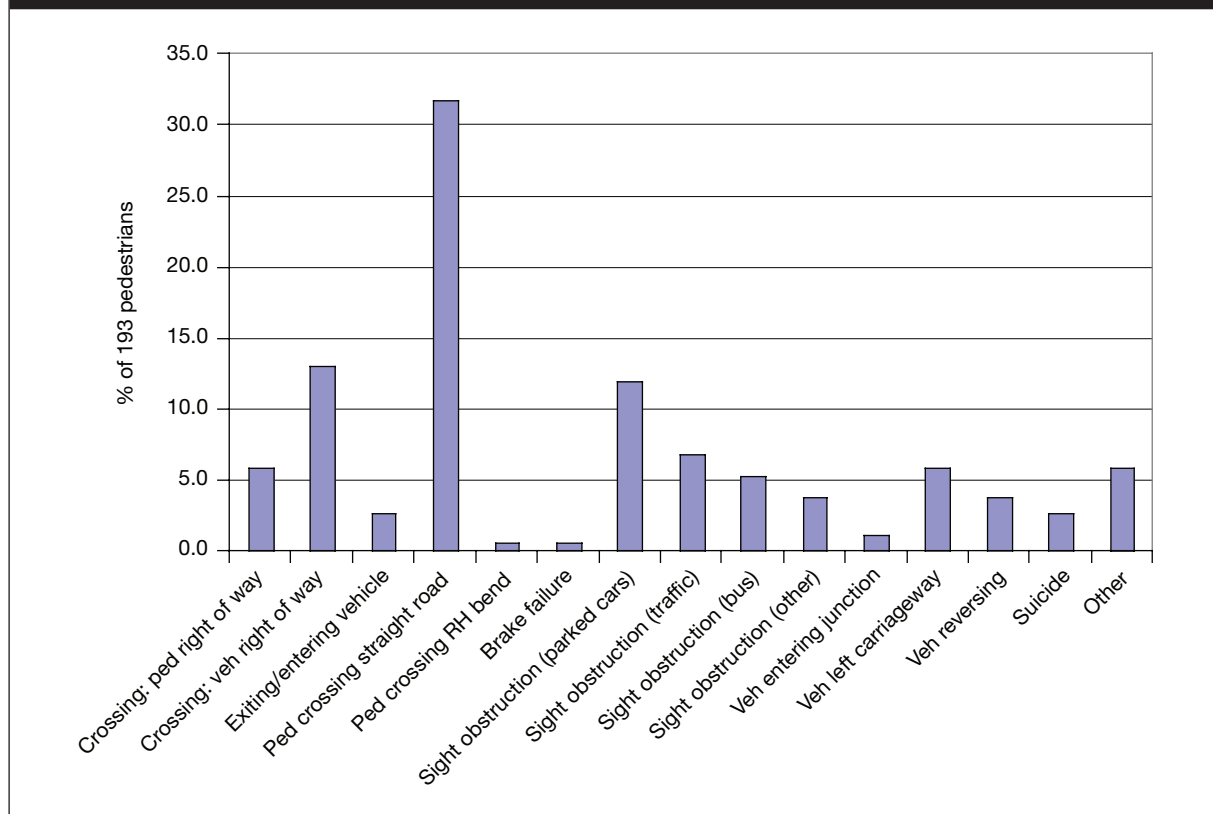
Accident characteristics

Over 80% of the pedestrians were hit by cars. Of other vehicles, impacts with passenger service vehicles (PSVs) were the most common, accounting for about 7% of the pedestrians. In the RCGB data for 2005, 77.7% of injured pedestrians were hit by cars, and 5.9% were hit by buses or coaches.

The road class for the accident was defined as being the road class the vehicle was travelling on **before** it struck the pedestrian (e.g. a footpath is not included if the vehicle left the carriageway). Very few accidents (2.6%) occurred on trunk 'A' roads

and motorways, which would be expected as there is much less exposure of pedestrians to these types of road. The most frequent were non-trunk 'A' roads (44.6%) and unclassified (or private) roads (39.4%). All of the 193 pedestrians were examined, and a type of crash configuration was chosen for each one. Figure 8 shows these crash configurations, and the percentage of the 193 pedestrians who fell into each category.

Figure 8 Accident configuration for 193 pedestrians in the OTS dataset



Some of these categories may require more explanation and this is shown in Table 5.

The most frequent accident configuration (over 30% of accidents) involved a pedestrian crossing a straight road, which had no obvious obstruction of view for the pedestrian or the driver of the vehicle. This category included instances where the pedestrian did not look before they crossed the road, as well as pedestrians under the influence of alcohol running across the road.

Figure 9 investigates whether some of these accident configurations are more likely to occur if the pedestrian is a child. In the study, 166 pedestrians had a known age, and the percentage of each accident configuration where the pedestrian was under 16 or was 16 and over is shown.

The final column shows that, of all the 166 pedestrians for whom age was known, about 60% were 16 and over, and 40% were under 16. Accidents where the vision of the pedestrian or the traffic was obscured seem to be more frequent for child pedestrians. Accidents involving pedestrian crossings, suicide, reversing vehicles and vehicles leaving the carriageway are more frequent when the pedestrian is an adult.

Table 5 Possible accident configurations

Configuration	No.	Explanation
Crossing: ped right of way	11	The pedestrian was hit on a pedestrian crossing while the pedestrian had the right of way
Crossing: veh right of way	25	The pedestrian was hit on a pedestrian crossing while the vehicle had right of way
Exiting/entering vehicle	5	The pedestrian was (or had recently been) in the process of entering or exiting the vehicle
Ped crossing straight road	61	The pedestrian was crossing a straight road, with no obvious objects obscuring the view of the traffic or the pedestrian
Ped crossing RH bend	1	The pedestrian was hit while crossing a right-hand bend
Brake failure	1	The pedestrian was crossing the carriageway, and was hit by a vehicle whose brakes had failed
Sight obstruction (parked cars)	23	The view of the pedestrian/the vehicle was obscured by parked cars
Sight obstruction (traffic)	13	The view of the pedestrian/the vehicle was obscured by moving or stationary traffic
Sight obstruction (bus)	10	The view of the pedestrian/the vehicle was obscured by a stationary bus at a bus stop
Sight obstruction (other)	7	The view of the pedestrian/the vehicle was obscured by some other object
Veh entering junction	2	The vehicle entered a junction and struck a pedestrian on the new road
Veh left carriageway	11	The vehicle left the carriageway and struck the pedestrian off the carriageway (e.g. on the footway)
Veh reversing	7	The vehicle struck the pedestrian while reversing
Suicide	5	The pedestrian was attempting to commit suicide
Other	11	Any other accident configuration
Total	193	

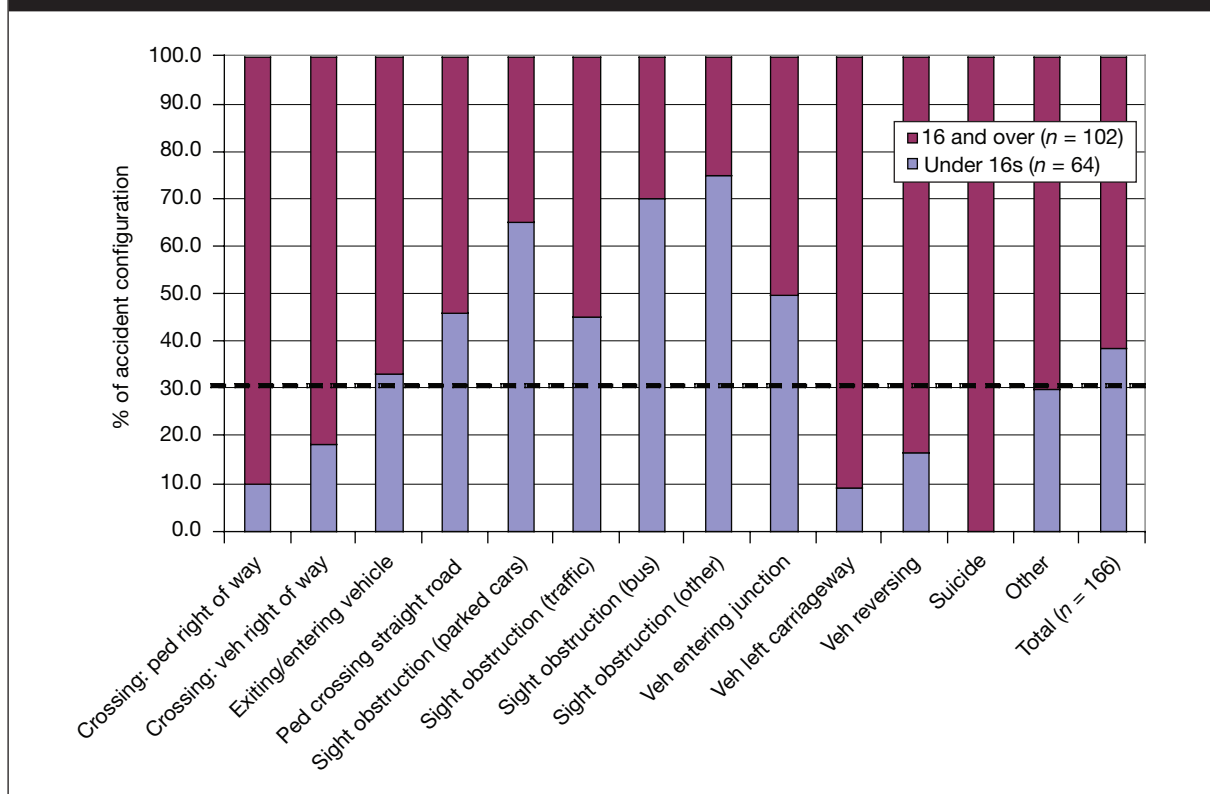
Accident causation

Table 6 shows the light conditions at the time of the accident for the 192 pedestrians for whom the light conditions were known, and whether they were considered to be causative towards the accident.

The majority of pedestrian accidents occurred in daylight. Of all the accidents, only 1% were definitely related to darkness.

Table 7 shows the precipitating factor for the accidents involving the 193 pedestrians, and whether it was judged to have been causative towards the crash. Only one precipitating factor is selected for each accident.

Table 8 shows which of these precipitating factors related to the vehicles and pedestrians involved.

Figure 9 Relationship between accident configurations and pedestrian age**Table 6 Light conditions at the time of accident**

Light conditions	Causative?	Number	%
Daylight	–	122	63.5
Twilight	No	11	5.7
Twilight	Possibly	3	1.6
Darkness	No	37	19.3
Darkness	Possibly	13	6.8
Darkness	Probably	4	2.1
Darkness	Definitely	2	1.0
Total		192	100

The vast majority (71.5%) of precipitating factors related to failings of the pedestrian.

Table 9 shows the ten most frequent factors that contributed towards the accident and whether these were caused by the vehicle or the pedestrian.

For code 801, one of the contributory factors has been miscoded as relating towards the vehicle rather than the pedestrian. Once this is recoded, 100% of the code 801 contributory factors relate to the pedestrian, as would be expected.

The four most frequent contributory factors are all mostly failures of the pedestrian.

Table 7 Precipitating factors for pedestrian accidents

Precipitating factor	Causative? Number of pedestrians			
	Definitely	Probably	Possibly	No
Failed to stop	4	1	0	0
Failed to avoid pedestrian (pedestrian not to blame)	21	5	1	0
Failed to avoid object or vehicle on carriageway	1	0	0	0
Failed to signal or gave misleading signal	1	0	0	0
Loss of control of vehicle	6	0	2	0
Pedestrian entered carriageway without due care (driver not to blame)	133	5	1	0
Pedestrian fell in road	8	0	0	0
Poor turn or manoeuvre	3	0	0	0
Other	1	0	0	0
Sub-total	178	11	4	0
Total	193			

Table 8 Vehicles related to the precipitating factors

Vehicle	No. of precipitating factors
Car	48
LGV	3
HGV	2
Bus	1
Motorcycle	1
Pedestrian	138
Total	193

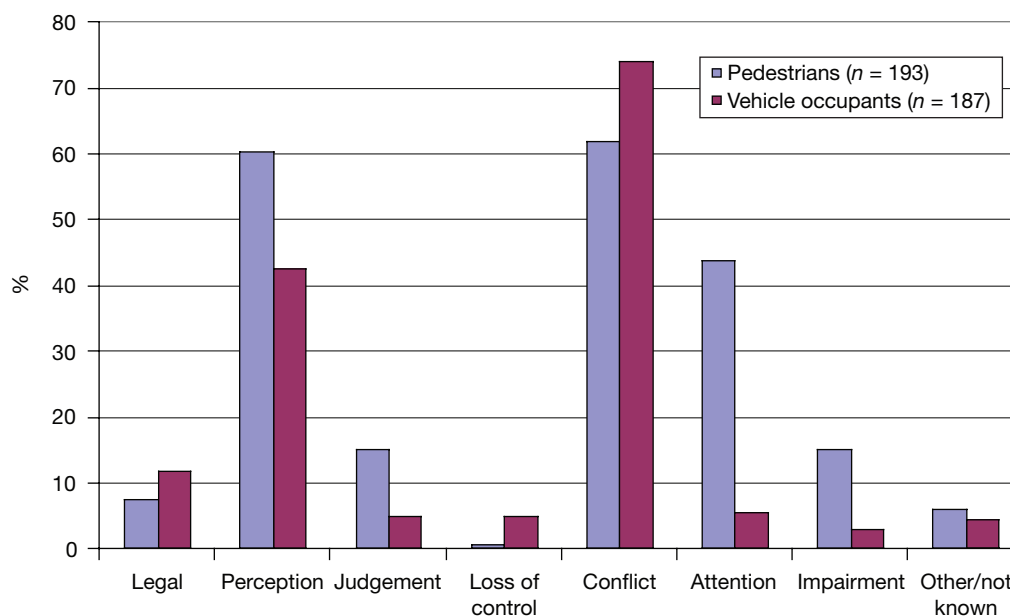
Table 9 Contributory factors in pedestrian accidents

Code	Contributory factor	No. known	% vehicle	% pedestrian
802 + 405	Failed to look properly	153	16.3	83.7
808 + 602	Careless, reckless or in a hurry	89	21.3	78.7
801	Crossing road masked by stationary or parked vehicle	41	2.4	97.6
803	Failed to judge vehicle's path or speed	21	0.0	100.0
701	Vision affected by stationary or parked vehicle(s)	19	78.9	21.1
804	Wrong use of pedestrian crossing facility	18	0.0	100.0
806 + 501	Impaired by alcohol	18	5.8	94.4
805	Dangerous action in carriageway (e.g. playing)	15	0.0	100.0
306	Exceeding speed limit	8	100.0	0.0
403	Poor turn or manoeuvre	9	100.0	0.0

Figure 10 shows the distribution of interactions for the pedestrians and the occupants of the vehicle which hit them. These interactions with the environment and other road users are grouped into one of eight different categories. These are:

- **legal** – compliance with applicable laws and regulations, to the team’s best interpretation, irrespective of prosecution (e.g. disobeyed signs or markings or was legally unfit to drive due to alcohol);
- **perception** – expecting, looking, planning (e.g. did not look for other vehicle or saw but did not perceive a hazard);
- **judgement** – understanding, deciding, acting (e.g. interpreted information incorrectly from a road sign or travelled excessively close to another vehicle);
- **loss of vehicle control** – for example, due to excessive braking or excessive cornering;
- **conflict** – interpersonal communication (e.g. adopted a path conflicting with that of another road user or behaved aggressively towards another);
- **attention** – for example, suffered a distraction due to a mobile phone or was distracted by another road user;
- **impairment** – for example, suffered illness or impairment due to fatigue; and
- **other/not known.**

Figure 10 Distribution of interactions in pedestrian accidents



The majority of the pedestrian accidents involve some sort of conflict, as the pedestrian will usually be crossing the path of traffic when the accident occurs. Problems with perception, judgement and attention are most likely to be related to the pedestrian, as is impairment.

Case examples

While the above analysis gives an overall picture of the pedestrian accidents studied by OTS, it is also possible to look at individual accidents in more detail to find the exact circumstances in which they occurred. Here, three of the accidents where the accident configuration was ‘pedestrian crossing straight road’ are examined, with an emphasis on the speeds and distances involved. This sort of work would relate to future technology which could detect the presence of pedestrians and apply the brakes accordingly. It is presented here as another example of how the OTS study can be used.

EXAMPLE 1: CRASH SCENARIO

A 13-year-old pedestrian ran across the road without looking, from the right of a red Peugeot 306. The Peugeot braked and skidded, and the child also tried to stop as he saw the vehicle at the last minute, but the vehicle still collided with the child, knocking him back into the opposing lane, where he fell on the road (Figure 11).

The accident occurred in darkness, although the scene was well lit by street lamps. The road before the accident site was straight, and there were no objects blocking the view of the driver or the pedestrian. There was no footway on the side of the carriageway where the child was before he attempted to cross the road. The pedestrian travelled across one side of the road and was hit by the offside of the car, approximately 3.5 m away from the side of the road where he started to cross. This is the distance the pedestrian travelled in sight of the car across the road, s_{ped} .

Figure 11 View of vehicle path in case example 1



Speeds and distances

Table 10 shows the speeds recorded by OTS for the pedestrian and vehicle, and the likely range in these. The travelling and impact speed of the vehicle are assumed to have an error of $\pm 10\%$. The error in the pedestrian speed is generally much larger, as it is often not clear whether the pedestrian was walking or running, or if they were running at top speed. If they paused while crossing the road, the error would be even larger.

Table 10 Speeds of vehicle and pedestrian in case example 1

	Speed recorded (mph)	Max. (mph)	Min. (mph)
Speed limit	30	–	–
Travelling speed of car, v_{trav}	41	45	37
Travelling speed of pedestrian, v_{ped}	8	12	4
Impact speed, v_{imp}	37	41	33
Average speed of car, \bar{v}_{veh}	39	43	35

The time the pedestrian took to reach the position in the road where he was struck, t_{ped} , can be calculated using the speed of his travel and the distance he ran into the road:

$$t_{ped} = \frac{s_{ped}}{v_{ped}}$$

This time can be used to calculate the distance between the vehicle and the child when he started to cross:

$$s_{veh} = \bar{v}_{veh} t_{ped}$$

The average speed of the car, \bar{v}_{veh} , is calculated as the average of the travelling and the impact speeds. This assumes that the car underwent constant deceleration from the moment the child stepped off the pavement until the impact, which is an approximation likely to give a lower limit on the average speed. The error on the distance is calculated by combining the errors of the separate values in quadrature. This means the fractional error in s_{veh} is equal to the square root of the sum of the squares of the fractional errors in the other quantities:

$$\frac{\Delta s_{veh}}{s_{veh}} = \sqrt{\left(\frac{\bar{v}_{veh}}{\bar{v}_{veh}}\right)^2 + \left(\frac{\Delta s_{ped}}{s_{ped}}\right)^2 + \left(\frac{\Delta v_{ped}}{v_{ped}}\right)^2} \quad \text{where } \Delta \bar{v}_{veh} = \sqrt{\frac{\Delta v_{imp}^2 + \Delta v_{trav}^2}{2}}$$

In this example, the fractional error in the vehicle travelling speed, impact speed and the distance travelled by the pedestrian are all assumed to be 10%. For this case, the error in the speed of the pedestrian is much larger, at 50%. These combine to give the fractional error in the distance of the vehicle as 52%.

Using the above speeds and distances, it is calculated that the car was 17 ± 9 m away when the pedestrian began to cross the road. To avoid crossing the path of the pedestrian, the vehicle would have to stop within this distance. The stopping

distance at 40 mph (including reaction time) is given by the Highway Code as 36 m, which is further than the distance the vehicle had available to stop before contact was made with the pedestrian. The thinking distance is given as 12 m by the Highway Code at 40 mph, which could explain, in this case, why the impact speed was so close to the travelling speed of the vehicle.

EXAMPLE 2: CRASH SCENARIO

A 14-year-old girl stepped into the road while arguing with friends and into the path of a VW Golf. The vehicle was unable to stop in time and collided with the pedestrian. The accident occurred in darkness, although the scene was lit by street lamps. The road leading up to the accident was straight, and there were no objects blocking the view of the driver or the pedestrian (Figure 12). The pedestrian was struck approximately 1.5 m into the left-hand lane.

Figure 12 View of vehicle path in case example 2



Speeds and distances

Table 11 shows the speeds the vehicle and pedestrian were travelling at, using similar reasoning as before to calculate the error levels.

Table 11 Speeds of vehicle and pedestrian involved in case example 2

	Speed recorded (mph)	Max. (mph)	Min. (mph)
Speed limit	30	–	–
Travelling speed of car	39	43	35
Travelling speed of pedestrian	4	6	2
Impact speed	13	14	12
Average speed of car	26	29	24

Using the same method as before, the distance between the pedestrian and the vehicle when the pedestrian stepped off the pavement is estimated as 10 ± 5 m. The stopping distance at 40 mph is 36 m, so the car could not have stopped before it reached the path of the pedestrian. In this case, the driver seems to have done well to reduce the speed of the vehicle to 13 mph before it hit the pedestrian. This is possibly because the driver anticipated the movement of the pedestrian before they stepped off the curb, or that the pedestrian was in fact walking along the road rather than stepping straight off the curb, in which case they would have been in view on the carriageway for longer and the driver would have had longer to react.

EXAMPLE 3: CRASH SCENARIO

A 57-year-old male pedestrian ran into the path of a Rover 216 from the nearside. The Rover was travelling in the right-turn lane on a busy five-lane carriageway (Figure 13). The pedestrian, after contact with the vehicle, came to rest in front of another vehicle travelling in the opposing direction. It is not believed that contact was made with this third vehicle.

Figure 13 View of vehicle path in case example 3



The accident occurred in daylight and the road leading up to the accident locus was straight, with no obvious objects obstructing the view of the pedestrian or the vehicle. The pedestrian appears to have crossed almost three lanes, and has been struck by the front offside of the vehicle in the right-turn lane. The pedestrian has travelled approximately 9 m across the carriageway.

Speeds and distances

Table 12 shows the speeds of the vehicle and the pedestrian.

Using these speeds, it is estimated that the vehicle was 47 ± 24 m away when the pedestrian began to cross the carriageway. The Highway Code gives the stopping

Table 12 Speeds of vehicle and pedestrian involved in case example 3

	Speed recorded (mph)	Max. (mph)	Min. (mph)
Speed limit	30	–	–
Travelling speed of car	30	33	27
Travelling speed of pedestrian	5	7	3
Impact speed	22	24	20
Average speed of car	26	29	24

distance at 30 mph as 23 m. This is an example of an accident which could have been prevented by braking shortly after the pedestrian began to cross the road.

Conclusions

This paper has used pedestrian accidents as an example of the functions OTS can perform, as the OTS pedestrian dataset is now large enough to produce interesting analysis and results. These include information on the causes and consequences of accidents, as well as the ability to investigate cases in finer detail. While this paper has not studied the data in great statistical detail, interesting conclusions can still be drawn, each of which could be investigated in more detail:

- General trends of the OTS pedestrian dataset, such as pedestrian age, time of accident and vehicle type, reflect the distributions seen in pedestrians in the RCGB data.
- The qualitative effect of impact speed on the injury severity of pedestrians is clear: as the impact speed increases, the probability of suffering more serious injuries also increases. But there is also a wide spread of impact speeds causing injuries of the same severity. Slight injuries can be the result of pedestrian impacts at high speeds, and severe injuries can result from low-impact speeds. This is because impact speed is only one of many factors that affect the injury severity of the pedestrian. Other important factors include the vehicle structure contacted by the pedestrian and the age of the pedestrian.
- Injuries suffered by pedestrians are most likely to be to the head, arms and legs. Serious AIS 3+ injuries are most common in the head, leg and chest regions. Very few pedestrians are run over – most have contact with the vehicle and the ground only.
- Of the different accident configurations, pedestrians crossing a straight road, with no obvious obstructions to view, are the most common. These make up about 32% of pedestrian accidents in the OTS dataset. The configuration is also related to the age of the pedestrian: accidents involving a sight obstruction are more likely to occur for pedestrians under 16, while accidents involving suicide or pedestrian crossings are most likely to involve pedestrians aged 16 and over.
- The pedestrian is most often to blame for the accident, using all the different methods of determining accident causation. Using the precipitating factor, of

which one is recorded for each pedestrian, 72.5% of accidents were caused by the actions of the pedestrian. This usually involved poor judgement, perception or lack of attention in crossing the road.

The case examples presented in this paper are an example of what can be done by looking at individual cases in detail. In this paper, estimates were made of the distance the driver of a vehicle would have in order to avoid or lessen an impact with a pedestrian. If more cases were investigated, a clear picture could be made of the types of accidents that could be prevented by, for example, early warning systems, as well as the typical distances and times to react involved.

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3

Contributory factors in road accidents

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Introduction

The contributory factors reported by the police following a road accident summarise the events and influences that led directly to that accident. The information is inevitably subjective, as it depends upon the investigator's reconstruction of the circumstances leading up to the accident from the available evidence. It reflects the reporting officer's opinion shortly after the accident and may not be the result of extensive investigation. Nevertheless, the information can suggest possible interventions and countermeasures that would have prevented an individual accident, and statistical analysis of the factors reported for large numbers of accidents can help to develop measures for improving road safety.

This paper begins with a brief history of the recording of contributory factors by the police in Great Britain. A system for coding contributory factors has recently been added to the national STATS19 accident reporting system, and this is described. Examples of how these data may be used are then provided.

A brief history

The STATS19 accident reporting system began on 1 January 1949. Its design was far-sighted in many respects, and it included a system for recording contributory factors. It was recognised that, although subjective, such information could be valuable in deciding how to prevent further accidents, but in 1959 doubts over the reliability of the information being collected led to the termination of its collection on the national scale. Several forces subsequently ceased to record contributory factors, but in 1994 a Transport Research Laboratory (TRL) survey of the 43 police forces in England and Wales found that over half were still collecting these data. The systems being used by individual forces had diverged over time, however, so it was very difficult to compare directly the patterns of causation in different areas.

The fact that many forces still recorded contributory factors so long after the national requirement ended indicated the local value of this information. Its value would be greatly enhanced, however, if the factors could be recorded in a consistent way by all forces and assembled into a database closely linked to the national STATS19 database. Accordingly, the then Department of Transport (now the Department for Transport) commissioned the TRL to develop a prototype system and test it ‘in the field’ with a number of police forces.

Broughton *et al.* (1998) describes the new system, its development and the results of a trial that was carried out by eight police forces for three months in the summer of 1996. The system was designed to supplement the regular STATS19 system, and the trial found it to be practical and to work well. The system was adopted in the following year by the Cleveland Constabulary as a routine part of their accident reporting system. Several other forces followed the Cleveland example in 1999, and by 2001 a total of 15 forces spread throughout the country were routinely using the new system.

The operation of the national accident reporting system is reviewed every five years. The most recent review began in 2002, and it was proposed that contributory factors should be added to the system; this proposal was accepted. The revised STATS19 accident report form came into use on 1 January 2005, so contributory factors have now been collected throughout Great Britain for over two years.

STATS19 contributory factors

The current system for reporting contributory factors came into operation on 1 January 2005, and the main details are summarised in this section. Instructions for completing the STATS19 accident report form are provided in the STATS20 manual (Department for Transport, 2004), and this is the source of the material presented here.

Figure 1 reproduces the standard form used to report contributory factors, so it indicates the reporting procedure as well as providing a list of the available factors. The reporting officer assesses the available evidence and selects up to six factors that contributed to the causation of the accident. Factors can be attributed to any of the drivers, riders or pedestrians who were involved in the accident. Each factor is recorded as very likely or possible.

The data are entered in the boxes at the bottom of the form. Each factor is attributed to a specific ‘participant’ so, for example, if the reporting officer considered that the vehicle recorded in the STATS19 data as number 2 had exceeded the speed limit, and that this had contributed to the accident, then the code 306 would be entered for V002. A or B would be entered in the box below, depending upon the officer’s confidence in the factor.

An important caveat appears at the bottom of the form: ‘These factors reflect the reporting officer’s opinion at the time of reporting and may not be the result of extensive investigation’. These data are inevitably subjective, and their quality will depend upon the training and experience of the reporting officer.

The form includes 77 codes, but it will be seen below that relatively few are reported frequently. Observe that some factors are in effect duplicates, for example 501 is entered if a driver or rider is impaired by alcohol, while 806 is entered if a pedestrian is impaired by alcohol.

The STATS20 manual includes a series of explanatory notes for these codes. The notes for some of the more common contributory factors are provided below:

306 Exceeding speed limit:

Driver/rider caused, or contributed to the accident, by exceeding the posted speed limit. This code should also be used in cases where the actions of another road user were the immediate cause of the accident but a speeding vehicle also contributed to causing the collision.

Includes exceeding variable speed limits (e.g. on motorways) and speed limits based on vehicle type (including towing).

Use this code (not code 307) if the driver/rider was exceeding the speed limit and travelling too fast for the conditions.

307 Travelling too fast for conditions:

Driver/rider was travelling within the speed limit, but their speed was not appropriate for the road conditions and/or vehicle type (including towing), and contributed to the accident.

410 Loss of control:

This code should be used where a driver/rider lost control of their vehicle, thereby causing or contributing to an accident, whether or not they were considered to be at fault. Wherever possible, at least one more code should be allocated to the same driver/rider to give an indication of why they lost control. Includes ridden horses.

501 Impaired by alcohol:

Driver/rider was affected by alcohol and behaved in a way which caused, or contributed to, the accident – whether or not they were above the legal limit.

Initial analyses

This section provides details of the STATS19 contributory factor data for 2005. Table 1 shows that at least one contributory factor was reported in the great majority of accidents. The modal number of factors reported per accident was 2 and the mean was about 2.4, varying slightly with accident severity. About two-thirds of the factors were recorded as being very likely to have contributed to the accident.

The reporting rate varied widely among police forces, with seven reporting contributory factors for every accident and one reporting no factors at all. Table 2 shows the distribution of forces by reporting rate. Arguably, it is unrealistic to expect a 100% reporting rate since there will be insufficient evidence in some cases to

Figure 1 The current STATS19 contributory factors form

MG NSRF/D

CONTRIBUTORY FACTORS

Sept. 2004

1. Select up to six factors from the grid, relevant to the accident.
2. Factors may be shown in any order, but an indication must be given of whether each factor is **very likely (A)** or **possible (B)**.
3. Only include factors that you consider contributed to the accident. (i.e. do NOT include "Poor road surface") unless relevant).
4. More than one factor may, if appropriate, be related to the same road user.
5. The same factor may be related to more than one road user.
6. The participant should be identified by the relevant vehicle or casualty ref no. (e.g. 001, 002 etc.), preceded by "V" if the factor applies to a vehicle, driver/rider or the road environment (e.g. V002), or "C" if the factor relates to a pedestrian or passenger casualty (e.g. C001).
7. Enter U000 if the factor relates to an uninjured pedestrian.

Road Environment Contributed	101	102	103	104	105	106	107	108	109	
	Poor or defective road surface	Deposit on road (e.g. oil, mud, chippings)	Slippery road (due to weather)	Inadequate or masked signs or road markings	Defective traffic signals	Traffic calming (e.g. speed cushions, road hump, chicanes)	Temporary road layout (e.g. contraflow)	Road layout (e.g. bend, hill, narrow carriageway)	Animal or object in carriageway	
Vehicle Defects	201	202	203	204	205	206				
	Tyres illegal, defective or under-inflated	Defective lights or indicators	Defective brakes	Defective steering or suspension	Defective or missing mirrors	Overloaded or poorly loaded vehicle or trailer				
Driver/Rider Only (Includes Pedal Cycles and Horse Riders)	301	302	303	304	305	306	307	308	309	310
	Injudicious Action	Disobeyed automatic traffic signal	Disobeyed 'Give Way' or 'Stop' sign or markings	Disobeyed double white lines	Disobeyed pedestrian crossing facility	Illegal turn or direction of travel	Exceeding speed limit	Travelling too fast for conditions	Following too close	Vehicle travelling along pavement
	Driver/Rider Error or Reaction	401	402	403	404	405	406	407	408	409
		Junction overshoot	Junction restart (moving off at junction)	Poor turn or manoeuvre	Failed to signal or misleading signal	Failed to look properly	Failed to judge other person's path or speed	Passing too close to cyclist, horse rider or pedestrian	Sudden braking	Swerved
	Impairment or Distraction	501	502	503	504	505	506	507	508	509
Behaviour or Inexperience		Impaired by alcohol	Impaired by drugs (illicit or medicinal)	Fatigue	Uncorrected, defective eyesight	Illness or disability, mental or physical	Not displaying lights at night or in poor visibility	Cyclist wearing dark clothing at night	Driver using mobile phone	Distraction in vehicle
	601	602	603	604	605	606	607			
	Aggressive driving	Careless, reckless or in a hurry	Nervous, uncertain or panic	Driving too slow for conditions or slow vehicle (e.g. tractor)	Learner or inexperienced driver/rider	Inexperience of driving on the left	Unfamiliar with model of vehicle			
Vision Affected by	701	702	703	704	705	706	707	708	709	710
	Stationary or parked vehicle(s)	Vegetation	Road layout (e.g. bend, winding road, hill crest)	Buildings, road signs, street furniture	Dazzling headlights	Dazzling sun	Rain, sleet, snow or fog	Spray from other vehicles	Visor or windscreen dirty or scratched	Vehicle blind spot
Pedestrian Only (Casualty or Uninjured)	801	802	803	804	805	806	807	808	809	810
	Crossing road masked by stationary or parked vehicle	Failed to look properly	Failed to judge vehicle's path or speed	Wrong use of pedestrian crossing facility	Dangerous action in carriageway (e.g. playing)	Impaired by alcohol	Impaired by drugs (illicit or medicinal)	Careless, reckless or in a hurry	Pedestrian wearing dark clothing at night	Disability or illness, mental or physical
Special Codes	901	902	903	904						*999
	Stolen vehicle	Vehicle in course of crime	Emergency vehicle on a call	Vehicle door opened or closed negligently						Other – Please specify below

	1st	2nd	3rd	4th	5th	6th
Factor in the accident	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Which participant? (e.g. V001, C001, U000)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Very likely (A) or Possible (B)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

* If 999 Other, give brief details

(Note: Only use if another factor contributed to the accident **and include it in the text description of how the accident occurred**)*These factors reflect the reporting officer's opinion at the time of reporting and may not be the result of extensive investigation*

Table 1 Number of accidents and availability of contributory factors

	Fatal accidents	Serious accidents	Slight accidents
STATS19 accident total	2,913	25,029	17,0793
Proportion with factors	91%	92%	91%
Proportion of factors 'very likely'	62%	71%	70%
In the accidents reported with factors			
Factors reported per accident: 1	25%	27%	29%
2	33%	34%	35%
3	22%	22%	20%
4	12%	11%	10%
5	5%	4%	4%
6	3%	3%	3%
Mean number of factors per accident	2.49	2.41	2.32

Table 2 Distribution of police forces by reporting rate

Reporting rate	Number of police forces	Proportion of accidents
100%	7	12%
99.0–99.9%	20	41%
95.0–98.9%	6	12%
90.0–94.9%	4	5%
80.0–89.9%	4	7%
70.0–79.9%	6	15%
<70.0%	3	9%

select even possible contributory factors, for example an accident reported at a police station by only one of the people involved.

The new system allows contributory factors to be attributed to more than one of the people involved in an accident, including uninjured pedestrians. Table 3 shows factors were attributed to two or more people in about a sixth of accidents, i.e. responsibility was considered to be shared in these accidents.

Table 3 Attribution of contributory factors

Contributory factors attributed to:	Fatal accidents (%)	Serious accidents (%)	Slight accidents (%)
1 driver	72	69	74
1 injured pedestrian	11	15	9
1 uninjured pedestrian	0.07	0.28	0.28
At least two people	17	16	16

Analyses of contributory factors

2005 data

Table 4 summarises the incidence of the principal contributory factors in the overall data. Each number is obtained by dividing the number of factors recorded for a particular group of accidents, so, for example, code 410 was entered 915 times in the 2,913 fatal accidents for which at least one factor was reported and $915/2913 = 0.314$. The columns headed 'A' include all factors and the columns headed 'B' include only the very likely factors: observe that the pairs of columns are broadly similar.

Table 4 Incidence of contributory factors

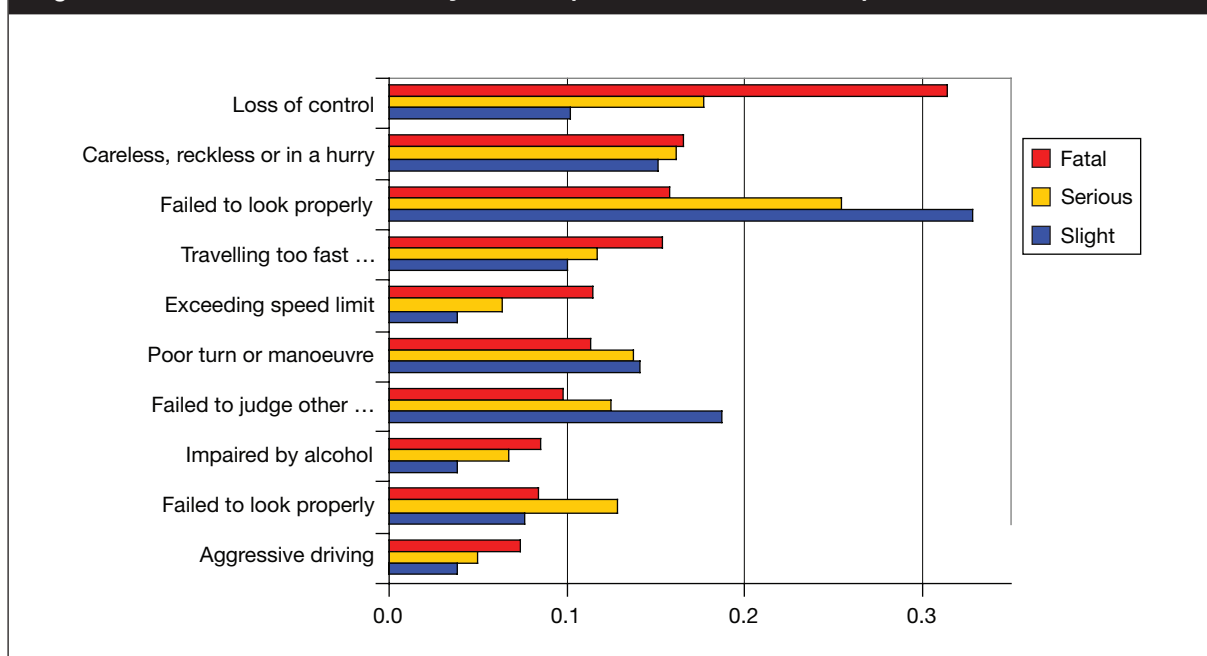
Code	Contributory factor	Fatal accidents		Serious accidents		Slight accidents	
		A	B	A	B	A	B
410	Loss of control	0.314	0.346	0.177	0.180	0.102	0.104
602	Careless, reckless or in a hurry	0.165	0.138	0.161	0.143	0.152	0.139
405	Failed to look properly	0.158	0.137	0.254	0.244	0.328	0.327
307	Travelling too fast for conditions	0.154	0.125	0.117	0.100	0.100	0.088
306	Exceeding speed limit	0.115	0.101	0.063	0.049	0.038	0.027
403	Poor turn or manoeuvre	0.113	0.108	0.137	0.135	0.141	0.145
406	Failed to judge other person's path or speed	0.099	0.070	0.124	0.101	0.187	0.160
501	Impaired by alcohol (driver/rider)	0.085	0.065	0.068	0.067	0.038	0.041
802	Failed to look properly	0.084	0.080	0.129	0.132	0.077	0.083
601	Aggressive driving	0.074	0.071	0.050	0.047	0.038	0.037
409	Swerved	0.059	0.052	0.037	0.034	0.030	0.029
103	Slippery road (due to weather)	0.052	0.034	0.071	0.059	0.086	0.076
605	Learner or inexperienced driver/rider	0.047	0.039	0.050	0.040	0.041	0.032
803	Failed to judge vehicle's path or speed	0.046	0.033	0.041	0.030	0.023	0.019
999	Other	0.046	0.043	0.036	0.035	0.027	0.028
108	Road layout	0.038	0.025	0.030	0.021	0.026	0.020
806	Impaired by alcohol (pedestrian)	0.038	0.032	0.029	0.029	0.012	0.013
808	Careless, reckless or in a hurry	0.038	0.036	0.059	0.058	0.033	0.033
505	Illness or disability, mental or physical	0.031	0.019	0.016	0.012	0.008	0.007
809	Pedestrian wearing dark clothing at night	0.029	0.028	0.012	0.010	0.004	0.004

A = either confidence level; B = very likely

Loss of control is the factor reported most frequently in fatal accidents; it is reported less frequently in non-fatal accidents, where 'failed to look properly' is the most frequently reported factor. The role of speed in accident causation is somewhat obscured as a result of the decision to have two speed-related factors; if factors 306 and 307 are combined to form a single factor, 'Excessive speed', then this would rank second in fatal accidents, second/third in serious accidents and fifth in slight accidents. Further, it is likely that 'Careless, reckless or in a hurry' often involves speed as well.

The incidence of the first 10 factors from Table 4 is illustrated in Figure 2. It highlights the fact that the incidence of several factors is less among the less severe accidents, most notably loss of control but also the speed-related factors and aggressive driving. While this relationship is certainly plausible, its strength may not have been predicted and it does provide some confidence in the overall reliability of the reporting of contributory factors.

Figure 2 Incidence of contributory factors (either confidence level)



These analyses have included all road accidents, but the patterns of causation among groups of accidents vary considerably. A group of accidents of particular interest comprises those accidents in which car occupants were killed or injured because of the recent adverse trends for car occupant fatalities. These 'car' accidents will now be studied, although as they form around a half of all accidents, the patterns may well be broadly similar to those already seen.

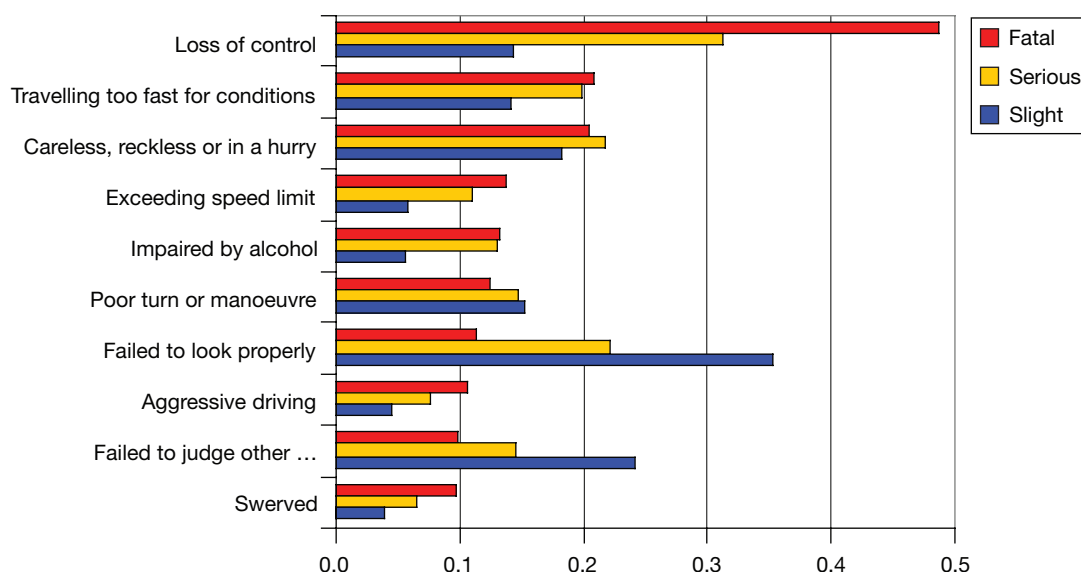
Table 5 lists the 20 factors that were recorded most frequently in fatal car accidents. Loss of control again heads the list, with a considerably greater incidence than was seen in Table 4. The other leading factors, such as the speed-related factors, also have a greater incidence (Figure 3).

The note relating to factor 410 that was reproduced above from the STATS20 manual requests the reporting officer to allocate further codes to indicate the reasons for the loss of control, so it is interesting to examine the contributory factors that

Table 5 Incidence of contributory factors in car accidents

Code	Contributory factor	Fatal accidents		Serious accidents		Slight accidents	
		A	B	A	B	A	B
410	Loss of control	0.488	0.495	0.312	0.294	0.143	0.134
307	Travelling too fast for conditions	0.208	0.149	0.199	0.160	0.141	0.113
602	Careless, reckless or in a hurry	0.205	0.161	0.218	0.179	0.182	0.150
306	Exceeding speed limit	0.138	0.113	0.109	0.086	0.057	0.037
501	Impaired by alcohol	0.131	0.092	0.129	0.120	0.056	0.055
403	Poor turn or manoeuvre	0.124	0.108	0.148	0.132	0.152	0.140
405	Failed to look properly	0.114	0.086	0.221	0.195	0.352	0.318
601	Aggressive driving	0.106	0.095	0.075	0.065	0.045	0.040
406	Failed to judge other person's path or speed	0.099	0.065	0.145	0.110	0.241	0.189
409	Swerved	0.097	0.081	0.066	0.056	0.040	0.035
103	Slippery road (due to weather)	0.091	0.051	0.133	0.100	0.126	0.102
605	Learner or inexperienced driver/rider	0.068	0.050	0.061	0.045	0.049	0.035
505	Illness or disability, mental or physical	0.050	0.032	0.035	0.026	0.012	0.010
108	Road layout (e.g. bend, hill)	0.044	0.020	0.044	0.029	0.035	0.024
999	Other – please specify below	0.043	0.034	0.031	0.027	0.023	0.020
503	Fatigue	0.037	0.019	0.029	0.014	0.014	0.008
201	Tyres illegal, defective or under-inflated	0.030	0.023	0.018	0.011	0.008	0.005
302	Disobeyed sign or markings	0.030	0.029	0.044	0.042	0.046	0.047
408	Sudden braking	0.030	0.021	0.050	0.037	0.091	0.067
502	Impaired by drugs (illicit or medicinal)	0.027	0.008	0.014	0.006	0.004	0.002

A = either confidence level; B = very likely

Figure 3 Incidence of contributory factors in car accidents (either confidence level)

were associated with loss of control. Table 6 lists the 10 factors most frequently reported in fatal car accidents where loss of control was also reported (very likely and possible factors together). The speed-related factors are reported most frequently with loss of control, and 'Slippery road (due to weather)' is also frequently reported in non-fatal accidents.

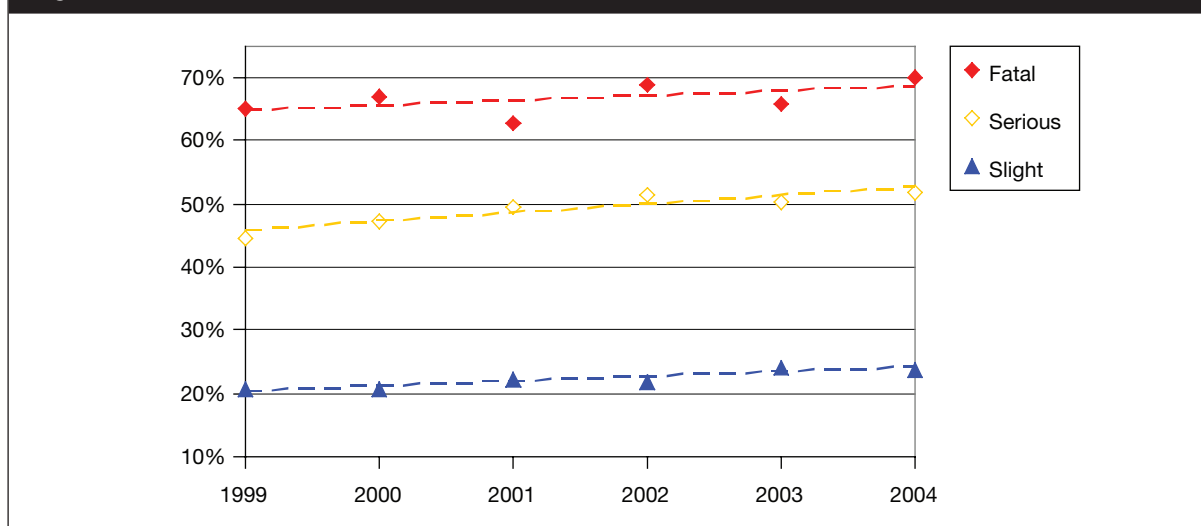
Table 6 Contributory factors associated with loss of control

Code	Contributory factor	Fatal accidents	Serious accidents	Slight accidents
307	Travelling too fast for conditions	0.20	0.25	0.20
602	Careless, reckless or in a hurry	0.16	0.19	0.16
306	Exceeding speed limit	0.14	0.14	0.10
409	Swerved	0.12	0.11	0.12
501	Impaired by alcohol	0.10	0.13	0.09
103	Slippery road (due to weather)	0.09	0.16	0.20
601	Aggressive driving	0.09	0.08	0.05
605	Learner or inexperienced driver/rider	0.07	0.08	0.08
403	Poor turn or manoeuvre	0.07	0.07	0.08
108	Road layout (e.g. bend, hill)	0.03	0.05	0.04

Trend analyses

Analyses of contributory factor data have made a valuable contribution to understanding recent car occupant casualty trends. The regular STATS19 data have shown an increasing proportion of casualties occurring in single-vehicle accidents, accidents at bends and in cars that hit objects off the carriageway, such as trees (Broughton and Buckle, 2007). Analyses of the contributory factors collected between 1999 and 2004 by 12 police forces using the TRL system showed that the proportion of car accidents caused by loss of control had risen. The results are illustrated in Figure 4.

Figure 4 Proportion of car accidents caused by loss of control



Further analyses found that the incidence of three contributory factors in car accidents rose significantly between 1999 and 2004:

- behaviour – careless/thoughtless/reckless;
- behaviour – in a hurry; and
- aggressive driving.

Conclusions

Since 1 January 2005, contributory factors have been routinely collected throughout Great Britain as part of the national accident reporting system. It is important to be aware of the possible limitations of the data, namely that they reflect reporting officers' opinions at the time of reporting and may not be the result of extensive investigation. The results presented in this paper, and other results that have been reported elsewhere, are generally credible and suggest that the data being collected can provide valuable insights into patterns of accident causation.

The new STATS19 contributory factor dataset is a valuable additional resource for road safety research. The process of persuading the police to record contributory factors was lengthy, and there may well be pressure in future to cease to record these factors if the police do not see that the data are being used extensively. It will be important for the road safety research community to learn to make full use of these data over the next few years.

Acknowledgements

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4

Methods for data modelling

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Introduction

This paper considers self-reported accidents from a large sample of UK new drivers. The sample study, generally referred to as the Second Cohort study, was undertaken by the Transport Research Laboratory (TRL) and commissioned by the Road Safety Division of the Department for Transport. The study has also provided a comprehensive database on the driver learning process and their driving experiences in the first three years of driving.

One function of this survey was to provide a base platform that could be used to investigate any interventions introduced into the driver licence acquisition process, for example the introduction of a hazard perception test (November 2002) within a theory test that has to be passed by learner drivers.

The study consisted of 16 cohorts selected at random from the population of new drivers booked to take their practical driving test during a specific week. Four surveys were selected per year in November, February, May and August from 2001 to 2005, and 8,000 practical test candidates were sent a questionnaire that asked about the 'learning to drive' experience. Subsequently, those candidates who passed their practical driving test were sent a questionnaire 6 months, 12 months, 24 months and 36 months after taking their test. These follow-up questionnaires asked about their early driving experiences, including their accident history.

The accidents in the first six months and from three years of driving are considered in this paper. The three most recent accidents in the reporting period were asked about in some detail. The type of accident could thus be categorised, and the following are considered within the main report of this study (Wells *et al.*, 2008):

- all accidents within the reporting period (i.e. those accidents within the six-month reporting period);
- all non-low-speed accidents occurring on public roads (i.e. those accidents which may have serious consequences for those involved);
- low-speed accidents, not necessarily on public roads (i.e. hitting gate posts, incidents in a car park or low-speed manoeuvring accidents); and

- ‘active’ public road accidents where the first thing that happened was probably due to the driver, i.e. hitting another vehicle.

The different types of accident occur with different rates and may be influenced by different factors. They may require different types of models, and certainly different parameters within models. These are investigated within the main report of this study. This paper considers the options available for modelling and investigates which models may best represent the observed self-reported accident data. The cohort study is a convenient dataset on which to conduct this research. Four types of generalised linear model (GLM) are discussed:

- Poisson models – assumes that accidents follow a Poisson distribution, albeit there may be over-dispersion;
- negative binomial model – assumes that accidents follow a negative binomial distribution, where the variance term will allow for over-dispersion;
- zero-inflated Poisson (ZIP) model – which is a hybrid of two models, a binary logit model to predict accident involvement and a Poisson model to predict how many accidents given an involvement;
- binary logit (binomial) models – assumes that a driver is either accident-involved or not, and does not take into account the number of accidents;
- path models – which hypothesise a causal path for an outcome measure and allow for inter-correlations between ‘causal’ variables. For example, a path model may include the outcome of accident liability as a function of driver behaviours which, in turn, may be influenced by their attitudes and other rider characteristics, such as age and gender.

It is accepted that a zero-inflated negative binomial is also a possibility, but it has not been considered.

Accident models

Different types of accident models are considered. They all have similar structures in that they are all GLMs that need to take into account the non-normal nature of the accident data distribution. There are several statistical packages available that fit GLMs (e.g. SAS, GLIM, MPlus), as defined by Nelder and Wedderburn (1972).

The class of GLM is an extension of traditional linear models that allows the mean of a population to depend on a **linear predictor** through a non-linear **link function**, and allows the response probability distribution to be any member of an exponential family of distributions.

Many other useful statistical models can be formulated as GLMs by the selection of an appropriate link function and response probability distribution. See McCullagh and Nelder (1989) for a discussion of statistical modelling using GLMs. The books

by Aitkin *et al.* (1989) and Dobson (1990) also provide references with many examples of applications of GLMs. Firth (1991) provides an overview of GLMs.

What is a generalised linear model?

A traditional linear model is of the form:

$$y_i = x_i' \beta + \varepsilon_i$$

where y_i is the response variable for the i_{th} observation. The quantity x_i is a column vector of covariates, or explanatory variables, for observation i that is known from the experimental setting and is considered to be fixed, or non-random. The vector of unknown coefficients β is estimated by a least squares fit to the data y . The ε_i are assumed to be independent, normal random variables with zero mean and constant variance. The expected value of y_i , denoted by μ_i , is:

$$\mu_i = x_i' \beta$$

While traditional linear models are used extensively in statistical data analysis, there are types of problems for which they are not appropriate. A GLM extends the traditional linear model and is, therefore, applicable to a wider range of data analysis problems. A GLM consists of the following components.

The linear component is defined just as it is for traditional linear models:

$$\eta_i = x_i' \beta$$

A monotonic differentiable link function g describes how the expected value of y_i is related to the linear predictor η_i : $g(\mu_i) = x_i' \beta$

The response variables y_i are independent for $i = 1, 2, \dots$ and have a probability distribution from an exponential family. This implies that the variance of the response depends on the mean μ through a **variance function** V :

$$\text{var}(y_i) = \phi V(\mu_i) / w_i$$

where ϕ is a constant and w_i is a known weight for each observation. The **dispersion parameter** ϕ is either known (for example, for the binomial or Poisson distribution, $\phi = 1$) or it must be estimated.

What is a Poisson regression model?

Poisson regression is a statistical methodology for analysing data consisting of counts, rates or organised into contingency tables. The natural distribution for count data is assumed to be the Poisson distribution.

The Poisson distribution is a discrete probability distribution. It expresses the probability of a number of events occurring in a fixed period of time if these events occur with a known average rate and are independent of the time since the last event.

The probability that there are exactly k occurrences (k being a non-negative integer, $k = 0, 1, 2, \dots$) is:

$$F(k;\lambda) = e^{-\lambda} \lambda^k / k!$$

where $k!$ is the factorial of k and λ is a positive real number equal to the expected number of occurrences during the given interval, i.e. the mean is λ as is the variance because for the Poisson distribution these take the same value. If the sample variance is larger than the sample mean, then the distribution is said to be overdispersed, and it is necessary to take this into account when estimating the statistical significance of the estimated parameters.

In terms of the GLM, the appropriate link function is the natural log, i.e.:

$$\log_e(\mu_i) = x_i'\beta$$

How does the negative binomial model differ?

The negative binomial distribution can be used as an alternative to the Poisson distribution. It is especially useful for discrete data over an unbounded positive range whose sample variance exceeds the sample mean. If a Poisson distribution is used to model such data, the model mean and variance are assumed to be equal. In that case, the observations are **overdispersed** with respect to the Poisson model.

Since the negative binomial distribution has one more parameter than the Poisson, the second parameter can be used to adjust the variance independently of the mean.

The idea is to use the negative binomial distribution for the error distribution instead of the Poisson distribution.

We can use the negative binomial distribution, instead of the some other distribution, because the model parameters and their meaning do not change when the errors are switched from Poisson to negative binomial and the counts are modelled with a log link function, the same as for a Poisson model.

The sample mean value for the negative binomial is equivalent to the λ for the Poisson, but the sample variance is $(\lambda\Phi)$; where $\Phi > 0$ is a (over/under) dispersion parameter. When $\Phi = 1$, we have the same structure as the Poisson distribution. The same model for the counts/rate using a negative binomial distribution can be used instead of a Poisson distribution. This allows us to be more flexible by allowing the variance of the counts to have a different value than the mean. The interpretation of the parameters in the mean model remains the same.

What is the zero-inflated Poisson model?

The simplest count model is the Poisson model. It has only one parameter, restricting the variance to equal the mean, and this is likely to be violated. In particular, over-dispersion is likely to be an issue. This means the distribution of accident frequencies across drivers is likely to have a larger variance than the Poisson variance. This can be dealt with by allowing the variance to be larger through the use of the negative binomial model or a scaling parameter.

However, a better representation of the observed accidents may be achieved by considering that some drivers will not have accidents, i.e. they are safe drivers (this may not be a tenable suggestion in the context of new drivers, but has been adopted for the purposes of investigating ZIP models). There is often a preponderance of zeros observed, and this may skew the distribution away from the traditional Poisson and negative binomial processes. Zero-inflated count models can handle this issue. Zero-inflated models use a logistic mixing distribution to add to the zero mass of the probability density function. These models have previously been used to model the frequency of vehicle crashes in roadway sections (Shankar *et al.*, 1997), albeit in the context of 'safe' sections of road where no accidents would be expected.

ZIP models are developed by adding a binary logit model as a mixing distribution. The distribution of no accidents or one or more accidents becomes:

$$\begin{aligned}\Pr(\text{accs} = 0) &= \Pr_B(\text{no accs}) + \Pr_B(\text{may have acc}) \times \Pr_p(\text{accs} = 0 \mid \text{may have accs}) \\ \Pr(\text{accs} = n \mid n > 0) &= \Pr_B(\text{may have acc}) \times \Pr_p(\text{accs} = n \mid \text{may have accs})\end{aligned}$$

where $\Pr_B()$ is the binary logic probability of having an accident or not, and $\Pr_p()$ is the Poisson model probability of how many accidents, given that the driver may have an accident.

What about a binary logit model?

We can consider drivers as either being accident-involved or not. This is analogous to the 'first part' of the ZIP model discussed above. However, it also may be a sufficient model to help identify which variables are important, i.e. being accident-involved is what matters, not how many times.

The binomial distribution is a discrete probability distribution. It expresses the probability of a dichotomous event occurring in a fixed period of time, i.e. accident-involved or not. These events occur with a known average rate and are independent of the time since the last event. The probability of observing k occurrences from a sample of n with an average of p is given by:

$$F(k;n,p) = \{n! / k!(n-k)!\} p^k (1-p)^{n-k} \text{ where } k = 0, 1, 2 \dots n$$

where $k!$ is the factorial of k and p is a positive real number equal to the expected proportion of occurrences during the given interval, i.e. the mean number of

occurrences is (np) and variance is $np(1 - p)$. In terms of the GLM, the appropriate link function is the logit, i.e.:

$$\log_e(\mu_i/(1 - \mu_i)) = x_i'\beta$$

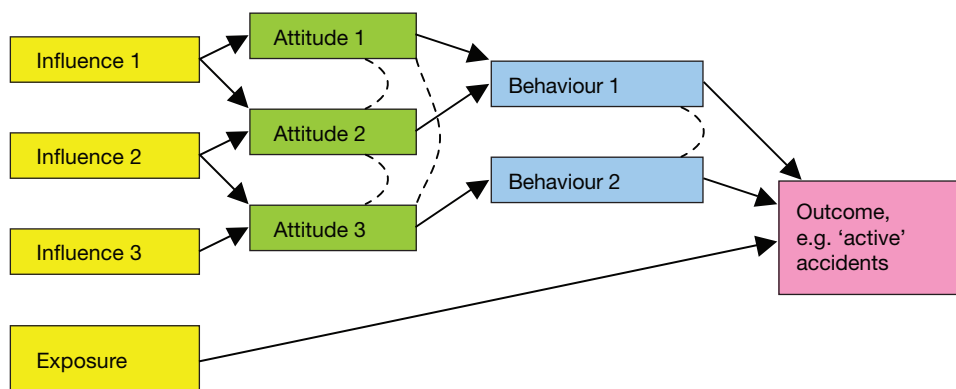
If there are very few drivers with more than one accident in the period of interest, then this model may provide a sensible alternative to fitting a Poisson model or ZIP model. Basically, in that instance the data are virtually dichotomous.

What are path models?

In path analysis, a model is formulated as a path diagram, in which arrows connecting variables represent (co)variances and regression coefficients. The path diagram is defined a priori and may be modified depending on the outcome of fitting the proposed model. It is helpful in defining a 'causal' path between different sets of measures that may be correlated. Path models can be defined by a series of regression, latent variable and correlation relationships and fitted by using covariance structure analysis.

Path analysis fits regression relations to a pre-defined set of measures seen as operating over a network of 'causal' links. A simple example of a path model is shown diagrammatically in Figure 1.

Figure 1 Path model



The arrows in the hypothetical path model illustrated in Figure 1 represent regression relationships between the variables in the 'boxes' – the 'influence' variables acting as explanatory variables for the 'attitude' variables. The curved dotted lines in the model represent correlations between the variables in the 'boxes'. Thus, for example, in Figure 1 'attitude 1' is determined by 'influence 1' alone, whereas 'attitude 2' is determined by 'influence 2' and 'influence 3' combined, and so on for the other variables. The dotted lines show that there are significant correlations between 'attitude 1' and 'attitude 2', between 'attitude 1' and 'attitude 3' and between 'attitude 2' and 'attitude 3', and so on for the other variables. The 'outcome' measure is the accident variable. In the above path model, this outcome measure is determined by the two behaviour measures as well as exposure, and the behaviour measures are, in turn, determined by the attitude variables.

Measuring goodness of fit

When fitting any model it is important, and helpful, to have an idea of how well the observed data are being fitted. Traditional measures of goodness of fit describe how much ‘variation’ in the dependent variable is ‘explained’ by the model estimated, as compared with the total variation present in the dataset. Variation is usually taken to mean ‘sample variance’, or ‘the sum of squared deviations from the sample mean’.

When using GLMs, it is usual to calculate a statistic known as the deviance. This is based on the log of the maximum likelihood ratio, where:

$$\text{Deviance} = -2 \log_e(\text{likelihood of current model} / \text{likelihood of full model})$$

The closer the model is to the ‘full’ model, the smaller the deviance value. More importantly, the difference between deviances from successive models is distributed as a chi-squared statistic, and so can be used to test the importance of the later model as compared to an earlier one – where perhaps an extra variable was included.

For completeness, it may be useful to define likelihood. The likelihood principle is a principle of statistical inference which asserts that all of the information in a sample is contained in the likelihood function. A likelihood function arises from a conditional probability distribution considered as a function of its second argument while holding the first fixed. For example, consider a model which gives the probability density function of observable random variable X as a function of a parameter θ .

Then, for a specific value x of X , the function $L(\theta | x) = p(X = x | \theta)$ is a likelihood function of θ : it gives a measure of how ‘likely’ any particular value of θ is, if we know that X has the value x . The log-likelihood function for the Poisson distribution is given by:

$$\log_e(L(\beta)) = \sum_i \{ y_i \log_e(\mu_i) - \mu_i - \log_e(y_i!) \}$$

where the expected value of y_i is μ_i and estimated by $\hat{y}_i = x_i' \beta = \exp(\beta_0 + \sum_j x_{ij} \beta_j)$.

The Pearson chi-squared value can be calculated and is useful when estimating the percentage of non-Poisson variation explained by the current model. It is approximately chi-squared distributed with $(n - k)$ degrees of freedom. It is calculated by:

$$\text{Pearson } \chi^2 = \sum_i \{ (y_i - \hat{y}_i)^2 / \hat{y}_i \}$$

where y_i is the observed number of accidents for the i^{th} person and \hat{y}_i is the predicted number of accidents from the current model, $i = 1 \dots n$.

The deviance for a Poisson model is estimated by:

$$\text{Deviance} = \sum_i \{ y_i \log_e(y_i / \hat{y}_i) - (y_i - \hat{y}_i) \}$$

The maximally obtainable fit depends on the level of measurement and distribution of the dependent variable, in particular on the true structure of the error-generating

process, which introduces random variation into the dataset. There is no point in trying to explain the purely random noise. On the contrary, the aim of the analysis is to explain all systematic variation, i.e. all variation except the part due to sheer randomness. But since we normally do not know how much random disturbance there should be, there is no yardstick against which we can measure a given goodness of fit in order to judge whether or not a given model explains all the systematic variation there is to explain. However, if the data are distributed as a Poisson variable, then we know the ‘noise’.

Hence, if the underlying accident data distribution is assumed to be Poisson, then we can estimate the ‘noise’ and consider just the non-Poisson variation. The percentage of non-Poisson variation explained by the fitted model is one possible measure of fit. In this situation the expected Pearson chi-squared for a model will be the Poisson part plus the non-Poisson part. The expected value for the Poisson part is estimated by the remaining degrees of freedom, and hence the non-Poisson part can be estimated. The percentage explained relative to a null-model (with only the intercept fitted) can then be easily calculated. However, this is only tenable if the model does not have a higher explanatory power than possible under these assumptions, and in this case the model should be discarded as under-dispersed (over-fitted).

Data

As was stated earlier, the data come from a study that consisted of 16 cohorts selected at three-month intervals in a four-year period. Samples were selected at random from the population of candidate drivers booked to take their practical driving test during a specific week. Candidates were sent a questionnaire that asked about their preparation for the practical driving test. Candidates who passed their practical driving test were sent a questionnaire 6 months, 12 months, 24 months and 36 months after taking their test. These follow-up questionnaires asked about their early driving experiences, including their accident history.

Table 1 shows the distribution of numbers of accidents for some of the accident types. A Poisson distribution has been fitted to each of the datasets and compared with the observed frequencies. The chi-squared test probability indicates that, strictly, only the non-low-speed public road accidents follow a Poisson distribution. The ratio of the variance to the mean indicates the degree of over-dispersion.

The degree of over-dispersion is not that large for any of the data being considered. It appears, for the ‘active’ public road accidents, that there are slightly fewer single accidents than would be expected if the data followed a Poisson distribution. This is shown in Figure 2, where there is a slight excess of candidates who had two ‘active’ public road accidents within their first six months of driving.

Specifically, ‘active’ public road accidents were identified as ones where the first thing that happened was any of the following:

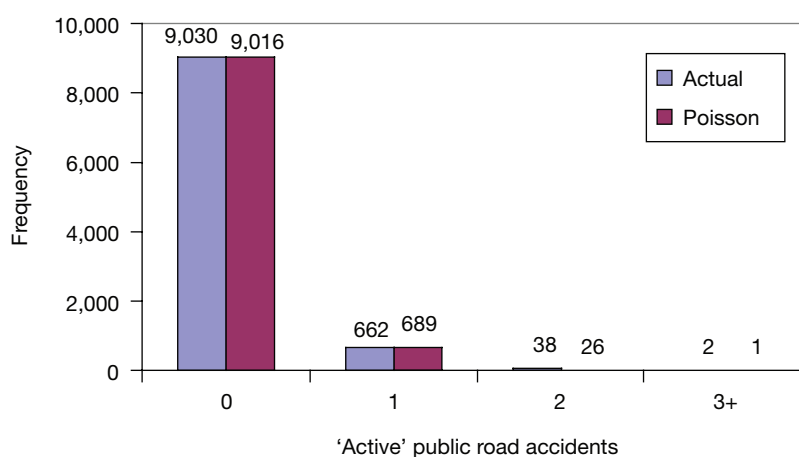
- driven vehicle hit a pedestrian;
- driven vehicle hit a cyclist;

Table 1 Frequency count for numbers of accidents in the first six months of driving

Number of accidents	Frequency of accidents in first six months of driving		
	All	Non-low-speed public road	'Active' public road accidents
0	8,529	9,100	9,030
1	1,104	606	662
2	89	25	38
3	12	2	2
Total cases	9,734	9,733	9,732
Mean	0.135	0.068	0.076
Variance	0.143	0.070	0.080
Ratio (var/mean)	1.054	1.026	1.042
Chi-squared test probability compared to Poisson distribution			
Probability that is Poisson distributed	0.0%	11.8%	3.1%

- driven vehicle hit the rear of another vehicle;
- driven vehicle hit the side of another vehicle;
- driven vehicle was hit by another vehicle in their lane;
- driven vehicle hit a roadside object; and
- driven vehicle left the road without hitting any other object.

'Active' accidents were thus the ones where, in all probability, the driver was most likely to be responsible for the accident.

Figure 2 Observed (actual) and predicted Poisson distribution of 'active' public road accidents in first six months

This suggests that there is a small level of over-inflation that can be taken into account by using a Poisson model with an over-inflation adjustment, a negative binomial model or a ZIP model.

Covariates and explanatory variables

The survey data contain a wealth of potential explanatory variables. These include exposure data, such as miles driven within the reporting period, the frequency of driving on a variety of different types of roads and conditions, the number of times driving more than 100 miles in a day, and on average how many times they have driven in a month. There are also a number of driver measures, such as their age, their sex, the time that it took to pass their driving test, if they took the hazard perception test as part of their driving theory test, etc.

Summary statistics for some of these measures for the sample that responded to the driving experience questionnaire after six months of driving are shown in Table 2. The sample has been restricted to those drivers who drove at least 100 miles in their first six months of driving and who did not drive more than 10,000 miles.

Table 2 Summary statistics for some potential explanatory variables

Descriptive statistics	Sample	Min.	Max.	Mean	SD
Age when passed their driving test	8,478	16.4	79.8	22.9	8.5
In first six months how many miles driven	8,478	100	10,000	2,645	2,245
In first six months frequency of driving on annualised basis (daily = 365, monthly = 12 ...)	8,478	0	365	288	102
Proportion that take hazard perception in theory test	8,442	–	–	0.50	–
HP test score – in theory test (if taken)	4,160	38	71	52.8	6.0
Months from theory test to driving test (no gap in learning)	6,383	1	63	6.1	4.8
Months to test from starting to drive (no gap in learning)	6,542	1	119	10.6	8.9
Total hours of tuition or practice	8,384	0	700	68.2	68.8

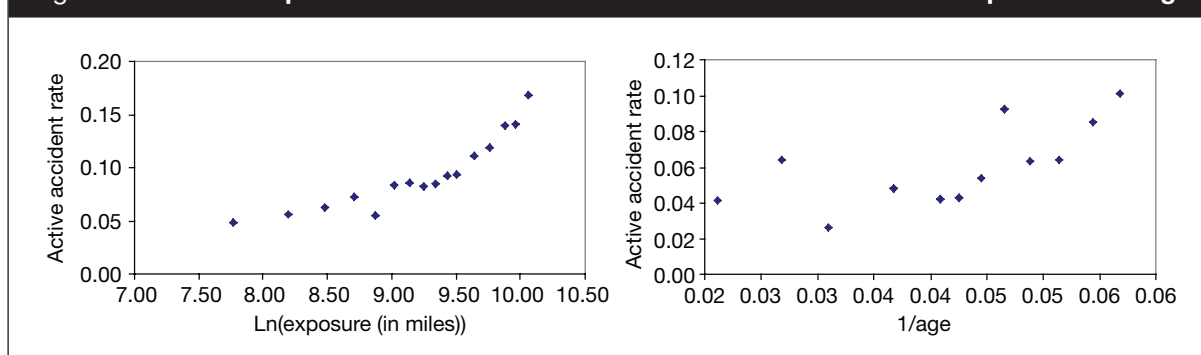
Questions such as the frequency of driving on different roads and in different conditions, as well as those on the frequency of driving generally, will be highly correlated with each other. They will also be correlated with the estimated mileage driven during the reporting period. This is illustrated in Table 3, where the number of miles driven increases the more frequently the candidates drive. The relationship between accident rate and miles driven across each of the six groups in Table 3 is also highly correlated (correlation = 0.88), indicating the close relationship between exposure (in miles driven) and accident rate. This variable was combined with the annualised miles driven in order to derive an ‘exposure’ measure, which was used within the modelling.

Table 3 Frequency of driving and average miles in first six months

How often drive (times per month)	Sample	Active public road accidents	Average annualised miles
Every day (30)	4,655	0.087	6,846
4–6 days a week (20)	2,332	0.071	4,298
1–3 days a week (8)	1,161	0.047	2,071
About once a fortnight (2)	169	0.024	1,173
About once a month (1)	55	0.055	779
Less than once a month (<1)	48	0.021	579

The relationship between mileage (or a related measure of ‘exposure’) and accident risk and age and accident risk have been investigated in many previous studies – see Maycock *et al.* (1991), Maycock and Forsyth (1997), Taylor and Lockwood (1990), and Sexton *et al.* (2004). A similar relationship is assumed between these explanatory variables and accident risk in this study, i.e. the natural logarithm of miles and an inverse function of age. Figure 3 shows the data points and fitted relationships between accident rate and $\log_e(\text{exposure (in annualised miles)})$ and $1/\text{age}$ for the first six months of data.

A major advantage of using the logarithm of miles is that, given that a log link function for the GLM is required, then the accident rate per mile to a power (to be estimated) is being modelled. The other advantage of using the log of miles in the GLM is that the predicted accident rate for zero miles is also zero, whereas using other functions for miles may lead to the anomalous result of a non-zero accident rate even for zero miles driven in the reporting period.

Figure 3 Relationship between ‘active’ accidents in first six months with ‘exposure’ and age

The analysis focuses on ‘active’ public road accidents in the first six months of driving. Models have been fitted separately for males and females, and include the following covariate measures:

- natural log of an ‘exposure’ measure (miles pa + 10 ? frequency of driving);
- inverse function of age at time of passing the driving test; and
- the number of months learning before passing the driving test.

For illustrative purpose, a negative binomial model and a path model have been fitted. Separate GLM models were fitted for males and for female candidates.

Results from fitting a generalised linear model

As an example, let us suppose we are interested in the relationship between the months taken to learn prior to taking the practical driving test and the ‘active’ accident risk observed. Figure 4 shows the relationship for male and female drivers for those ‘active’ accidents within the first six months of driving. However, the relationship is a bit fuzzy, but by grouping the months of learning the apparent underlying relationship becomes clearer – see Figure 5.

Figure 4 ‘Active’ accidents in the first six months of driving by months learning to drive

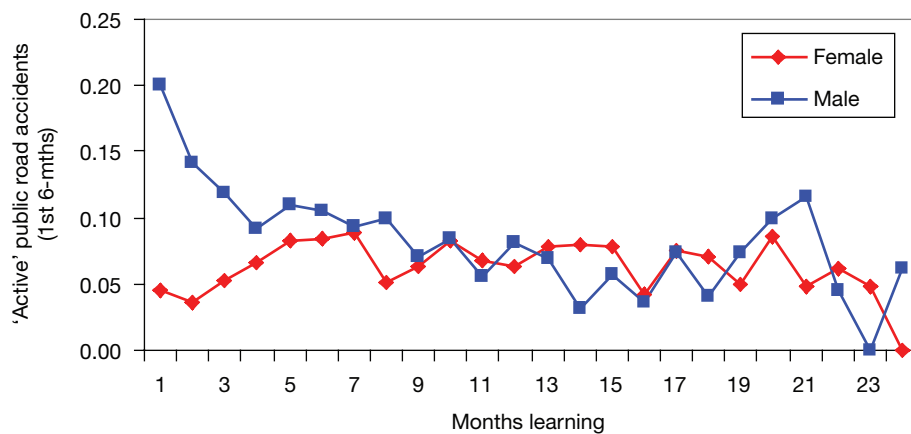
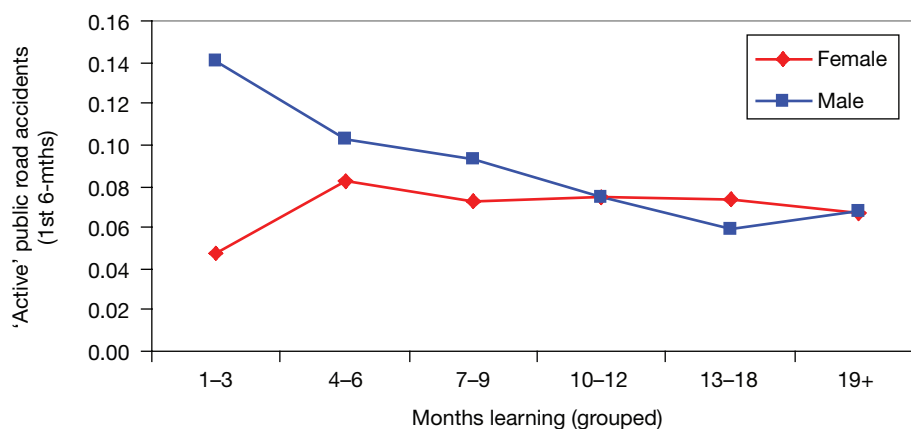


Figure 5 ‘Active’ accidents in the first six months of driving by months learning to drive (grouped)



The relationship suggests that for male drivers the accident risk reduces with the time taken to learn to drive, but for female drivers there is little relationship (except for those who take only one or three months to learn, who have a lower risk).

However, it is likely that those who take longer to learn may be older and may drive fewer miles than younger drivers (or perhaps the reverse). Hence it may not be wise just to consider the apparent relationships shown in Figure 5. This is confirmed if we look at age and miles with time taken to learn, as shown in Figures 6 and 7, where there is an apparent relationship.

Fitting a model that includes age, miles (or exposure) and months taken to learn thus seems a sensible way forward. Further, given the differences between male and female drivers, it seems prudent to fit models for each sex.

Figure 6 Age by months learning to drive

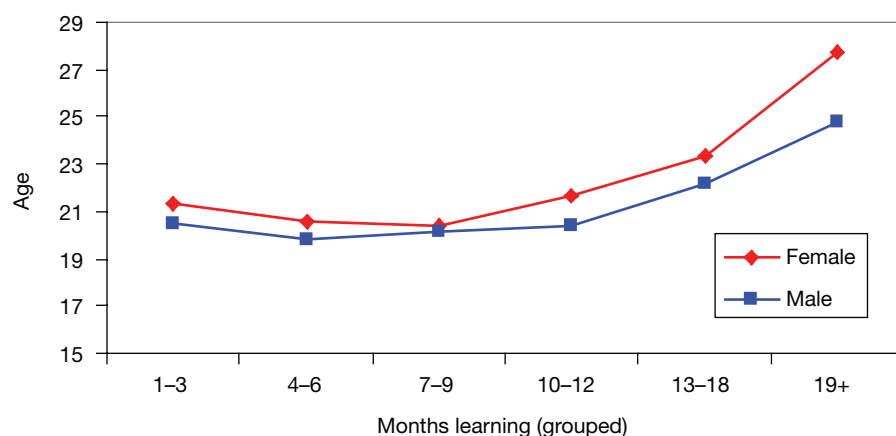
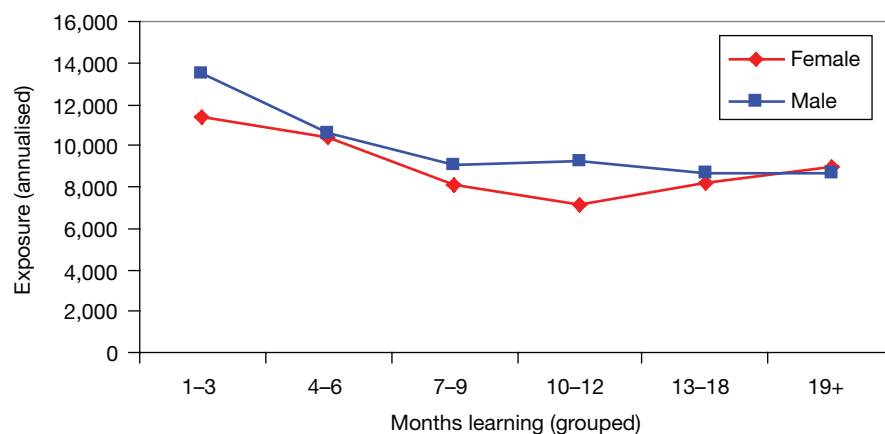


Figure 7 Exposure (annualised) by months learning to drive



Fitting a model to female and male data separately generated the following parameter estimates for age, exposure and months learning, shown in Table 4. The probability that the parameter is zero is given in column 4 and shows that they are all statistically significant except for the months of learning estimate for male drivers.

Table 4 Estimated model parameter coefficients for ‘active’ public road accident model – in first six months of driving

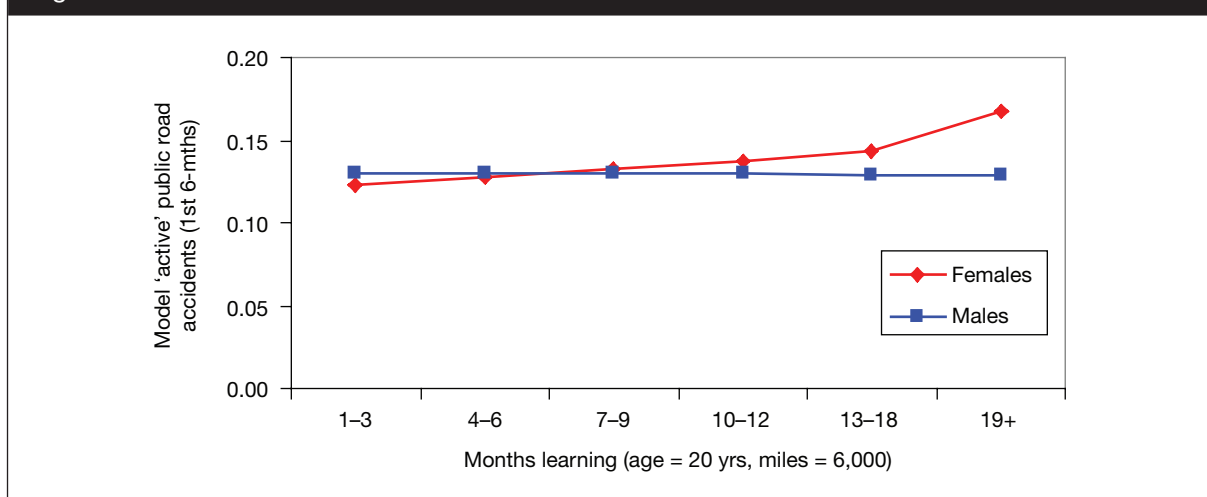
Model	Parameter	Estimate	pr(= 0)	se
Female	Intercept	-6.54	<0.1%	0.790
	1/age	26.86	<0.1%	6.421
	loge(exposure)	0.35	<0.1%	0.082
	Months learning (mtotest)	0.0181	<2%	0.005
Male	Intercept	-9.11	<0.1%	1.022
	1/age	48.93	<0.1%	10.108
	loge(exposure)	0.53	<0.1%	0.096
	Months learning (mtotest)	-0.0003	ns	0.007

The equations for each of the models are as follow for female and male drivers (the non-statistically significant months learning parameter for males has been included for completeness):

$$\text{ACACC} = \exp(-6.54) \text{ exposure}^{0.35} \exp[26.86/\text{age} + 0.0118 \times \text{mtotest}] \dots \text{(female)}$$

$$\text{ACACC} = \exp(-9.11) \text{ exposure}^{0.53} \exp[48.93/\text{age} - 0.0003 \times \text{mtotest}] \dots \text{(male)}$$

The relationship between months learning to drive and ‘active’ accident risk in the first six months of driving can be estimated from these equations. The estimates for ‘active’ accidents during the first six months of driving are shown in Figure 8 for drivers aged 20 years with an average of 6,000 annualised miles’ ‘exposure’. The lack of relationship between accident risk and months of learning for male drivers is clearly indicated. It also can be seen that there is an increase in risk for female drivers with an increase in the number of months taken to learn.

Figure 8 Estimated ‘active’ accident rate from model

Comparing the unadjusted relationship in Figure 4 with the adjusted relationship in Figure 8 suggests a completely reversed interpretation. The unadjusted data suggest that the accident rate reduces with increase in learning time for males and is fairly stable for females, whereas the adjusted data suggest there is no relationship for

males and an increase in risk for females with an increase in months taken learning to drive. The reverse conclusion is reached because age and exposure factors have been taken into account. Those taking less time to learn tend to have greater exposure values and are younger and, once this is allowed for, then the apparent relationships reverse.

A path model example

An example of a path model fitted for female drivers is illustrated and uses data from the first three years of driving. Accidents were assumed to follow a Poisson distribution, and each model included only those measures which prove to be statistically significant at the 5% level.

The initial model was formulated in discussion with those knowledgeable about driver psychology to provide a logical starting point. Only the final models are presented here; the early development of these models is not discussed in detail. In formulating path models, it is sensible to include only those variables that are relatively strongly correlated, because otherwise the model can become unmanageable and difficult to interpret. The final path models are most useful in helping to identify the key 'causal' influences that can be thought as 'driving' the 'outcome' measure. If the models are too complex, much of the insight provided by the model can be obscured by the complexity.

The attitudinal or behavioural measures used in the modelling were derived from the drivers' responses to the driving experience questionnaire. It will be appreciated that there are potentially a large number of variables that could be derived from the driving experience questionnaire for use in this path modelling work. In practice, however, only those measures considered to be of key importance have been used. Table 5 describes the measures used and identifies their role in the path model. All of these variables have been used in the accident models described earlier in this section. Only those that were statistically significant remained in the final models.

The female path model

The path model for female drivers is shown in Figure 9. As previously indicated, the arrows represent regression relations, and the dotted lines correlations. However, the figure only shows the stronger relationships. Other statistically significant variables, but weaker, have not been included in the figure so as not to overcomplicate the diagram.

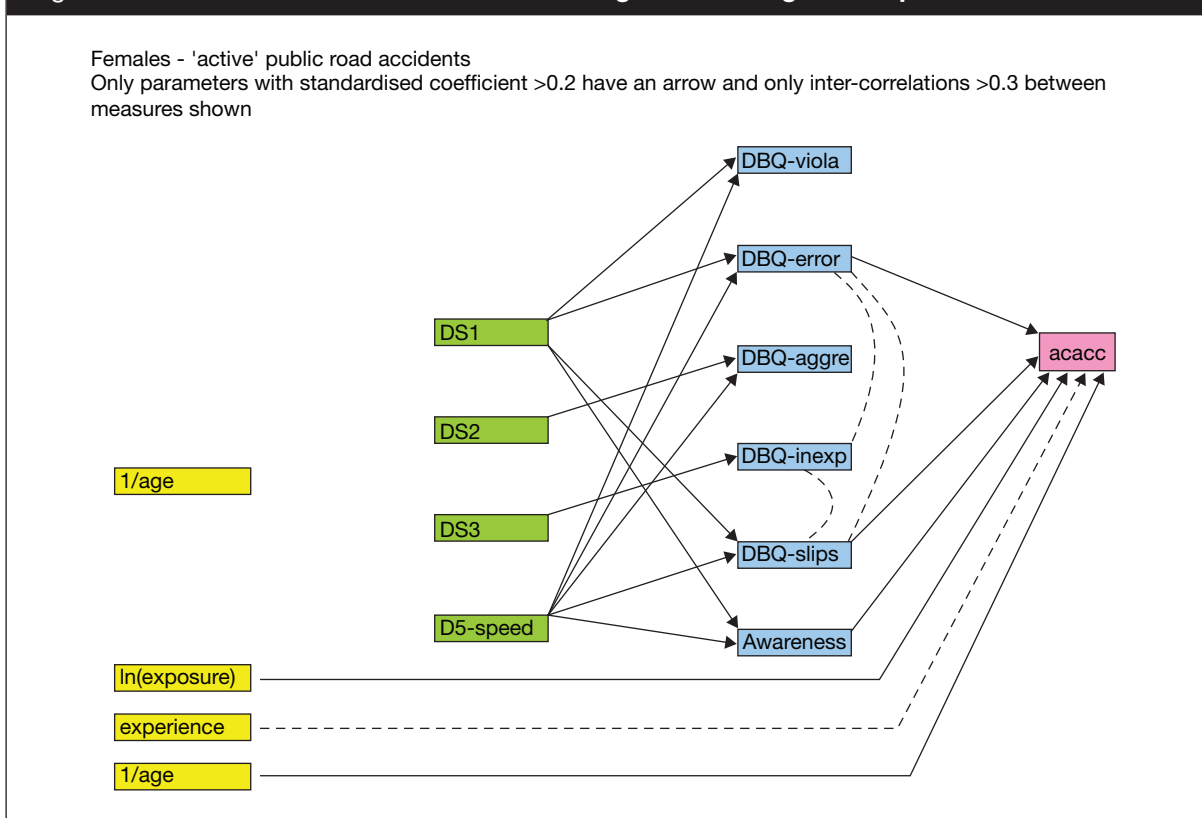
The path model for female drivers shows that the number of accidents is influenced by the driver's age, the driver's driving experience (i.e. the time that has elapsed from passing the test) and her exposure to the risk of an accident (measured by the composite exposure variable previously described – a combination of miles driven and the frequency of driving). Accidents are also influenced by the number of driving errors and driving slips reported by the drivers (as derived from the DBQ questions) and by the 'awareness' variable – a variable related to the ability of being able to detect potentially hazardous situations while driving.

Table 5 Names and descriptions of measures used in the path models

Measure name	Description	Meaning of a high value	Meaning of a low value	Position in path model
acacc	'Active' accidents which happened on public roads	Unsafe driver	Safe driver	Outcome measure
1/age	1/age at time of test	Younger driver	Older driver	Influence
ln(exposure)	$\log_e(\text{miles driven p.a.} + 10 \times \text{times drove p.a.})$	High exposure	Low exposure	Influence
mtttest	Months from theory test to driving test	Took time to learn	Learnt quickly	Influence
DS1	Guppy scale 1	Attentive, careful, responsible, safe	Inattentive ...	Style
DS2	Guppy scale 2	Placid, patient, considerate, tolerant	Irritable ...	Style
DS3	Guppy scale 3	Decisive, experienced, confident, fast	Indecisive ...	Style
DBQ viola	DBQ driving violation scale	More driving violations	Fewer driving violations	Behaviour
DBQ error	DBQ driving errors scale	More driving errors	Fewer driving errors	Behaviour
DBQ aggre	DBQ aggressive violation scale	More aggressive violations	Fewer aggressive violations	Behaviour
DBQ inexp	DBQ inexperience errors scale	More inexperience errors	Fewer inexperience errors	Behaviour
DBQ slips	DBQ driving slips scale	More driving slips	Fewer driving slips	Behaviour
Awareness	Awareness, observation and anticipation of potential hazards	Very unaware (unsafe)	Very aware (safe)	Behaviour
D2 – compared	How compare to other drivers?	Much worse than average	Much better than average	Attitude
D3 – confidence	How confident in driving ability?	Not at all confident	Very confident	Attitude
D5 – speeding	How often exceed speed limits?	Always	Never	Behaviour

The behavioural variables indicate that the more 'errors' and 'slips' (as defined by the DBQ) that are made while driving, the higher the driver's accident liability is expected to be. Also, the poorer the driver's awareness of potential hazards (as measured by the 'awareness' scale) is, the higher her accident liability will be.

The DBQ variables are strongly inter-correlated; driving 'errors' are correlated with both 'slips' and with the 'inexperience' DBQ measure; 'slips' are also correlated with 'inexperience'. The driving style measures, as well as being correlated with the measure related to exceeding speed limits, are also inter-correlated. All such correlations that have correlation coefficients greater than 0.3 are included as

Figure 9 Path model for female drivers showing the more significant paths

‘dotted’ lines in Figure 9. In general, it is only to be expected that behavioural variables of this kind will be correlated – indeed, statistically speaking, one advantage of the path modelling method is that these correlations are dealt with explicitly. However, the actual values of the correlation coefficients are not of any great interest in interpreting the accident model.

Figure 9 shows that both the DS2 driving style scale (‘placid, patient, considerate and tolerant’) and the ‘D5 – speed’ scales are related to the age of the driver. In the case of DS2, the associated coefficient is negative, which, in combination with the reciprocal age term, indicates that older drivers are more ‘placid, patient, considerate and tolerant’ than younger drivers. As regards speeding, the D5 scale is a simple non-inverted scale measuring how often a driver is prepared to exceed the speed limit; the positive coefficient generated by this variable indicates that older drivers do not exceed the speed limit (or at least do not report exceeding the speed limit) as often as younger drivers.

The path model suggests that the attitude to speed measure (D5) and the ‘attentive, careful, responsible and safe’ driving style (DS1) are associated with all three of the driving behaviours that link with accidents, specifically, DBQ ‘errors’ and ‘slips’, and the ‘awareness’ scale.

Here then is a suggested ‘path’ of influence for women drivers that links the age of the driver and her attitudes to active accidents. The attitudes of importance are measured by the driving style scales (DS1 and 2) and the willingness to exceed the speed limit (D5). The behaviours of importance are: the self-reported slips and errors made while driving, and her awareness, observation and anticipation of potential hazards.

Conclusion

This paper identifies mathematical models that can be used to identify potentially influential measures on accidents. Modelling is necessary because of the underlying noise found in any set of data. The noise tends to obscure relationships among measures, and the modelling process helps to see what measures have some explanatory power. Different GLMs can be used, and they make different assumptions. It may be necessary to consider a number of approaches and models in order to find the ‘best’ model for the data being analysed. A ‘goodness of fit’ statistic can be used to identify which model explains most of the variation in the data.

An example of a simple GLM illustrates how models can be used to identify relationships between accidents and available measures. Specifically, the example showed how an apparent relationship reversed, once influencing measures had been controlled for. This is clearly desirable when the data contain interacting measures.

The use of path models is a different and more holistic approach. It recognises that an outcome, such as an accident, depends on many influences. The immediate influence, such as driving behaviour, may influence accident liability, but the behaviour may be influenced by an attitude that in turn may vary with age and sex. Modelling the ‘reality’ and paths of influences on driving may help to gain a better understanding. Further, it may help to identify which measures should be targeted because they not only influence the final accident risk but can be influenced via appropriate road safety campaigns.

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Road traffic injury and disadvantage: people and areas

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Introduction

Disadvantaged people and communities that experience a variety of poorer outcomes and policies at all levels increasingly seek to address such inequalities. Pedestrian road traffic injuries provide an example of this familiar pattern, and the issue has rightly been identified as an area requiring strategic intervention.

This paper explores what we know about road traffic injury and disadvantage, and also what we need to know. It begins by outlining how deprivation is measured and the problems this presents; it goes on to describe in detail the links between deprivation and road traffic injury. It outlines those interventions that have been shown to be effective in reducing pedestrian injuries and discusses the topics that need to be addressed by future research. The paper concludes by summarising the key messages and makes recommendations for an integrated approach.

Policy context

Acheson's (1998) *Independent Inquiry into Inequalities in Health* identified a range of policy areas for future development that included mobility, transport and pollution. In England, the White Paper, *Saving Lives: Our Healthier Nation* (Department of Health, 1999), included injuries as a priority area and children as a key target group. It acknowledged the importance of social, economic and environmental factors in poor health, and focused on the need to improve the health of the worst-off in society. The Accidental Injury Task Force (set up as a recommendation of the White Paper) listed social disadvantage as a criterion in the selection of priority injury areas, which includes pedestrian injuries in childhood (Department of Health, 2002).

In 2000, a new transport planning system, the Local Transport Plan (LTP), was introduced, which attempts a more integrated approach to transport planning, inclusiveness and consultation, and increasing emphasis on performance management (Department of Transport Environment and the Regions, 2000a). Local authorities' LTPs were required to include a road safety strategy that would contribute to the targets outlined in *Tomorrow's Roads – Safer for Everyone* (Department of the Environment, Transport and the Regions, 2000b). This document sets out targets to reduce the number of people killed or seriously injured in Great Britain, as a result of road traffic accidents, by 40% and the number of children killed or seriously injured by 50% (for the year 2010 compared with a baseline from 1994 to 1998). The Government's Spending Review of 2002 strengthened the universal road safety target by 'tackling the significantly higher incidence in disadvantaged communities' (HM Treasury, 2002). The second review of the road safety strategy was published in 2007 (Department for Transport, 2007a), which reported on progress against the targets and identified key areas, including children, drivers, speed and environmental initiatives. A separate Child Road Safety Strategy has also been launched in 2007 (Department for Transport, 2007b).

The Road Safety Strategy for Wales (Welsh Assembly Government, 2003) recognises that, despite an overall improvement in the total number of road traffic accident casualties since the 1980s, Wales still has a high proportion of child pedestrian casualties. It also recognises the link with poverty and sets targets to reduce the numbers both of major and minor injuries. The Strategy promotes initiatives to encourage walking and cycling, local speed management strategies, 20 mph zones, safe routes to school, and educational programmes for pedestrians, cyclists and drivers.

Falling levels of physical activity and rising obesity rates within our populations have prompted the development of strategies to promote walking and cycling in England and Wales (Department for Transport, 2004; Welsh Assembly Government, 2003). These strategies complement other sustainable transport strategies, all of which potentially influence road safety. It is important to recognise this relationship and ensure that road safety policies are not developed in isolation, but, rather, adopt an integrated approach to taking the combined agendas forward.

Road traffic injuries and deprivation – what we know

Measuring deprivation

The following terms are often used synonymously, but have specific meaning in the context of measuring deprivation and therefore need to be defined:

- **Inequalities** describe the differences between groups;
- **Disadvantage** indicates either a relative or absolute lack of benefit;
- **Material deprivation** is a lack of required amenities.

In order to measure the effect of inequalities, it is necessary to classify individuals based on the level of deprivation they experience. This can be done in two ways: either at the individual level or by area of residence. Both approaches have their strengths and weaknesses, and these are discussed below.

Individual indices of deprivation

Analyses that **accurately** code each individual's socio-economic standing will provide the most robust research results. The Office for National Statistics (ONS) has developed an individual classification, based on occupation, which has been in use since 2001, called the National Statistics Socio-economic Classification (NS-SeC) (National Statistics, 2005). This system has replaced the older Social Class (or Registrar General's Social Class) and Socio-Economic Group (SEG) classifications. It is designed to cover the whole adult population (aged 16 to retirement age), including those who do not work, and aims to differentiate individuals based on their typical 'employment relations'. It does not include full-time students or those who cannot be allocated to a group, such as retired people (although many people in the 60–74 age group are not retired, so do have an NS-SeC code). Dependent children under the age of 16 are coded according to the household reference person (see below). The most commonly used version of NS-SeC has the following eight classes plus an unclassified group:

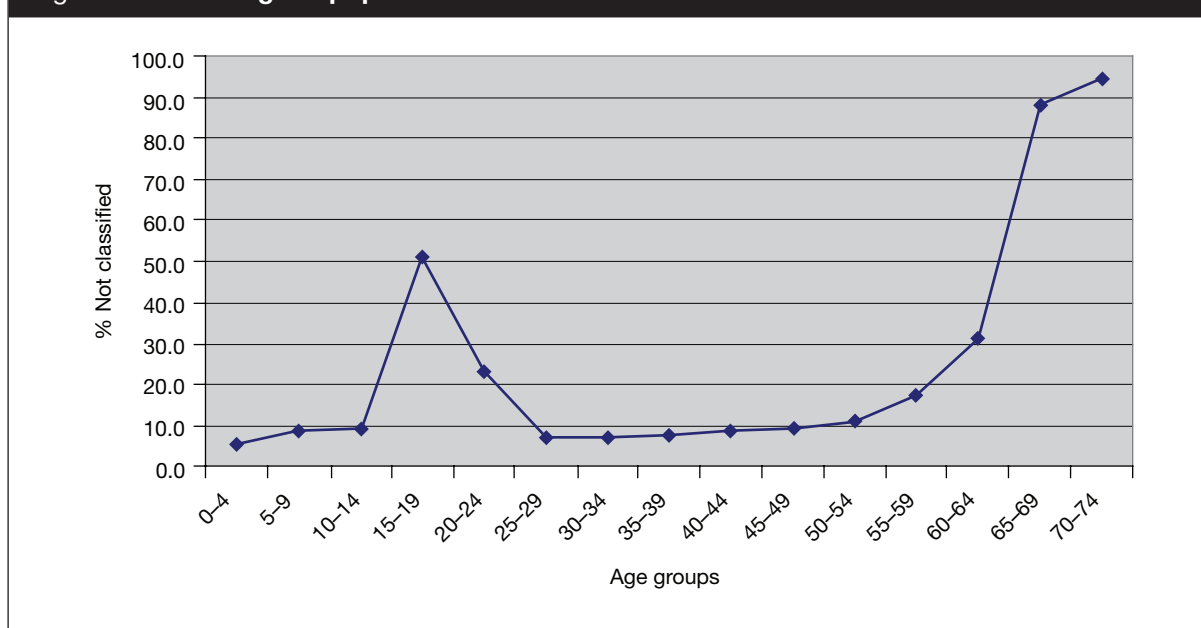
1. Higher managerial and professional occupations
 - 1.1. Large employers and higher managerial occupations
 - 1.2. Higher professional occupations
2. Lower managerial and professional occupations
3. Intermediate occupations
4. Small employers and own account workers

5. Lower supervisory and technical occupations
6. Semi-routine occupations
7. Routine occupations
8. Never worked or long-term unemployed

When a family unit or household is the unit of measurement, an influential member of that household is utilised to define the NS-SeC class. This person is termed the household reference person (HRP) and is defined as ‘the person responsible for owning or renting or who is otherwise responsible for the accommodation. In the case of joint householders, the person with the highest income takes precedence and becomes the HRP. Where incomes are equal, the oldest person is taken as the HRP’ (National Statistics, 2005).

The main problem with NS-SeC is that it is really only useful for working-age people, although the HRP can be used to classify children. For retired people in particular, the lack of current occupation may change their class and introduce bias. Figure 1 demonstrates this effect in the 2001 census, where the proportion of the population with missing and non-applicable data varied markedly with age group.

Figure 1 Percentage of population with no NS-SeC in the 2001 census



Death certification provides a more accurate way of classifying individuals, as details of previous occupation are collected. There are discrepancies between the occupation recorded at death registration (and hence the mortality data) and the census data. This arises because there is nearly always sufficient information on the death certificates to classify people, but not always on the census, which is essentially a self-report of current occupation. This problem is most acute for women of all ages and men over the age of 65. However, mortality data are clearly only of value where death is the outcome under study.

Area-based indices of deprivation

In view of the problems with NS-SeC and the complexity of collecting such detailed information on individuals, area-based measures are often utilised. The geographical areas most commonly used are termed Lower Super Output Areas (LSOA) and Medium Super Output Areas (MSOA) or electoral wards (National Statistics, 2007). LSOAs have a mean population of 1,500, with a minimum of 1,000; MSOAs have a mean population of 7,200, with a minimum of 5,000. England has 32,482 LSOAs (Communities and Local Government, 2007). Electoral wards are used to elect councillors for local authorities in England and Wales. The size of an electoral ward varies. They are subject to changing boundaries by the Boundary Commission.

The four indices summarised below allow routine data to be used to describe levels of deprivation within a geographical area. They each identify indicators thought to be associated with deprivation, and then calculate the proportion of households or individuals within the area experiencing this factor. The separate indicators are then combined to produce an overall deprivation score, allowing areas to be ranked. Generally, the higher the score, the greater the levels of deprivation experienced. Deprivation scores can be calculated for geographical areas of any size. Although different area-based measures of deprivation have been used in the studies reported in this paper, it is highly likely that the patterns observed will remain even if a different deprivation scheme were used, since previous research has found a high degree of correlation between indices (Morris and Carstairs, 1991; Morgan and Baker, 2006)

INDEX OF MULTIPLE DEPRIVATION (IMD 2004)

The version of the index published in 2004 replaces the previous version published in 2000, using more up-to-date data sources and including new measures (Office of the Deputy Prime Minister, 2004). The index is compiled from seven domains, each of which is calculated from a range of different indicators. For example, the income deprivation domain collates data on indicators such as the proportion of adults and children in income support households and in income-based 'job seeker's allowance' households. The domains carry different weights (Table 1). Each LSOA in England has had its IMD 2004 score (and rank) calculated, along with the component scores of the seven domains and their sub-domains.

Table 1 IMD 2004 domains and domain weights

Domain	Domain weight (%)
Income deprivation	22.5
Employment deprivation	22.5
Health deprivation and disability	13.5
Education, skills and training deprivation	13.5
Barriers to housing and services	9.3
Living environment deprivation	9.3
Crime	9.3

Source: Office of the Deputy Prime Minister, 2004.

WELSH INDEX OF MULTIPLE DEPRIVATION (WIMD 2005)

WIMD 2005 is compiled from seven factors, of which income and employment are classed as the most important (Table 2) (Welsh Assembly Government, 2005). Again, each of the seven is based on a range of different indicators, which are combined to produce an overall score. WIMD 2005 is similar to IMD 2004, but the differences in indicators and weightings mean that the two are not equivalent.

Table 2 WIMD 2005 domains and domain weights

Domain	Domain weight (%)
Income deprivation	25
Employment deprivation	25
Health deprivation and disability	15
Education, skills and training deprivation	15
Geographical access to services	10
Housing deprivation	5
Physical environment deprivation	5

Source: Welsh Assembly Government, 2005.

TOWNSEND INDEX OF MATERIAL DEPRIVATION

The Townsend Index (Townsend *et al.*, 1988) is calculated using four variables (unemployment, overcrowding, non-car-ownership and non-home-ownership), which are equally weighted and can be derived from census data.

CARSTAIRS INDEX

The Carstairs Index (Carstairs and Morris, 1991) is also calculated using four variables that are available from the census (male unemployment rates, the proportion of households in social classes 4 and 5, car ownership and overcrowding (more than one person per room in private households)). The four variables are again given equal weight.

In the absence of accurate personal data, it is possible to use the score for an individual's area of residence as a proxy measure of socio-economic status. Methods that attribute aggregated area-based measures to individuals are termed **ecological** methods and provide a useful way to overcome situations where individual data are either missing or inaccurate. However, in any ecological study, one must always be mindful of a bias called the ecological fallacy.

The ecological fallacy

Any composite index produces an average score for a defined population; it will inevitably not accurately reflect the socio-economic position of each individual within that population. It is possible for false conclusions to be drawn if the people developing the outcome, under test, are systematically different from that average. For example, a study that shows there is no association between road traffic injury

and deprivation in 10 MSOAs would be untrue if only the more deprived people within the MSOAs suffered the injuries. In this case the average score has masked an association that would have been apparent had individual-level data been available. The opposite situation is also possible, where an association is found that does not exist in truth. Both are termed the **ecological fallacy** and should always be considered as a potential explanation. Larger samples make this type of bias less likely. Therefore, despite this caveat, ecological studies are a very useful tool and have provided much good evidence of the negative effects of deprivation. The studies presented in this paper use both individual and ecological methods.

Road traffic injuries and deprivation

VEHICLE OCCUPANT INJURY

About a quarter of households in Great Britain did not have access to a car in 2005, compared with nearly a third in 1995–97 (Department for Transport, 2005). This rise has been seen across all income fifths, including the lowest (disposable income of £100–200 per week). However, the distribution of access to a car is not equally spread across all income groups, with a clear relationship between income and car use, with just over half (53%) of people in the lowest income fifth having no car, compared with 10% in the highest fifth (£1000+ per week).

Linked to this is the amount people travel, where both income and access to a car strongly determine the number of trips a person makes and the distance they travel. People living in the most deprived areas make the fewest trips – about a quarter fewer per person than those in the least deprived – but they travel, on average, 60% fewer miles, reflecting this lower access to a car (Department for Transport, 2005). From the highest to lowest income fifth, the number of trips on foot and by bus increases. Trips by taxi and minicab are also highest in the lowest income fifth.

Access to a car is not the only determinant of how much people travel, because driving a car requires a licence, and evidence suggests that full licence holding among the young is in decline, with fewer young people (17–20 years), both male and female, holding a full licence in 2005 compared with 1995–97 (Department for Transport, 2005). The percentage has fallen for males from 50% to 37%, and for females from 36% to 27%. Over this same period (1995–97 to 2005), licence holding among men of all ages is about 81% and for women it is about 63%.

Various reasons have been suggested, such as it is more difficult to pass the driving test and, as more young people are now students, they cannot afford the cost of owning a car, which is high for the under-25s (Noble, 2005). The introduction of the Road Traffic (New Drivers) Act 1995, which came into force on 1 June 1997, meant that if new drivers accumulate six or more penalty points on their licence within the two-year probationary period immediately following passing their test, the licence will be revoked until a further driving test is passed. Partly as a result of this, and for the cost reasons noted above, there is some indication that there may be as many as 100,000 young people, predominantly males, who may be driving without a licence.

There is also evidence that young males from more disadvantaged backgrounds are less likely than their more affluent peers to have a full driving licence and are more likely to be driving unlicensed and/or uninsured. There is also evidence which

suggests that accidents of unlicensed drivers are more frequent and more severe (Knox *et al.*, 2003).

A recent operation by the Metropolitan Police targeted high levels of hit-and-run accidents in three London boroughs where these types of accident make up nearly a quarter of the total. The rise in hit-and-run accidents is thought to be related to levels of uninsured driving, with prevalence being greatest in areas of higher deprivation, such as the three boroughs being targeted. An analysis of the age of vehicles showed that almost half of the 1,894 seized vehicles were 7–12 years old, with the peak age being 10 years. The profile of those arrested was biased towards young male drivers (18–24 years). Of those with sufficient personal details to record gender, the ratio of males to females was 30:1.

An above average number of young drivers with less disposable income tend to drive older cars, and for many young drivers their first car is often a hand-me-down from another member of the family or a cheaper used car, usually smaller and/or older. About half of the cars on the road in 2005 were less than six years old, and just over a third were between 6 and 12 years old. About 15% of cars were older than 12 years (Society of Motor Manufacturers and Traders, 2006).

Analysis of the STATS19 data for the period 1997–2005 (which excludes events where the age of the car was unknown) indicates that, for fatally-injured male drivers aged 17–22 years, about 21% were driving cars over 13 years of age, compared with the average for men of all ages of about 17% (Ward *et al.*, 2007). About another 48% of young male driver deaths were in cars aged 7–12 years, compared with an average of about 43% for men of all ages. For fatally-injured young women, the corresponding percentages are 14% and 45%, which are both close to the averages for females of all ages for cars aged over 13 years and 7–12 years.

HOW ACCURATE A REFLECTION OF RISK IS STATS19 FOR THIS AGE GROUP?

There is some evidence that the actual number of young drivers injured, especially at night, might be higher than the STATS19 figures indicate. Several studies have demonstrated that young people are less likely to report their injuries to the police than other age groups. In a study of reporting rates to the police in Gloucester, the 20–24 year group only report 41% of their injuries to the police, compared with 52% for all ages. For vehicle occupants of all ages, the level of reporting was about 50% (Ward and Robertson, 2002), compared with 59% for all modes. On the other hand, older people tend to have higher than average reporting rates, at about 65%.

IS THE RISK OF FATAL INJURY EVENLY DISTRIBUTED ACROSS SOCIETY?

Research suggests that socio-economic status is an important factor in understanding those most at risk of road traffic injury (Christie, 1995; Lyons *et al.*, 2003; Towner *et al.*, 2004). There is a steep social-class gradient in child pedestrian fatalities, where children in the lowest class (parents who are long-term unemployed or never worked) are 20 times more likely to be killed than those in the highest social class (higher managerial and professional occupations) (Edwards *et al.*, 2006). Less is

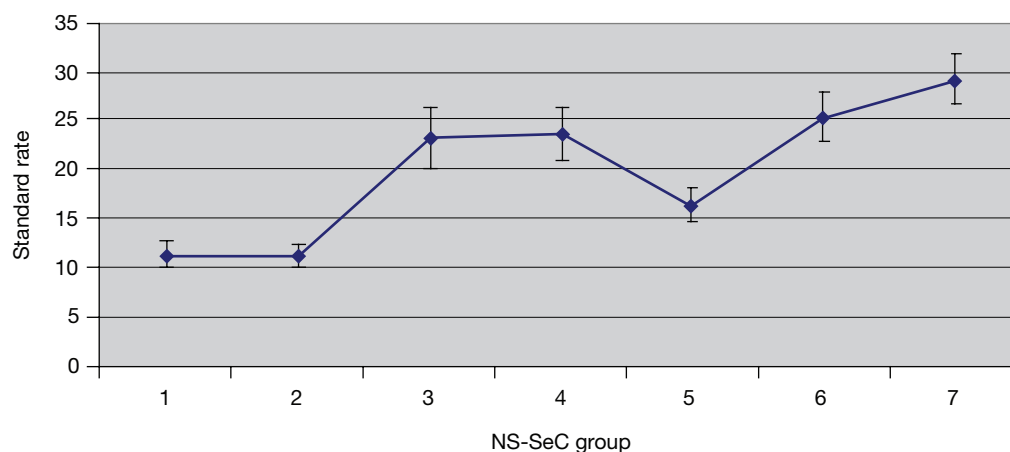
known about whether this gradient exists for all types of road user and for adults and children alike.

For vehicle occupants, factors that may enhance the survivability of road traffic accidents, such as newer cars and the use of appropriate restraints, may be less evident among the lowest socio-economic groups (Towner *et al.*, 2004). Therefore, understanding the socio-economic situation of injury can be beneficial in terms of targeting interventions.

For this analysis, the NS-SeC codes for people who had died in road traffic collisions in England and Wales were supplied by ONS. NS-SeC codes were present for all those aged 0–74 years. The denominator data were derived from the census.

The mismatch in proportions with an NS-SeC in census and mortality files is lower for men in occupations. NS-SeC Group 8 (never worked or long-term unemployed) and those under 20 years who are students are known to have particular problems. Thus, for the purposes of this analysis, mortality and census data were used for men aged 20–64 who could be categorised into Groups 1–7.

Figure 2 Standard mortality rates and 95% confidence intervals per 100,000 population by NS-SeC group for male car occupants aged 20–64, England and Wales 2001–04



Source: Ward *et al.*, 2007.

Given the caveats of a higher proportion of occupations being registered at death and being assigned to an NS-SeC group than in the general population, analysis of the ONS data shows that:

- about 40% of the population that can be categorised are in the top two social groups (1 and 2 – higher and lower managerial and professional occupations), but account for 22% of the classifiable road traffic fatalities;
- 13% of the population that can be categorised fall into NS-SeC Group 7 (routine occupations), but they account for 20% of the fatalities; and
- those with more intermediate, technical or semi-routine occupations have about the number of fatalities expected given the population size.

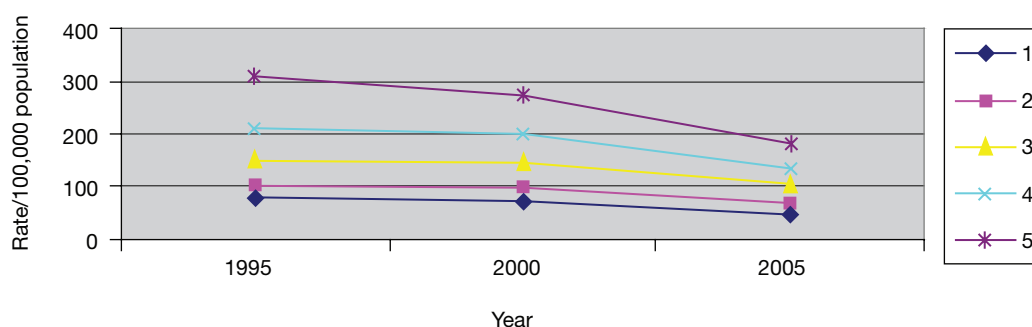
For male car occupants aged 20–64 years, there appears to be a socio-economic gradient in deaths between NS-SeC Groups 1–2 and Groups 3–7, and this is shown in Figure 2. Groups 1 and 2 have an age-standardised mortality rate of about 11 per 100,000 population and, on average, Groups 3–7 have a rate that is about double this.

The implication of this analysis of the mortality data indicates that those who are in Groups 1 and 2, who may be assumed to be in the top decile for income and to have higher car ownership and use, are less likely to be fatally injured than those in other occupations.

Pedestrian injury

Figure 3 displays the results of an analysis of trends in pedestrian injury in children aged 5–14 years of age in England by equal fifths of deprivation. In this case the fifths were divided on the basis of equal denominator populations. It is clear from this that, while rates in the most affluent groups have remained the same or fallen slightly, the rate reduction in the most deprived fifth is very marked (although the rate remains higher than the more affluent fifths).

Figure 3 Trends in pedestrian injuries (STATS19, all severities) in children aged 5–14 years of age in England by fifths of deprivation



Source: Townsend *et al.*, 1988.

There are several possible explanations to be considered for this apparent change:

1. There is less exposure to risk, possibly as a result of there being more cars and thus more journeys being driven, or that there is less walking generally, or a combination of both.
2. Environments are safer because of increasing traffic-calming interventions.
3. That there is less risk-taking because of better road safety education and training (such as Kerbcraft).
4. There is less risk per unit exposure because of lower speeds.

There is insufficient evidence to identify which of these is most important, and this is therefore a subject which requires further investigation.

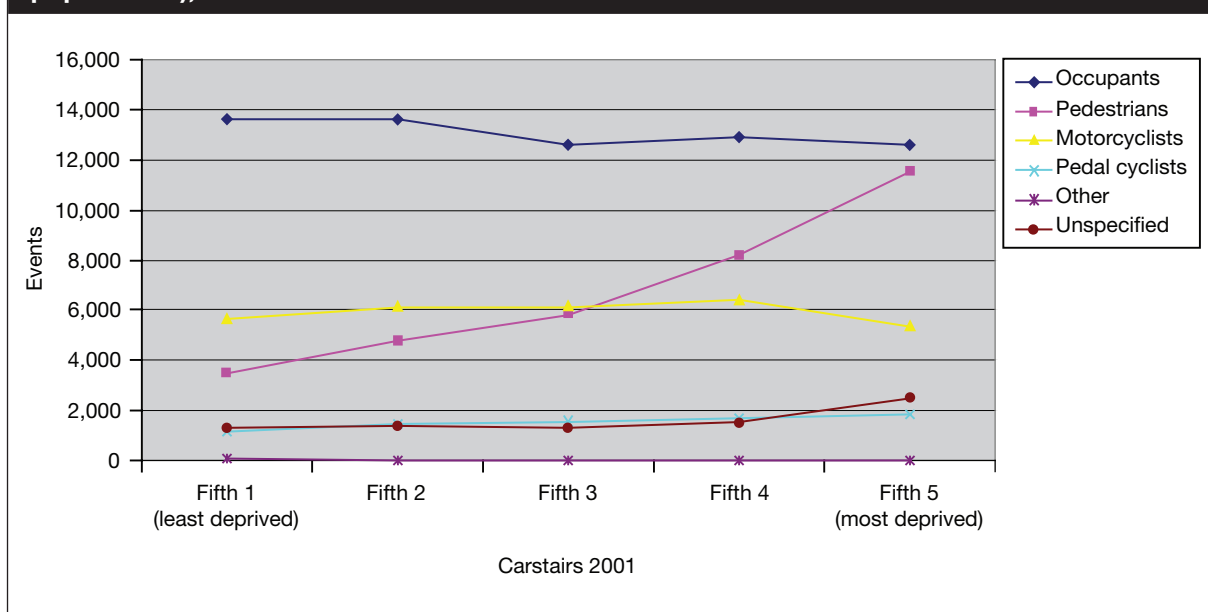
Relationship between hospital admission and road traffic casualties by deprivation

The use of available hospital inpatient data can also help to provide insights into the nature and distribution of injuries sustained in road traffic accidents. It also allows investigation by fifths of deprivation by converting the residential address to a Carstairs score and then allocating to a fifth of deprivation.

It is important to recognise that, since the deprivation profile of the three home nations is different, the deprivation levels represented by the fifths are different in each figure. It is therefore not possible to compare directly the casualty rates among the countries in Figures 4–6. Hence the interpretation focuses on a description of trends.

Hospital inpatient statistics are collected by hospitals and compiled separately for England, Wales and Scotland. Figures 4–6 show hospital admission by deprivation fifth by road user class for England, Scotland and Wales. In each case it can be clearly seen that admissions to hospital for injuries sustained as a pedestrian rise sharply with deprivation fifth. A similar gradient for pedal-cycle casualties is also apparent but much shallower, possibly due to low levels of bicycle ownership in less affluent areas. The gradient for motorcyclists is interesting. In England it is fairly flat, then dips for those in the most deprived fifth; whereas in Scotland, the gradient, while shallow, decreases towards the most deprived. In contrast, there is a tendency for the small number of motorcyclists admitted to hospital in Wales to rise with increasing deprivation.

Figure 4 Road traffic casualties – England (hospital admissions) by deprivation fifth (equal populations), 1999–2003



The gradient in admissions for vehicle occupants in England indicates a slowly-declining trend across the deprivation fifths, while for Wales and Scotland it is more pronounced, with admissions highest in the second least deprived fifth.

Unfortunately, National Travel Survey data are not published by deprivation fifths to determine whether the gradients for vehicle occupant admissions are consistent with the amount of travel by people in the different fifths. The apparently low rate in the most deprived fifths could be consistent with an elevated risk when exposure is taken into account.

Figure 5 Road traffic casualties – Scotland (hospital admissions) by deprivation fifth (equal populations), 1999–2003

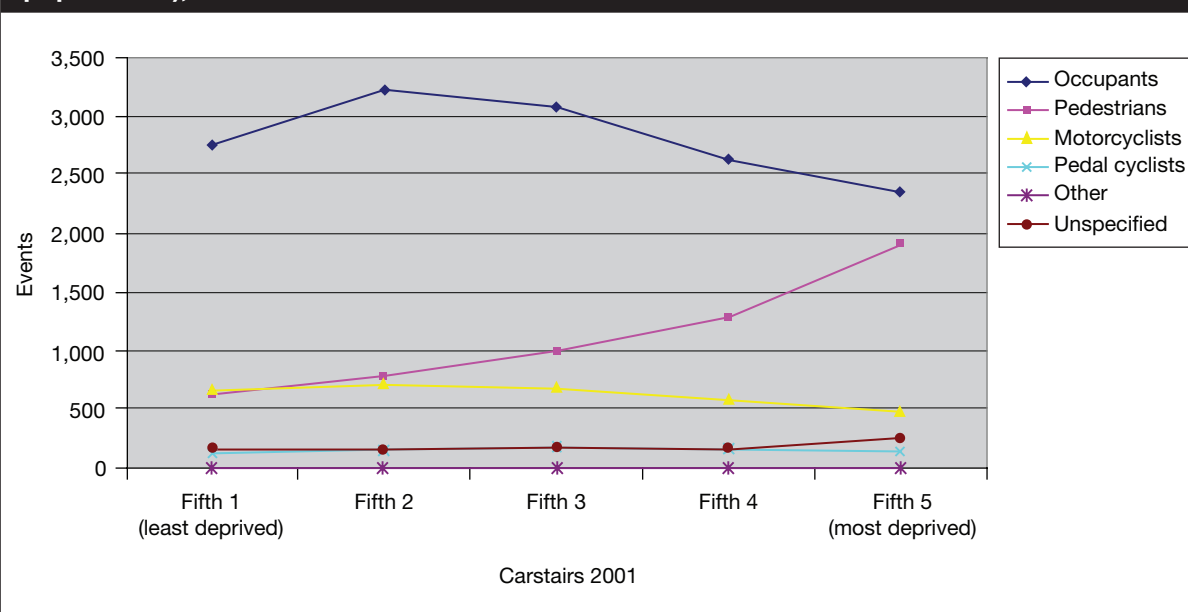
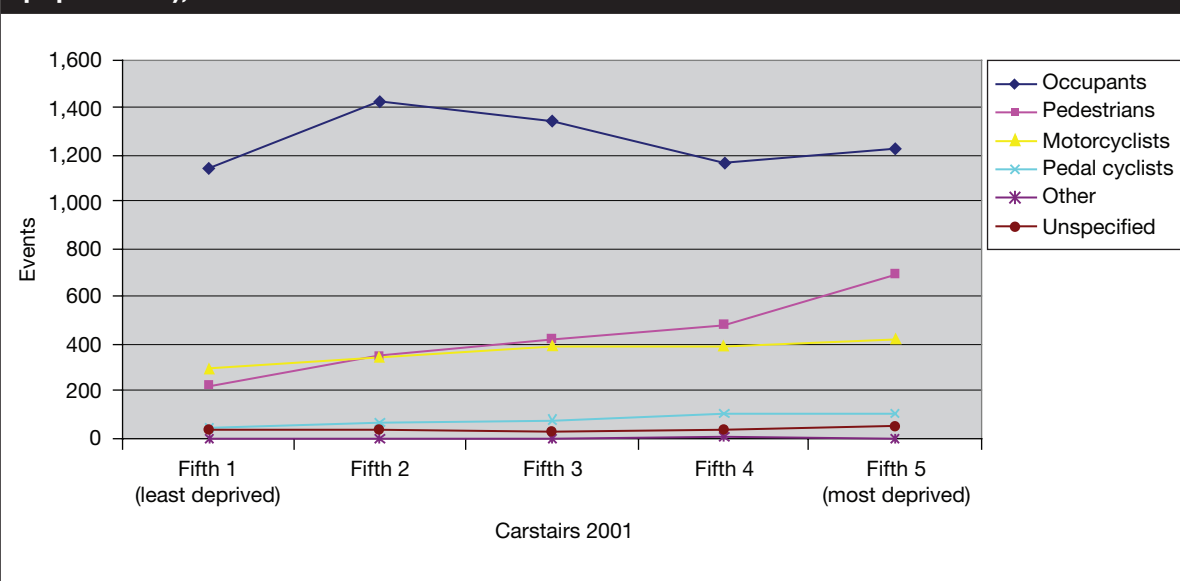


Figure 6 Road traffic casualties – Wales (hospital admissions) by deprivation fifth (equal populations), 1999–2003



Figures 4–6 therefore show that, other than for pedestrian injury, the relationship between injuries resulting from most categories of road use and deprivation is fairly flat. They would seem to suggest that deprivation has little influence. However, this interpretation ignores the potentially important effect of exposure and assumes that people in each fifth participate in cycling, walking, travelling by car, etc., to the same degree. It follows, therefore, that the three key factors in any road traffic accident, namely the person, the car and the environment, are equally safe in all areas. Our previous discussion has highlighted that this is not true. Generally, data on exposure/participation are not available to be able to estimate the effect of differing exposure. It is therefore possible that the apparent flat relationships above may, in fact, disguise inequalities linked to deprivation. More detailed investigation into the influence of differing exposures is a priority for future research.

Effective interventions

Injury-prevention professionals often discuss intervention strategies in terms of the ‘three Es’ – **engineering**, **education** and **enforcement**. Engineering strategies involve changing the environment (e.g. separated walking paths, junction design). Educational strategies focus on changing individual behaviour (e.g. pedestrian training, speed-reduction campaigns), influencing policy through advocacy (e.g. campaigns highlighting the extent of the problem and possible solutions) and changing social attitudes (e.g. campaigns targeted at increasing willingness for environmental change). Enforcement strategies rely on changing laws and imposing fines to control behaviour (e.g. school speed zones, seat-belt legislation, speed cameras).

The following points summarise the current state of knowledge for effective interventions in reducing pedestrian injuries:

- The most effective child pedestrian safety education programmes tend to include (Klassen *et al.*, 2000; Schieber and Vegaga, 2002):
 - practical, interactive training in the (real or simulated) road environment; and
 - parental involvement.
- Some promising education programmes exist that incorporate these elements, such as ‘Kerbcraft’, which is a practical-based road training scheme for primary schools. However, few such education programmes, including Kerbcraft, are evaluated with respect to injury reduction outcomes.
- Education campaigns targeted at older adults should include the following information (Dunbar *et al.*, 2004):
 - information about age-related functional declines and how they impact on pedestrian behaviour;
 - advice on the importance of regular checks on perceptual, cognitive and motor abilities (e.g. vision and hearing);
 - advice to use glasses and hearing aids;

- advice that compromising for functional declines may undermine the ability to respond quickly; and
 - information on the benefits of walking for health and the importance of physical well-being and mobility in pedestrian safety.
- Little is known about the effect of driver education on pedestrian injuries in disadvantaged areas, but research suggests the importance of targeting adult male drivers in these areas.
- Reductions of injuries through engineering measures, such as pedestrian priority walking routes and improved crossing facilities, speed humps and 20 mph speed zones, are effective and cost-beneficial, and have been shown to reduce inequalities.
- For older pedestrians, measures that simplify road-crossing tasks may be effective.
- Visibility aids improve the detection of pedestrians and shorten driver reaction times.
- Community-based interventions represent promising avenues for injury prevention. However, their effect on pedestrian injuries is unclear.
- The World Health Organization (WHO) Safe Community model has been implemented throughout the world with varying levels of success. The most successful programmes include a mixture of intervention types.
- Transport and safety policies have a crucial role to play in pedestrian safety, as is evident in countries with low rates of injury. These countries have speed-reduction measures, signalised crossings, outside play areas, national publicity campaigns on pedestrian safety, and legislation regarding driver responsibility.
- Public-transport policies have an enormous impact on mobility, particularly for children and the elderly.
- The more pedestrians and cyclists there are, the safer streets become for them.
- Safety and mobility must be considered simultaneously when developing policies.

Future research – what we need to know

Understanding the entire picture is always helpful. As has been described, we have detailed analyses of injury rates, but we need to put this in the context of understanding the exposure of different groups to the risk of injury. Substantial inequalities may be evident in vehicle occupant injuries by deprivation, for example, if differing exposures were taken into account. Future research should address this gap.

We also know little about the distribution of road safety interventions. Evidence exists for the effectiveness of interventions such as 20 mph zones, traffic calming and road safety education. However, we do not have an accurate picture of where these interventions have been deployed within our communities and are thus missing an opportunity to evaluate their effect, particularly in relation to deprivation.

Detailed mathematical modelling is necessary to better understand levels of exposure. No traffic models are available for residential and mixed-use areas, and neither are there any real pedestrian models. It is possible to produce integrated models using data from multiple existing sources, and these sources should be utilised. Furthermore, data can be specifically collected on the movement of people and traffic at selected locations to refine the analysis. Large-scale computing will be required to conduct the detailed analysis.

At the strategic level, we know that there is a relationship between road safety, transport/land planning use and other health-related strategies. Recent policies in all the home nations emphasise the need to increase levels of walking and cycling, and the links with road safety must be recognised.

Conclusions

This paper has discussed what is known about the relationship between road traffic injury and disadvantage. Despite the methodological problems in researching links with deprivation, there is good evidence for the existence of inequalities connected with deprivation. In particular, child pedestrian injuries are diminishing but are still substantial. It is not clear whether this reduction is due to the effects of education, training and publicity or to engineering solutions. Differing exposures may also be critical. Future investigation should concentrate on the relative and absolute contribution of each of these three factors for all types of road traffic injury.

We know which interventions are effective in reducing road traffic injury, but we know little about where they are within our communities. There is a huge gap in our knowledge about the social distribution of these expensive interventions.

Finally, integrated traffic and pedestrian activity models would be extremely useful in understanding road safety and effective injury prevention. However, answering these questions is important not only to refine future prevention strategies for road safety, but also to improve strategic interventions in transport/land planning and health improvement.

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6

Traffic injury risks for children in deprived areas: a qualitative study of parents' views

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Abstract

The objective of the research was to gain an in-depth qualitative understanding of parents' views about their children's exposure to road traffic injury risk in disadvantaged areas in order to inform intervention development as part of the Neighbourhood Road Safety Initiative. The study involved focus groups facilitated by a moderator with thematic content analysis of data. Focus groups were conducted in 11 of the most deprived local authorities in England, which also have the highest child pedestrian injury rates. Research was carried out in community venues within each deprived area. The participants were parents of children aged 9–14 living in disadvantaged areas. The findings showed that parents felt the main reasons that led children to play in the streets were:

- children liked playing out with their friends near home;
- a lack of accessible parks that are well maintained, with good facilities, and which are safe and secure for children;
- a lack of accessible, affordable clubs; and
- a lack of parental responsibility.

Parents felt that the main risks for children playing in the street were:

- illegal riding and driving, especially around estates and on the pavements;
- the speed and volume of traffic;
- illegal parking
- drivers being poorly informed about where children play; and
- children's risk-taking behaviour.

The study concludes that intervention programmes need to consider holistically how living in disadvantaged areas increases road traffic injury risks for children by considering the wider determinants of exposure to risk. Multi-agency partnerships involving the community are needed, utilising traditional road safety approaches, such as education, engineering and enforcement, alongside the provision of safe, accessible facilities in terms of public space, activities for children and greater support for parents.

Introduction

In the UK children from the lowest social class are more likely to be killed on the roads as pedestrians compared to their peers from the highest social class, a persistent relationship that has been observed for over 20 years (Black *et al.*, 1980; Edwards *et al.*, 2006).

UK studies have shown a link between area-based or ecological measures of social deprivation and child pedestrian injuries recorded on police casualty data, fatality data and hospital admission data (Kendrick, 1993; Graham *et al.*, 2005; Sharples *et al.*, 1990; Hippisley-Cox *et al.*, 2002). This association has also been reported in other countries. Research in Sweden has linked occupational class data of children's parents from the census with the hospital discharge register via personal identification number and showed a socio-economic gradient for lower occupational classes, such as self-employed and farmers, compared with intermediate and high-level salaried employees for road traffic injury (Hasselberg *et al.*, 2001; Laflamme and Engstrom, 2002). Similar gradients have been shown in Germany and the USA (Rivara and Barber, 1985).

In 2004 the Neighbourhood Road Safety Initiative (NRSI) was set up by the UK Department for Transport as part of the Government's road safety target to take into account the significantly higher incidence of road traffic injury in disadvantaged communities (www.nrsi.org.uk/). The NRSI involved 15 of the most deprived local authorities in England with the highest child pedestrian accident rates nationally. Deprivation was defined as those local authorities that are the most disadvantaged nationally against any of the seven domains of the Indices of Deprivation (2004):

- income;
- employment;

- health and disability;
- education skills and training;
- barriers to housing and services;
- crime;
- and the living environment.

The Department for Transport identified these local authorities by ranking them in terms of their child pedestrian casualty rate per 1,000 population and correlating this with the indices of deprivation. These local authorities were asked to bid for funding to address the link between deprivation and child traffic injury in their area. In the commissioning criteria the Department for Transport encouraged local authorities to adopt holistic approaches to casualty reduction, treating the root cause rather than symptom, including a variety of solutions such as engineering, education, enforcement and health promotion activities, and working together with a range of local stakeholders to share experience and expertise.

One of the reasons disadvantaged children are more likely to be injured as pedestrians is because they live in more hazardous road environments (Christie 1995a; Towner *et al.*, 2004; Ward *et al.*, 1994; Sharples *et al.*, 1990). These areas are older residential areas built before mass car-ownership and are characterised by long straight roads, which give rise to high vehicle speeds and which tend to have considerable on-street parking because there are few facilities for off-road parking. These areas were built before 1960, after which road safety became an integral part of the housing development guidance. Disadvantaged children are also more likely to spend time in the road environment playing while unsupervised or hanging out, and are much less likely to go to clubs after school compared with their more advantaged counterparts (Christie, 1995b).

Parents have a key responsibility for keeping children safe, but children also need some independent mobility at an appropriate age in order to develop social networks and learn about the external environment through interacting with it (Bjorklid, 1992; The Children's Society, 2007). This research was commissioned by the Department for Transport to provide information about parents' perceptions of the risks for children in the neighbourhood, how parents feel about children's exposure to risk while having independent mobility playing or hanging out in the street, and the accessibility of alternatives such as parks and clubs. The information was needed to inform intervention development for the NRSI.

Method

The aim was to conduct focus groups with parents of school children who live in deprived areas participating in the NRSI. The recruitment criteria were that the parents lived within an NRSI area and had children aged 9–14. This age group is at high risk of pedestrian injury because of increasing independent mobility in the road environment and a range of developmental, behavioural and social factors

(Department for Transport, 2007). A participant information sheet and consent form were used to recruit parents. The consent form also sought agreement for the proceedings to be taped. Parents were recruited through a variety of means – through residents associations, via liaison with schools and through other community-based initiatives, such as regeneration projects. The participants were paid a cash incentive. Each group engaged 8–10 participants. A topic guide was developed that sought to elicit discussion on parents' perceptions of the risks for children in the neighbourhood, how parents feel about children's exposure to risk while playing out in the street and the accessibility of alternatives such as parks and clubs.

Trained facilitators conducted the focus groups using the topic guide. All focus groups were taped and transcribed, and emergent themes were identified using thematic content analysis (Krippendorff, 2004). Transcripts of the data were read and re-read to identify themes. From a review of the first few transcripts, a coding frame was developed to classify the data into themes. Constant comparison was made between data in order to classify subsequent data under the existing codes or develop new codes. These themes were then examined to explore relationships between them.

Results

Sample characteristics

Focus groups were planned in all 15 deprived areas, in order to be inclusive of all areas, but only 11 were achieved, and these included some ethnically-diverse populations. The focus groups were carried out in the North West of England and the Midlands. On average there were eight participants per group and over 90% were female parents. One group was conducted exclusively among Sikh and Muslim women, and one group among parents where at least one child had special needs.

Key findings

The key themes are illustrated with anonymous quotes from different participants.

Hazards caused by drivers and riders

One of the key themes that emerged was that the streets were perceived to be unsafe for children because of the reckless behaviour of young people illegally joy-riding around the estates in cars, scooters and mini-motorbikes. This behaviour was thought to pose a risk for children on the streets and to be highly risky for the drivers and riders themselves:

'You are not even safe to walk on the paths now because of the bikes and scooters, they cannot go on the road because they are not allowed, so they go on the path.'

'Lads around my way are getting away with murder, no tax, no insurance, no helmets.'

'They are joy riders, cars get abandoned and set on fire more often now, there was one just weekend before.'

Parents were also concerned that there was a lot of illegal parking in their area, especially near schools, which posed a big risk for children:

'We need a traffic warden, a policeman ... if we were in a city centre we would get one because the schools are on main roads, but because we are in the middle of a council estate, we don't get it, they put money in other things.'

The speed and volume of traffic were also regarded as a hazard, especially on journeys from home to the shops. Drivers were regarded as poorly informed about where children play, and parents felt that there was a lack of 'children at play' signs.

Lack of parental responsibility

Parents also felt that many other parents in the area where they lived did not take responsibility for their children's safety. Many parents commented that younger children were often left in the care of older children for long periods of time:

'Where I live little kids, seven-year-olds, are still out at 10 o'clock at night.'

Some parents were perceived as being more interested in drinking alcohol than supervising their children.

Risk taking by children

Children as pedal cyclists and pedestrians were also thought to take risks:

'They ride down the middle of the road on their bikes, pull out in front of the cars, and play chicken on the main road with their bikes. Children are forever racing each others on their bikes. Both boys and girls, and younger ones who are not allowed off the street; they will start at the top, there could be five or six of them, cars are parked both sides, and they shoot down to the bottom.'

'As a driver, young people, especially when they hit their mid-teens, have an arrogance about them ... they challenge you by walking slowly and you might not have seen them and I think "if you want me to kill you fine, stand up against my car then", they are ridiculous, they play with you as drivers, it is really stupid.'

Lack of activities and facilities

Parents felt that children played out in the street because there was little else for them to do. Parents did not like them playing on the streets, though the advantages were that they were close by and the children enjoyed it.

Parents felt that children would like to go to clubs more than play in the street, but clubs were expensive and inaccessible. There were mixed views on the provision of club facilities in the local areas, and some parents felt that there was nothing on offer while others felt that there were activities but parents were not aware of them or were expected to be told about them.

Parents also felt that there were few safe areas, such as parks, for children. Parks were regarded as inaccessible and at times unsafe. Parents' main concerns about safety in parks related to gangs, bullies and stranger danger, as well as the environmental threat caused by dogs, alcohol and drug abuse, especially discarded syringes that were littered throughout the neighbourhood:

'I counted 20 syringes on the way round to the shop.'

Parents' views on solutions

Parents felt that the streets could be improved through engineering and enforcement, although there was mixed reactions to traffic-calming measures. Some felt that traffic calming should be implemented in their area, but others felt that drivers circumvented the safety value of speed humps:

'It's the same all over [the area], if they get the car they are not bothered where they will drive it. You put speed bumps up, but it doesn't stop them because they just fly over it.'

'Even though there are speed bumps they just launch themselves at them.'

It was also felt that the police could play a much more active role in their neighbourhood. They were perceived as spending too much time in cars rather than integrating with the community:

'I think more police in schools would be more educational for the kids, get them to know the dangers, get them to know dangers with cars, stranger danger, the whole thing. So the policemen are more familiar, and not hiding in cars.'

Parents felt that parks could be improved by making them safe and secure by having wardens, fencing, improved and better maintained facilities, and to be more accessible through better crossings and lighting.

It was felt that activities for children after school needed to involve the community, be better publicised, cheap and accessible, especially for older children. Parents felt that both they and their children needed to be involved in helping with activities and in deciding what activities children would like to do. Parents felt that children would like to walk and cycle more but would like more crossings, better cycle paths (that do not stop abruptly) and better street lighting. There was some concern about bicycle theft. They would also like better public transport, with routes to where children want to go, more frequent and reliable buses, cheaper fares and seat belts.

Discussion

This research was conducted in highly-deprived areas where road-traffic injury causes one of the greatest health inequalities (Edwards *et al.*, 2006). Previous research has suggested that children in disadvantaged areas are the most likely to get injured when they play out in the streets in hazardous environments (Christie 1995b; Sharples *et al.*, 1990). This study obtained the views of parents about factors that lead children to play out in the streets, the risks they face and what strategies may reduce children's exposure to risk.

A strength of this study is that it has sought the views of parents living in highly-deprived areas using a qualitative methodology to explore in-depth how they feel about their children's safety in the local neighbourhood. The study has identified parent's views about the immediate traffic hazards that children face and also why they are exposed to these risks in the first place. A weakness is that the parents who agreed to participate may be those who are more responsible or keen to provide a viewpoint, and therefore the findings may not represent the views of other types of parent in the area.

The picture that emerges is that parents feel that children play in the street because there is little else to do, with clubs' activities being perceived as scarce, expensive and inaccessible. Streets were regarded as dangerous because of joy-riding, the inappropriate riding of motorised bikes on the pavements, the speed and volume of traffic and illegal parking. Children's risk-taking and poor parental supervision were also regarded as increasing exposure to risk. Parents felt that there were not enough parks for children to play and those that did exist had limited facilities, were poorly maintained and an arena for gangs, dogs, drug and alcohol abuse, and concomitant litter. Moreover, parents felt that their children would prefer access to facilities and affordable activities than play out on the street, although they acknowledged that children liked to play out near their home with their friends. It was felt that police enforcement was limited and there were mixed views of the effectiveness of speed-reduction measures.

This research suggests that there are multiple factors that lead children to play in the street and, once there, increase their exposure to the risk of injury. Factors that lead children to play in the streets included:

- children liked playing out with their friends near home;
- a lack of accessible parks that are well maintained, with good facilities, and which are safe and secure for children;
- a lack of accessible, affordable clubs; and
- a lack of parental responsibility.

For children that play in the street, the key sources of risk identified by parents were:

- illegal riding and driving, especially around estates and on the pavements;

- the speed and volume of traffic;
- illegal parking;
- drivers being poorly informed about where children play; and
- children's risk-taking behaviour.

This study suggests that, for children living in deprived areas, intervention programmes need to consider not just the immediate risks in the traffic environment but also the factors that lead children to play out in the streets in the first place. Therefore, key intervention partners are not just road engineers – they are youth services, in order to provide more accessible and affordable activities for children, and those with responsibility for parks and recreational activities. The health and social services may also be needed to provide educational awareness and support to parents who are not adequately supervising their children. The police, traffic wardens and those involved in community safety also need to ensure that traffic law is enforced and that the community feels safe in other public spaces and is not threatened by the anti-social behaviour of those involved in alcohol or drug abuse. It is also clear that parents felt that they and their children would like to be partners involved in creating better facilities for young people.

Road-traffic injury among children causes one of the greatest health inequalities. Intervention programmes need to consider how living in disadvantaged areas increases risks for children by considering both why children are exposed to high-risk traffic environments and the risks they face when exposed.

Looking at the wider determinants of risk for children as vulnerable road users in deprived areas indicates that intervention approaches need to consider not just traditional road safety approaches of education, engineering and enforcement, but also the provision of safe, accessible facilities in terms of public space, activities for children and greater support for parents.

Injury prevention programmes in disadvantaged areas need to adopt a partnership approach among those responsible for health and social support, youth services, community safety, parks and facilities, enforcement and the community.

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7

Car drivers' attitudes towards motorcyclists and their relationship to accidents

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Abstract

Motorcyclists are over-represented in the accident statistics. Analysis of accident causes, however, has found that in two of the three most common accidents, the primary responsibility lies with a car driver who collides with a motorcycle. It is possible that attitudes, knowledge and self-reported visual skills may help identify certain car drivers who have a high risk of collision with a motorcycle. To assess car drivers' attitudes towards motorcyclists, a questionnaire containing 26 general and motorcycle-related items and the 24 items of the reduced Driver Behaviour Questionnaire was distributed. A total of 1,355 respondents were split into four groups based on driving experience. Compared with the experienced dual driver group (10 years' experience of both cars and motorcycles), all other drivers showed divergent attitudes and self-reported skills, some of which had a relationship with self-reported accidents.

Introduction

Fatalities resulting from a motorcycle accident accounted for 18% of transport-related deaths in 2005 despite making up less than 2% of all licensed vehicles (Department for Transport, 2006). This high level of over-representation has attracted recent efforts to isolate the causes that lie behind the statistics. One such study was conducted by Clarke *et al.* (2004). From an in-depth analysis of police accident reports they identified three main causes of motorcycle accidents. The most prevalent scenario was a right of way violation (ROWV) typified by a car driver pulling out from a side road into a main carriageway, violating the right of way of an approaching motorcycle. Typically such car drivers report that they 'looked but

failed to see' (LBFTS) the approaching motorcycle, though it has been acknowledged that this response might be seen by the car driver to mitigate their responsibility more so than admitting to failing to look, or perhaps having looked and seen the motorcycle, then misjudging the level of risk and making the manoeuvre regardless (Brown, 2002). The second most common accident scenario was the loss of control on a bend, where the motorcyclist misjudges the appropriate speed. The third key accident scenario has been classed as motorcycle manoeuvrability (MM) accidents, which occur when a car driver fails to consider the increased manoeuvrability of motorcycles compared to cars. For instance, if a car driver decides to turn off the main carriageway into a side road on the right, perhaps to avoid congestion, failure to appreciate that a motorcyclist might be filtering through the slow-moving traffic could lead to an accident. Similar classifications of accidents have been found in other countries (Hurt *et al.*, 1981; Haworth *et al.*, 2005). The ROWV accidents and the MM accidents both involve other vehicles, and in many cases the other driver is usually held to be primarily responsible. On this basis one must ask: What is it about these car drivers that leads to such accidents?

It has been found that the likelihood of car drivers being involved in such car-motorcycle accidents is partly dependent on experience with, and exposure to, motorcycles. There is evidence that dual drivers (those who drive cars and ride motorcycles) are less likely to be involved in car-motorcycle accidents (Magazzù *et al.*, 2006), and this even extends to car drivers who merely have friends or relatives who ride motorcycles (Brooks and Guppy, 1990). Experience and exposure to motorcycles must therefore affect the way that these car drivers interact with motorcycles on the road. These influences may lower thresholds for detection, increase motivation for visual search, and may raise the awareness of the drivers to the possibility that motorcycles may appear from previously unexpected quarters. All of these influences, we argue, impact upon the driver's schema for dealing with motorcycles. Schemata are the rules or guidelines that we use to guide us through specific situations, such as our understanding of how to conduct a transaction at a petrol station or how to deal with complex junctions. Similarly we have a schema in regard to our interactions with motorcycles on the road (where can they appear from, how fast are they likely to be travelling, what sort of person rides a motorcycle, etc.). We suggest that drivers who are more likely to be involved in a car-motorcycle accident are likely to have sub-optimum schemata for dealing with motorcycles. This, of course, requires a definition of an 'optimum' schema, which would be hard to achieve in absolute terms. Instead we have assumed that the lower accident liability of dual drivers in relation to car-motorcycle accidents is indicative of improved schemata compared with other drivers.

The second problem is how to assess the schemata of these drivers. To this end we devised a questionnaire with 24 items designed to probe the attitudes, knowledge and self-reported skills of car drivers in relation to motorcyclists. In addition, we included the 24 items of the reduced Driver Behaviour Questionnaire (DBQ; Parker *et al.*, 1995a) to assess self-reported errors, lapses and violations, and we also asked participants to report any accidents and near-accidents they had been involved in over the previous year. We predicted that drivers of varying levels of experience would hold different attitudes and beliefs towards motorcyclists compared with the dual drivers, and that these might relate to their self-reported accidents.

This paper focuses on the relationship between the questionnaire responses and self-reported accidents. An overview of the analyses that compared items across groups is also given, though a more detailed account of these results has been reported by Crundall *et al.* (under review).

Method

Participants

Of 1,355 responses (21% printed, 79% online), 1,314 respondents were divided into four groups:

1. drivers with under two years' experience since passing their driving test ($n = 77$);
2. drivers with between 2 and 10 years' experience ($n = 166$);
3. drivers with over 10 years' experience ($n = 561$); and
4. respondents who had over 10 years' experience of both driving a car and riding a motorcycle ($n = 507$).

Items

Demographic items included age, driving history, annual mileage and accidents. A second section contained 26 items in the forms of statements with a seven-point scale on which respondents could mark their level of agreement (see Table 1). Twenty-four of these items related to attitudes, knowledge and self-reported perceptual skills, with the remaining two assessing general attitudes ('I find driving a car is enjoyable and rewarding' and 'I perform all appropriate visual checks when driving or riding, e.g. mirror use, blind-spot checks, etc.'). A third section contained the 24 items of the DBQ and a final general item ('How often do you need to take evasive action (e.g. swerve or brake suddenly to avoid a collision/accident)?'), with the same answer scale as the DBQ items.

Results

The results section is divided into two subsections. The first reports an overview of the factor analysis on the items, and MANOVAs and ANOVAs that compared responses across the four driver groups. These results are dealt with briefly but are reported in greater detail in Crundall *et al.* (under review). The second section reports the relationship between item responses and self-reported accidents.

Factor analysis of items and comparisons across driver groups

The three DBQ scales were reliable with Cronbach's Alphas of 0.74, 0.77 and 0.77 for lapses, errors and violations, respectively. Women reported more lapses and men reported more violations. Drivers with between 2 and 10 years' driving experience reported the most violations. The two least experienced driver groups reported the most errors.

Fifteen of the 24 motorcycle items produced four factors, reflecting:

- (a) negative attitudes toward motorcyclists;
- (b) empathic attitudes toward motorcyclists;
- (c) awareness of perceptual problems; and
- (d) spatial understanding.

Table 1 Twenty-six items used in the questionnaire. Qs 1 and 2 are general items, while the remainder are motorcycle specific. Respondents marked their agreement with each statement on a seven-point scale, ranging from strongly disagree to strongly agree. Qs 24, 25 and 26 had different response options

Q1	'I do find driving a car is enjoyable and rewarding'
Q2	'I perform all appropriate visual checks when driving or riding, e.g. mirror use, blind-spot checks, etc.'
Q3	'When driving in interweaving streams of fast moving traffic, with many other drivers often changing lanes, I am constantly aware that motorcycles can be more difficult to spot than under normal driving conditions.'
Q4	'It is easier for motorcyclists to make sudden swerves to avoid an accident than car drivers.'
Q5	'Motorcyclists are allowed to "filter" past stationary or slow moving traffic.'
Q6	'It is difficult to estimate the speed of approaching motorcycles while waiting to turn at a junction onto a main carriageway.'
Q7	'I do (or expect that I would) find riding a motorcycle is enjoyable and rewarding.'
Q8	'When waiting to turn at a junction onto a main carriageway, I find that approaching motorcycles are as easy to spot as approaching cars.'
Q9	'When riding a motorcycle, taking risks is part of the thrill.'
Q10	'Motorcycles are as easy to see at night as cars.'
Q11	'Motorcyclists tend to have headlights on more often than car drivers in the daytime to increase visibility.'
Q12	'Other motorists should take extra care to look for motorcyclists.'
Q13	'The average motorcyclist takes greater precautions than the average car driver in wet weather conditions.'
Q14	'Motorcyclists often perform manoeuvres that are inappropriate.'
Q15	'When a car and a motorcycle collide it is typically the fault of the motorcyclist.'
Q16	'On the open road you can be suddenly be surprised by the appearance of a motorcycle coming from behind you.'
Q17	'Motorcycles are easily hidden from view by parked vehicles and other parts of the road environment, e.g. buildings or overgrown vegetation.'

continued

- Q18 'It is easier to pass the current motorcycle test than the current car driving test.'
- Q19 'I have similar personal characteristics to the average motorcyclist.' This is regardless of whether you actually ride a motorcycle yourself.
- Q20 'Motorcycles are usually easy to spot even against a "cluttered" background (containing road signs, adverts, etc.).'
- Q21 'It costs less to repair the average motorcycle after a minor accident, compared with an average car.'
- Q22 'Car drivers are typically more law-abiding than motorcyclists.'
- Q23 'When in slow moving traffic I am often surprised by motorcyclists filtering through the traffic.'
- Q24 Motorcycles should travel in which of the following positions within a lane? [Response options were letters A to G corresponding to a location on the image below]

PAVEMENT

GUTTER

A
B
C
D
E
F
G

?

CENTRE LINE

- Q25 When a motorcyclist overtakes a car at 40 mph what size of gap should be left between the car and the passing motorcycle in order to remain safe? [Response options ranged from 1–7 feet]
- Q26 What proportion of the width of a car does a motorcycle occupy? (e.g. 20% would indicate that a motorcycle was a fifth of the width of a car and 100% would mean it was the same width as the car) [Response options ranged from 10–70%]

Analyses performed on the negative attitudes toward motorcyclists suggested that all driver groups have higher negative attitudes compared with the dual drivers, and in some cases it is the drivers with between 2 and 10 years' experience who have the most negative attitudes towards motorcyclists. Analysis of the empathic attitudes revealed greatest empathy from the dual drivers, followed by those drivers with over 10 years of car-driving experience. Analysis of the perceptual problems suggested that females report greater problems with spotting motorcycles at junctions and estimating their speed. All driver groups with no experience of riding a motorcycle reported that motorcycles were difficult to spot at junctions. Finally, the analysis of spatial understanding scores suggested that females give larger estimates of the width of a motorcycle compared with males.

Non-factor items also produced some interesting results:

- dual drivers gave higher ratings for performing all appropriate visual checks when driving;
- the least experienced drivers believed it was easier for motorcyclists to make sudden swerves to avoid accidents compared with car drivers;

- dual drivers agreed more strongly than other drivers that motorcyclists take greater precautions in wet weather compared with car drivers;
- females gave higher ratings on a number of items relating to an inability to spot motorcycles;
- drivers without any motorcycle experience believed that the motorcycle should ride closer to the gutter compared with the responses given by the dual-driver group; and
- drivers without any motorcycle experience also agreed more strongly than the dual-driver group with the statement that motorcyclists often perform inappropriate manoeuvres.

Regression analyses attempted to predict the DBQ factors (errors, lapses and violations) from responses to the motorcycle items. Lapses and errors were predicted by self-reported failure to make all appropriate visual checks, and by reported surprise at filtering motorcycles. Violations were higher for those drivers who believed riding a motorcycle was partly a thrill-seeking behaviour. They also believed they would enjoy motorcycling and rated themselves as having similar characteristics to the average motorcyclist.

Relating responses to self-reported accidents

Previous studies have suggested that violations are strongly related to accidents (e.g. Parker *et al.*, 1995b). As a further series of analyses, we investigated whether there was a relationship between the three factors of the DBQ and all of the other motorcycle measures with the number of accidents reported by respondents. The number of reported accidents across the sample was typically low (Table 2).

Table 2 The percentage of respondents who reported one or more accident across gender and driving experience for three severities of accident

		Driving experience			
		Less than 2 years	2–10 years	10 or more years (dual drivers)	10 or more years
<i>Scratch</i>	Female	2.56	6.67	9.92	5.88
	Male	8.82	15.38	10.83	13.22
<i>£200</i>	Female	2.56	6.67	7.02	1.96
	Male	8.82	14.29	9.24	7.27
<i>Injury</i>	Female	2.56	2.67	2.48	5.88
	Male	2.94	2.20	1.59	5.73

Three multiple linear regressions were performed for three sets of accident measures:

- accidents that resulted in only a scratch to the vehicle;
- accidents that resulted in £200 worth of damage or more; and
- accidents that resulted in injury.

Age, gender, months since passing the driving test and annual car mileage were entered as demographics at the top level of the analysis. Violations, lapses and errors were entered stepwise at a second level, and the 24 motorcycle items and two general items were entered stepwise at a third level.

The regression against accidents causing a scratch produced a significant model, ($F(8,955) = 4.3, p < 0.001$), yet it only accounted for 2.6% of the total variance. After demographics were taken into account, the model included violations (adjusted $R^2 = 0.012$), lapses ($R^2 = 0.005$), a negative relationship with the item 'It is easier to pass the current motorcycle test than the current car driving test' ($R^2 = 0.003$), and a positive relationship with the item 'When in slow moving traffic I am often surprised by motorcyclists filtering through the traffic' ($R^2 = 0.003$).¹

The regression with accidents resulting in £200 worth of damage also produced a significant model, ($F(4,945) = 4.0, p < 0.005$, accounting for 1.3% of the variance) but none of the DBQ or motorcycle items contributed to it.

The regression with accidents resulting in injury produced a model that accounted for only 1% of the variance but this was still significant, ($F(7,1257) = 2.8, p < 0.01$). After the demographics it included lapses ($R^2 = 0.004$), a positive relationship with the item 'When driving in interweaving streams of fast moving traffic, with many other drivers often changing lanes, I am constantly aware that motorcycles can be more difficult to spot than under normal driving conditions' ($R^2 = 0.004$), and a negative relationship with the item 'When driving in slow moving traffic I am often surprised by motorcyclists filtering through the traffic' ($R^2 = 0.003$).

Discussion

The motorcycle factors in the questionnaire study have identified that all car drivers tend to have more negative attitudes towards motorcyclists than dual drivers, and are less empathic with regard to understanding motorcyclists and being aware of the dangers they face. It is unsurprising that the dual drivers give the most positive and empathic responses, though the extent of the differences between dual drivers and the other groups across such a wide selection of factors is staggering. It suggests that there are many areas of attitudes and knowledge that need to be improved in the general driving population if we wish all drivers to have the same favourable perspective that dual drivers report towards other motorcyclists.

¹ R^2 refers to the increase in total variance accounted for through the addition of a specific variable to the regression model. When multiplied by 100 it represents the percentage variance accounted for by that variable.

Dual drivers also report better perceptual skills. They gave the highest levels of agreement with 'I perform all appropriate visual checks ...', and are the most optimistic about spotting approaching motorcycles at junctions. This may reflect improved visual skills developed through exposure to motorcycles, and empathy for the difficulties that motorcyclists face on the roads every day.

The highest violators are the 2–10 group. This group also gave the highest scores to the item 'When riding a motorcycle taking risks is part of the thrill' and were least likely to be aware of motorcycles when driving in interweaving streams of fast moving traffic. In addition to rating motorcycling as a relatively thrill-seeking activity, high violators were predicted by a belief that they would enjoy motorcycling and that they perceive themselves to have similar characteristics to the average motorcyclist (though our experienced dual-driver group were least likely to rate motorcycling as a thrill-seeking activity). This suggests that the 2–10 group identify with a perceived stereotype of younger motorcyclists who enjoy the risk of riding. They may therefore behave less responsibly when confronted with motorcycles because they perceive that the motorcyclist may actually enjoy the risk of interacting with a fellow member of the thrill-seeking fraternity.

Drivers with limited experience of driving may have inappropriate expectations of motorcycles. They may over-estimate some capabilities ('It is easier for motorcyclists to make sudden swerves to avoid an accident than car drivers') and under-estimate others (e.g. 'On the open road you can suddenly be surprised by the appearance of a motorcycle coming from behind you'). They also tend to report more errors.

Female drivers report more perceptual problems. They report greater problems with spotting motorcycles at junctions and estimating their speed. They also believe that motorcycles are harder to spot at night. They are less likely to believe that motorcycles are allowed to filter past stationary or slow-moving traffic, and are consequently more surprised when this happens. They are also surprised by overtaking motorcycles on the open road. All of these items are reflected in the higher number of lapses reported by females.

The regressions against the accidents are hard to interpret because of limited data, though being surprised by filtering traffic was a significant predictor for both accidents resulting in a scratch and accidents resulting in injury. Self-reported frequency of visual checks also proved to be a very useful item and its use is recommended in future research.

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8

A comparison of drivers' eye movements in filmed and simulated dangerous driving situations

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Abstract

One of the most difficult problems in driver training is the challenge of exposing learner drivers to hazardous situations in a realistic but safe manner. While the introduction of hazard perception testing in the British driving test has substantially increased awareness of hazards among both learners and trainers, there are still limited opportunities for learner drivers to experience real hazards while actually driving, and there are questions about the value of learning to respond to hazards in a purely video-based task. A three-year project at the Accident Research Unit, University Nottingham, is exploring the possibility of using hazard-perception training in simulators owned by the British School of Motoring. One of the main aims of the current training intervention is to improve the visual search performance of novice drivers. This paper compares the typical visual search behaviour of drivers in the simulated hazardous scenarios with the behaviour of drivers in actual dangerous situations, and while watching videos of driving hazards. The results show that the typical patterns of attention-focusing in hazard situations occur in most simulated hazards and that they are particularly noticeable during the precursors to these hazards. Differences in visual behaviour among three types of hazard are explored and the time course of changes in visual behaviour is analysed.

Introduction

Numerous studies have explored the visual behaviour of car drivers (for reviews see Chapman and Underwood, 1998; Crundall, 2005; Underwood *et al.*, 2007). One of

the most important considerations in such studies is the way in which visual behaviours are modified in dangerous or stressful driving situations. The idea that attention is altered in stressful situations has a long history in psychology. Easterbrook (1959) proposed the general idea that arousal causes a narrowing in the range of cues attended to by an organism. Applied cognitive psychologists have extended this idea to 'weapon focus' (Kramer *et al.*, 1990) in which a witness to a crime may look at the weapon, but fail to remember the face of an assailant. Loftus *et al.* (1987) had participants watch situations where a shop customer holds either a gun or a cheque. They found that viewers fixated more on the gun than they did on the cheque. In a similar study, Christianson *et al.* (1991) observed more frequent and extended fixations on central information in stressful conditions. If such attention-focusing occurs in driving situations, we might expect that in hazardous situations participants would focus on the information directly ahead of them and fail to attend to more peripheral sources of information. Chapman and Underwood (1998, 1999) tested this hypothesis by having drivers watch hazard-perception videos while their eye movements were recorded. They found that there were a few minor differences in the general locations fixated in hazardous situations, but there was no clear overall tendency for a focus on central locations at the expense of peripheral ones. Chapman and Groeger (2004) argue that memory tests in such situations are consistent with the idea that what drivers focus on in dangerous situations is not information that is spatially central, but information that is central to the driving task. Consistent with this idea, although there is little evidence for spatial attention-focusing from records of eye movements, there is plenty of evidence that drivers' visual search is systematically different if hazards are present. Chapman and Underwood (1998) made systematic comparisons of a wide range of eye movements, variable for safe and dangerous situations, while participants watched hazard-perception videos. They found that, during hazards, fixation durations increased, the mean saccade amplitude decreased, and the overall spread of search (as measured by both vertical and horizontal variance in fixation locations) decreased. Although drivers did focus on hazards, the location of hazards was not always spatially central to the driving scene. To observe attention-focusing in hazardous situations, it is necessary to define eye-movement measures relative to individual hazard locations. Underwood *et al.* (2005) did just this, defining each fixation relative to the appearance of an individual hazard. They found a dramatic increase in fixation duration at the time an individual driver detects a hazard. Although this increase in fixation duration can be detected by comparisons across broadly safe and dangerous situations (e.g. Chapman and Underwood, 1998), the data from Underwood *et al.* (2005) strongly suggest that the actual duration of attention focusing is likely to be limited to the single fixation at the time a hazard is detected.

Training drivers' visual search

Relatively few researchers have attempted to directly influence novice drivers' patterns of visual search. A danger in any such training is that eye movements are likely to be a consequence of other aspects of visual processing – thus a driver may fixate on a region until information from that region is fully processed. At that point they may move onto a new region, searching for additional information. Differences in fixation durations between novice and experienced drivers in unfamiliar situations (e.g. Chapman and Underwood, 1998) will thus reflect the additional time a novice

driver requires to process risk-related information. A visual search-training intervention that encourages novice drivers to copy the search strategies of experienced drivers may simply cause them to leave a region of fixation before the relevant information is fully processed. Such training could be potentially dangerous. If an intervention is aimed at reducing fixation durations, it makes better conceptual sense to teach novice drivers about hazardous situations with the intention that this will allow them to process relevant visual information faster and, consequently, reduce fixation durations and allow an increased spread of search. Thus, training that improves hazard perception is itself likely to improve visual search.

Studies on hazard perception training (e.g. Deery, 1999; Mills *et al.*, 1998; McKenna and Crick, 1994; Horswill and McKenna, 2004; McKenna *et al.*, 2006) provide a useful basis for training broader visual search strategies, but relatively few studies have actually measured the influence of such training on drivers' eye movements. The first large-scale study attempting to train and measure drivers' visual search strategies was reported by Chapman *et al.* in 2002. Their training intervention took the form of a one-hour video-based task designed to train three specific components: knowledge, anticipation, and scanning. Similar to previous hazard perception studies, it was assumed that watching videos of potentially dangerous situations while providing commentaries and listening to expert commentaries would improve novice drivers' knowledge of hazardous road situations and they would potentially process them faster. Anticipation training was provided using a 'What Happens next?' prediction test similar to that used by McKenna and Crick (1994). The final component of this intervention was designed to more directly influence drivers' visual scanning. Here drivers were shown videos of dangerous situations with multiple areas of potential hazard circled. Such videos were played initially at half speed to give drivers time to fully process information in all areas and were subsequently played at full speed to encourage a scanning strategy that was both wide and rapid. Chapman *et al.* monitored their novice drivers' eye movements while performing hazard-perception tests before training, immediately after training and in a long-term follow-up condition between three and six months after the training intervention. Chapman *et al.* (2002) found that the training intervention reduced fixation durations and increased the novice drivers' spread in a laboratory hazard-perception test.

Chapman *et al.* (2002) conclude that eye-movement training can help novice drivers to develop visual search strategies in filmed hazardous situations that are more like those of experienced drivers. Pollatsek *et al.* (2006) have found similar effects in a driving simulator. They showed novice drivers overhead views of road scenarios and asked them to mark on the pictures the location of hazards that were obscured from view. They then drove in a simulator while their eye movements were recorded. Trained drivers showed more successful visual search for potential hazards on those scenarios that were structurally the same as the overhead views on which they had been trained. There was also evidence that visual search in new scenarios had been affected by the training, suggesting transference of skill between driving situations. A follow-up study found that such training effects were reasonably long-lasting (Pradhan *et al.*, 2007).

Chapman *et al.* (2002) also reported evidence that eye-movement training can influence visual search during real on-road driving. They recorded the eye movements of their drivers, both before and after training, while driving on a real

road in an instrumented vehicle. Although there were no significant differences in fixation durations, they did find significant differences in the spread of horizontal search immediately after the intervention, although these differences were no longer significant in a follow-up three to six months after the intervention.

Pollatsek and colleagues have recently followed up a variant of their aerial view training technique using eye tracking on real roads (Pradhan *et al.*, 2006). Here they explored eye movements in critical scenarios that either occurred naturally or were staged. They found significant training effects both for scenarios that were like those in the training phase, and those that were less similar. The training effects were, however, smaller for less similar scenarios, and they attribute this reduction to the modified training procedure used, in which photographed situations may have been very visually similar to those encountered during the actual drive (Pollatsek *et al.*, 2006).

There is thus evidence that various types of training can improve drivers' visual search strategies, that these benefits can be observed in hazard-perception tests, simulated driving and actual driving, and that some of these benefits are reasonably long-lasting. Despite this promising conclusion, there are still a number of unanswered questions about the effectiveness of training. Although the training described by Pollatsek *et al.* (2006) does appear to be successful in encouraging drivers to look to the location of potentially-obscured objects, it is arguable that this is only one component of expert visual search in driving. In contrast, a problem with eye-movement based training is that it may encourage a general scanning strategy that is not always appropriate; indeed, there was evidence from Chapman *et al.* (2002) that changes in scanning strategy occurred in both dangerous and safe situations. Video-based hazard-perception training can also be criticised on the grounds that a good driver could have avoided many hazards by an appropriate approach speed and direction. A clear improvement over training using videos would thus be the use of simulated driving, in which car control was required but hazardous situations could be created for the driver to deal with in a safe and controlled environment.

Our suggestion, therefore, is that further efforts at training drivers' visual search patterns might be best concentrated on strategies that are appropriate in both general driving and in specific hazardous situations. The advent of low-cost high-fidelity driving simulators suggests that these may be an ideal location for training in simulated hazardous situations. In addition to proposing the driving simulator as an ideal location for training, we have specific proposals for the components of training that are most likely to be effective in producing optimal visual search strategies in novice drivers.

Predicting the behaviour of other road users

Many real accidents are preceded by the unexpected behaviour of other road users and could have been prevented if the driver had correctly predicted their behaviour in advance. Realising that an oncoming vehicle might be planning to turn in front of

your car, or that a pedestrian walking on the pavement might be about to step into the road, requires very deep processing of the visual scene. In such cases a driver needs to be aware of potential sources of danger, fixate them at length and return to them frequently. A driver can never be sure of the behaviour of other road users, but knowledge about how potential hazards might develop will help the novice driver choose appropriate areas of the visual scene on which to concentrate their search. This may be one of the main benefits of expert commentaries, and important knowledge may be gained by simply watching a wide variety of hazardous scenarios. Additional training based on getting the driver to predict 'what happens next' in a variety of scenarios may also be valuable.

Developing a mental model of the situation

Some of the dangers to a driver cannot be seen until they become hazardous. For example, a child who steps out into the road from behind a parked ice-cream van becomes an immediate hazard. Experience allows a driver to identify and monitor these dangerous areas prior to the appearance of the hazard. This component is similar to the concept of 'anticipation' as used by McKenna and colleagues (e.g. McKenna *et al.*, 2006) and is clearly one of the main skills trained in Pollatsek *et al.*'s (2006) training regime.

Dividing and focusing attention

The ability to monitor multiple potential sources of hazards is essential when navigating congested urban roads. The driver must prioritise locations in the visual scene according to their importance and must frequently monitor the most likely hazard spots, while inhibiting the impulse to fixate non-hazard related information. Such an ability is similar to the concept of 'scanning' training as proposed by Chapman *et al.* (2002). However, one particular focus is the need to not just scan the road continually but particularly to disengage from hazards once they have been detected. Crundall *et al.* (1999, 2002) have observed a reduction in the ability to detect peripheral targets in hazardous situations that may be particularly pronounced for inexperienced drivers. Thus, training should focus on ensuring that, once a hazard has been appropriately identified, attentional resources are redistributed and the remainder of the driving scene is also considered.

Hazard management

One danger with emphasising the role of eye-movement training in novice drivers is that it avoids the general issue that many hazards can be avoided by simply adopting a safe and defensive driving style. There is always a danger that any training

intervention will encourage overconfidence in a driver. Although there is evidence that components of hazard-perception training can be safely trained without encouraging an increase in risk-taking behaviours (McKenna *et al.*, 2006), great care needs to be taken during any skill-based driver training. It is thus important that any training of visual search is integrated into a more general model of safe and responsible driving.

In order to assess and train these aspects of driving, it is important to develop simulated hazardous driving that measures each of these four components of driving, and to demonstrate that visual search in such situations is representative of that found in real and videoed driving studies of the type described above. The remainder of this paper thus reviews some pilot data that examine the visual search behaviour of drivers while driving a simulator through three different types of hazard, namely those that are particularly important for three aspects of training:

- predicting the behaviour of other road users;
- developing a mental model of the situations; and
- dividing and focusing attention.

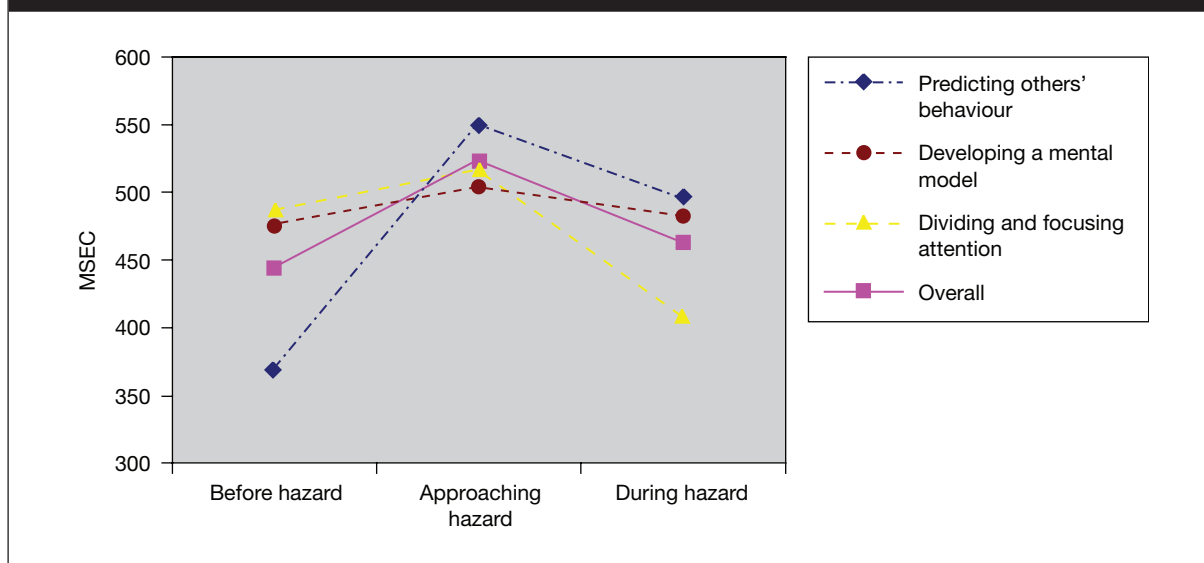
Visual search results during simulated hazardous driving

For the purposes of these analyses, pilot data from drivers in the simulated hazardous scenarios described in Crundall *et al.* (2006) were analysed. Eye-movement data were aggregated over three windows:

- a window in which the hazard was actually present;
- a window in which the driver is approaching the location of the hazard, but the hazard is not actually in progress; and
- a window immediately preceding where the road and traffic situation are similar but the hazard location is not present.

For comparison with Chapman and Underwood (1998), eye-movement data in each case were split into mean fixation duration, mean saccade amplitude, and spread of search both horizontally and vertically.

Figure 1 shows the mean fixation durations of pilot drivers in each of the three hazard types, and an overall average across the three hazard types. There was a main effect of hazard window, $F(2,32) = 3.85$, $MSE = 22,837$, $f = 0.49$, $p < 0.05$, such that fixation durations tended to be longest when the driver was approaching a hazard, and an interaction between time window and hazard type, $F(4,64) = 4.80$, $MSE = 11,866$, $f = 0.55$, $p < 0.01$. Although all three types of hazard show the general pattern of longer fixation durations during the approach to a hazard, the 'predicting others' behaviour' hazards show a particularly strong increase in fixation

Figure 1 Drivers' mean fixation durations (ms) when approaching and negotiating three types of hazard in a simulator

durations as the hazard is approached, while the 'dividing and focusing attention' hazards show a particular reduction in fixation durations when the hazard actually starts.

Figure 2 presents the mean saccade amplitudes for each of the three windows. Low saccade amplitudes are associated with a tendency to make multiple fixations on, or around, specific objects rather than scanning widely between different locations. The patterns of change in saccade amplitude are consistent across all three types of hazard, with a main effect of hazard window, $F(2,32) = 3.59$, $MSE = 1,536$, $f = 0.47$, $p < 0.05$, showing a significant reduction in saccade amplitudes during the approach to a hazard. When the actual hazard is in progress, saccade amplitudes remain low, but are, if anything, higher than during the approach to the hazard.

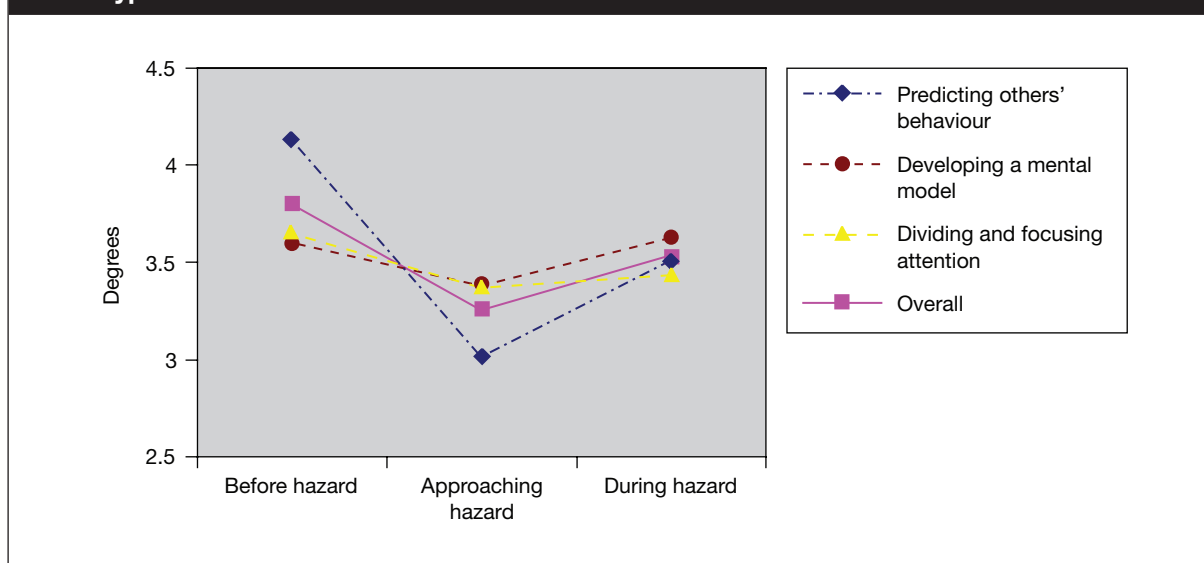
Figure 2 Drivers' mean saccade amplitudes (degrees) when approaching and negotiating three types of hazard in a simulator

Figure 3 shows the spread of horizontal fixation locations within each window averaged across drivers. This measure is related to both saccade amplitude and fixation duration, and gives a general measure of how variable in horizontal location the places fixated by the driver are within each window and type of hazard. There was a significant main effect of hazard window, $F(2,32) = 12.59$, $MSE = 7,082$, $f = 0.89$, $p < 0.001$, once again showing a general reduction in search when the hazard is approached, and an interaction between hazard window and the type of hazard, $F(4,64) = 4.90$, $MSE = 2,044$, $f = 0.55$, $p < 0.01$, suggesting that this reduction is particularly pronounced for the predicting of others' behaviour hazards.

Figure 3 Drivers' mean spread of horizontal search when approaching and negotiating three types of hazard in a simulator

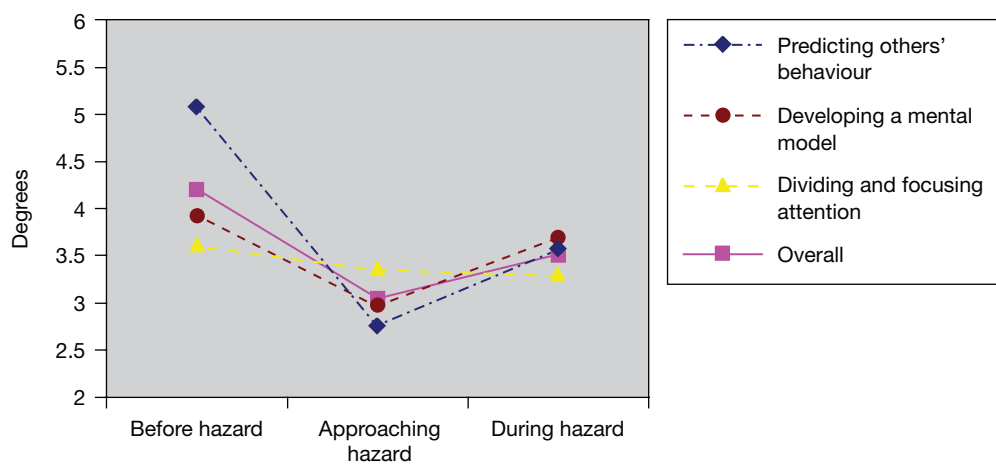
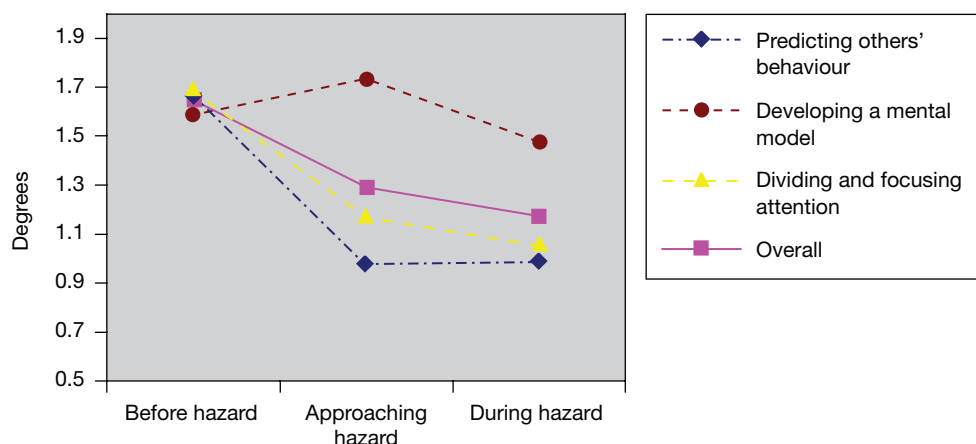


Figure 4 shows the vertical spread of search, calculated in the same way as for horizontal search. However, in this case, vertical movements are likely to represent the balance between looking at items close to the driver and those further ahead in the roadway. For this measure only there was a main effect of hazard type, $F(2,32) = 5.97$, $MSE = 866$, $f = 0.61$, $p < 0.01$, suggesting that hazards where the

Figure 4 Drivers' mean spread of vertical search when approaching and negotiating three types of hazard in a simulator



driver has to develop a mental model of the situation are unusual in requiring more vertical search than the other situations. There was still an overall main effect of hazard window, $F(2,32) = 11.84$, $MSE = 1,237$, $f = 0.86$, $p < 0.001$, consistent with reduced vertical search during the approach to a hazard and while the hazard was in progress. There was also a significant interaction between hazard window and the type of hazard, $F(4,64) = 3.76$, $MSE = 353$, $f = 0.48$, $p < 0.01$, confirming that the increased vertical search behaviour in the mental model hazards persists throughout the three windows unlike the other two types of hazard.

General discussion

The purpose of these preliminary analyses was to assess the degree to which visual search behaviour in the simulator is consistent with that observed in hazard perception tests (e.g. Chapman and Underwood, 1998, 1999) and on-road driving (e.g. Crundall and Underwood, 1998). A secondary aim was to explore the way in which visual behaviour changes during the course of a hazard, and the final aim of these analyses was to explore potential differences in search behaviour among three different hazard types. An initial analysis of fixation density plots suggested that, like Chapman and Underwood (1999), there were not large overall differences in the overall spatial distributions of fixation locations as a function of window. In contrast, all four analyses of visual search parameters in terms of durations and moment-to-moment spread revealed substantial differences between dangerous and safer situations broadly consistent with those reported in Chapman and Underwood (1998). In the Chapman and Underwood (1998) study, hazard windows were defined as those in which participants tended to press a hazard-perception response button. As such, it is likely that they represent the approach to a hazard rather than the times a hazard is in progress, and the general pattern of results from the current analyses is consistent with this interpretation. Broadly, the before-hazard results in the current analysis seem to be equivalent to the 'safe' windows used in Chapman and Underwood (1998), and the approaching-hazard windows seem to be equivalent to the 'danger' windows. Thus, in the approach to a hazard, as expected, there is a pattern of increased fixation durations, reduced saccade amplitudes and a reduction in the spread of both horizontal and vertical search. This is consistent with the idea that attention-focusing in hazardous situations is readily observable in the simulator and implies both that our simulated hazards are realistic and that the additional car control requirements of the simulated driving do not alter the broad patterns of visual search that have been observed in hazard-perception tests.

The contrast between the approaching hazard window and during the hazard window is of interest and is not something that has been systematically studied previously. The fixation data suggest that the increased fixation durations are specific to the time at which a hazard is being approached, and that fixation durations have broadly returned to normal lengths while the hazard is actually being negotiated. We have previously interpreted fixation durations as being indicative of workload, such that as processing difficulty increases, so do fixation durations. This interpretation is consistent with the idea that the challenging aspect of hazard perception is the anticipation of hazards, not the particular car control that is necessary to deal with a hazard. This 'rebound' pattern can be observed, to a lesser extent, in both saccade amplitudes and the spread of horizontal search. Thus, in each case the time the

actual hazard is being negotiated actually shows greater search than the time it is being anticipated. Note that in these cases the 'rebound' is only partial, and spread of search during the hazard is not at the same level as during the pre-hazard period. This is even more marked for the spread of vertical search where there is no evidence for rebound; if anything, spread of vertical search is further reduced during the negotiation of the hazard. One interpretation of these findings is that, although the actual mental workload associated with hazard anticipation is removed when the hazard unfolds, and fixation durations consequently decrease, spread of search remains constrained by the need to concentrate on the hazard and this is particularly marked for vertical search, which might represent search of the roadway ahead for forthcoming hazards.

The final findings from the current analyses are to do with the differences among the three types of simulated hazards. Perhaps the most striking feature here is the overall similarity, in that all three hazard types exhibit typical patterns of attention-focusing, to greater or lesser degrees, in all the four measures we have analysed. Nonetheless, there are minor differences, particularly in the time course of changes. For example, the developing mental model hazards are unusual in the level of vertical search and in the fact that this is not reduced until the hazard is actually being negotiated. Similarly, the dividing and focusing attention hazards are unusual in producing relatively little difference in horizontal search across the three windows. Both these changes may be related to the fact that all our pilot drivers were relatively experienced drivers. It may be that they have already developed many of the compensation strategies that allow them to maintain good visual search even in hazardous situations. It will be of great interest to explore data from learner drivers in the same situations and compare these patterns with those from experienced and expert drivers. We have already conducted such studies and are currently in the process of analysing such data.

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9

Do we really drive as we feel?

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Introduction

Learning to drive has been conceptualised as a series of stages that take the learner from mastery of the basic mechanics of driving, through anticipation of other road users' behaviour, to the development of a driving style consistent with the skill achieved in the first two stages (Parker and Stradling, 2001). Deery (1999) suggests that hazard perception is one of the main skills to be acquired in the second stage and that this skill is poorly developed in the inexperienced (and usually young) driver.

While strategic deliberation has an obvious role to play in general decision-making and, more specifically, in hazard perception, Damasio (1994, 2004) has suggested that a complementary emotional learning system also influences behaviour independently from conscious strategic processes. For example, if a situation were to develop that could advance into something threatening or dangerous, a feeling of unpleasantness would be produced in the body (i.e. a gut feeling). This bodily feeling will be marked against the developing scenario so that the organism will learn that, should this scenario begin to be built up again, the body can respond earlier (Damasio, 1996). The process has been labelled the Somatic Marker Hypothesis (SMH) (Damasio, 1994).

Damasio writes:

‘Somatic markers (SM) are a special instance of feelings generated from secondary emotions. Those emotions and feelings have been connected by learning to predicted future outcomes of certain scenarios. When a negative SM is juxtaposed to a particular future outcome the combination functions as an alarm bell ... SMs may operate covertly (without coming to consciousness).’

(Damasio, 1994; p. 174)

Therefore, it is likely that if such an emotional process does exist, then it could be applied to the driving scenario and specifically the area of hazard perception. It is presupposed that somatic markers would unconsciously bias decision making in such situations (Damasio, 1996). Damasio (2004) suggests that the application of somatic markers is sub-served by the ventro-medial pre-frontal (VMPF) area of the brain, and clinical populations with damage to this area show abnormal learning of punishment and reward in spite of relatively intact conscious strategic processes. Support for this and the existence of an unconscious emotional learning system that responds to threat/punishment and gain/reward has been demonstrated to operate in laboratory settings through the Iowa Gambling Task (Bechara *et al.*, 1994, 1997). While these findings support the SMH, unsurprisingly, the SMH as a neurological framework has been the focus of debate (Maia and McClelland, 2004; Dunn *et al.*, 2006). Responses to most critiques have been given by Damasio and supporters, and a revision of the SMH thus states that:

‘the central feature of the somatic marker hypothesis is not that non-conscious biases accomplish decisions in the absence of conscious knowledge, but rather that emotion-related signals assist cognitive processes even when they are non-conscious.’

(Bechara *et al.*, 2005; p.159)

Experiencing traumatic/hazardous situations while driving, even when not resulting in injury, has been shown to be associated with negative affect and increased concern for personal safety (Lucas, 2003). Such development of substantial fear and anxiety in a real-life situation, which may have dramatic consequences for individuals, would intuitively be exactly the type of situation where emotional learning would have an influential role in guiding behaviour. It may be the case that the development of an emotional learning response/somatic marker to various situations of potential risk while driving is a critical component of becoming an ‘experienced’ driver and guides safer driving behaviour in conjunction with improved strategic hazard perception.

This paper describes two laboratory experiments that were set up to explore whether the principles behind the SMH can be applied to the realm of driver behaviour. Experiment 1 examined the Skin Conductance Response (SCR) of experienced and inexperienced drivers to three types of still images. These still images were of ‘safe’, ‘hazardous’ and ‘developing hazard’ situations. Subjective judgements of how hazardous the situation appeared to be were also collected. It is predicted that experienced and inexperienced drivers will not differ in their emotional response to safe and hazardous scenarios. However, if there is emotional learning via experience, then experienced drivers should be more likely to demonstrate an SCR to a picture portraying a potential hazard. A purely cognitive explanation would be that inexperienced drivers fail to appreciate the potential risk inherent in the depicted situation. If this were the case, then subjective ratings of danger should also show a difference by experience level. However, if the ratings of danger are similar, then this would support the idea of an emotional system that operates independently of a cognitive appraisal system.

Experiment 2 builds on the results of experiment 1 and examines the SCRs of learner, inexperienced and experienced drivers to 12 Driving Standards Agency

(DSA)¹ Hazard Perception clips, similar to those used within the UK Hazard Perception Test. It is expected that there would be a difference between the driver groups SCR during the build-up to a hazardous situation, such that experienced drivers would be more likely to elicit an SCR.

Experiment 1

Method

Eighteen inexperienced (held UK licence for under three years) and 17 experienced drivers (held UK licence for three years or over) viewed 15 still images of road situations (five safe, five hazardous and five ‘developing hazards’) taken from a commercially available CD-ROM. The images were presented for five seconds each. After each clip, participants were asked to rate, on a scale of 1–7 (safe to hazardous), how hazardous the situation appeared. Respiration and SCR data were recorded throughout the experiment. The images were randomly presented, full screen, on a 19-inch computer monitor. A button box was used to record the participants’ ratings. The psychophysiological measurements were taken using Biopac 10 software and associated hardware.

Results and discussion

Table 1 shows the mean cognitive ratings for how hazardous each still image was judged to be. The increase in ratings across hazard type is statistically significant for both experienced and inexperienced drivers (Page’s L trend test, inexperienced: $L = 230, p < 0.01$; experienced: $L = 252, p < 0.01$). Both the experienced and inexperienced drivers gave similar ratings to the hazards and developing hazards. A Kruskal-Wallis test shows that only the ratings for the safe images were significantly different, with experienced drivers giving higher ratings than inexperienced. However, the crucial comparison is that of developing hazard and it can be seen that not only do the two ratings not differ in statistical significance, they are also numerically very similar.

Table 1 Mean hazard ratings for still images

	Safe	Developing hazard	Hazard
Inexperienced	1.59 (0.31)	3.47 (0.79)	4.87 (0.82)
Experienced	2.18 (0.97)	3.49 (1.26)	4.40 (1.51)
²	4.78*	0.11	0.40
* $p < 0.05$			

1 The DSA is not involved with the current research. Any views reported here are those of the researchers alone and are not representative of those of the DSA.

Table 2 shows the mean number of SCR responses per stimulus item condition for experienced and inexperienced drivers. Experienced drivers numerically show more SCRs across all stimulus conditions, though this difference only reaches statistical significance for ‘developing hazard’ items, as shown by a Kruskal-Wallis analysis.

Table 2 Mean percentage of responses showing an SCR to the stimulus item

	Safe	Developing hazard	Hazard
Inexperienced	21.1 (20.0)	14.4 (20.4)	24.4 (22.3)
Experienced	28.2 (23.5)	34.1 (27.2)	32.9 (30.8)
²	0.68	5.74*	0.47
* $p < 0.05$			

In summary, no difference was found for cognitive ratings of danger for developing-hazard stimuli among drivers of differing experience, yet these stimuli did show a significantly different number of emotional responses for experienced and inexperienced drivers. This lends support to the idea of an emotional learning system that is separate from a cognitive decision-making system. The inexperienced drivers knew that the developing hazards were riskier situations to encounter than safe situations, but they did not appear to feel that they were riskier. In contrast, the experienced drivers treated developing hazards as emotionally identical to the actual hazards while cognitively recognising them as less risky than a hazardous scene. Experiment 1 also supports the idea that experience is necessary for the formation of these emotional markers. If emotional learning plays a crucial role in safe driving, then this component appears to be lacking in the inexperienced driver. The results of experiment 1 call for replication using stimuli with enhanced ecological validity to further explore the effect of experience on the emotional appraisal of developing hazards.

Experiment 2

Experiment 2 also examined SCR, but this time it was continuously monitored while participants viewed hazard perception DVD clips from the driver’s perspective. This allows a more dynamic and ecologically valid measure of the role of emotion in driving.

Method

PARTICIPANTS

Eleven learner drivers ($m = 5$; $f = 6$), 21 inexperienced ($m = 9$; $f = 12$) and 18 experienced drivers ($m = 10$; $f = 8$) took part. Inexperienced drivers were defined as having held a driving licence for less than three years (mean = 13.33 months, std dev. = 8.86, range 1–29) and experienced drivers as having held their licence for over three years (mean = 86.22 months, std dev. = 43.63, range 36–168).

The learner driver group had a mean age of 21.7 years (std dev. = 2.9, range 17.6–27.3), the inexperienced driver group had a mean age of 21.7 years (std dev. = 3.6, range 17.8–33.8), and the experienced driver group had a mean age of 25.4 years (std dev. = 2.9, range 20.3–31.0).

MATERIALS AND APPARATUS

Twelve Hazard Perception clips were purchased from the DSA under contract. Each clip was around one minute in length and involved one major hazard. The 12 clips were randomly presented, full screen, on a 19-inch monitor. Participants dynamically responded throughout the duration of the clip by using a slider to rate how hazardous the scene was. The slider was labelled 'safe' at one end to 'hazardous' at the other. Psychophysiological measurements were taken using Biopac 10 software and hardware.

PROCEDURE

Participants were seated approximately 60 cm from the computer monitor, with the slider at a comfortable distance on the desk. Electrodes were attached to the participant's index and middle finger of their non-dominant hand, and they were asked to position a belt attached to a respiratory transducer around their chest. Heart rate was also monitored, although this is not reported here. They were asked to take several large breaths in order to check that the recording equipment was operational and to provide a comparison respiration trace. Participants were informed that they would see 12 clips of normal driving scenarios and were asked to imagine that they were the driver of the vehicle. It was not mentioned that there were any hazards in the scenes they would encounter. In order for participants to become accustomed to the slider and to check the equipment, each participant had a practice trial before they began.

Results

For an SCR to be included in the data, it had to be equal to or exceed 0.05 delta micro mhos (Dawson *et al.*, 2000). In order to extract data from participants' continuous SCR response during the HP clips, timing markers were required.

HAZARD START MARKER

The start of the hazard was defined using digital video editing equipment. This enabled the Hazard Perception clips to be broken down into frames with exact timings. The item that eventually became the hazard was defined and analysed for the first frame in which that item occurred. This was therefore the Hazard Start Marker, as it was the first moment at which the hazard began to be built up.

This practice was followed for all clips except clip 9, where two bikers ride along a parallel road for a considerable period of time. It is only when the parallel road then joins the driver's road that a hazard ensues. For clip 9 the Hazard Start Marker was defined from the moment at which the junction became visible.

CRITICAL MOMENT MARKER

The critical moment was defined as being the moment at which the driver in the Hazard Perception clip takes avoiding action to the hazard. Avoiding action involved either braking or changing direction. Again, the use of digital video editing equipment allowed for the exact timing of this moment.

EVENT PERIOD

Preliminary analysis indicated that most drivers elicited a large SCR response around the Critical Moment Marker. The researchers defined this as an Event Response. However, as the critical moment was the final moment at which the driver in the clip responded to the hazard, some drivers demonstrated this event response prior to our defined Critical Moment Marker. To allow for event response variation, a period of time was defined around the Critical Moment Marker. This was termed the Event Period. The Event Period started from 75% of the total hazard time for each clip to three seconds after the Critical Moment Marker. All participants' event responses fell within this period. Three seconds after the Critical Moment was incorporated, as this is a normal range for including responses when coding SCR data (Dawson *et al.*, 2000).

ANTICIPATORY PERIOD

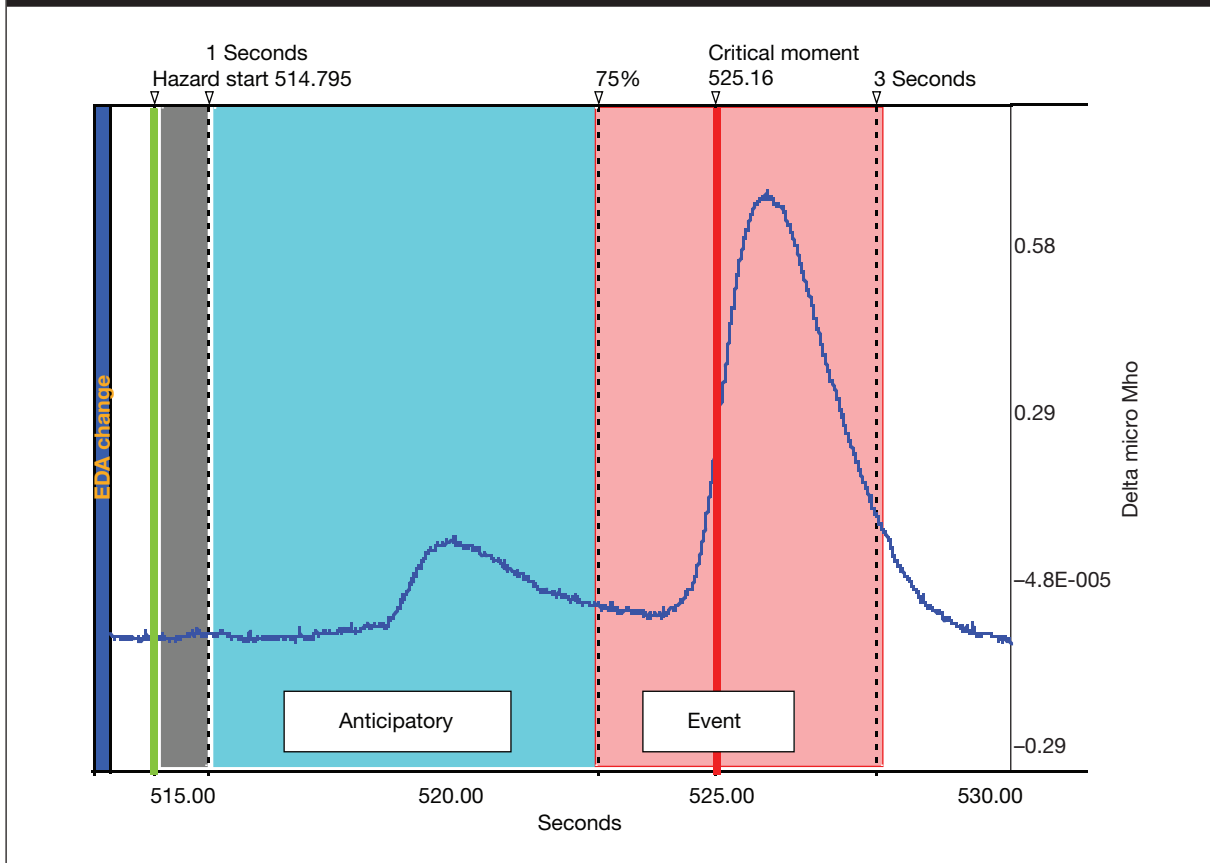
The knock-on effect of defining the Event Period meant an area was defined that started from the Hazard Start Marker to 75% of the total time of the hazard. This area was therefore defined as the Anticipatory Period and any responses within this area would be considered an anticipatory response to the build-up of a hazard.

Owing to the slight delay of SCR responses (Dawson *et al.*, 2000), any response within one second of the Hazard Start was not included, as this may have been caused by something that happened prior to the start of the hazard period.

A demonstration of the Anticipatory Period, Event Period and timing markers can be seen in Figure 1.

ANTICIPATORY SCORE

So that the three experience groups could be compared for their frequency of demonstrating an anticipatory response, an overall anticipatory score was produced. The anticipatory score involved collating the number of clips in which a participant demonstrated an SCR response within the anticipatory area. If a participant had more than one SCR response within the anticipatory area, this was only counted as having demonstrated an anticipatory response for the purpose of the anticipatory score. All participants viewed 12 Hazard Perception clips and therefore had 12 SCR readings that could be coded using the above definition. However, as SCR is an extremely sensitive measure, interference can cause a change in SCR that compromises the reliability of measuring an emotional response. Irregular respiration (as measured by the respiration belt), sudden movement or a technical fault were all reasons for excluding some hazard responses from the current sample.

Figure 1 Demonstration of timing markers and areas used to extract SCR data from participants' responses**Table 3 Number of participants per clip who had a valid response or who were excluded from analysis**

	No. of valid responses	No. of participants with excluded data	Total
Clip 1	44	6	50
Clip 2	44	6	50
Clip 3	41	9	50
Clip 4	46	4	50
Clip 5	43	7	50
Clip 6	42	8	50
Clip 7	44	6	50
Clip 8	45	5	50
Clip 9	46	4	50
Clip 10	41	9	50
Clip 11	45	5	50
Clip 12	45	5	50

Therefore, although a participant had viewed 12 clips, they may not have had valid data for all 12 clips. Table 3 summarises the number of excluded cases per clip.

The following equation was used to determine a participant's anticipatory score:

$$\text{Anticipatory score} = \frac{\text{No. of valid clips with an anticipatory response}}{\text{No. of valid clips}} \times 100$$

This therefore gave each participant a percentage score of the percentage of clips that they would demonstrate an anticipatory response.

For the analysis of the anticipatory score, four participants were excluded for having valid responses to fewer than eight of the twelve clips. Of these four participants, one had no valid data, two had valid data for only two clips, and one had valid data for only seven clips. All other participants had data for at least nine clips. Three of the excluded participants were from the inexperienced group and one was from the experienced group.

Table 4 summarises the anticipatory scores for the three experience groups. A difference of mean score can be seen among the learner, inexperienced and experienced groups. While the difference between the mean score of the learner group and the inexperienced group is around 9%, the experienced group score is just over double that of the inexperienced group. Owing to a wide range of scores within each group, the median score is also reported and suggests a similar but more extreme trend between the groups.

Table 4 Summary of anticipatory scores by experience group

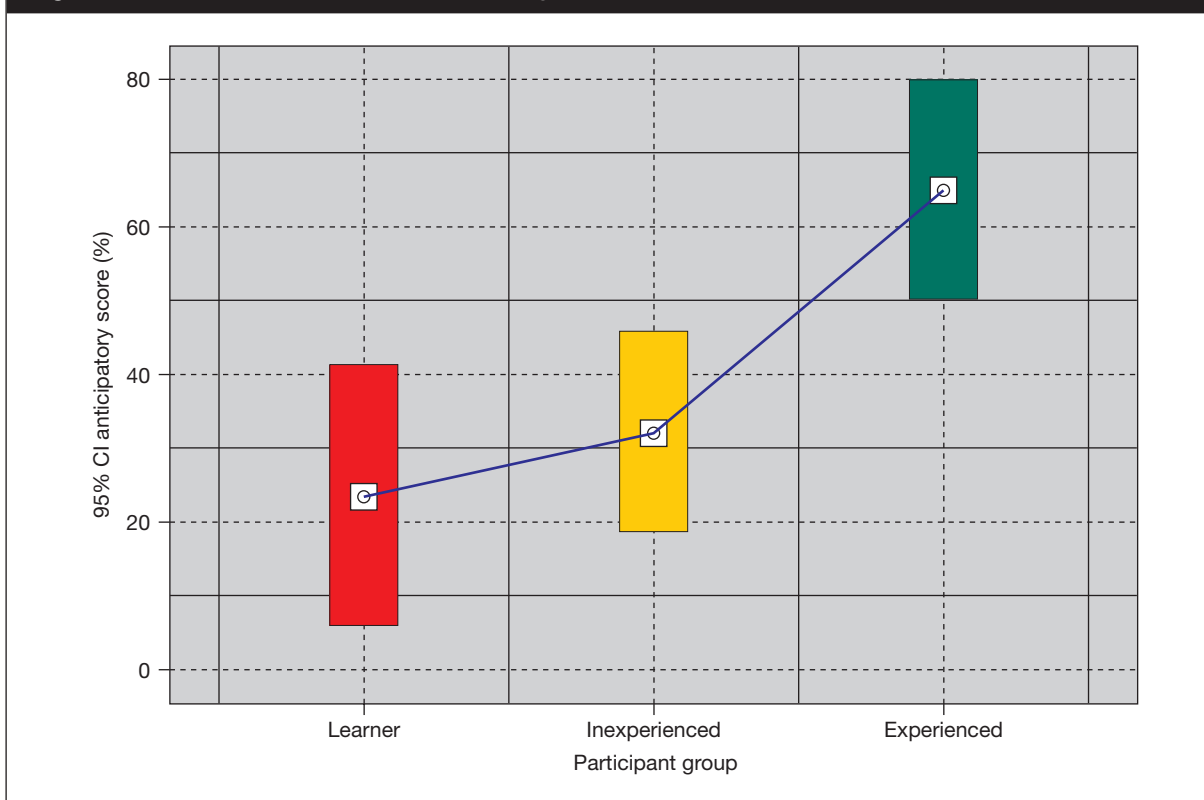
Participant group	<i>n</i>	Mean (%)	Median (%)	Min. score (%)	Max. score (%)	SD
Learner	11	23.61	16.67	0.00	81.82	26.20
Inexperienced	18	32.19	25.00	0.00	80.00	27.34
Experienced	17	65.20	81.82	8.33	91.67	28.69
Total	46	42.34	36.67	0.00	91.67	32.43

An error bar chart demonstrates that there is a relatively large difference between the experienced group and the inexperienced and learner groups, with no overlap of the 95% confidence intervals (CIs). However, there was overlap of the 95% CIs between the learner and inexperienced groups. A plot of mean scores with 95% CIs can be seen in Figure 2.

A one-way Analysis of Variance (ANOVA) was performed and suggested a significant difference among the groups ($F(2,43) = 9.583$; $p < 0.001$). Post-hoc Tukey analysis determined that significant differences were found between the experienced group and both the inexperienced group ($p = 0.004$) and learner group ($p = 0.002$). No significant difference was found between the learner and inexperienced groups.

Owing to the potential influence of age, gender and exposure when analysing data related to driving, a Univariate analysis was performed with age, gender and miles driven in the past 12 months as covariates. This demonstrated that there was still a significant overall group effect ($F(2,46) = 13.554$; $p < 0.001$) and that age, gender and miles driven were not significant influences at the 0.05 level.

Figure 2 Graph of 95% CI of participant group's anticipatory scores



INEXPERIENCED DRIVERS

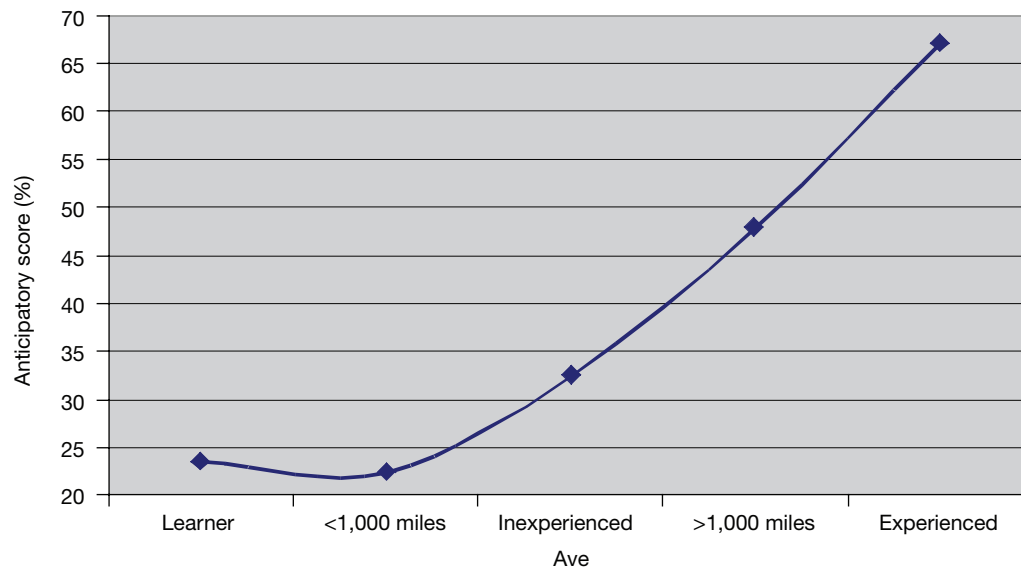
Inexperienced driver responses were further analysed. Breaking this group down by the number of years driving (one, two or three years since passing their test) demonstrated no significant difference in anticipatory score. However, a natural gap in exposure was evident within the group, with those who had driven fewer than 1,000 miles in the last 12 months ($n = 12$) and those who had driven more than 1,000 miles in the last 12 months ($n = 6$). There was a significant difference in anticipatory score between these two groups ($t = -2.456$, $df = 16$, $p = 0.026$).

The two inexperienced driver groups were compared with the learner and experienced groups. One-way ANOVA demonstrates that there is still a significant overall group effect ($F(3,42) = 8.647$; $p < 0.001$) with Tukey post-hoc analysis showing a significant difference between experienced drivers and both learners ($p = 0.001$) and the fewer than 1,000 miles inexperienced group ($p = 0.001$). No significant difference was found between experienced drivers and the over 1,000 mile inexperienced group ($ns = 0.713$).

Univariate analysis was performed with age, gender and miles driven in the past 12 months as covariates. This demonstrated that there was still a significant overall group effect ($F(3,46) = 11.820$; $p < 0.001$) and that age and gender were not significant influences at the 0.05 level. However, miles driven in the last 12 months was significant ($p = 0.029$).

When these two groups are plotted with all driver groups, a pattern emerges whereby inexperienced drivers who have driven fewer than 1,000 miles in the previous 12 months differ little from learner drivers (see Figure 3). On the contrary, inexperienced drivers who have driven more than 1,000 miles in the last 12 months

Figure 3 Graph of anticipatory score by experience group



demonstrate a mid-range score between the inexperienced average and that of experienced drivers.

Discussion

The results of experiment 2 build on those of experiment 1. Experiment 1 demonstrated a significant difference in the proportion of SCRs between inexperienced and experienced drivers to developing hazards. Experiment 2 repeated this finding and found a further relationship when including learner drivers. However, experiment 1 also demonstrated that inexperienced and experienced drivers cognitively rated developing hazards the same, therefore suggesting a crucial difference between their cognitive and emotional responses. Unfortunately, similar analysis is not currently available for experiment 2. However, the results do support the hypothesis and the theoretical concept of an emotional learning system.

Results in experiment 2 suggest that, during the learner phase, drivers have the ability to emotionally anticipate a low level of hazardous situations. Furthermore, it would appear that, as a driver gains UK driving licence status, their ability to emotionally anticipate hazards is no better off. Only once active experience of solo driving begins do drivers embark on an apparent learning curve, whereby they increase their emotional anticipation of hazards.

Importantly, it was demonstrated that the time of having held a licence was not important and that only through experience of the task will drivers begin to increase their ability to emotionally appraise developing hazards. Concurrent findings of self-report data suggest that novice driver crash-risk reduces dramatically after the first 500 miles of on-the-road solo driving experience (McCartt *et al.*, 2003). This could be comparable to the increase in anticipatory score demonstrated within the current sample when having driven more than 1,000 miles.

Driver behaviour research also reports that initial solo driver experience is more important than even age as an accident-reducing factor (Maycock *et al.*, 1991; Forsyth *et al.*, 1995). Yet, despite this, there is little understanding of the process by which this initial crash risk reduces. During this period, the vast majority of novice drivers are not undergoing any further education or training, yet they are continuing to learn something. The current results would suggest that the driver is learning processes that allow an emotional appraisal of the driving task that facilitates an early warning of potential hazards.

Of course, the role of feelings and emotion in driving is not without foundation (Fuller, 2005; Kinnear *et al.*, (in press); Vaa, 2005). In support of the Task Capability Interface model, Fuller (2005) and Kinnear *et al.* (in press) reported finding that drivers rate their feelings of risk in the same way as they rate the difficulty of the task. This suggests that the feedback drivers receive from the driving scenario may be appreciated through feelings, hence allowing a driver to understand both the difficulty and the risk of the task at the same time. If this were the case, then the current results would lend further support for the role of emotions and feelings in the driving task.

Conclusion

In conclusion, three important points are of note across the two experiments. Firstly, both experiments have demonstrated a difference in the SCR rate to developing hazards between inexperienced and experienced drivers. Secondly, experiment 1 provided evidence that emotional appraisal of potentially hazardous situations is something that is separate from cognitive judgement of the scenarios. Thirdly, experiment 2 demonstrated a learning curve in the emotional appraisal of developing hazards that is mediated by driver experience. Therefore, this paper not only provides support for the underlying principles of the SMH being applied to driver behaviour, but it also suggests that we do drive as we feel.

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10

Possible application of the PRIME theory of motivation to promote safer driving

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Introduction

Most road crashes occur because of what is often termed in litigation ‘driver error’ as opposed to mechanical defects (e.g. www.expertlaw.com/library/car-accidents). The term ‘error’ is somewhat misleading, however, because it conjures up an image of drivers operating their vehicles in a way that is normally perfectly safe but occasionally they make a ‘mistake’ that causes a crash. The implicit presumption is also that the ‘mistake’ was unintentional. It is well recognised, however, that drivers routinely operate their vehicles in a way that carries a certain degree of risk, which typically varies from driver to driver, and that occasionally they encounter a sequence of events that translates that risk into a crash (West, 1997). Moreover, the so-called ‘mistake’, i.e. the action that led to the crash, was often completely intentional – it was the consequence of the mistake that was not intended. Thus, routinely driving close to the vehicle in front, adopting driving speeds that leave little margin of safety, overtaking without clearly being able to see that it is safe to do so, or with too little margin of error, failing to look carefully when pulling out, changing lanes impulsively in order to get ahead in heavy traffic, driving when intoxicated or tired, etc. (see Petridou and Moustaki, 2000) are all behaviours which drivers can avoid, if they choose to do so, but in fact adopt to a greater or lesser degree as quite a consistent behaviour pattern (Elander *et al.*, 1993).

So in a real sense every driver can be regarded as an accident waiting to happen with higher or lower probability as a function of the way he or she drives. Once they have accumulated a few thousand miles of experience, drivers should almost all have acquired a level of skill that would make this risk negligible, so for those who routinely adopt relatively unsafe driving practices, it is not their skill so much as the choices they make and their habits that are at the root of the problem: this is the province of ‘motivation theory’.

Therefore, a more complete understanding of human motivation ought to provide clues as to how one can promote safer driving practices. Such an understanding

could feed into a population level behaviour change model of the kind that has been proposed for reducing smoking prevalence (Table 1) (West, 2006b).

Table 1 The EPICURE taxonomy of approaches to behaviour change in populations

Approach	Description
Education	Increasing knowledge and understanding about the behaviour and its effects, e.g. road safety education
Persuasion	Actively attempting to shape attitudes and behaviour through argument, imagery, etc., e.g. mass-media campaigns
Inducements	Making the desired behaviour more attractive – not widely used in road safety
Coercion	Making the undesired behaviour less attractive, e.g. use of the criminal justice system
Upskilling	Providing training or instruction on how to achieve the desired behaviour, e.g. basic and advanced driver training
Regulating access	Restricting opportunities to engage in the undesired behaviour, e.g. minimum driving age
Empowerment	Making it easier to engage in the desired behaviour – not widely used in road safety

There is evidence already of the effectiveness of certain types of intervention within this framework, mostly focusing on coercion and regulation (Grabowski and Morrissey, 2001). For example, 0.08 mg/100 ml blood alcohol limits, minimum legal drinking age laws and sobriety checkpoints have been found to be effective when enforced (Shults *et al.*, 2001). There is also good evidence that improving speed enforcement detection systems can reduce crashes (Wilson *et al.*, 2006). Graduated licensing systems for novice drivers also appear to reduce crash rates (Gillan, 2006). Conversely, other types of approach, such as driver education programmes, have yet to be shown to be effective (Mayhew, 2007). Other approaches, including driver re-training programmes have uncertain effectiveness (Kua *et al.*, 2007). It is noteworthy that interventions that appear to have the clearest evidence for effectiveness are those that involve coercion and regulation rather than education and persuasion (Berg, 2006). This may be because our approaches to the latter have not been sufficiently informed by a comprehensive account of motivation.

There are numerous theories of motivation which emphasise its different aspects, such as attitudes, decision making, habit learning, emotion, drives, etc. (for an excellent review see Mook (1996)), but surprisingly none attempts to canvass the full range of elements that we know to be important.

The PRIME theory of motivation is an attempt to pull together insights from existing theories and everyday understanding into a more complete account using concepts and terms that are as close to those in everyday usage as possible (West, 2006a). Thus it attempts to describe how impulses, instincts, habits, drives, wants, emotions, needs, goals, values, beliefs, analysis, choice and planning interact to generate our behaviour at any given moment in time, and how our experiences shape our dispositions to react through thoughts, feelings and actions in particular ways to events. It notes the primacy of feelings over 'cold cognitions' as sources of motivation, and proposes that all motivation is ultimately channelled through the moment-to-moment balance between competing impulses and inhibition. It also notes how, for humans, our capacity for self-awareness has the potential to generate

powerful motivations arising from our sense of identity, and a great deal of deliberate changes to behaviour patterns derive fundamentally from a change in identity.

This paper gives a brief outline of the PRIME theory in its current, very early stage of development, and derives some predictions for interventions that may promote safer driving practices.

An outline of PRIME theory

This paper uses the term ‘motivation’ to describe the system of forces that energise and direct our behaviour. Given all the things we are physically capable of doing at a given moment, it determines what we actually do and the enthusiasm with which we do it. It is what makes us do some things and what stops us doing other things. It includes deliberate choices as well as ‘automatic’ processes, such as instinct and habit. It includes ‘biological’ drives, such as ‘hunger’, emotional responses and ‘higher values’.

A great deal is known about what motivates us: in the implicit understanding contained in everyday conversation; in art and literature; and in the formal study of psychology, sociology, anthropology and economics. We know that most of our actions are largely automatic, driven by stimulus-response patterns that are ‘hardwired’ or have become ingrained or moulded through reward and punishment, but that superimposed on this are choices that arise from the consideration of different alternatives that we observe or can imagine and preferences for different outcomes (Mook, 1996). We know that basic ‘biological’ drives such as hunger, thirst, need for sleep, etc., feed into these processes, as do emotions, and we know a great deal about how they do so (Mook, 1996). We know a lot about how people generate the beliefs and images that feed into the choices we make, for example when judging the likelihood of something happening as a result of different actions that we might take (Baron, 2000). We know about the role that our view of ourselves plays in the process and about the exercise of self-control (Baumeister *et al.*, 1994). We know how emotions and habits of thought and feeling affect, not just our motivations, but the very way that we arrive at motivations. For example, much is known about how stress affects how we canvass and evaluate the options in front of us (Janis and Mann, 1977).

PRIME theory does not seek to provide an alternative to this considerable body of knowledge, but only to provide a common, parsimonious conceptual framework into which these individual pieces of the jigsaw can be fitted so that we can gain some new insights that might otherwise elude us.

The structure of the motivational system

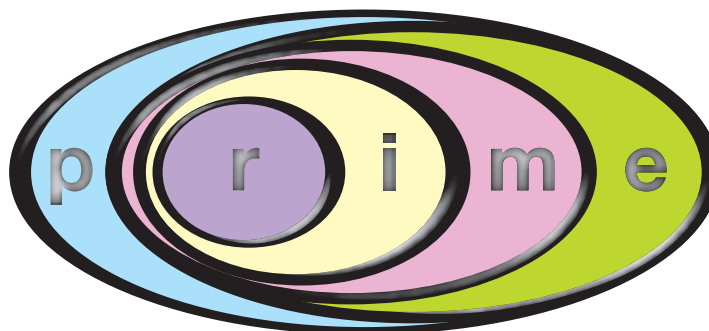
The first step in this process is to describe the structure of the ‘motivational system’. The theory takes as a clue to this structure the fact that actions are often characterised in terms of the dominant motivational process operating at the time:

- **Reflex behaviours** that are simple stimulus-response sequences that are fixed ('He just froze').
- **Instinctive and habitual behaviours** that are driven by triggers that directly generate **impulses** to act in a particular way but which can, in principle, be overridden by other motivations ('He instinctively slammed his foot on the brake'; 'He looked to the right, instead of the left, out of habit').
- **'Motive'-driven behaviours** that stem from anticipated **feelings** of pleasure or satisfaction ('want') or relief from present or anticipated discomfort or distress ('need') ('He wanted to feel what it would be like to drive at over 100 mph'; 'He needed to get home by 6 pm to avoid being told off for being late for dinner').
- **Evaluation-driven behaviours** that stem from **beliefs** about what is the correct, right or appropriate thing to do ('He believed it was OK to drive after a couple of beers') – i.e. what one **should** do as distinct from what one might feel one **wants** or **needs** to do.
- **Plan-driven behaviours** that stem from the execution of a predefined plan ('He had always intended to drive home whether or not he got drunk').

Whatever the dominant motive, it is apparent that with almost all of our actions, any number of different types of motivation might come into play and that many of these may compete with each other. The motivational system needs to have some way of integrating these different types of motivation and deciding priorities between them.

The hypothesis is that the human motivational system can usefully be construed in terms of five levels (Plans, Responses, Impulses/inhibition, Motives and Evaluations). The proposed levels are shown in Figure 1, the 'PRIME diagram'. The diagram is intended to convey the hierarchical structure of the system – with 'responses' at the lowest level, 'impulses/inhibition' at the next and so on, and that each level can only be influenced directly by adjacent levels. For example, evaluations can only influence responses by generating 'motives' (wants or needs) that, in turn, generate impulses or inhibition.

Figure 1 The PRIME diagram. 'Responses' are generated on a moment-by-moment basis by the balance between potentially competing 'impulses and inhibition' which can be stimulated directly by triggers or by 'motives' (feelings of want or need) that can be stimulated by reminders or by 'evaluations' (beliefs). Motivation to engage in behaviours that are only appropriate, or better carried out, in the future generate 'plans' which provide overarching structure to our behaviour but which need to generate evaluations and motives at the appropriate time if they are to influence that behaviour



Thus, responses (starting, modifying or stopping action sequences) are either (in rare cases) driven by simple reflex, or (more commonly) are generated by the balance between competing impulses and inhibition operating at that moment.

Impulses and inhibition are generated by:

1. 'triggers' which interact with innate dispositions (instincts) and learned dispositions (habits); and
2. 'motives' which are feelings of want (derived from anticipated pleasure or satisfaction) and/or need (derived from anticipated relief from unpleasantness or tension) for some imagined thing, event or situation.

The triggers may be external stimuli or they may be thoughts, emotions or 'drives', or involve an interaction between these. It is assumed that impulses decay quickly once the triggers or motives are no longer present. Normally we are not conscious of impulses, but when we stop ourselves acting on them we experience them as 'urges'.

The term 'urge' is being used here to describe the feeling of being impelled to engage immediately in a specific action sequence. In the theory it is distinguished from the term 'drive' which involves a state of motivational tension energising and directing a potentially wide range of behaviours that could reduce it. For example, the drive labelled 'hunger' could motivate any number of different behaviours necessary to acquire and consume food. Thus drives can serve as a source of impulses but need to be distinguished from them.

What are termed 'motives' in PRIME theory rely completely on our ability to imagine a possible state of affairs. That is to say, we must form some kind of mental representation and find the prospect attractive or unattractive. The theory makes a distinction between 'wants' and 'needs', and uses the terms in a more specific way than is used in everyday language. It recognises, however, that the two can influence each other. Thus, one can want something so much that the thought of not having it creates anxiety from which we then feel the need for relief. Conversely, relief from a drive state such as hunger or thirst, or a negative emotion such as anxiety, can be pleasurable and anticipation of that pleasure can generate wants.

It was mentioned earlier that drives can generate impulses. They can do this through innate mechanisms and learned habits but, mostly, it is argued that they do so through generating wants and/or needs. That is, they cause us to think about particular things, such as food, and make us imagine states of affairs that are pleasurable or satisfying or that will provide relief. The precise behaviours that we devise and undertake in response to this will depend on the circumstances.

Thus, 'motives' are generated by:

1. 'reminders' which are cues that bring to our minds images (**any** mental representations, not just visual images) that we find attractive or unattractive in interaction with our current state of motivational tension, which itself stems from our current emotional states and drives; and
2. 'evaluations' which are beliefs about what is good/bad, right/wrong, useful/detrimental, etc.

The term ‘reminder’ is being used in a broader sense than that in everyday language. It is any stimulus or thought that brings to mind a mental representation of something that we have experienced in the past that we remember as being attractive or unattractive **or something sufficiently like it** so that we feel attracted to an imagined state of affairs that we have not actually experienced. Reminders can also draw our attention to a feeling or drive state which, in turn, creates attractive or unattractive images.

Evaluations are beliefs which explicitly or implicitly attribute value to things because they are right or wrong, good or bad, useful or detrimental to some purpose or goal, aesthetically pleasing or ugly, etc. A belief is anything that can be expressed as a sentence that is held to be true.

Evaluations are generated by:

1. the cued recall of observations relating to the thing in question (reminders);
2. analysis and inference;
3. accepting what others say;
4. motives (as previously defined); and
5. ‘plans’ which are intentions to engage in an activity and often a set of conditions to trigger implementation.

Thus, if we observe someone doing something that we disapprove of, we are inclined to form a negative evaluation of that person, obviously. Alternatively, we might infer that a course of action is good or bad to varying degrees by working out the likely consequences and how good or bad each of these will be. The various ways in which we do this is the province of much of ‘decision theory’ (Baron, 2000). We often accept something as good or bad just because someone whom we trust or have no reason to distrust says that it is. There is also an emotional logic in operation in our evaluations; if we want or need to do something we are inclined to judge it to be ethical or good in some way.

Plans represent the highest level of the motivational system in that they provide the greatest opportunity to interact adaptively with our environment by anticipating future events and providing maximum flexibility when it comes to prioritising our actions.

Plans are intentions that are generated when:

1. actions are considered to be required in the future;
2. actions are considered to be more likely to meet ‘goals’ if undertaken at a future time; and
3. actions are attractive but do not have a sufficient priority to be enacted at the moment.

The term ‘goal’ here refers to an imagined state of affairs that is attractive (generating a want or need) in the context of the formation or enactment of a plan.

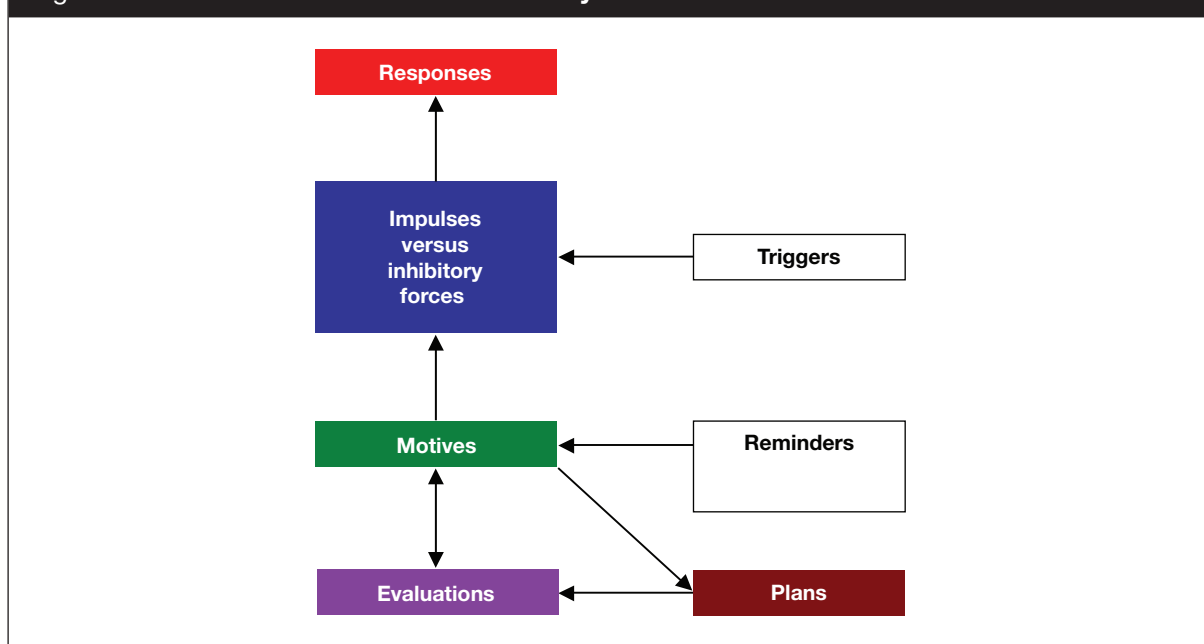
It is important to note that plans can be very specific and closely tied to well-defined starting conditions or vague and even without any starting conditions. For example, someone may have a vague intention 'not to drink too much' at a party, or they may have a specific plan to have one glass of wine. In general, the more specific the plan, the more likely it is to be enacted when the time comes. Plans may also vary in the degree of commitment attached to them. In general, this commitment derives from the strength of the motives that led to the plan being formulated plus additional motives derived from wanting or needing to stick to a plan once it has been formulated. Clearly, however, the commitment to a plan can vary from the time of formulation to potential implementation.

Formulating a plan can be regarded as a motivated act. An individual is motivated to do something but for some reason it is not considered appropriate or possible to do it immediately, so a plan is formulated. Where the starting conditions for the plan are externally driven, for example planning to walk rather than drive the next time one goes to the shops, the plan can be taken as a positive index of motivation. However, when an action could easily be undertaken immediately but the individual chooses to make a plan instead, it can be taken as a marker of ambivalence or even weak motivation. Formulating a plan in that case is merely procrastination.

The theory proposes that the paths of influence through the motivational system are such that plans can only influence actions by being remembered and then generating evaluations at the appropriate time (Figure 2). Evaluations, however generated, can only influence actions by being brought into existence and creating motives at a given moment. Motives, however generated, can only influence actions by generating impulses or inhibitions at a given moment, and responses are only generated by impulses and inhibitions in force at that moment.

As our immediate environment is such a powerful source of beliefs, images and impulses, a major practical implication of PRIME theory is 'carpe diem' (seize the day) – controlling behaviour is very much about taking advantage of motivations present in the moment before they are superseded or die away.

Figure 2 The structure of the motivational system in more detail

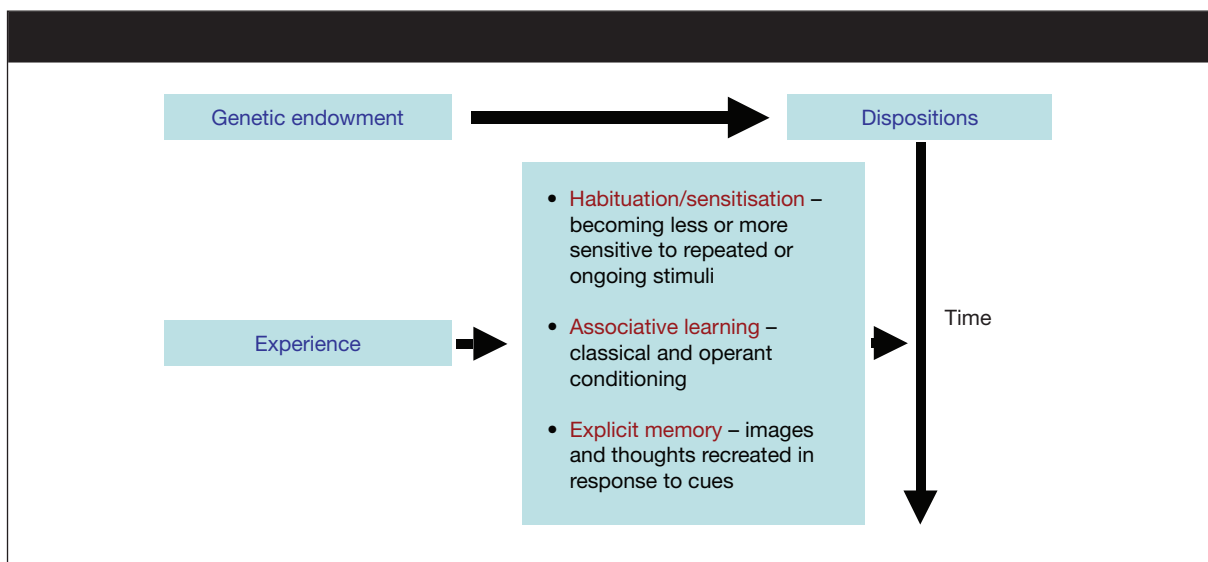


Dispositions and how they are generated and modified

The way that the system reacts to events in generating impulses, wants, needs, etc., is determined by its 'dispositions'. These are more or less stable features of the functioning of our nervous system, deriving substantially from the attributes of, and interconnections between, neurones. At a psychological level, long-term dispositions are thought of in terms of 'personality', 'attitudes', 'mind sets', etc. Short-term dispositions include things such as 'mood' and 'frames of mind'.

Dispositions can be thought of as broadly stable but only in the sense that weather patterns are stable – different parts of the globe experience different 'climates' but most experience rain at some time, and weather patterns change with the 'seasons', with times of day and sometimes suddenly, violently and with little warning. Similarly, while it is possible to chart, with some accuracy, the weather patterns over a region, when it comes to specific locations and times, there is inherent unpredictability at the very local level in time and space caused by the combined effects of immeasurably small influences. So it is with dispositions. As with weather systems, these are inherently 'chaotic' in the sense used in chaos theory. This does not mean that they are unpredictable but that the prediction needs to follow stochastic (probabilistic) rather than deterministic principles.

PRIME theory recognises what has been established elsewhere that the development of motivational dispositions involves at least three primary adaptive mechanisms: habituation/sensitisation, associative learning and explicit memory (Figure 3).



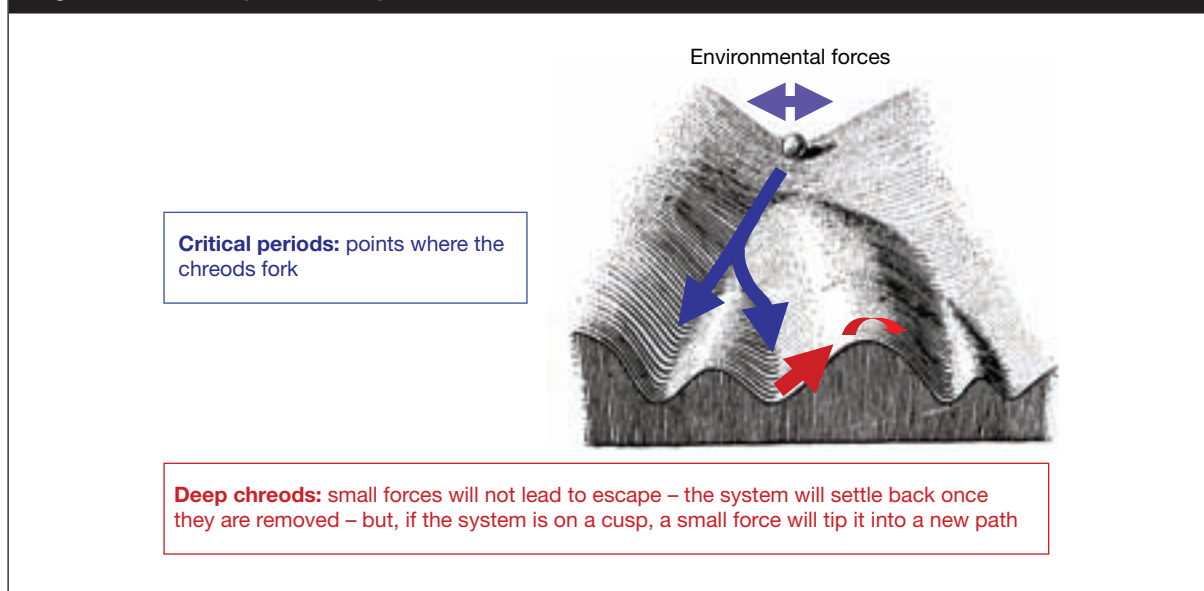
Habituation refers to a decrease in motivational force arising from a stimulus as a result of continued or repeated exposure, while sensitisation refers to an increase in this force. Thus some experiences elicit powerful motives or impulses the first time they are presented which decrease on repeated exposure, while others elicit little or no response initially but with repetition the effect becomes magnified.

Associative learning is the process by which we learn ‘habits’ of thought, emotion and impulse; that is to say, the ‘automatic’ generation of ideas, images, emotions and impulses by virtue of learning that two different events occur or happen together. It includes classical (Pavlovian) conditioning in which stimuli come to take on emotional or motivational properties through association with other stimuli, and operant conditioning in which impulses and motives are generated by the association of cues with behaviours that are rewarding or punishing. There are known to be individual differences in propensity to learn from different kinds of experience. Of particular relevance here is the observation that more social deviant individuals learn poorly from punishment but well from reward (Dadds and Salmon, 2003). This is relevant because of the clear association between social deviance and traffic accident rates (West *et al.*, 1993).

Explicit memory simply refers to the generation of mental representations of things or events by cues that were associated with the experience of those events previously. These representations may be images or involve any of the senses, and typically also include some level of propositional representation (beliefs).

In very general terms, a potentially useful model of the way that dispositions change is Waddington’s metaphor of the ‘epigenetic landscape’ (Waddington, 1977) (Figure 4). One can think of a disposition as a ball rolling down an ever-changing landscape whose contours are established through our genes. Environmental forces push us to one side or another within that landscape. As the landscape unfolds, one may get ‘critical periods’ in which a small environmental influence can send us off down one path or another while at other times we may find ourselves in deep valleys so that even powerful environmental forces have little impact, or push us up the side of the valley only for us to fall down to the bottom again if that force is released.

Figure 4 Waddington’s ‘epigenetic landscape’



This metaphor captures some important concepts in behaviour change, including the idea that in individuals who are near the cusp of making a major change to their behaviour pattern, a small trigger will often be enough to tip them into a new ‘valley’. Thus, it can be that major changes in behaviour patterns can be triggered by apparently small events.

PRIME theory proposes that the dynamics of dispositional change are underpinned by an inherent instability in the nervous system such that change does not so much involve pushing or pulling the individual in one direction or another but rather shaping its natural tendency to chaotic transformations. Thus the landscape is often jagged and full of gullies and potholes. The analogy is with ‘fly-by-wire’ fighter aircraft that are built to be inherently unstable and are made to fly as intended by the pilot by means of constant micro-adjustments to the control surfaces made by computers. This makes the aircraft highly responsive and manoeuvrable but requires constant ‘balancing input’ to prevent them spiralling out of control. By analogy, human brains are exquisitely sensitive to environmental contingencies and highly creative and innovative but at the cost of susceptibility to:

- developing patterns of thought, feeling and action that are anything from quirky to pathological;
- sudden unpredictable shifts in dispositions; and
- the development of unhealthy dispositions because there is insufficient correcting influence preventing this.

One manifestation of this is the ‘epiphany’, ‘moment of clarity’ or ‘Road to Damascus experience’, in which individuals suddenly ‘see the light’ or undergo a major transformation in their outlook, motives and value system. Religious conversions are obvious examples, but this also appears to happen with regard to giving up smoking or alcohol, or leaving an abusive relationship. The conditions in which such events occur are not clear, but if it is essentially a stochastic event arising from inherent instability in the brain, it can be made more likely by raising the level of energy in the system to disturb existing connections and providing a path for the ‘relaxation’ of the system into a new configuration. One possible approach to generating such epiphanies, therefore, would be to raise arousal levels by some means and then apply a stimulus that provided a new structure to the individual’s thinking.

Identity, self-control and rules

It was noted that wants and needs arise out of anticipated feelings of pleasure and distress (as well as basic drives such as hunger and thirst). This anticipation derives, in large part, from the learning mechanisms outlined in the previous section. As social animals capable of self-awareness, an important source of pleasure and distress is how we think other people regard us and how we regard ourselves. Through a complex process of socialisation, we come to think of ourselves in particular ways, adopt certain roles and identify with individuals, groups and values.

In terms of PRIME theory, ‘identity’ refers to the disposition to think and feel about ourselves in particular ways, and can be a very powerful source of evaluations, wants and needs. Once we adopt a certain persona and set of core values, the prospect of a violation of these can be deeply unattractive and the prospect of acting in accordance with them can be very attractive.

Individuals clearly differ greatly in terms of the salience, coherence and nature of their identities in relation to particular attributes. They also differ in terms of their dispositions to think about themselves more generally – to be self-conscious. Bear in

mind that, while we all have the capacity for self-awareness, most of the time we go about our lives perceiving the world and not thinking about ourselves.

PRIME theory proposes that 'self-control' refers to evaluations, wants and needs arising from self-awareness that are sufficiently strong to overcome those arising from other sources. Thus individuals with salient, coherent identities, which set clear boundaries around their behaviour, will be more successful in exercising self-control in the face of the moment-to-moment wants, needs and impulses to which they might be subjected. Very often these boundaries take the form of 'rules' about what we 'do' and 'don't do'. Such rules can be a powerful source of wants and needs that come into play on the occasions in which they are called for.

It is noted in PRIME theory that the exercise of self-control appears to be effortful and require and use-up 'mental energy'. This means that individuals whose reserves of mental energy are low because they are required for other mental tasks, or because of a continuing need for self-control, or because of depression or tiredness, will be less successful in the exercise of self-control.

Safe and unsafe driving

With these general ideas in mind we can return to what is meant by unsafe driving, how this is influenced by motivation and how ideas from PRIME theory may suggest better ways of getting people to drive more safely.

Leaving aside deliberate crashing, all unsafe driving practices appear to boil down to three things:

- being insufficiently attentive;
- leaving too little margin for error; and
- driving under conditions or in a state in which fitness to drive is, or could become, impaired.

This is distinct from inept driving which involves inadequate knowledge or driving skills.

Given the inherent risk involved in driving and the moment-by-moment motivations operating while driving, the thesis proposed here is that safe driving is not merely the absence of unsafe driving practices, but involves being **actively** and **continually** motivated to adopt safe driving practices. Thus 'safe driving' involves actively taking care to minimise the risk of collision by:

- trying to remain attentive;
- trying to leave a wide margin of error; and
- trying to avoid putting oneself in a position in which one might not be fit to drive, not just in the abstract or occasionally, but **all the time**.

Safe driving requires developing motives or habits to ‘take precautions’ and ‘adopt rules’ that counterbalance the momentary motives to:

- drive when fitness to do so might be impaired;
- engage in activities that impair fitness to drive;
- arrive at the destination as quickly as possible;
- experience excitement from driving; and
- express aggression through driving;

and to counterbalance impulses to engage in driving behaviours that derive from:

- instinctive emotional reactions; and
- habits.

This requires ‘push back’ or a ‘reaction’ against these motivations whenever they are present. If this does not ‘come naturally’ through habit or fear of collision or other adverse consequences, it requires **self-control**, at least initially.

PRIME theory leads to a number of predictions regarding interventions to increase the rate of adoption of safe driving practices in different categories of driver. This paper will only describe one of these.

The key role of identity in generating motives that override momentary impulses and motives derived from the immediate situation suggests that greater emphasis should perhaps be placed on attempting to foster, in society, a higher prevalence of a strong, coherent identity that values safe driving practices (not simply labelling oneself as a ‘safe driver’). Indeed, it may not be necessary for that identity to value safety: the driving practices could arise from another desirable self-attribution, such as ‘competence’ or ‘self-importance’. The important shift in the communication strategy is away from admonishments to adopt particular practices, or attempts to convince drivers of the benefits of these practice. Rather it is to develop communication techniques designed to generate an **identity** that motivates drivers to adopt what are known to be safe driving practices. This may seem a subtle distinction, but PRIME theory predicts that it should be more effective in generating behaviour change.

This suggests an approach to promoting safer driving that involves and generating **an emotional commitment** to being **the kind of driver** that tries hard:

1. ‘always to keep within the speed limit’;
2. ‘never to drive after having drunk alcohol’;
3. ‘always to leave the recommended distance from the vehicle in front’;
4. ‘always to look very carefully before pulling out’;
5. ‘always to avoid driving when feeling sleepy’;

6. 'never to let my anger affect my driving';
7. 'never to give in to a desire to experience the thrill of driving fast';
8. 'always to leave plenty of time for my journey';
9. 'always to take it slowly when going through narrow gaps';
10. 'always to look around carefully when reversing';
11. 'always to look carefully before changing lanes';
12. 'always to regularly check my tyres';
13. 'always to slow down when there are children playing on the pavement';
14. 'always to watch out for other drivers to do something unexpected';
15. 'never to change lanes without checking very thoroughly first';
16. 'always to drive more slowly when it is wet or icy';
17. 'never to overtake unless I can clearly see that it is definitely safe';
18. 'always to slow down approaching traffic lights that might change to red';
19. 'never to pull out unless I am completely sure it is safe';
20. 'always to avoid doing anything that would distract my attention from the road'.

There are numerous ways that one might attempt to move drivers' identities in this direction. Many of these are well-established practice in persuasion, such as the use of repetition, using sources that have high credibility with the target audience, etc. The following are some that are less obvious:

1. Focus messages specifically on the identity, as in 'being the type of driver that ...'.
2. Tailor messages to the core values of drivers' current identities. For example, for drivers with high levels of self-importance, associate the safe driving practices with being better than other drivers. With drivers low in social deviance, associate safe driving practices with what is morally right.
3. Foster a sense that being the kind of person that adopts safe driving practices is the norm for the reference group of the target audience.
4. Prime receptiveness to the message with a stimulus that raises physiological arousal levels and message salience.
5. Frame messages that create a feeling of attractiveness to the new identity rather than punishing the old identity.

A starting point in testing these ideas could be to develop a simple 'Driver Identity Inventory' based on the self-statements listed above. Drivers would be asked 'How

important is it to how you feel about yourself to be the kind of driver that tries hard to ...'. A simple response scale might be 'very important, quite important, not very important, not at all important'. PRIME theory would predict that scores on such an inventory would forecast individual crash rates better than existing attitudinal or even driving behaviour measures. PRIME theory would also predict that a great deal of the variance in such a scale and in accident rates would be accounted for by a response to a self-statement of the kind 'I am the kind of driver who is always thinking about safety as I drive'. The inventory and the single safety rating could then be used as baseline and outcome measures when screening communications that are intended to promote safe driving and thus reduce crash risk.

Conclusions

This paper has argued that motivation plays a significant role in traffic crashes and that more should be done to motivate drivers actively to adopt safe driving practices, rather than just not adopting risky ones. It outlined an attempt to bring together diverse aspects of motivation into a single framework using concepts as close to everyday language as possible. This 'PRIME theory' of motivation proposes that it is useful to distinguish five levels of the motivational systems – Plans, Responses, Impulses/inhibitions, Motives, and Evaluations – and that ultimately all 'higher' motivations can only influence behaviour through the balance between impulses and inhibitory forces acting at a given moment. This tends, in practice, to establish a primacy on stimuli that generate impulses directly over those that generate other motivations, and those that generate feelings of want or need (motives) over those that generate beliefs about what one 'should' do (evaluations).

A major factor redressing this imbalance is our sense of identity. Hence, interventions that profoundly affect identities have the capacity to generate sustained behaviour change. The process of identity change is complex and not well-understood, but attempting to work with, rather than against, existing core values and self-perceptions could be important as could creating a strong sense that the identity being promoted is normative. The distinction between this approach and what is currently being done may seem subtle in that it is largely about the way that messages are framed. However, it could be important and the difference in effect should be detectable.

Research testing these ideas could progress through development of a 'Driver Identity Inventory' that asks drivers to indicate how important it is to see themselves as the kind of driver that engages in particular safe driving practices. Such an inventory is predicted to forecast crash rates better than existing measures and potentially to provide a focus, and a benchmark, for evaluating communications aimed at reducing crash risk.

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Testing the effects of a volitional intervention on drivers' compliance with speed limits: selected findings from a study on implementation intentions

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Introduction

Road safety education is one of the main tools available for promoting safer driver behaviour. Underpinning educational interventions is the idea that increasing (decreasing) drivers' motivation to perform 'safe' ('unsafe') driving behaviours (e.g. through attitude change) will influence actual on-road behaviour (e.g. increased compliance with speed limits, increased following distances, reduced drink-driving, and so on). Empirical evidence on the relationship between goal intentions (overall summary of motivation to perform a behaviour) and behaviour provides support for this view. In the present context, a series of prospective studies have found correlation coefficients for the 'goal intention – speeding behaviour' relationship that are in the range of $r = 0.48$ to $r = 0.76$ (Conner *et al.*, 2007; Elliott *et al.*, 2003, 2007). These findings are consistent with research in other domains (e.g. Armitage and Conner, 2001) and demonstrate that goal intentions have a reliable association with behaviour. However, it is clear that the relationship between motivation and behaviour is not perfect. In the present context, this implies that, for many drivers, there is a 'gap' between what they intend to do and what they actually do. This intention–behaviour gap was the starting point for the present study, which was concerned with testing a volitional intervention, based on Gollwitzer's (1993, 1996, 1999) concept of implementation intentions.

The intention–behaviour gap

While the majority of studies in the literature focus on assessing the overall level of association between motivation and behaviour (for reviews see Armitage and Conner, 2001; Godin and Kok, 1996), it has been pointed out that indices of association, such as r or R^2 , do not illuminate the **sources** of consistency and discrepancy (e.g. Orbell and Sheeran, 1998). These sources of consistency and discrepancy between motivation and behaviour can be shown by decomposing the goal intention–behaviour relation into a 2 (intention: to behave vs not to behave) \times 2 (behaviour: performed vs not performed) matrix (see Orbell and Sheeran, 1998; Sheeran, 2002). This shows that the consistency between goal intentions and behaviour is due to what Orbell and Sheeran (1998) term ‘inclined actors’ (people with positive intentions that subsequently perform the target behaviour) and ‘disinclined abstainers’ (people with negative intentions that do not subsequently perform the target behaviour). On the other hand, the discrepancy in the ‘goal intention – behaviour relation’ is due to ‘disinclined actors’ (people with negative intentions that actually go on to perform the target behaviour) and ‘inclined abstainers’ (those that have positive intentions but do not subsequently perform the target behaviour).

Studies of health behaviour have shown that discrepancies in the ‘goal intention – behaviour relation’ are primarily due to inclined abstainers rather than disinclined actors (e.g. Orbell and Sheeran, 1998; Sheeran, 2002). In the present context, a re-analysis of our data on the relation between drivers’ goal intentions and speeding behaviour (Elliott *et al.*, 2007) supports that finding. Across four types of road, 10% of drivers, on average (mean), were disinclined actors – they did not intend to comply with the speed limit, but they were subsequently observed to comply with the speed limit more often than did the average (median) driver in the sample. On the other hand, an average (mean) of 25% of drivers were inclined abstainers – these drivers were observed to comply with the speed limit less often than did the average (median) driver in the sample, despite their positive goal intentions. Our re-analysis also showed that 41% of drivers intended to comply with the speed limit and subsequently did so more often than the average driver in the sample (inclined actors), and 24% did not intend to comply with the speed limits and subsequently did not comply (disinclined abstainers).

The findings reviewed above imply that being motivated is not necessarily enough, on its own, to ensure that drivers will comply with the speed limit. Many drivers who are motivated to comply with the speed limit may actually go on to do so, but many motivated drivers may not. From an applied perspective, the implication is that ‘traditional’ road safety interventions that aim to increase drivers’ motivation to perform safe driving behaviours may not be effective at influencing the behaviour of a potentially large number of drivers. The question then arises as to what can be done to bridge the motivation–behaviour gap. In other words, ‘How can drivers translate their positive goal intentions into action?’ Theoretical models, such as the Theory of Reasoned Action (Fishbein and Ajzen, 1975) and Planned Behaviour (Ajzen, 1985) are limited in the extent to which they can help answer this question, because they are primarily concerned with the formation of a goal intention. On the other hand, the model of action phases (e.g., Gollwitzer, 1990; Heckhausen, 1991; Heckhausen and Gollwitzer, 1987) views motivation (intention formation) as only a

first stage that people need to reach to ensure successful behavioural performance. A second, post-intentional, or **volitional**, stage is also posited by the model of action phases in which people need to develop strategies to ensure that motivation is translated into action (known as **intention realisation**). Gollwitzer's (1993, 1996, 1999) concept of implementation intentions is important in this regard.

Implementation intentions

Implementation intentions are volitional strategies that help promote intention realisation (for reviews see Gollwitzer and Schaal, 1998; Sheeran, 2002; Sheeran *et al.*, 2005). Whereas goal intentions summarise overall levels of motivation to perform a behaviour (e.g. 'I intend to comply with the speed limit'), an implementation intention requires people to specify when, where (i.e. the situations) and how (i.e. the strategies) the intended behaviour will be carried out. Therefore, there are two critical components to an implementation intention:

- (a) the identification of a response that will lead to goal attainment;¹ and
- (b) the identification of a suitable situation in which to initiate that response.

The formation of an implementation intention then requires an individual to link the identified situational cues to the goal-directed response, via a conscious act of will (Sheeran *et al.*, 2005). This creates an association in memory between the specified situational cues and the desired behavioural response (e.g. 'Starting next Monday, if I am driving home from work, then I will ignore any pressure to drive fast from other drivers to ensure that I comply with the speed limit').

Theoretically, implementation intentions help people to successfully perform their intended behaviours because:

- (a) the situational cues specified in the implementation intention become highly accessible, which helps people to avoid missing good opportunities to act (e.g., Orbell *et al.*, 1997; Sheeran and Orbell, 1999; Webb and Sheeran, 2004); and
- (b) they lead to automated action initiation when the environmental conditions specified in the implementation intentions are met (e.g., Brandstätter *et al.*, 2001; Gollwitzer and Brandstätter, 1997; Orbell and Sheeran, 2000; Webb and Sheeran, 2004).

In other words, when an implementation intention has been formed, it means that people do not have to think about the appropriate behavioural response in situ, because control over the behaviour is, in effect, passed over to the situational cues that are specified in the implementation intention. In this way, the effects of implementation intentions are similar to the effects of habits (Sheeran *et al.*, 2005). Habits originate from repeatedly performing behaviour in stable contexts, meaning that strong associations develop in memory between contextual cues and behavioural

¹ In the present context, goal attainment can be thought of as the performance of safe driving behaviours.

performance, and when those contextual cues are encountered the behaviour is automatically initiated with little conscious effort or control (e.g., Mittal, 1988; Triandis, 1977, 1980). However, because the associations between contextual cues and behavioural performance originate from past experience, which may be counter-intentional, the automated behaviour produced by habit may not be consistent with people's goal intentions. On the other hand, because implementation intentions are formed through a conscious act of will, the automated behaviour produced by implementation intentions is strategic and consistent with people's goal intentions (Gollwitzer and Schaal, 1998).

In the present context, both expert opinion (e.g. Manstead and Parker, 1996; McKenna, 2005) and empirical evidence (see Elliott *et al.*, 2003) suggest that drivers' speed choice is strongly habitual. This is one possible reason why many drivers may not comply with speed limits in spite of their positive motivation (i.e. situational cues may be triggering an unwanted behavioural response). It is therefore plausible that implementation intentions will be an effective strategy for promoting compliance with speed limits, because they may break the effects of bad driving habits through **strategic** automaticity.

In other domains, empirical studies have shown that forming an implementation intention increases the likelihood that people will carry out a number of behaviours. Specifying an implementation intention has been found to be effective at increasing:

- attendance for cervical cancer screening (e.g. Sheeran and Orbell, 2000);
- vitamin supplement uptake (e.g. Sheeran and Orbell, 1999);
- breast self-examination (e.g. Orbell, *et al.*, 1997);
- exercise (e.g. Milne *et al.*, 2002);
- healthy eating (e.g., Armitage, 2004; Verplanken and Faes, 1999);
- functional ability after surgery (e.g. Orbell and Sheeran, 2000); and
- workplace health and safety behaviour (e.g., Sheeran and Silverman, 2003).

In each of these studies it has been found that, despite equivalent levels of motivation, participants randomised to experimental groups (who are asked to specify an implementation intention) increase their performance of the required behaviour, whereas control participants (who do not specify an implementation intention) do not. This supports the contention that supplementing a goal intention (e.g. 'I intend to comply with the speed limit') with an implementation intention increases the likelihood that people will carry out the required behaviour.

The present study

As far as we are aware, the present study was the first study to have tested the efficacy of implementation intentions in the domain of driver behaviour. Given that

implementation intentions had been shown to aid intention realisation in other contexts, their ability to promote drivers' compliance with 30 mph speed limits was tested in the present study, using a randomised controlled design. The specific target behaviour under study was compliance with 30 mph speed limits, because official statistics show that most traffic accidents occur on roads in 30 mph areas (Department for Transport, 2004).

Initially, 600 drivers were randomly selected from a participant pool held by the UK's Transport Research Laboratory (TRL). These drivers were then randomly assigned to experimental and control conditions. All participants were sent postal questionnaires to obtain baseline measures of motivation (goal intention to comply with 30 mph speed limits) and behaviour (self-reported compliance with 30 mph speed limits). The implementation intention manipulation (see Figure 1) was inserted into the experimental participants' baseline questionnaire, after the items to measure motivation and behaviour. Control participants completed the questionnaire measures only. Participants who returned a completed baseline questionnaire were issued a second postal questionnaire, one month post-baseline. The follow-up questionnaires contained the same standard items as used in the baseline questionnaires to measure goal intentions (e.g. 'To what extent do you intend to comply with 30 mph speed limits when driving over the next month?' *not at all – a lot*) and behaviour (e.g. 'How often have you kept within the speed limit when driving in 30 mph areas over the last month?' *never – nearly all the time*). All items were measured on seven-point scales. All participants were instructed to complete the questionnaires on their own and confidentiality was assured.

At baseline, 300 drivers completed and returned a questionnaire ($n = 129$ in experimental condition; $n = 171$ in control condition). At follow-up, 258 drivers completed and returned a questionnaire (overall response rate = 43%).

Selected findings from the study are discussed here, although no details of the statistical results are reported. A full report on this study can be found in Elliott and Armitage (2006). That article presents results that show the effects of specifying an implementation intention both on drivers' motivation and on behaviour. It also presents moderator analyses that examined the effects of implementation intentions on behaviour at different levels of motivation to comply with the speed limit (low, moderate and high levels of goal intention) – the idea being that implementation intentions should have stronger effects on behaviour with increasing motivation to comply with the speed limit. This is because implementation intentions are subordinate to goal intentions (Gollwitzer, 1993), and therefore specifying an implementation intention should influence behaviour to the extent that motivation is present (i.e. people must be motivated to comply with the speed limit before implementation intentions can be expected to have an effect on behaviour). Finally, the full paper for this study investigates the relationship between the number of implementation intentions that people specified and the extent to which behaviour changed.

One issue is considered here: Does specifying an implementation intention increase compliance with speed limits? We hypothesised that, despite equivalent levels of motivation, drivers who are asked to specify an implementation intention to comply with the speed limit would be more likely to subsequently comply with the speed limit than would drivers who do not specify an implementation intention.

Figure 1 Implementation intention manipulation

Many drivers exceed the speed limit, even though they may not intend to. If you form a specific plan of exactly when, where and how you will keep to the speed limit, you are more likely to actually do it. We would like you to try to keep within the speed limit when you are driving in 30 mph areas over the next month. Please decide now when you will start to keep to the speed limit while driving in 30 mph areas, and where and how you will do it. Please use the spaces below to write down in as much detail as possible when, where and how you will try to keep to the speed limit.

☐ Tick this box if you do not want to try to keep within the speed limit.

A. When will you try to start keeping within the speed limit in 30 mph areas? [YOUR WHEN PLAN]

B. Where will you try to keep within the speed limit? (e.g. particular roads or journey types) [YOUR WHERE PLAN]

C. How will you ensure that you keep within the speed limit while driving in 30 mph areas? [YOUR HOW PLAN]

You may find it useful to think about those situations in which you are likely to exceed the 30 mph speed limit and think about how you will stop yourself from doing so.

To ensure you have made a link in your mind between the situations you have described and the act of keeping within the 30 mph speed limit, imagine yourself in those situations and tell yourself 'If I find myself in this situation, I will ...[insert how plan]... to ensure that I do not drive faster than the speed limit'.

Analyses of the baseline data confirmed that there were no significant differences between the experimental and control conditions on the baseline measures of motivation and behaviour, indicating that the randomisation of participants to experimental and control conditions was successful. However, there were significant differences between those who participated at both time points of the study and

those who dropped out at follow-up. Importantly, however, no significant condition \times attrition interactions were found, demonstrating that both conditions were affected equally by attrition (note that, because there were significant differences between those who participated in the study at both time points and those who dropped out at follow-up, the intention-to-treat principle was used to investigate implementation intention effects – see Elliott and Armitage, 2006).

Inspection of the mean scores on the measures of motivation and behaviour showed that participants in each condition were highly motivated to comply with 30 mph speed limits and that they reported often complying with 30 mph speed limits. However, it was notable that the mean scores on the baseline measures of behaviour were almost one scale point lower than were the means on the baseline motivational measures, implying that, on average, there was a gap between participants' motivation to comply with the speed limit and their actual compliance with the speed limit.

Consistent with predictions, reported compliance with the speed limit:

- (a) increased significantly between baseline and follow-up for the experimental group but not for the control group; and
- (b) was significantly greater at follow-up for the experimental group than it was for the control group.

Participants who regularly complied with the speed limit (defined as those who scored 6 or more on the 7-point behaviour scales) were significantly (1.4 times) more likely to report that they regularly complied with the speed limit at follow-up than were participants in the control group.

Discussion

The starting point for the present study was the apparent gap between drivers' goal intentions and speeding behaviour, with drivers who do not comply with the speed limit despite their positive motivation being primarily responsible for this gap. The concern was that 'traditional' forms of road safety education, which focus solely on increasing motivation, will not have the desired effect on the behaviour of this potentially large group of drivers. We therefore tested whether supplementing drivers' existing levels of motivation (i.e. their goal intentions) with an implementation intention increased compliance with speed limits.

The findings demonstrated that implementation intentions are an effective strategy for promoting drivers' compliance with speed limits. Despite equivalent levels of motivation and behaviour at baseline, participants who specified an implementation intention reported a greater amount of compliance with 30 mph speed limits at follow-up than did control participants, and, compared with control participants, they reported that they significantly increased their compliance with speed limits over the two time-points of the study. Overall, therefore, these results add to the growing support for the efficacy of implementation intentions as a means of promoting 'desirable' social behaviour.

From a road safety perspective, the findings imply that interventions are likely to be most effective when they incorporate volitional strategies, and future interventions might usefully incorporate the implementation intention manipulation used here. As discussed earlier, implementation intentions are subordinate to goal intentions (Gollwitzer, 1993). This is consistent with the model of action phases (e.g. Gollwitzer, 1990; Heckhausen, 1991; Heckhausen and Gollwitzer, 1987), which states that, in order to successfully perform a behaviour, people first need to be motivated and then they need to develop volitional strategies. Therefore, it seems likely that the most effective way to promote safer driver behaviour will be to incorporate implementation intention manipulations into existing forms of driver education that aim to increase drivers' motivation to comply with the speed limit (e.g. speed awareness courses). More generally, the major advantage of this form of intervention is that it can be self-directed and therefore inexpensive to administer (Armitage, 2004).

A possible limitation of the present study is that self-reported behaviour measures were used. However, there is good reason to be confident in the validity of the findings. Self-reports are regarded as a valid methodology in the social sciences (e.g. Corbett, 2001) and previous studies (e.g., Aberg *et al.*, 1997; De Waard and Rooijers, 1994; Elliott *et al.*, 2007) have shown that self-reports are strongly correlated with objective measures of drivers' speed (also see Elliott and Armitage (2006) for evidence which suggests that the present findings were not the result of demand characteristics). That said, avenues for future research include the use of more objective measures of driving speed (e.g. black-box technology). A potentially more contentious issue, however, is the use of the reasonably short (one-month) follow-up period that was used in the present study. The concern is whether the effects of implementation intentions would persevere over a longer period. Previous research evidence on this issue is mixed. A study by Jackson *et al.* (2005) found no effects of implementations on fruit and vegetable consumption over a three-month follow-up period (but note that no effects of implementation intention were found in the short term either). Sheeran and Silverman (2003), on the other hand, found that, over a three-month period, attendance at workplace health and safety training courses doubled when participants specified an implementation intention to attend a course. Therefore, future research should use longer follow-up periods to assess implementation intention effects in the driving context. More generally, further research is needed to test whether the effects of implementation intentions generalise to driver behaviours other than speeding, such as the avoidance of drink-driving and mobile phone use, and wearing seat belts.

Overall, the present study provides encouraging results for the efficacy of implementation intentions as a means of promoting desirable driver behaviour. However, further research is needed to establish whether these effects will persist over time and generalise to other driving behaviours.

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The drink-drive rehabilitation project

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Introduction

The drink-drive rehabilitation (DDR) scheme has, since January 2000, permitted courts throughout Great Britain to refer drink-drive offenders to a Department for Transport approved rehabilitation course. It is a voluntary decision by the drink-drive offender to take up the offer, which is made during the court hearing, following sentencing. Upon satisfactory completion of the course, offenders receive a reduction in their disqualification period (which is a minimum of 12 months) of up to 25%. The Department for Transport has produced guidelines for the accreditation of courses (in 2002 and re-issued in 2004) which cover minimum standards while allowing a degree of flexibility.

Prior to the nationwide expansion of the DDR scheme, the Transport Research Laboratory (TRL) conducted a detailed evaluation of the effectiveness of pilot courses that were introduced in 1993 in a few areas. The study demonstrated that the courses were effective in reducing the reconviction rates of offenders who had attended a DDR course between 1993 and 1996, when compared with drink-drive offenders who had not attended a course during this time (Davies *et al.*, 1999).

The take-up rate of the DDR courses and subsequent reconviction rates for drink-drive offences were monitored in a three-year study including all convicted drink-drive offenders who were referred to the scheme from 1 April 2000 to 31 March 2002. Within the previously reported scheme monitoring research (Smith *et al.*, 2004), differences in format, tutor training and experience were found among the course providers (which vary from private companies to probation services and alcohol charities).

The recently published report (TRL 662; Inwood *et al.*, 2007) presents the findings of the most recent study, which was commissioned by the Department for Transport to:

- monitor the take-up and reconviction rates of offenders identified in the previous study who were referred to rehabilitation courses between 1 April 2000 and 31 March 2002;

- research the differences in course provider practices in order to investigate any differential effect on reconviction rates; and
- investigate the attitudes, behaviours and opinions of referred offenders via a postal survey in order to consider implications for the future design and development of the scheme.

This report identifies key findings, the main one being that the DDR scheme is effective in reducing subsequent drink-drive convictions. The results of the postal survey of referred offenders and its limitations are discussed, as well as the implications for future research.

Methodology

Monitoring study

Within the previous study (Smith *et al.*, 2004) the Rehabilitation Database was developed from information supplied to TRL by course providers. This database contained information on all drink-drive offenders convicted between 1 April 2000 and 31 March 2002 who had been referred to a DDR course-providing organisation. In order to analyse both course take-up and reconviction rates of this sample, the Rehabilitation Database was matched with data received from the Driver and Vehicle Licensing Agency (DVLA) using driver number and sentence date. These data were received in January 2006 and were complete for records up to 31 March 2005. The DVLA database contains confirmation of course completion, as well as information about offenders' motoring convictions both before and after the criterion drink-drive offence for which they were entered in the Rehabilitation Database.

Survey of course providers

Between December 2003 and January 2004, telephone interviews were conducted with an appropriate representative from each course provider. One course provider was also visited in order to conduct the interview and see how the course is structured. A questionnaire was developed to structure the interviews and record the information given. The aim of the questionnaire was to obtain more detailed information on the points of interest found in the previous study and investigate:

- the duration and number of sessions;
- the day and time of sessions;
- the number of weeks over which the course runs;
- whether, and how, the format that each offender attends is recorded;
- the qualifications and experience required of new tutors and their background;
- the number of tutors employed;

- the methods used to train tutors; and
- how tutors' performance is monitored.

Survey of referred drink-drive offenders

The sample for the survey was obtained from course providers who had a Data Protection statement covering correspondence sent to referred offenders. A total of 150,012 records of referred offender contact details was subsequently provided by six course providers with a good geographical coverage. A representative sample was required and, for initial planning purposes, the overall expected response rate was taken as 30%. A sampling frame was derived from data supplied by course providers. It was calculated that it would be necessary to send approximately 10,000 questionnaires, split between 5,000 DDR course attendees and 5,000 non-attendees. The strong bias towards males, and experience from previous studies that they are less likely to respond to a questionnaire survey, required a differential sampling process. In round terms, in order to achieve the required sample sizes of 1,000 females and 1,000 males, a sample of 2,500 females and 7,500 males was selected, i.e. the expected response rates were 40% and 13.3% respectively. In practice, questionnaires were sent out to 10,028 referred drink-drive offenders. A reminder survey of 5,000 drivers who had not responded to the original survey was also carried out using the same sampling rates.

Exploratory investigations helped to develop the survey and ensure that all aspects were addressed. These involved two focus groups with referred drink-drive offenders who had attended a DDR course and four face-to-face depth interviews with referred drink-drive offenders who had not attended a DDR course. In addition, the questionnaire was sent to all course providers, allowing them the opportunity to comment and suggest additional or alternative questions, topics and wording (particularly concerning literacy levels). Driving style was measured using a seven-point bipolar rating scale proposed by Guppy *et al.* (1990), and items to measure general driving behaviour in terms of violations and aggressive violations were taken from the driver behaviour questionnaire (Reason *et al.*, 1990; Parker *et al.*, 1995). The questionnaire was piloted with 10 referred drink-drive offenders and explored the following aspects:

- circumstances around their offence;
- alcohol-related knowledge;
- attitudes towards drinking and driving;
- intentions, expectations and perceived control regarding future drink-drive behaviour;
- reported driving style and drink-drive behaviour;
- motivations to attend a course; and
- opinions on reducing drinking and driving in general.

Results

Monitoring study

Up to five years after sentencing for their original drink-drive offence, 44% of those referred to the scheme during the two-year sampling period had completed a DDR course. An additional 0.1% (118) referred offenders within the national sample had attended a DDR course in the previous year, compared with an additional 6% (5,623) whose disqualification period had ended during the previous year but who had not attended a course. The remaining 1% (1,075) of referred offenders were still able to attend a course.

This investigation has identified those groups where at least one half of the sample attended a DDR course once referred:

- female offenders;
- older offenders (aged 40+); and
- offenders of higher social status (wealthy achievers, ACORN category).

The reasons behind these groups' over-representation in the course attendance figures are likely to vary and can only be hypothesised. For example, the above average rate of attending among these groups may be due to personal circumstances, such as increased income and ability to pay to attend a course, or increased reliance on their vehicle and a need to return to driving as soon as possible. At the other end of the scale, only one in three HROs (High Risk Offenders) attended a course. HROs include drivers disqualified for:

- having an alcohol concentration at least 2½ times the legal limit;
- committing two or more offences of having excess alcohol or being unfit to drive through drink within a period of 10 years; or
- failing without reasonable excuse to provide an evidential specimen for alcohol analysis.

The main conclusion from this analysis of the subsequent drink-drive offences committed by this group of drivers is that, over the long-term course, non-attendees are about 1.75 times more likely than attendees to be convicted of a subsequent drink-drive offence.

While investigation of the reconviction rates for any motoring offence had previously shown a positive effect of course attendance, the latest results demonstrate that course attendees' and non-attendees' offence rates are similar between four and five years after their original drink-drive convictions. Since course attendees are generally disqualified for shorter periods, which are further reduced by course attendance, it is likely that they regain their licences earlier and thus have driven more, which may increase the reconviction rate.

DDR course attendance has been shown to be more effective in reducing reconvictions among the following groups:

- offenders with a recent previous motoring conviction (including HROs);
- younger offenders (aged under 30 years); and
- male offenders.

As with course take-up, the reasons for these differences may vary. However, in all cases, the greater effectiveness is largely due to the increased level of reconvictions among these groups of offenders who have not attended a DDR course (compared with other non-attendees). For example, young offenders are reconvicted more often than older offenders if neither group attends a DDR course, while the level of reconvictions among this younger age group reduces towards that of older offenders when both have attended a DDR course. The greater effect of course attendance can therefore be explained, at least in part, by its ability to 'homogenise' the reconviction rates of both groups.

Survey of course providers

Although there were apparent differences among course providers, depending on the background of their organisation, some common practices emerged. The majority of providers favoured a course format consisting of one session per week, allowing time between sessions to reflect on the material learnt and to take in what has been taught in each session; it also allows time to complete homework. Weekend or weekday blocks are only offered by a quarter of all course providers and, even then, do not seem to be favoured as the best method by course providers and are mainly offered for the convenience of course participants. Over half of course providers used two tutors to run sessions, with the majority of providers always using the same tutor to run every session within a course, to ensure consistency and familiarity to the participants.

Providers tended to favour experience over qualifications when recruiting tutors, in particular looking for experience in alcohol work, probation services or adult education. The most common qualifications looked for in tutors involved those obtained by trained counsellors or probation workers, or teaching qualifications, although not all providers felt qualifications were a vital ingredient for a successful tutor. The course providers from a probation service background tended to employ tutors exclusively from the probation services, while the charities or private companies had tutors from social work, health or road safety backgrounds. All these professions will give tutors valuable knowledge and experience in the health and psychological aspects related to drinking and driving as well as experience dealing with offenders.

Of the 25 course providers, 22 offered training to their tutors, which was mostly internal, with senior tutors or management. External training was also provided by 10 course providers, as a way of ensuring that all their tutors felt fully competent before leading a course, particularly in specific areas. In order to maintain this competency and improve tutor skills, the majority of providers made use of methods to monitor tutors' performance. The most commonly used method was a post-course

evaluation questionnaire, with tutors observing other tutors' courses also widely used. Formal external assessments and mystery shoppers were only used by the larger providers, possibly because other providers could not afford such measures.

The background of a provider is likely to affect their view of the best practice for course delivery, although all providers are dedicated to raising the awareness of participants of the issues surrounding drinking and driving. The competition among course providers may prove to be detrimental to the quality of the course offered, as most offenders will choose to attend the course with the lowest course fee. However, if a course fee is lower, the staff and tutors employed will not be paid as well, and there may not be enough money for monitoring methods, such as mystery shoppers. Some providers have suggested that magistrates who have a preferred course that they recommend to each drink-drive offender may reduce the competition among course providers.

Survey of referred drink-drive offenders

SAMPLE OVERVIEW

The overall response rate was a disappointing 8.38% (840 out of 10,028), despite sending a reminder survey and allowing additional time to respond. However, the upshot of designing the sampling frame with reference to expected differential response rates was that all sub-groups of referred drink-drive offenders were represented in the achieved sample. This, in turn, enabled weighting of the sample, so that analyses could be conducted based on the population rather than the (potentially biased) achieved sample. As the achieved sample was self-selected, there was some potential for a bias. The poor response rate and potential bias means that even statistically significant results should be treated with caution, as a different picture might have emerged with a fuller response.

In order to correct the balance of respondents (on age group, gender, disqualification period and whether attended a DDR course), sample weights were taken into account when analysing the findings. Weights were calculated as a ratio of the data that were obtained from the survey to population data and adjusted to sum to unity. A statistically significant difference was found between the demographic variables of the (weighted) sample between those who had attended a course and those who had not, on gender, age group, disqualification period and ACORN category (but not on HRO status) in line with the take-up rate for DDR courses and that seen in the monitoring study. For further analyses throughout the rest of the report, these variables were entered as covariates in statistical analyses in order to control for their potential effects on the outcome, i.e. to be confident that any difference between attendees and non-attendees was as a result of the DDR course rather than these demographic variables.

CIRCUMSTANCES AROUND THE OFFENCE

Course attendees reported consuming significantly less alcohol prior to their offence (13.39 units) than non-attendees (15.64 units). The findings in respect of self-reported alcohol consumption according to demographic variables were much as

expected from previous studies, which gives some confidence in the reliability of the remaining questionnaire responses:

- men drank significantly more than women – 15.01 units on average compared with 10.79;
- HROs drank significantly more than non-HROs – 17.36 units on average compared with 13.60;
- the lowest and highest ACORN category (wealthy achievers and the hard pressed) drank significantly more than the comfortably-off and those with moderate means; and
- those aged 55 and over drank less than all other age groups (statistically significantly less than all except 40–54) and 40–54-year-olds drank significantly less than 21–29- and 30–39-year-olds.

There was no statistically significant difference according to course attendance or ACORN category in terms of the reason for driving when over the legal drink-drive limit. More male than female respondents thought they would get away with it (20% and 10%). HROs were more likely than non-HROs to say that they did not think about whether they were under or over the limit (35% and 19%) and, perhaps understandably in light of this, less likely to say that they thought they were still safe to drive (27% and 35%). There seems to be a tendency for older drink-drive offenders to think that they were still safe to drive and less likely to think they would get away with it.

Overall, the six principal reasons given for drinking and driving were:

1. I thought I was safe to drive (33%).
2. I thought I was under the legal drink-drive limit (26%).
3. I did not think about whether I was under the legal drink-drive limit (23%).
4. I did not have far to travel (23%).
5. I thought I would get away with it (19%).
6. I had to go somewhere unexpectedly (17%).

In terms of the reasons given by respondents for being stopped or approached by police, course attendees were more likely than non-attendees to have been involved in an accident (29% of attendees and 16% of non-attendees) and less likely to have had a vehicle fault (11% of attendees and 16% of non-attendees). It is possible this may be interpreted as being the accident itself that induced shock and possible feelings of guilt (they may have felt responsible for the accident) and that provided the motivation for attendance. HROs and those aged 55 and over were more likely to report that the reason given by police for testing them was they had been told or suspected that the respondent had been drinking alcohol (20% of HROs compared with 12% of non-HROs, and 35% of those aged 55+ compared with 21% or less for the other age groups).

Of the 42 respondents who refused to provide a sample of blood, breath or urine to the police, the most common reasons given were that:

- they thought it was their ‘right to refuse’ (33%);
- they thought they ‘would be over the legal drink-drive limit’ (23%);
- they were ‘unable to give a sample with the equipment available (16%);
- they were ‘not told it was a serious offence to fail to give a sample’ (6%); and
- they panicked (4%).

The mean self-reported level of alcohol measured by police for this drinking and driving offence for this sub-group of respondents was 12.41 units. The overall mean was 14.52. For those who felt that they would be over the legal drink-drive limit, the mean self-reported units was 28.21.

ALCOHOL-RELATED KNOWLEDGE

Attendees scored significantly higher on the alcohol-related knowledge questions than non-attendees (5.7 out of 10 for attendees and 3.8 for non-attendees), and there was no statistically significant difference according to the time lapsed between attending a course and completing the questionnaire (indicating that there were no decay effects over time). There was a tendency for those in higher ACORN categories (i.e. more wealthy) to score higher.

ATTITUDES TOWARDS DRINKING AND DRIVING

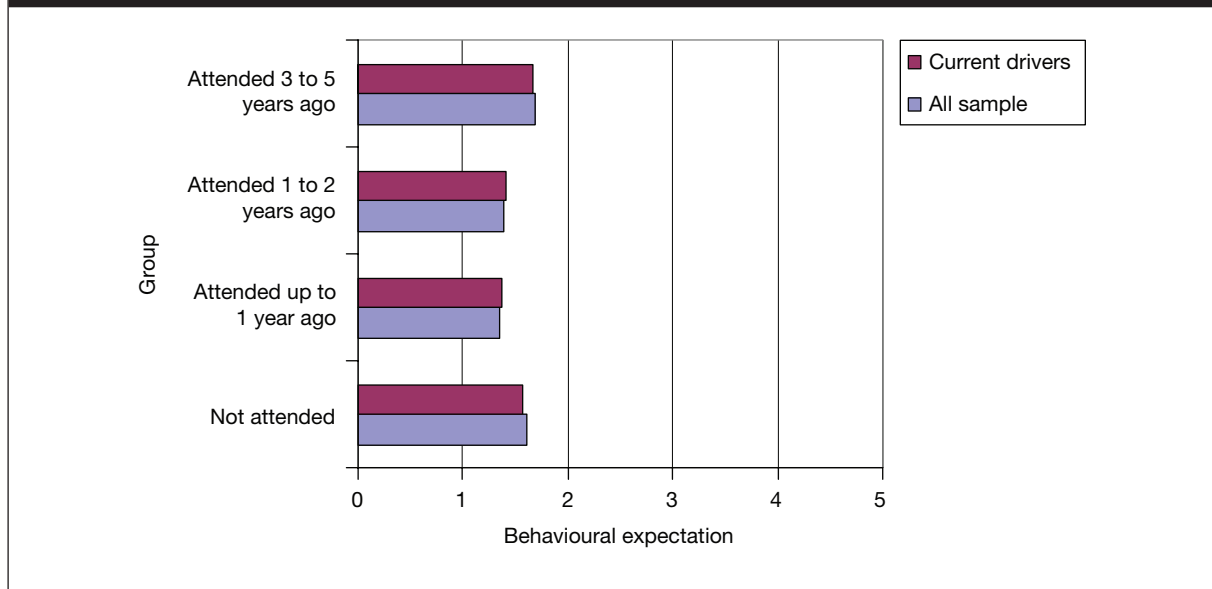
There was no statistically significant effect of course attendance on attitudes towards drinking and driving, either overall or when looking at the effect with time. However, all respondents had a high score (at least 3.86 out of 5), showing a very safe attitude. This suggests that the offence, or being convicted itself, improves someone’s attitude towards drinking and driving – or that the sample is biased.

FUTURE DRINK-DRIVE BEHAVIOUR

Respondents reported a very strong intention to avoid drinking and driving in the future, regardless of course attendance, with both attendees and non-attendees scoring over 4.4 out of 5. Although there was no difference between non-attendees and attendees overall in terms of behavioural expectation regarding the likelihood of drinking and driving in the future, a statistically significant effect was found between groups when divided by time since course completion. Those who had not attended a course reported a greater expectation of their drinking and driving in the future compared with those who had attended a course up to two years ago, and a lower anticipated future drink-driving compared with those who had attended a course between three and five years ago, suggesting a decay effect of course attendance with time. The pattern was the same when looking at only those who have returned to driving since the end of their disqualification period (current drivers). Figure 1

shows this as measured on a five-point Likert scale, where the higher the figure the greater the expectation offenders had of drinking and driving in the future. This finding has implications for refresher or top-up courses to ensure that lessons to be learnt are remembered over the longer term. However, it should be noted that the four groups consisted of different respondents, so these differences could be due to differences among the respondents themselves or the different DDR courses attended rather than the time delay.

Figure 1 Expectation of future drink-drive behaviour



EXPECTATION OF FUTURE DRINK-DRIVE BEHAVIOUR

There was a significant difference overall between attendees and non-attendees, in that attendees had greater perceived behavioural control (PBC) in relation to their ability to avoid drinking and driving in future. Attendees scored 4.5 out of 5, while non-attendees scored 4.3. No difference was evident among the groups of those who attended, suggesting that the PBC did not diminish with time since course completion.

REPORTED DRINK-DRIVE BEHAVIOUR

Among those who had returned to driving, there was no significant difference in reported drink-drive behaviour after the conviction between course attendees as a whole and non-attendees. However, there appeared to be a decay effect of course attendance over time. Non-attendees scored 1.28, recent attendees 1.26, and 1.22 and 1.61 for 1–2 years and 3–5 years since course completion respectively (the higher the score the more drink-drive behaviour reported). Those who had attended a course between three and five years prior to questionnaire completion reported significantly more drink-drive behaviour than all other groups. This could be due to inherent characteristics in the group or (although there are guidelines on the format of the course and course providers monitor the tutors) to changes in the course over time. Looking at the self-reported drink-drive behaviour before and after the conviction for this group shows that the behaviour had reduced overall with time. Indeed, there

was no statistically significant difference between the groups in the measure of behaviour change, because all reported less drink-drive behaviour after than before. Although there were limitations of the study design in that no actual ‘before’ measures were taken (e.g. in the form of a survey prior to the conviction or even prior to course completion), meaning that there could be inherent differences in the characteristics of offenders who go on to attend a course and those who do not, no differences were evident between the groups in terms of their reported drink-drive behaviour before their conviction.

When looking at driving style, as measured by the Guppy scale, those who had attended a course were found to be more attentive, careful, responsible and safe, but it is not known whether this is due to the course itself or a characteristic of the respondents. Compared with non-attendees, attendees reported driving when they suspected they ‘may be over the legal alcohol limit’ less frequently. This means that those who did not attend a course reported more frequently drinking and driving than those who did attend a course even though earlier on in the questionnaire, when respondents were asked how often they drink-drive (measured using three items which included drinking alcohol when planning to drive soon afterwards, driving after drinking alcohol, and driving when over the legal limit), there was no significant difference. Potentially this is due to being a more subtle measure. This second finding also matches the reconviction rates as described in study 1.

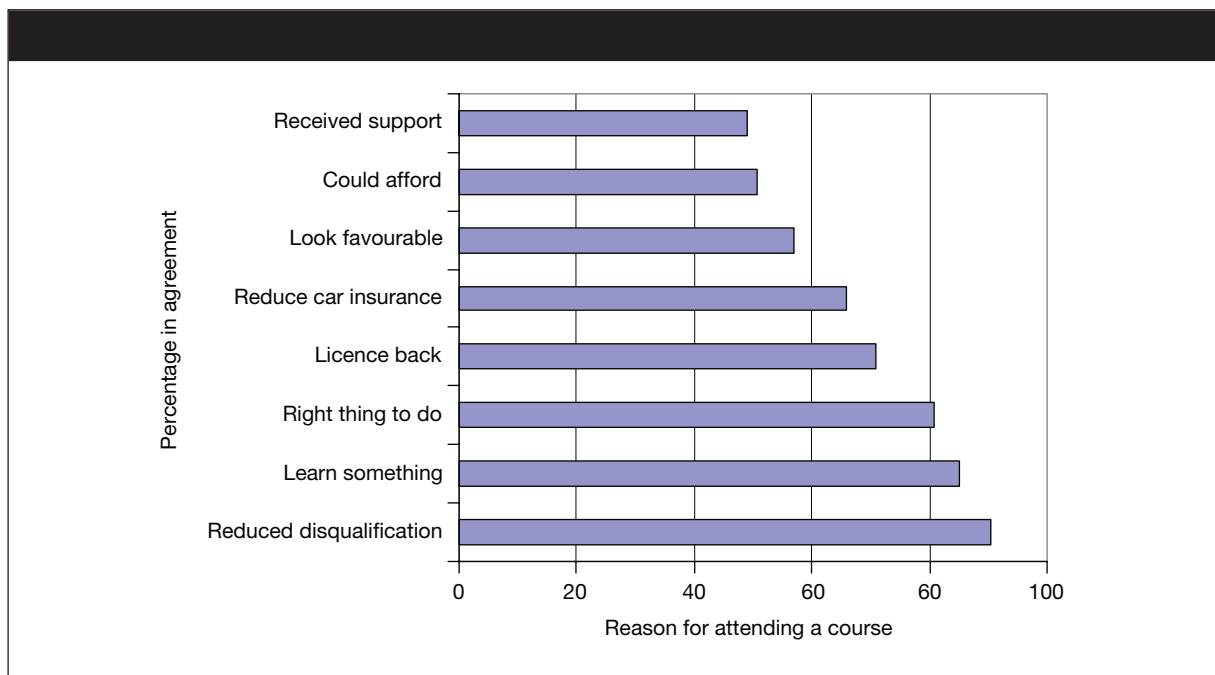
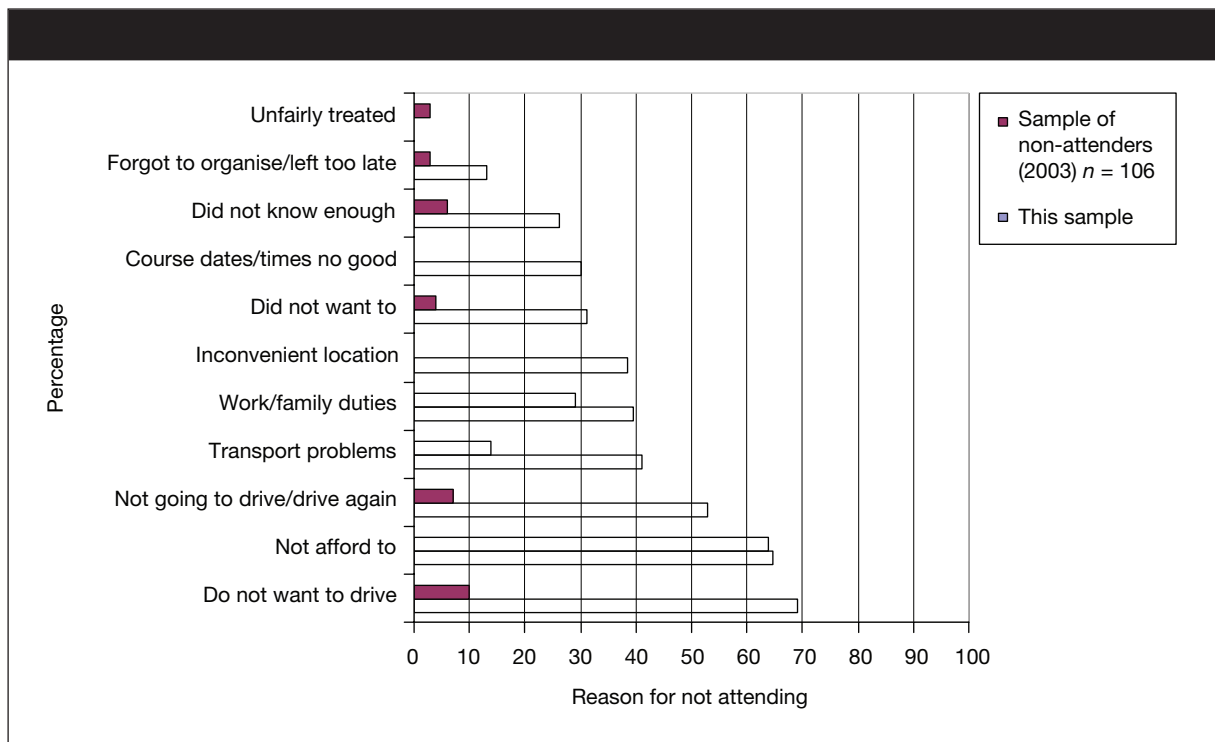
MOTIVATION TO ATTEND A DDR COURSE

The most common reason given by respondents for not attending a course (multiple responses were allowed) was that they did not want to drive again, and that they could not afford the fee. Stone *et al.* (2003) found that the main deterrent was the cost of the course. The sample from the current survey is compared with that from Stone *et al.*’s study in Figure 2. It is worth noting that over half of the respondents who did not attend a course believed that they were not going to drink-drive again and so there was no point in attending a course. There was a tendency for younger respondents to have forgotten to organise it or left it too late, for younger and older offenders to have transport problems and work/family commitments. Respondents in a higher ACORN category were more likely to report that the reason for not attending was because they did not wish to drive again, so there was no need. HROs were less likely than non-HROs to report that they ‘did not want to attend’, although it was not a strong reason for either.

No differences were found by ACORN category, gender or HRO status for the level of agreement with the reasons listed for attending a DDR course in Figure 3. However, younger attendees were more likely than older attendees to report that they received support and that a possible reduction of their car insurance was an incentive (probably because the cost of car insurance is so great for under-25-year-old drivers) and were less likely to report that they felt they would learn something useful.

OPINIONS ON REDUCTION OF DRINKING AND DRIVING

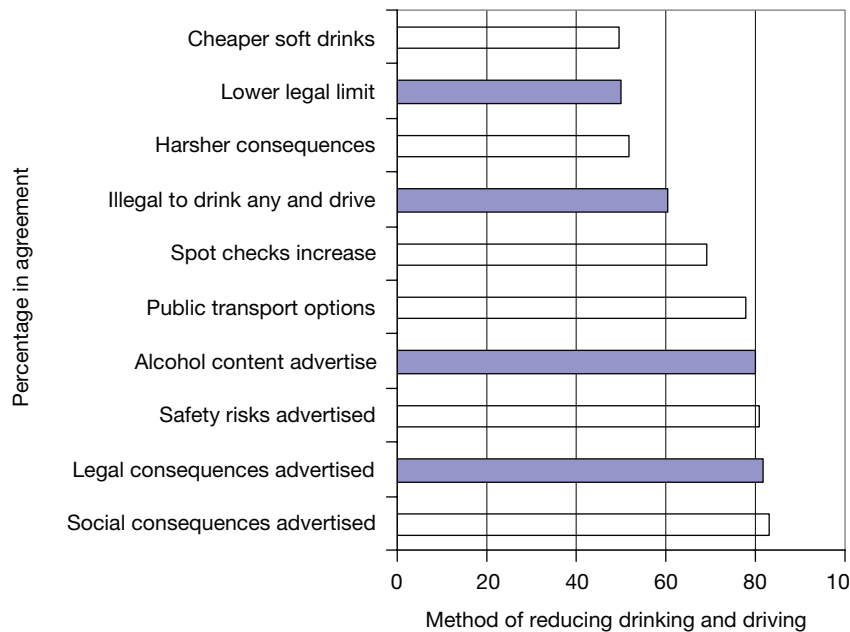
Figure 4 shows the proportion of respondents who agreed that the proposed ways of reducing drinking and driving would work. Course attendance had a significant



effect on opinions about ways of reducing drinking and driving, with attendees agreeing with the following significantly more than non-attendees:

- advertise the amount of alcohol in drinks better;
- advertise the legal consequences of drinking and driving more widely;
- landlords to serve cheaper soft drinks; and
- better public transport.

Figure 4 Opinions on ways to reduce drinking and driving



This suggests that course attendance raised awareness of the issues around drinking and driving or that attendees felt that drinking and driving could/should be reduced more than those who did not attend a course. However, non-attendees believed that making the legal consequences of drink-drive offences harsher would be more beneficial than attendees did.

Conclusions

The DDR scheme continues to be effective as measured by the lower drink-drive reconviction rates of course attendees. The main conclusions from the survey of referred offenders are that course attendees had more alcohol-related knowledge as well as greater perceived behavioural control over their drink-driving behaviour. All offenders who responded to the survey reported a strong intention to avoid drink-driving in the future. Those who had attended a course were more careful, attentive, responsive and safe drivers as measured by a Guppy scale, but conclusions about whether this difference was due to course attendance cannot be made with certainty, as they may have been more safety-conscious prior to attending the course. There was also an indication that those who did not attend a course were more likely to drive when they suspected they were over the legal drink-drive limit. The main motivation for attending a course was reported as the reduction in the disqualification period, while the main reasons not to attend were cost and not intending to drink and drive (or drive) again. Offenders' opinions on the most effective way to reduce drink-driving included educational measures, greater enforcement and legislative changes, i.e. lowering the legal drink-drive limit and making the consequences more severe.

Possible improvements to the DDR course scheme and ways to encourage take-up were suggested, and implications for drinking and driving in general were discussed. Some of the recommendations have already been implemented by individual course providers and the magistrates' courts. These included the following:

- add to the content of the course (warn that someone is impaired even if they think they are not over the limit, and how to calculate alcohol consumption);
- run a similar course for novice drivers and driving instructors;
- make the course compulsory for all offenders and introduce refresher courses;
- standardise criteria for tutors and explore ways to increase support to providers;
- advertise that attendance may reduce the cost of car insurance (especially to younger offenders) and that the disqualification period from driving is reduced;
- advertise the potential consequences of drink-drive behaviour (especially in relation to accidents) as well as financial options to attend the course;
- widen publicity provided to magistrates and sheriffs in Scotland;
- provide more information on the HRO programme;
- bring alcohol knowledge into school curriculum as part of health education; and
- introduce and publicise more draconian consequences for drink-drive offences.

Although there may be difficulties with the recruitment of subjects, future studies could follow groups of referred offenders through the rehabilitation process with different course providers. Offenders would be interviewed at different stages:

- prior to their court appearance;
- at conviction;
- during course attendance;
- on return to driving; and
- 3–4 years later.

Greater incentive for participation in the research may allow more detailed exploration into sensitive issues and reduce the potential for response bias.

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Work-related road safety CD-ROM evaluation: Phase I results to date

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Introduction

Over recent years, the safety of people driving for work has attracted the attention of both road safety experts and political decision-makers. Research indicates that individuals who drive for business purposes are at an increased risk of accident relative to the general population. After controlling for annual mileage, age and gender, Lynn and Lockwood (1998) demonstrated a 49% increased risk for company car and van drivers being involved in road traffic accidents where nobody was injured. Broughton *et al.* (2003), who also included injury-accidents in their analysis, found a 53% higher accident liability for company drivers who drove more than 80% of their overall annual mileage at work, when controlling for the same variables. That study suggested company car drivers engage significantly more frequently in potentially risky behaviours, such as reading a map while driving, using a mobile phone or driving long hours. Against the background of their findings, Broughton *et al.* (2003) concluded that isolated measures, such as the introduction of driver training, would not suffice. Instead, the authors stressed the importance of an organisational safety culture for the successful reduction of work-related road accidents. Further evidence for the importance of an organisation's safety culture and the safety-related attitudes of staff driving for work was presented by BOMEL (2004), although the significance of the study was somewhat limited because of small sample sizes.

Based on analyses of commercial vehicle accidents, the Work-Related Road Safety Task Group (WRSTG) estimated that 25% of road traffic accidents involve someone driving for work at the time (WRSTG, 2001). The introduction of recording journey purpose as a variable in the STATS19 accident forms has made official statistics for work-related road casualties available. According to these data, 15% of all injury accidents involved someone on a business-related journey (Department for Transport, 2006). This figure is likely to be an underestimate for two reasons:

- accident-involved drivers without appropriate insurance cover may not disclose their true journey purpose to the police; and
- police forces across the country have only recently started to work with the new variable in the STATS19 form and may therefore not yet routinely include it in their accident investigation.

The need for detailed guidance on the management of work-related road safety led the Department for Transport, in 2005, to commission the Transport Research Laboratory (TRL) to develop an information resource that would help managers of organisations with vehicle fleets, including cars, vans and trucks, to manage the road-related risk of injury and fatality to their staff. In close co-operation with industry representatives and road safety practitioners, TRL thus developed the Work-Related Road Safety CD-ROM (WRRS CD-ROM). The resource contains an overview of relevant legislation, guidance on the development and implementation of a work-related road safety management system, and case studies of companies that have successfully implemented such systems. A strong message throughout the material is that the good management of work-related road safety saves businesses money. Template forms, such as incident report forms, can be downloaded from the CD-ROM and modified to be suitable for a specific organisation (see also Lang (2006) for further detail). Since its completion in May 2006, the content of the CD-ROM has been made available, free of charge, to interested parties on the Department for Transport's website (www.dft.gov.uk/drivingforwork/).

A 12-month evaluation study of the WRRS CD-ROM was devised to determine whether the WRRS CD-ROM meets its aims and, specifically:

- (a) succeeds at raising awareness of work-related road risks;
- (b) conveys the necessary knowledge to managers to implement or improve (existing) work-related road safety management systems; and
- (c) instils a change in the safety culture of the organisation that leads to improvements in driver behaviour and organisational practices, and thus to a reduced number of accidents.

The study used a pre-post comparative design with a sample of 60 public and private-sector organisations. It aimed to assess the effects of the CD-ROM at several hierarchical levels in the organisations involved, as well as on several outcome levels (Kirkpatrick, 1994). This paper describes preliminary findings from Phase I (pre) of the evaluation study.

Method

Participating organisations

A total of 60 public- and private-sector organisations were the recruitment target for participation in the 12-month evaluation trial. Recruitment activities included conference presentations, publications in bespoke fleet literature, as well as

advertising through public- and private-sector fleet and trade association networks and newsletters. Organisations who demonstrated an interest in participation were fully briefed on the purpose of the study and received a PowerPoint presentation that detailed the steps involved for participants as well as estimates of the time required for participation. To provide an incentive to take part in the evaluation, participants were offered the opportunity to benchmark their performance against other study participants, and they therefore received a two-page summary of their organisation's work-related road safety performance.

Eighty-seven organisations provided contact details to be included in the study, and their details were recorded in a database. Seven organisations were excluded because of their commercial interests in the WRRS CD-ROM. Twelve organisations decided not to go ahead with their participation in the study. Telephone interviews established that the most frequent reasons for this decision were:

- (a) lack of senior management support for getting involved in the study;
- (b) personnel changes (the person who had committed to participating had left his/her role and the successor did not pursue with the study);
- (c) company mergers; or
- (d) inconvenient timing of the study.

Fourteen organisations had not made a final decision about participation at the time this paper was written. Sixty-eight organisations had completed the first step of the study and had submitted a completed work-related road safety questionnaire. Fifty-nine of those had been visited by a TRL researcher and two more visits were scheduled at the time of writing this paper.

Evaluation procedure

Participation in the evaluation study was not limited to a particular geographical region. It was open to any organisation in Great Britain. In larger organisations the point of contact was usually the fleet manager or the health and safety manager. In smaller organisations this tended to be the managing director or financial director. Participants were asked to commit approximately three hours for each phase of the study (pre and post). Phase I consisted of the following steps:

1. Completion and return of the work-related road safety questionnaire by the contact person.
2. Preparation of an in-depth interview guide by a TRL researcher on the basis of the provided information.
3. Participation of the contact person in a two-hour semi-structured in-depth interview with a TRL researcher about the organisation's work-related road safety management system.
4. Distribution of questionnaires in freepost envelopes by the contact person to staff driving for work and to managers with responsibilities for staff driving for

work. The number of driver and manager questionnaires issued depended on the size of the organisation. Following the definition by the Central Office of Information, organisations were categorised as **small** if they employed fewer than 50 members of staff, as **medium** if they employed between 50 and 250, and as **large** if they employed more than 250 members of staff. Whereas in small organisations all staff driving for work were requested to complete the questionnaire, only a relative proportion of the driving workforce and of the management were sampled to complete the questionnaire in medium and large organisations. In total, 2,594 driver questionnaires and 385 manager questionnaires had been sent out by the time this paper was written.

5. Receipt of the WRRS CD-ROM by the participating organisation.

In order to maximise response rates for the driver and manager questionnaires, e-mail reminders were sent out and followed up by phone calls where necessary.

Questionnaire measures

The evaluation objectives guided the development of the three sets of questionnaires: work-related road safety, driver, and manager. As the results presented in this paper focus on the work-related road safety questionnaire predominantly, only this questionnaire is described in detail.

The work-related road safety questionnaire was aimed at obtaining basic details from the contact person on the participating organisation's work-related road safety system. Topic areas incorporated:

- background information – industry sector, number of employees at the site/in the UK;
- vehicle fleet details – vehicle types used for work, ownership status, journey purposes and frequency of travel;
- road safety policy details – endorsement of policy, topics and stakeholders covered by policy, policy review cycles, other safety-related documents (dichotomous 'in place/not in place' items);
- driving-related risk assessments, rules and procedures with regard to the driver, the journey and the vehicle (dichotomous 'in place/not in place' items);
- work-related road accident figures and accident analysis;
- driver assessment and driver training provision (dichotomous items);
- driving-related reward and enforcement schemes (dichotomous items);
- perception of the organisation's management of work-related road safety (10 items; agreement rated on five-point scales); and
- perception of co-workers' driving-related safety behaviour taken from Hayes *et al.* (1998) (10 items; agreement rated on five-point scales).

The driver questionnaire sought information on a number of general demographic and background variables, including age, gender, and position and driving exposure at work (miles driven per week, types of roads used, vehicle type driven, journey purpose). Additional topics covered drivers' experiences of accidents and motor offences when driving at work, attitudes towards driving (Driver Attitude Questionnaire (DAQ)), driving style (Guppy *et al.*, 1990), frequency of engaging in potentially dangerous driving behaviours (from Broughton *et al.*, 2003, and Lawton *et al.*, 1997), knowledge of the organisation's driving-related rules and procedures, as well as the drivers' perceptions of the organisation, supervisor and co-workers management of work-related road safety (Hayes *et al.*, 1998).

Managers completed a considerably shorter questionnaire that included general demographic and background information consisting of driving exposure at work (miles driven per week, types of roads used, vehicle type driven, journey purpose). Additional items included their knowledge of the organisation's driving-related rules and procedures, knowledge of facts and good practice in work-related road safety, as well as the manager's perception of the organisation and co-workers management of work-related road safety (Hayes *et al.*, 1998) and perceived importance of work-related road safety to the organisation.

Results

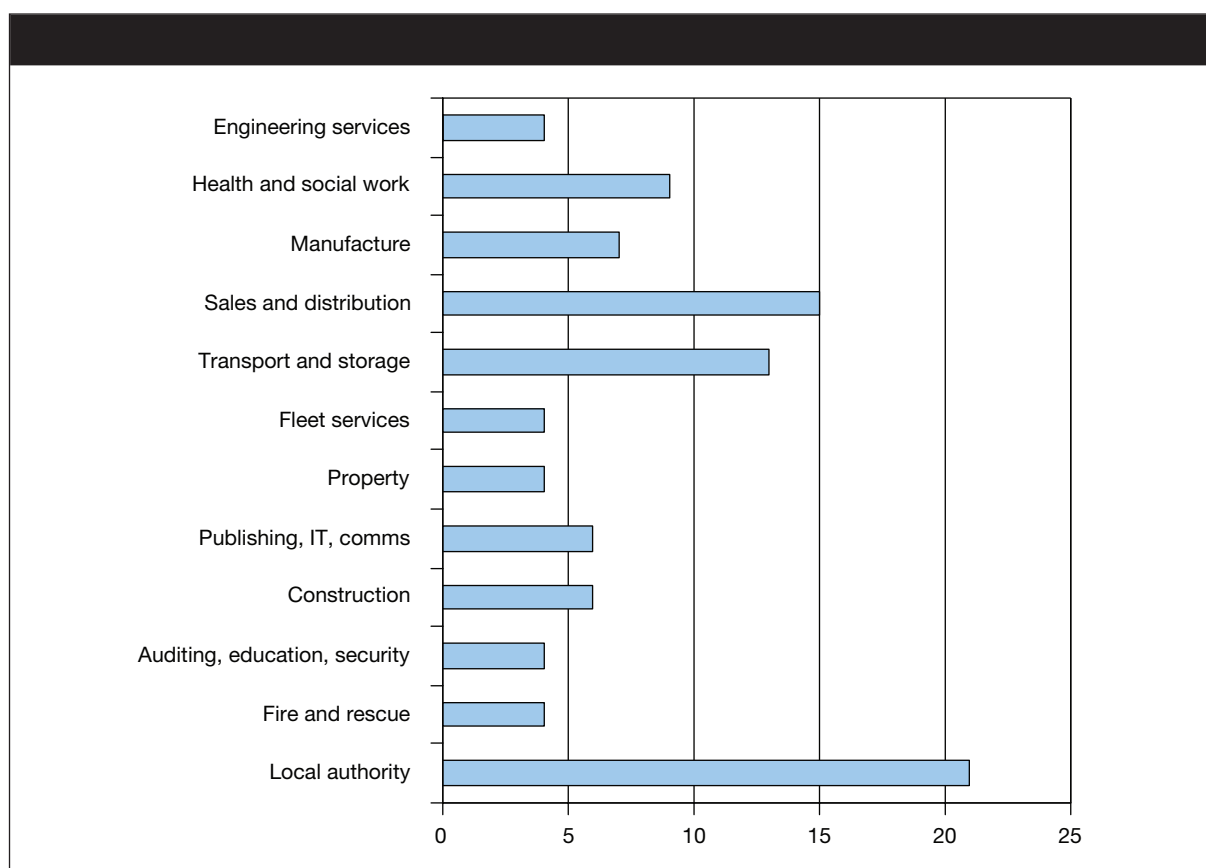
The results section focuses on the analyses of the 68 organisations that had returned the WRSS questionnaire to TRL, as driver and manager questionnaires were still being returned to TRL at the time of writing this paper. SPSS version 14.0 was used to analyse the findings.

Background information

The sample comprised 43 private-sector companies and 25 public-sector organisations. Local authorities were the largest single group ($n = 21$) followed by companies operating in sales and distribution (see Figure 1). The majority of participating organisations was large ($n = 45$); 17 organisations were medium-sized and six organisations were small.

Vehicle fleets and journey frequencies

The majority (98.5%) of the participating organisations used cars, 72.1% used vans, 54.7% used trucks, 5.9% used motorcycles and 23.5% used 'other' vehicles for work-related purposes. Open answers in the 'other' category identified passenger transport vehicles, plant equipment and tractors to be the most frequent vehicles in this category. All other vehicle types mentioned were used by public-sector organisations.



As the number of vehicles operated by the participating organisations varied considerably as a result of organisation size, the median was calculated as a measure of central tendency (see Table 1).

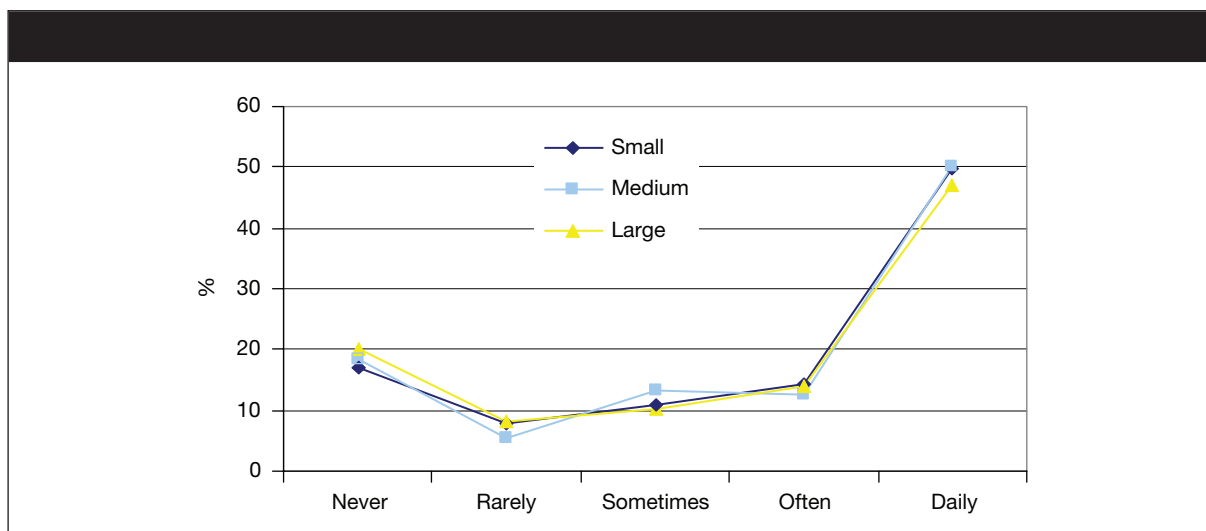
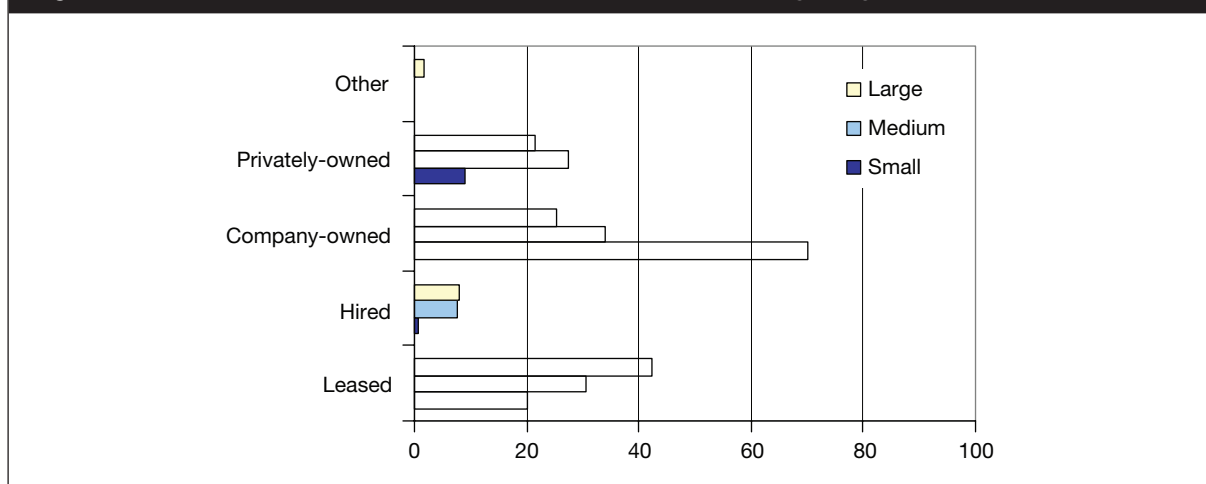
Table 1 Average size of vehicle fleets operated (median and standard deviations displayed)

Vehicle type	Median no of vehicles	SD
Cars	80.0	708.0
Vans	98.5	266.8
Trucks	50.0	202.4
Motorcycles	3.0	2.6

Respondents were asked to specify the ownership status of the vehicles used for work purposes. The analysis of vehicle ownership was differentiated by organisation size to reveal potential differences among small, medium and large organisations. The results are displayed in Figure 2. The largest difference was apparent for company-owned vehicles, where small companies reported a larger proportion than the other two groups.

The proportions of the workforce that travelled for work ‘never’, ‘rarely’, ‘sometimes’, ‘often’ or ‘daily’ did not differ significantly among small, medium and large organisations (see Figure 3).

Figure 2 Vehicle ownership status for small, medium and large organisations (in %)



Using MANOVA, statistically significant differences were found with regard to journey purpose for trips to training/conferences ($F(2) = 4.109$; $p < 0.021$) and for internal meetings at other sites ($F(2) = 13.54$; $p < 0.00$): large organisations reported more journeys to training/conferences than medium-sized ones (Games Howell post-hoc test $p < 0.025$) and small organisations carried out fewer trips for internal meetings at other sites than large organisations (Games Howell post-hoc test $p < 0.012$). The differences are in line with expectations: smaller organisations will tend to have fewer sites than larger ones and will thus travel less. Similarly, large organisations are more likely to have centralised or outsourced training facilities and will thus report more such journeys (see also Figure 4).

Road safety policy details

No statistically significant differences were found among small, medium and large organisations with regard to the existence of a road safety policy, senior management's involvement with signing off the policy or with the regular review of the policy (using χ^2 -square tests). Therefore no further differentiation by company size was made. Fifty-one respondents reported to have a road safety policy, either as

Figure 4 Frequency of different journey purposes in small, medium and large organisations (1 = never to 5 = daily)



a stand-alone document ($n = 33$) or as part of an overall safety policy ($n = 18$). Forty-two organisations stated that their road safety policy had been signed off by senior management, and 38 organisations (just over 50%) reported that their road safety policy was reviewed and modified on a regular basis.

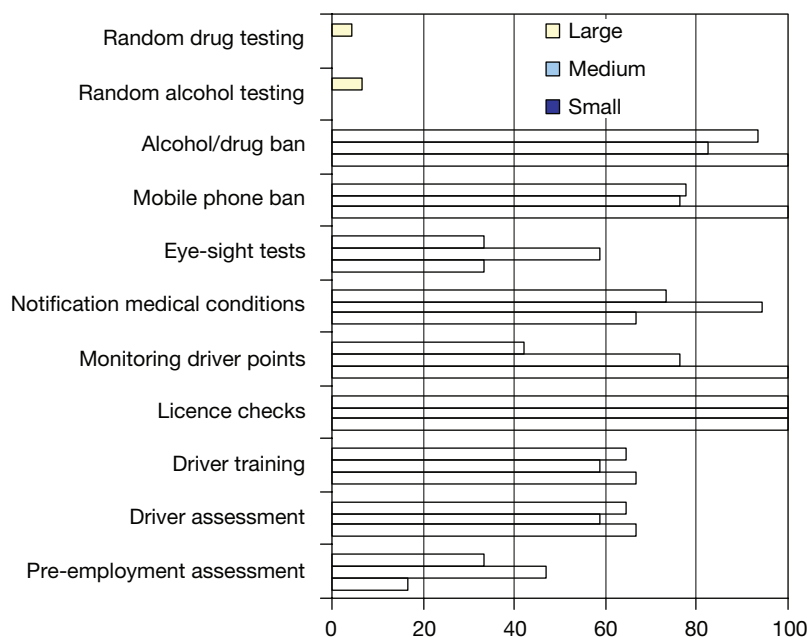
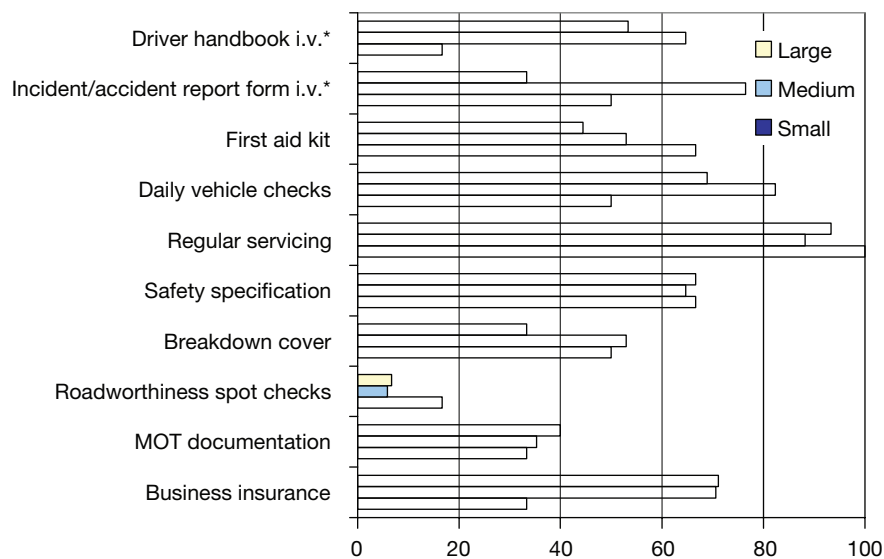
Rules and procedures

Respondents were asked to specify what rules and procedures they had in place with regard to staff driving at work, vehicles used for work and work-related journeys. To test for statistically significant differences between rules and procedures in place in the participating organisations, small and medium-sized organisations were combined to provide large enough cell sample sizes for χ^2 -square tests.

Figure 5 provides an overview of the rules and procedures that the participating organisations had in place for their staff driving for work. As illustrated in Figure 5, all participating organisations reported carrying out checks of driver licences; however, the questionnaire did not require respondents to specify how often these checks were carried out. Procedures that were also frequently in place in the majority of participating organisations were bans on alcohol and mobile-phone use. The procedures least frequently in place included random alcohol and drugs testing, eyesight tests and pre-employment assessments.

The only statistically significant difference found between small/medium and large organisations was with regard to the monitoring of drivers with points on their licence ($\chi^2 = 9.56$; $p < 0.02$). Small and medium organisations reported using this measure proportionately more frequently than large organisations.

Figure 6 illustrates the findings on the existence of rules and procedures relating to vehicles used for work purposes (including privately-owned vehicles). None of the

Figure 5 Proportion of organisations that have staff-related rules and procedures in place (in %)**Figure 6 Proportion of organisations that have vehicle-related rules and procedures in place (in %)**

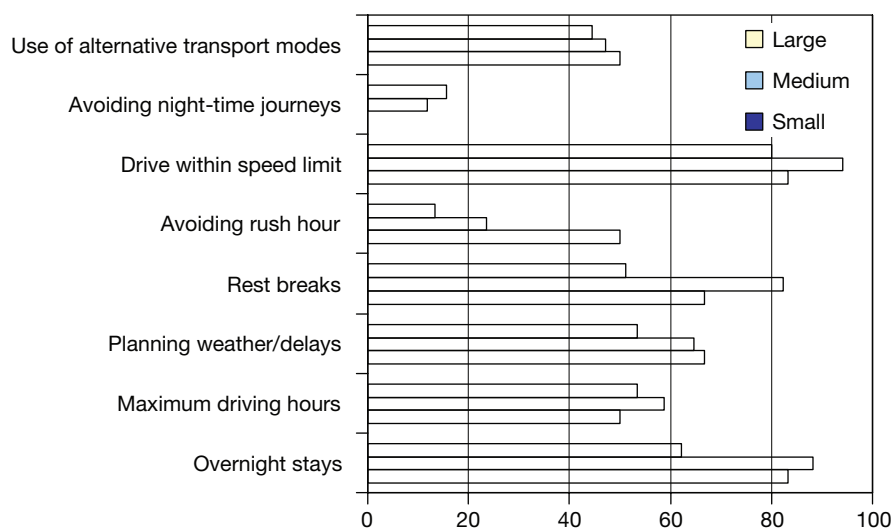
* 'i.v.' stands for 'in all vehicles'.

participating organisations had all of the rules and procedures specified in the work-related road safety questionnaire in place; however, most respondents reported that regular servicing intervals were in place. The last three items shown in the graph pertain to privately-owned vehicles only. While the requirement for business insurance for privately-owned vehicles used for work was in place in over half of the medium and large organisations; MOT documentation checks and spot checks of vehicles' road worthiness were most frequently not in place.

Statistically significant differences were found between large and small/medium organisations with regard to blank accident report forms kept in the vehicle ($\chi^2 = 8.06$; $p < 0.005$). Such forms were more often available in vehicles operated by small/medium organisations.

Findings on journey-related rules and procedures in place in the participating organisations are displayed in Figure 7. The prescription most frequently in place was for staff driving at work to stay within the specified speed limit. Overnight stays to avoid driving when tired were permitted in the majority of participating organisations. Statistically significant differences between small/medium and large organisations were found with regard to the prescriptions of rest breaks on long drives. Such breaks were proportionately more frequently prescribed in small/medium organisations ($\chi^2 = 4.30$; $p < 0.038$).

Figure 7 Proportion of organisations that have journey-related rules and procedures in place (in %)



Accident costs

The work-related road safety questionnaire asked respondents to indicate the total amount of insurance claims for work-related road accidents in their organisation over the period of the last 12 months. An ANOVA was used to test for significant differences among small, medium and large organisations with regard to accident costs. No significant differences were found, and findings are thus not differentiated by organisation size. Table 2 shows the minimum, maximum and mean number of work-related road safety accidents (differentiated by severity grade) for the average total insurance claims for work-related road safety in a period of 12 months.

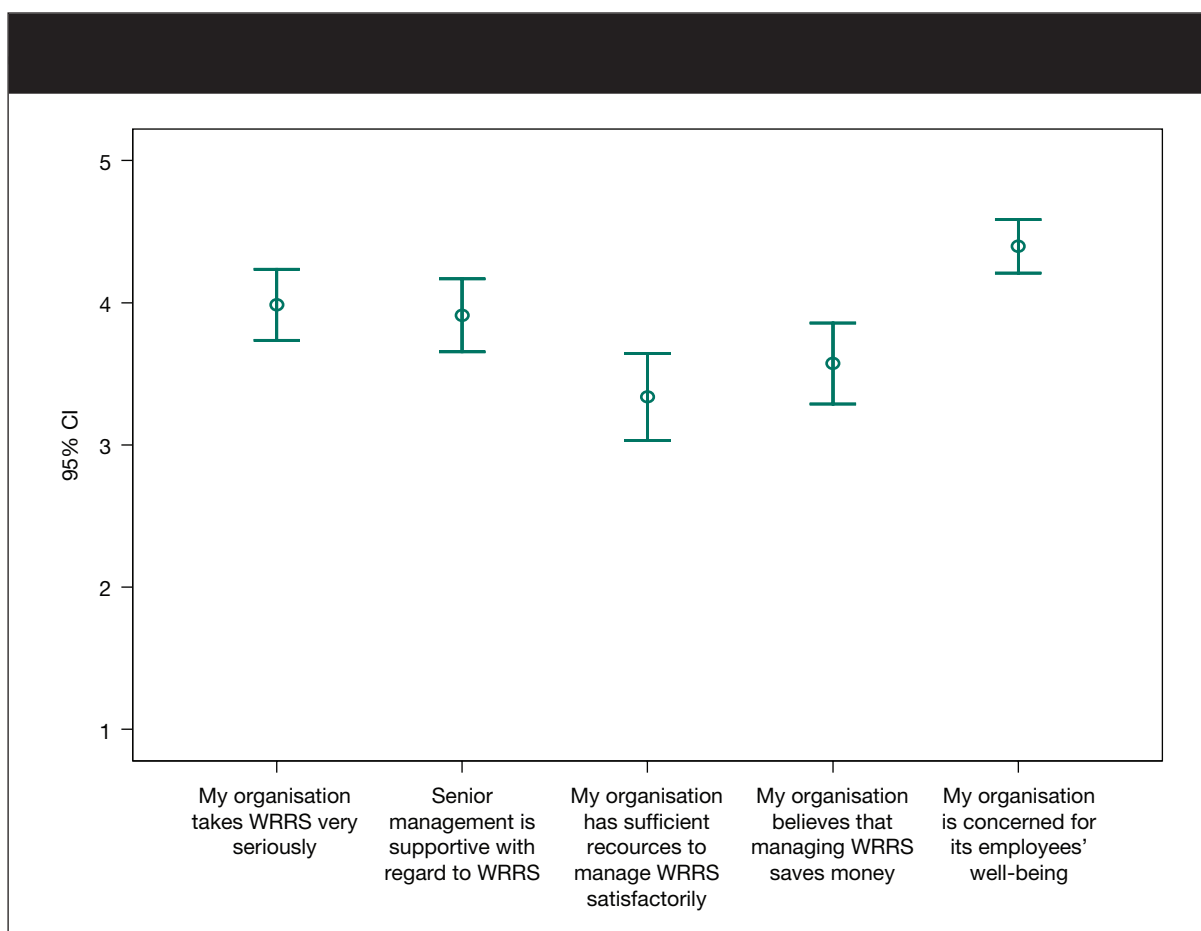
Table 2 shows that, on average, each of the participating organisations registered 80.3 damage-only accidents, 3.0 slight-injury accidents and 0.4 serious-injury accidents over a period of 12 months. The maximum sum of insurance claims was reported to be close to £9 million. The average (median) insurance claims over a 12-month period were £50,000. The median was calculated as a measure of central tendency, as the distribution of insurance claims was skewed.

Table 2 Total number of accidents and cost of insurance claims for work-related road safety

	<i>n</i>	Minimum	Maximum	Central tendency (median)	SD
Damage only	60	0	959	80.3	188.4
Slight injury	62	0	50	3.0	8.7
Serious injury	62	0	12	0.4	1.6
Fatality	63	0	1	0.0	0.1
Annual insurance claim	47	£0	£8,955,475.00	£50,000	£1,376,477.20

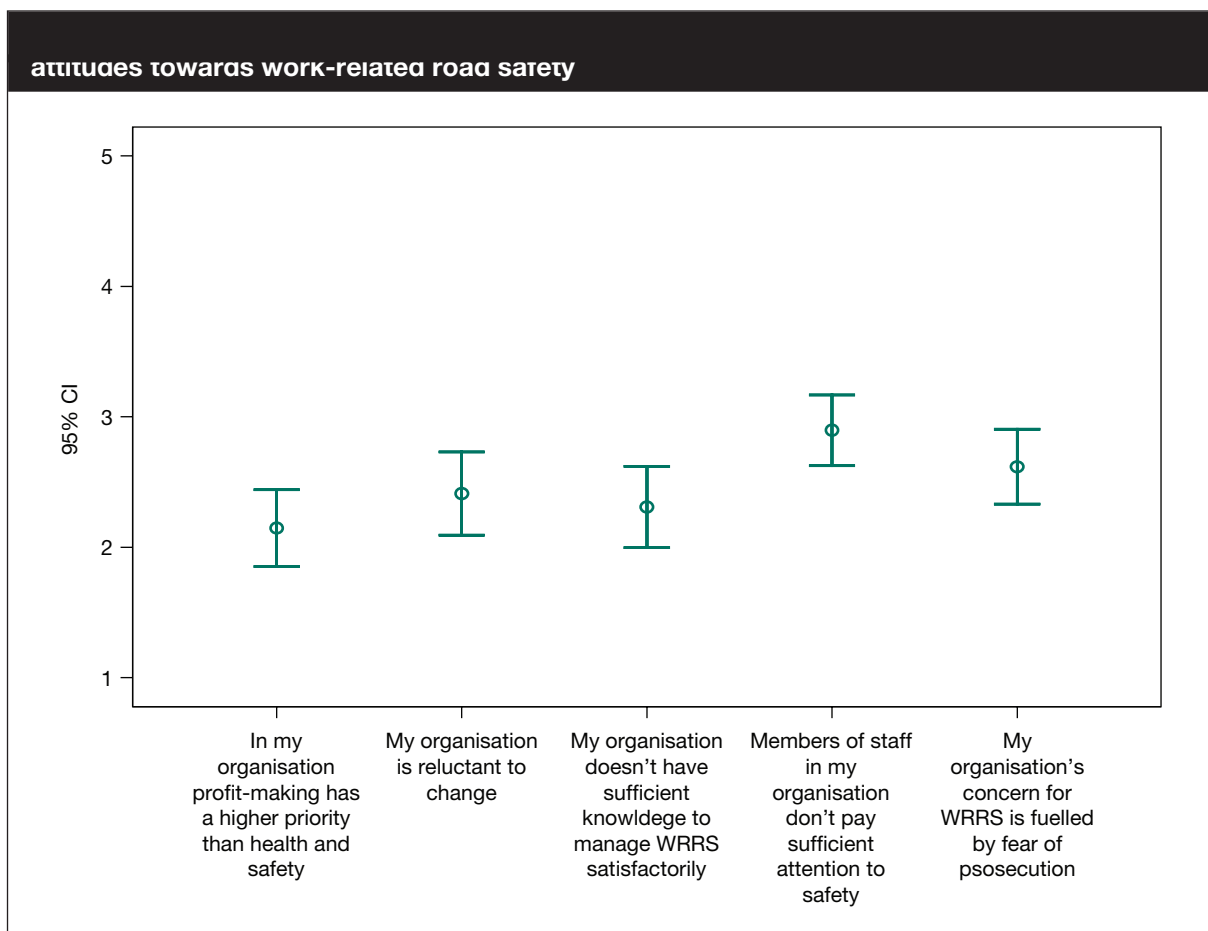
Perception of work-related road safety management in the organisation

In the work-related road safety questionnaire, the contact person was required to indicate his/her agreement on a five-point scale (1 = strongly disagree to 5 = strongly agree), with 10 statements concerning the organisation's attitude towards work-related road safety and its management. Five of these statements were worded positively, so higher scores indicated a perception of the organisation as having a positive attitude towards managing work-related road safety. Figure 8 shows the average ratings of positively worded items and the 95% confidence intervals for the means. It shows that, on average, the contact persons completing the work-related road safety questionnaire perceive the participating organisations as



taking work-related road safety seriously and being concerned about the well-being of their staff.

The remaining five statements were worded negatively, so high scores indicated the perception of the organisation as having a negative attitude towards managing work-related road safety. Means and 95% confidence intervals for the means are displayed in Figure 9. The findings show that, on average, the contact persons completing the questionnaire perceive the participating organisations as willing to accommodate change and being motivated to manage work-related road safety not predominantly as a result of a negative motivation (e.g. avoiding prosecution).



Using MANOVA, statistically significant differences were found between the item 'My organisation takes work-related road safety very seriously' ($F(2) = 7.106$; $p < 0.032$) and the item 'My organisation believes that managing work-related road safety saves money' ($F(2) = 9.655$; $p < 0.028$). Games Howell post-hoc test showed that work-related road safety was reported to be taken less seriously in large organisations than in medium-sized ones ($p < 0.038$), and that large organisations believed significantly less often than small organisations that managing work-related road safety would save them money ($p < 0.006$).

Conclusions

This paper presented initial findings from comprehensive research into the effectiveness of providing guidance on the management of work-related road safety to a broad range of organisations. Differences among organisations with regard to managing work-related road risk as a result of their size were explored. Few significant differences were found, indicating that the prevailing practices do not differ merely as a result of organisation size. Where significant differences were found, the results always indicated better practices in small or medium-sized, rather than large, organisations. This finding may come as a surprise when considering that larger organisations are more likely to have dedicated posts for the management of health and safety related matters, and thus may find it easier to dedicate sufficient resources to the process of putting appropriate procedures in place. If this is the case, the question arises whether the sample of organisations involved in the evaluation is a representative snapshot of all organisations currently operating in Great Britain. The answer to this question is certainly no. Let us explore this point further. The research relied on a self-selected sample of organisations that put themselves forward for participation in the evaluation study. These stakeholders were most likely individuals or organisations that actively sought out opportunities to improve their business or to keep abreast of the latest developments in the transport field and had thus already recognised a need to improve performance in the area of managing work-related road risk. In terms of Heckhausen and Gollwitzer's (1987) Rubicon model, which differentiates among a pre-decisional (where the motivation and intention to act is built up), post-decisional (where plans are specified what action to take), actional and evaluative phase of action, the participants that decided to get involved in the scheme were most likely to be already in the post-decisional phase and were thus actively planning actions to solve a problem that they had recognised. When considering the preliminary findings presented in this paper, this does not suggest that the participating organisations had identified and implemented all the necessary steps to manage work-related road safety effectively. The results rather illustrate that many organisations have some systems in place, but that a comprehensive coverage of all relevant areas is exceptional. Important areas, such as pre-employment assessments, monitoring of medical conditions, non-managed use of privately-owned vehicles for work, effective measures to guard against substance misuse or mobile-phone use, are rarely in place. When considering that the sample involved in the study is, in all likelihood, biased in terms of performing better at managing work-related road safety than the majority of organisations in Great Britain, the need for further action becomes clear. Applying the Rubicon model again, the first step to shift organisations from the pre-decisional phase to the post-decisional phase is the creation of awareness of work-related road safety as an important risk, especially when considering that several risks are competing for managers' attention in any organisation at any time. This, at the same time, is a goal that cannot be fulfilled by any one project but will need continuous intervention efforts over several years. Encouraging steps have already been made in the latest Department for Transport Think! campaign, which targeted work-related road risk in commercial vehicles. The provision of guidance that advises organisations on how to manage work-related road safety effectively becomes relevant once companies have entered the post-decisional phase.

Data gathering within the project included quantitative as well as qualitative methods across the hierarchy levels of the organisations involved in the evaluation study. The methodology chosen accounts for the fact that organisations can be highly complex and that many safety cultures may prevail within different subgroups of an organisation. To establish how well work-related road safety is managed in an organisation, the review of procedures and documentation alone is not sufficient. Additionally, actual behaviour of organisation members with regard to driving needs to be investigated. This pertains to the way that staff actually drive, as well as to the value they attach to safety and the adherence to good driving principles. The analysis of the driver and manager questionnaires will provide further insights in this area.

The qualitative research element in the study included two-hour interviews with the contact person in the organisation, usually the health and safety manager or the fleet manager. The information provided in the interviews was captured in organisation summaries that detail an organisation's performance in the management of work-related risk at time point one and that will allow the identification of even small changes to the system at time point two. The summaries were also used to revisit and check the data provided in the work-related road safety questionnaire to increase their accuracy. The benefit of this resource-intensive approach pays off when considering the increased understanding of how organisations operate and how they completed the work-related road safety questionnaire. For example, the work-related road safety data suggest that there was no significant difference with regard to vehicle ownership between medium and large organisations (see Figure 2). However, interviews with transport managers in local authorities revealed that they typically did not know the number of privately-owned vehicles in their council and rather based their estimations and information provided in the work-related road safety questionnaire on their division and the vehicle group under their direct control, namely the vehicles used for services provided by the council, including waste management, cleaning or passenger transport. Further analysis of the data needs to be carried out to identify subgroups of organisations/organisation members that may have specific issues with the management of work-related road safety and thus may require specific assistance and guidance.

The next step within the research project will be to agree success criteria that can be used to determine whether the project objectives of:

- (1) increasing the awareness for work-related road safety;
- (2) increasing the knowledge about how work-related road safety should be managed; and
- (3) improving the prevailing safety culture

have been achieved in the participating organisations. Phase II data gathering will commence in early December 2007.

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14

Assessing fuel-efficient driver behaviour through tachograph information

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Introduction

In evaluating haulage companies for participation in a project examining the fuel efficiency of individual drivers (see Parkes, 2005), it was found that, although haulage companies tend to keep accurate fuel usage records for their entire fleet, they do not keep sufficiently detailed records to allow them to monitor the fuel usage of an individual driver. This makes it very difficult to monitor the impact of fuel efficiency training given to individual drivers.

Parkes and Reed (2005) showed that training in a truck simulator could cause drivers to show significant improvements in their on-road fuel efficiency. However, these results were calculated from a limited dataset based around fuel used and distance travelled by the driver in the five working days that preceded and the five working days that followed the simulator training. There was no assessment of how (or indeed if) the trainees had changed their on-road driving behaviour in order to achieve this improved fuel efficiency figure.

This study uses the TRL's full-mission, high-fidelity truck simulator, TruckSim, to examine how variation in driving behaviour affects fuel efficiency. This may enable the use of readily available data, such as that obtained from a tachograph, to be used to assess driving performance in relation to fuel efficiency. Such an assessment could then be used to determine the effectiveness of any training programme in causing drivers to change their behaviour so that they drive more efficiently. The TruckSim is an excellent tool for investigating this behaviour, since the experimental driving conditions can be controlled precisely and repeatably, as well as data being recorded at a high frequency and great accuracy.

The first experiment examined five drives completed under very tightly controlled conditions and in which the driver was required to achieve a variety of different target speed profiles at all times. The purpose of the second experiment was to investigate whether the results of experiment 1 are transferable to a more realistic

driving task performed by a number of professional commercial-vehicle drivers. The third experiment used similar data to those used in experiment 2. However, the data in experiment 3 were sampled at 1 Hz, rather than the 60 Hz at which they are produced by the simulator, thus replicating the frequency at which data are recorded by a digital tachograph. The fourth experiment used a variety of vehicle configurations and driving styles to investigate how the variations in driving behaviour that might be observed on a day-to-day basis may affect any relationship with fuel efficiency.

The work carried out in the TruckSim explores the relationships between the information recorded by tachographs and the resulting fuel efficiency of the driven vehicle. In order to validate that the observed relationships are matched by those demonstrated by drivers in real vehicles, experiment 5 used digital tachograph information from professional drivers using a real truck while undergoing training to improve their fuel efficiency. The changes in performance as a result of the training should be detected in the recorded data.

Experiment 1: relationships between fuel used and simulator driving behaviour

In experiment 1, the author completed a series of drives under strictly defined conditions in TruckSim.

Method

A basic motorway drive was created on TRL's full-mission, high-fidelity truck simulator, TruckSim. There were no other traffic vehicles introduced into the scenario. After a distance of approximately 1,600 metres, a line of traffic cones across lanes one and three of the motorway signalled the start of the test section. The driver was required to be travelling at 30 mph when entering the test section. Throughout the route, the driver was required to stay in lane two of the motorway until the end of the test section, which ran for 8,660 metres. The end of the test section was again signalled by a line of cones across lanes one and three of the motorway.

All drives were completed using the TruckSim configured as a rigid lorry with a 100% full solid load. Throughout the test section of the route, the driver remained in gear six (of eight) at all times.

Five drives were completed along the designated route. In each, the driver was required to control the vehicle so that it followed one of three different speed profiles:

1. **Constant (30 mph).** The driver's objective was to keep the vehicle travelling at a constant speed, only controlling speed by the use of the accelerator.

2. **Sine wave (25 mph to 35 mph; 20 mph to 40 mph).** The driver's objective was to cause the vehicle's speed to vary continuously between a lower target speed and a higher target speed throughout the test section. The speed profile therefore approximated the appearance of a sine wave. Speed control was achieved only through the use of the accelerator.
3. **Square wave (25 mph to 35 mph; 20 mph to 40 mph).** The driver's objective was to cause the vehicle's speed to change rapidly between a lower target speed and a higher target speed continually over the course of the test route. The driver aimed to cause the periods of acceleration and deceleration to take approximately the same length of time.

By having lower and higher target speeds at the same magnitude of speed difference from the constant speed drive, the overall mean speed of the vehicle over the course of the complete test section should be approximately the same in each drive.

Data

The simulation computers recorded data regarding 62 different parameters, including control inputs and vehicle dynamics over the course of the entire drive. The TruckSim dynamic model calculates how fuel would be used by the vehicle under the prevailing circumstances within the trial. Under normal circumstances, data are recorded at 60 Hz. However, to ease data handling, the data files were reduced so that a data point was recorded every 5 metres along the driven route.

Trigger points were placed on the route to identify, within the dataset, the position at which the driver entered the test section and the position at which the driver left the test section. Consequently, all data relating to driving before and after the test section could be stripped from the complete dataset so that analysis could be focused upon the critical section.

Results

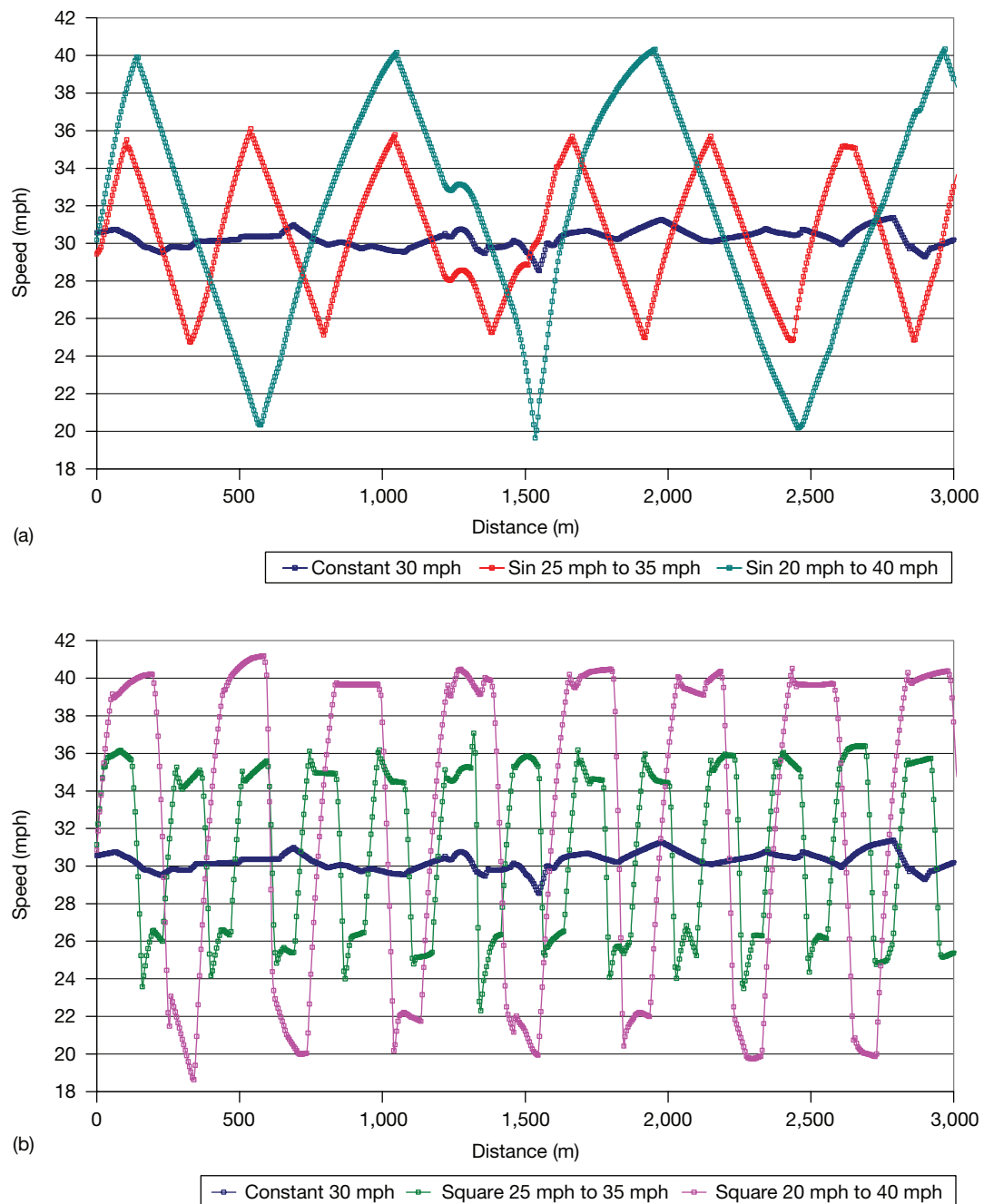
Figures 1(a) and (b) show the speed profile of the drives over the first 3,000 metres of the test route.

Figures 1(a) and (b) show that for each speed change, the driver was able to achieve a speed within ± 2 mph of the target speed. Figure 2 shows the resultant cumulative fuel used with each speed profile.

The speed profile has a dramatic effect on the rate of fuel consumption. The constant speed profile shows the lowest fuel consumption, using just less than 0.98 litres of fuel to complete the 8.6 km route. The remaining four drives were split into two distinct groups based on their profile. The two sine wave profiles show the next best efficiency, using around 40% more fuel than the constant speed profile. The two square wave profiles show the worst fuel efficiency, using nearly three times as much fuel as the constant-speed profile.

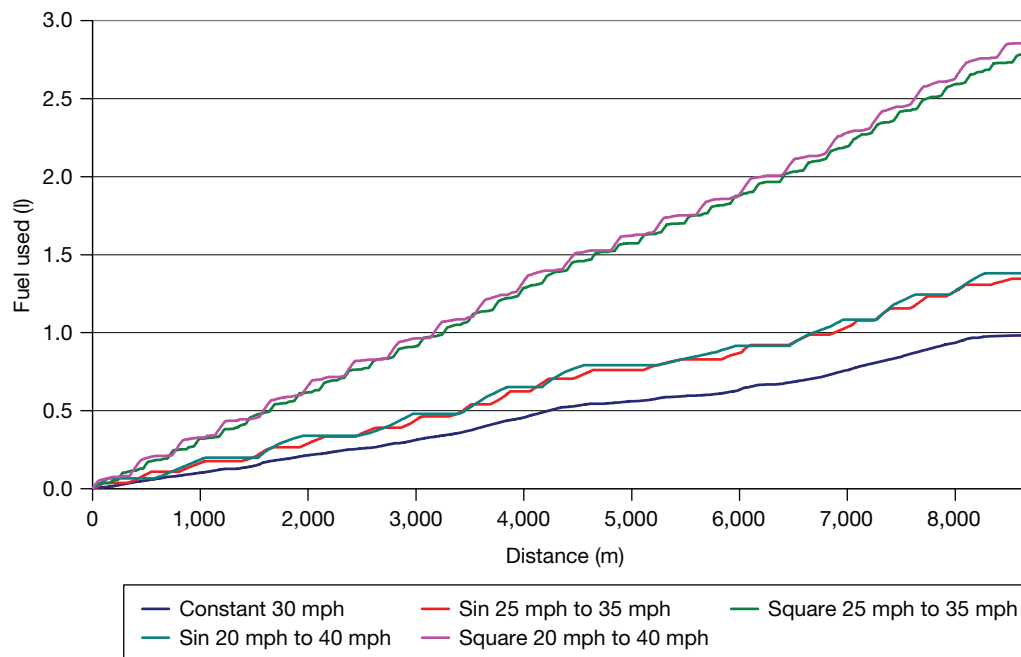
The specific driving behaviours applied in the test drives mean that a number of different variables can be ruled out in determining what caused the observed

Figure 1 The speed profile over the first 3,000 metres for (a) the constant speed drive and the sine wave speed drives; and (b) for the constant speed drive and the square wave speed drives



variation in fuel efficiency. Factors such as mean speed, road position and the number of gear changes were held constant across the drives, so these can be eliminated from the analysis. However, the fluctuations observed in certain driving parameters differed across each of the drives, so it was the variance of these parameters that was investigated. The chosen technique to measure variation in a parameter was to take the standard deviation (SD) of values across the entire test section.

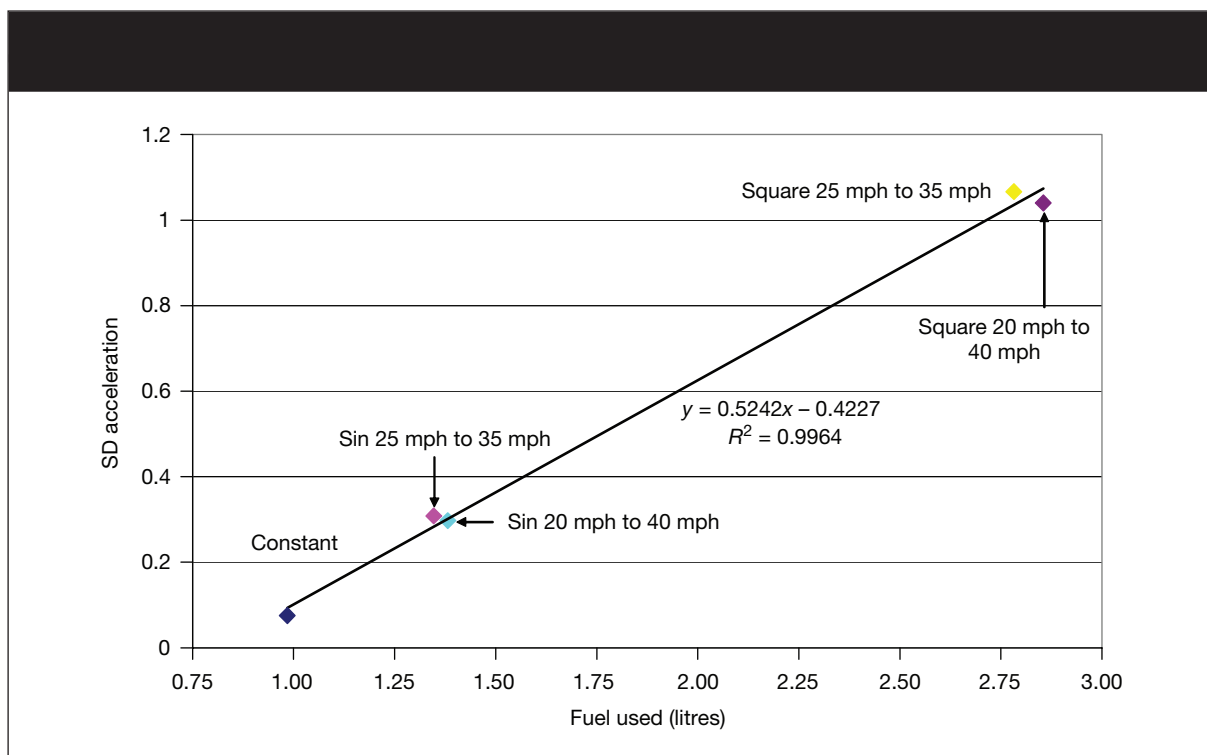
The first approach was to examine the relationship between fuel used and variation in speed. Although the fuel used in the sine wave 20 mph to 40 mph profile was

Figure 2 Cumulative simulated fuel used by the truck in completing the test section with the different speed profiles

much less than that for the square wave 25 mph to 35 mph profile, the SD of speed is higher. This results in a poor fit of the linear trend line. It therefore appears that speed variation is not a good predictor of fuel efficiency.

The constant-speed profile will have had the least variation in accelerator pedal input in order to maintain the vehicle at the target speed. Conversely, the square wave speed profiles required the greatest variation in accelerator pedal depression. Therefore the next approach was to examine whether variation in accelerator pedal position was better correlated with fuel used. The relationship is stronger than that between speed variation and fuel used. The R^2 value indicates that more than 85% of the variance in fuel used can be explained by the variation in accelerator pedal depression. However, this information will only be available from an advanced telematics system. In surveying companies for participation in the real-world driving data collection part of the experiment described in Parkes (2005), it was found that the penetration of such systems into the marketplace is as yet limited. A variable that will be correlated with the variation in accelerator pedal depression will be the variation in the acceleration of the vehicle itself in the direction of travel. A vehicle's longitudinal acceleration can be found by taking the derivative with respect to the time of a plot of speed against time. This plot is available in all commercial vehicles in the form of the tachograph record that operators are legally obliged to maintain. It could therefore be exploited easily if technology were available for accurately calculating this derivative to give the acceleration. Figure 3 shows the relation between the SD of vehicle acceleration and fuel used.

The relation between variation in acceleration and fuel used is even more closely related to fuel used than the variation in accelerator pedal position. The R^2 value indicates that, for the drives used in experiment 1, more than 99% of the variation in fuel used can be explained by the variation in vehicle acceleration. Variation in vehicle acceleration is therefore the best predictor of fuel usage.



Experiment 2: using previously recorded simulator data to test observed relationships

The driving observed in experiment 1 does not match any kind of driving that would be performed in the real world. Experiment 2 investigated the performance of professional drivers who completed a varied route in the simulator on two occasions as part of a fuel-efficiency training programme to find whether variation in acceleration was similarly related to the fuel used in a more realistic scenario. Unlike experiment 1, drivers were not constrained in how they drove the vehicle and had free choice over the gear ratio, speed and vehicle controls. The only restriction placed upon the drivers was that they should follow the automated voice instructions guiding them along the exercise route. Furthermore, the drives completed as part of experiment 2 were much more varied than those used in experiment 1, taking in rural roads with steep hills and roundabouts, and urban roads with traffic lights, mini-roundabouts and other traffic vehicles.

Method

The behaviour of 49 drivers was analysed. Each driver was required to complete two drives on an identical route in the TruckSim. All participants were professional commercial vehicle drivers. Their age ranged between 23 and 60 years old (mean = 43.8 years; SD = 7.90). Their experience as professional drivers ranged from less than a year to 39 years (mean = 15.3 years; SD = 10.0).

For this task, drivers were required to operate a fully-loaded semi-articulated vehicle. This vehicle was chosen to achieve maximal differentiation between the drivers displaying good and bad fuel efficiency techniques.

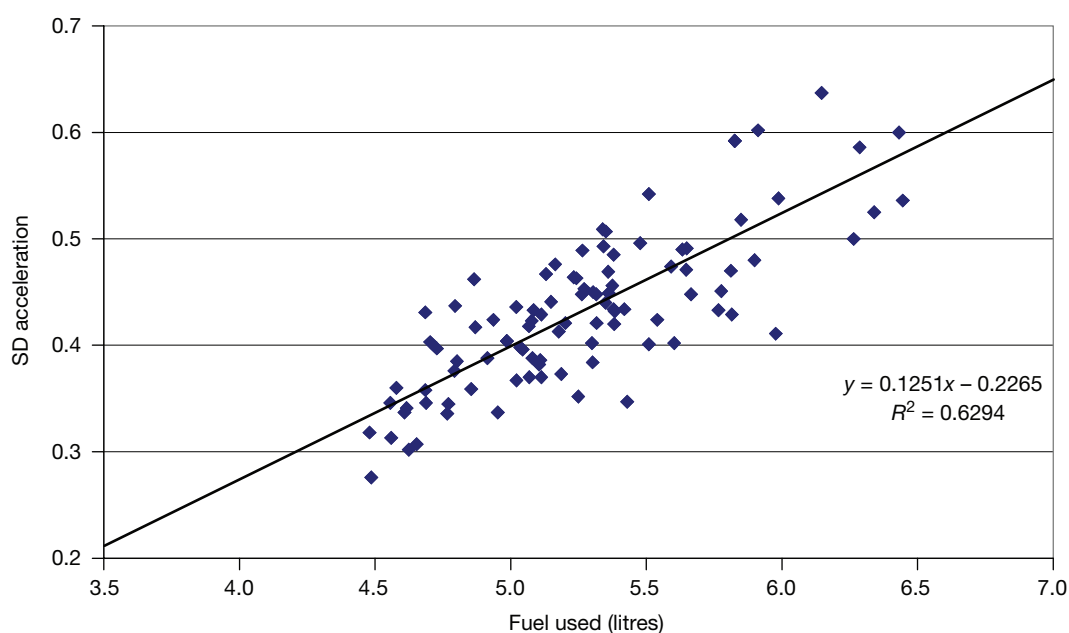
The entire route completed in each drive was 8.3 km in length and typically took around 17 minutes (± 3 minutes) to complete. The route began in a rural environment with a drive up a steep hill (1 in 10 gradient) before a descent down the other side of the hill (1 in 12 gradient). After a roundabout, there followed a less severe upward gradient and descent before the route progressed into the urban environment. Autonomous traffic vehicles, though present, were programmed not to interfere with the driving of the participant, except in a consistent manner (e.g. a parked vehicle around which the participant had to manoeuvre the vehicle). A pedestrian unexpectedly crossing the road and a cyclist unexpectedly pulling onto the road from the pavement were triggered as hazards to which the driver had to respond. The driver would not have to stop in response to either of the hazardous events, provided they were travelling at an appropriate speed and were suitably alert to the situation. The exercise ended at a blockage in the road within the urban environment.

Data recording proceeded as described for experiment 1, with the exception that all data points (recorded at 60 Hz) were used for the calculation of the SD of acceleration values.

Results

There were 49 drivers used for analysis, all of whom completed two drives in the simulator. Experiment 1 suggested that the SD of vehicle acceleration was correlated with the fuel used by the vehicle. In experiment 2, the SD of vehicle acceleration was calculated for the entire exercise. Figure 4 shows a scatter plot of this variable against the fuel used in that exercise for all drives completed.

Figure 4 Graph to show SD of vehicle acceleration against fuel used for all drives completed in experiment 2 (linear trend line shown)



Unlike experiment 1, drivers in experiment 2 were required to complete a varied route and were not constrained in their speed choice or gear selection, only in the route that they were required to follow. Figure 4 shows that, despite the greater variation in possible driver behaviours, the relation between the variation in vehicle acceleration and fuel used remains strong. The R^2 for the linear trend line suggests that around 63% of the variation in fuel used can be explained by the variation in the SD of vehicle acceleration. A Pearson correlation between the two variables produces a correlation coefficient of 0.793 ($p < 0.001$).

The results of experiment 2 suggest that, although drivers were completing a varied route and were not given any guidance on how they should drive the vehicle through the route, there still exists a strong correlation between the SD of vehicle acceleration and fuel usage. This suggests that it could be useful as a diagnostic tool for real drivers in real vehicles.

Experiment 3: simulator drives sampled at 1 Hz

In experiment 2, data were sampled at 60 Hz, exploiting the advantages of the computing power associated with the full mission simulator. For real vehicles, it is very unlikely that data would be available at such a high frequency, particularly across an entire fleet of vehicles. The data that are available from a real vehicle are the speed-trace information recorded at one-second intervals by digital tachograph devices. Experiment 3 uses the complete set of data from the training programme described in the introduction to experiment 2. The data used in experiment 2 were therefore a subset of this complete dataset. Digital tachographs provide speed information at one-second intervals. Therefore, in experiment 3, speed data were extracted at 1 Hz from the complete dataset recorded at 60 Hz for each drive and used to generate an acceleration value, determined by taking the derivative of the speed values with respect to the time period.

Method

The behaviour of 53 drivers was analysed. Each driver was required to complete two drives on an identical route in the TruckSim on three separate occasions over a period of six months. All participants were professional commercial vehicle drivers. Their age ranged between 23 and 60 years (mean = 43.6 years; SD = 7.95). Their experience as professional drivers ranged from less than a year to 39 years (mean = 15.1 years; SD = 10.2).

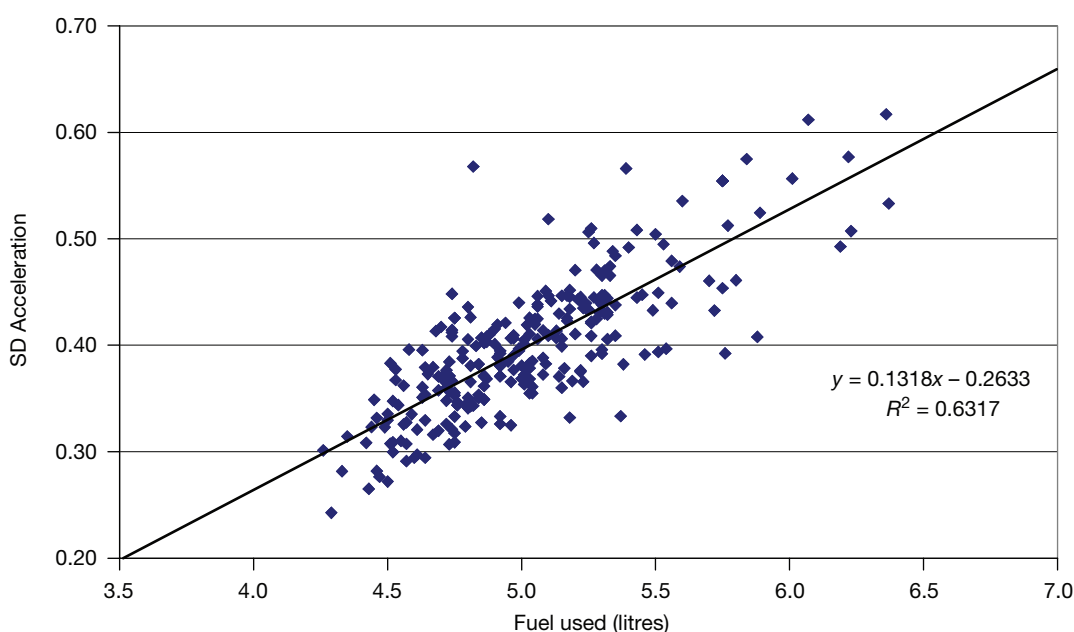
The vehicle and route were the same as in experiment 2. Data recording also proceeded as described for experiment 2. However, the calculation of acceleration values was achieved by sampling the data to extract speed values at one-second intervals and then differentiating those speed values to generate an estimate of the vehicle's longitudinal acceleration. This method was used to mirror the procedure that could potentially be applied to the analysis of speed data available from digital tachographs fitted to real commercial vehicles.

Results

There were 266 drives included in the analysis, completed by 53 drivers. Drivers completed between one and six drives over the course of three visits to TRL over a period of six months. Drivers failing to complete the six scheduled drives did so due to reasons such as companies withdrawing their driver(s) from the training programme, drivers withdrawing because of simulator sickness, drivers failing to show up for their training, and technical problems with the simulator on the scheduled training day.

Figure 5 shows a scatter plot of the SD of vehicle acceleration against the fuel used in the same exercise for all drives included in experiment 3. As with Figure 4, a linear trend line has been added and its equation and R² value are displayed.

Figure 5 Graph to show SD of vehicle acceleration against fuel used for all drives completed in experiment 3 (linear trend line shown)



If one compares Figure 4 with Figure 5, it is clear that, despite using a reduced sampling frequency, the relationship between the SD of acceleration and fuel used is still significant. A Pearson test of the correlation between these two variables shows a highly significant result ($n = 266$; $R = 0.795$; $p < 0.001$). Comparing fuel used with other measures, there are significant positive correlations for the number of gear changes ($R = 0.381$; $p < 0.001$), mean speed ($R = 0.261$; $p < 0.001$), SD of speed ($R = 0.381$; $p < 0.001$), mean torque ($R = 0.176$; $p < 0.005$), and SD of torque ($R = 0.419$; $p < 0.001$). There is also a significant negative correlation between fuel used and mean acceleration ($R = -0.178$; $p < 0.005$). This is counterintuitive, as it suggests that a higher average acceleration is associated with lower fuel use. An explanation for this result is that a fuel-efficient driving strategy is to maintain vehicle momentum, thus reducing the need to apply the accelerator to regain lost speed. A driver following this strategy will cause the vehicle to undergo fewer instances of negative acceleration and, as a result, the mean acceleration for that

drive is likely to be more positive. In addition, the adoption of this fuel-efficient strategy will also reduce the variation in the acceleration values that are observed, reinforcing the relationship between the SD of acceleration and fuel used.

Experiment 3 demonstrates that collecting data at 1 Hz rather than 60 Hz does not significantly impair the relationship between the SD of acceleration and fuel usage. This suggests that the speed information recorded by a digital tachograph at a frequency of 1 Hz could produce a valid metric for evaluating the fuel efficiency with which a driver operated their vehicle.

Experiment 4: stylised simulator drives

When drivers perform their everyday tasks, there is an array of different variables that will impact upon the fuel efficiency of their vehicle, in addition to the within- and between-driver variation caused by different driving styles. In experiment 4, the author completed a series of stylised drives using the same route as used in experiments 2 and 3 to investigate how a number of different variables might influence the relationship between the variation in vehicle acceleration and fuel used. Factors evaluated include the load carried, the type of vehicle and road friction.

Method

The route used in experiments 2 and 3 was used for the drives completed in experiment 4. The driver completed three instances of each of the following nine driving styles:

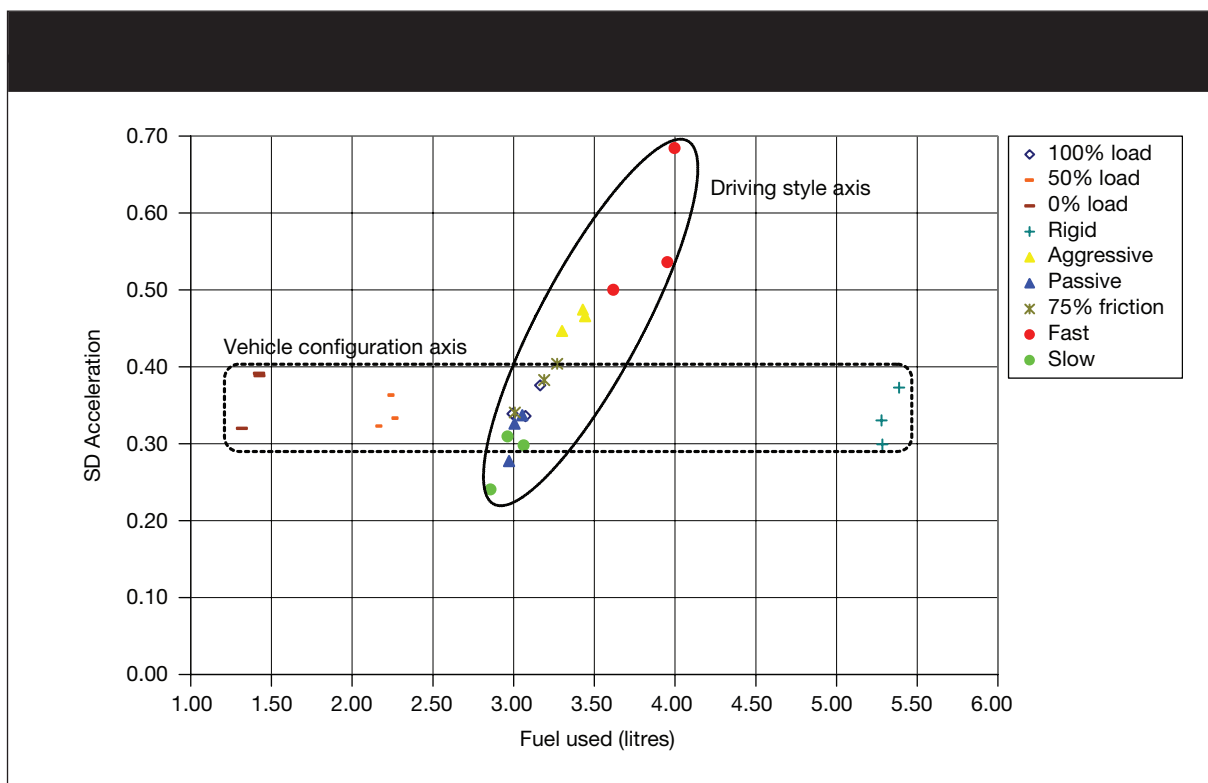
1. **Normal.** In the normal driving condition, the drive was completed using a 100% full semi-articulated vehicle as used by drivers in experiments 2 and 3. No special driving styles were adopted.
2. **50% load.** A 50% loaded vehicle was used to investigate how the reduced load would affect fuel consumption, given the same driving style.
3. **0% load.** A 0% loaded vehicle was used to investigate further how a reduction in load would affect fuel consumption, given the same driving style.
4. **Rigid vehicle.** TruckSim can be configured so that the driver is operating a rigid lorry rather than a semi-articulated vehicle. This has different dynamic and engine characteristics, to replicate those of the smaller vehicle.
5. **Aggressive.** 'Aggressive' driving in this instance referred to rapid acceleration, sharp braking and quick cornering. However, in periods of cruising, speed was no greater than in the normal style driving, resulting in a similar exercise completion time.

6. **Passive.** In the 'passive' driving style, drives were completed making minimal changes to vehicle acceleration, i.e. the vehicle accelerated slowly but also decelerated more slowly than perhaps could be considered safe in the urban environment. This again resulted in a similar exercise completion time to the normal driving style.
7. **75% friction.** The friction characteristics of the simulated roads can be adjusted on a sliding scale between 100% (normal, dry asphalt) to 0% (no effect of wheel movements on road). For this drive, friction was reduced to 75%, similar to that of a moderately wet road to investigate the effect on fuel economy. Where possible, driving style was as normal.
8. **Fast.** In the 'fast' driving style, the vehicle was simply driven as quickly as the driver was able to proceed without crashing the vehicle or disobeying traffic regulations (including speed limits and lane discipline).
9. **Slow.** Driving in a 'slow' style meant driving in a very relaxed manner – corners were taken slowly, speeds were always comfortably below the speed limit, and acceleration was leisurely.

Completing three of each of the nine driving styles resulted in 27 drives on which data analysis could be conducted.

Results

The results of experiment 4 are best summarised by Figure 6. The linear trend line is that observed for drives completed in experiment 3.



It appears from Figure 6 that the data from the nine different driving types have aligned onto two axes. The first relates to the vehicle load and type, and is highlighted using the dashed rounded rectangle in the figure. From left to right, the data points for the drives completed with a 0% load, 50% load, 100% load and rigid vehicle are all aligned along a horizontal band between SD acceleration values of 0.30 and 0.40. The second axis relates to the individual driving style with which each drive was completed and runs from bottom left to top right, highlighted by the dotted oval. The 'slow' drives typically showed the least variation in acceleration and the least fuel usage. Moving upward, next are the 'passive' drives, closely followed by the 'normal' behaviour, 100% load drives. Demonstrating more variation in acceleration and more fuel usage are the 'aggressive' drives and, finally, displaying the most variation in acceleration and greatest fuel usage are the 'fast' drives.

Finding two unique axes in the relationship between the SD of acceleration and fuel usage, dependent upon vehicle configuration and driving style, is very encouraging. This would suggest that, regardless of vehicle type or load, the fuel efficiency with which a driver has been able to control their vehicle on a particular route can be estimated by finding the SD of the vehicle acceleration. As a result, it may be possible to identify where, for example, driver A drove more fuel-efficiently than driver B by demonstrating a lower variation in vehicle acceleration, although driver A has completed a route with a full load and has used more fuel than driver B, who completed the same route with an empty load,.

Discussion of simulator results

The correlation between the variation in vehicle acceleration and the fuel used would seem to offer the possibility of assessing the fuel efficiency with which the vehicle has been driven. The results of experiment 3 and 4 suggest that the data available from digital tachographs are of sufficient quality to maintain the validity of the relationship between the SD of acceleration and fuel usage. This opens up the potential for every commercial vehicle operator to track the fuel-efficient behaviour of their drivers – even retrospectively (depending upon how long digital tachograph data are retained). Furthermore, by accessing the digital tachographs and/or vehicle Controller Area Network (CAN) bus, it may be possible for this measure to be calculated in real time and thereby act as a guide or driver training aid.

Taking the variation in acceleration as a measure of how fuel-efficiently a driver is operating a vehicle would allow the efficacy of different training schemes, for example classroom-based, simulator-based and invehicle, to be compared. Their relative cost-benefit ratio could be assessed not only in terms of fuel cost-reduction, but also how a driver's technique has improved as a result of the training.

One factor that could affect the validity of the variation in vehicle acceleration as a diagnostic tool is routing. On an urban route, a driver is likely to have to stop and start the vehicle continually, producing a high variation in acceleration, whereas on a motorway route the driver is more likely to be able to maintain a constant speed, thereby minimising variation in acceleration. Comparison of a driver's behaviour across these routes is therefore unlikely to give great insight into the driver's fuel efficiency. Another factor that must be taken into consideration when using this measure is the relative safety of the driver. Safety is a higher priority than fuel efficiency, and there are conceivable circumstances where a strategy that produces a

large variation in acceleration, such as an emergency stop, may have been necessary to avoid an accident. However, these events should be relatively rare, particularly if a driver is operating the vehicle with good anticipation and alertness.

A problem highlighted in experiment 4 by the difference between the relationships observed in experiments 3 and 4 is that all data collection so far has been conducted using a truck simulator as a proxy for a real vehicle. It was of concern when a technical adjustment to the simulator configuration had such a marked effect on the proposed relationship. Using the simulator has obvious advantages, since conditions can be strictly controlled and data are readily accessible at a high degree of accuracy. Yet, to have further confidence that the results are robust and do genuinely offer the possibility of creating a useful diagnostic tool for assessing driver fuel efficiency, the relationship must now be explored using data from real vehicles.

In conclusion, the variation in the acceleration of a vehicle appears to offer an instructive technique for monitoring the fuel efficiency with which a driver operates a vehicle. Furthermore, tachograph data offer the possibility of accessing this information for all commercial vehicle drivers. This would allow the behavioural benefit of fuel efficiency training programmes to be monitored objectively.

Experiment 5: testing real driving scenarios using digital data

In experiment 5, digital information recorded from the vehicle was used. EU regulation 1360/2002 states that all applicable vehicles made after 1 August 2005 had to be fitted with a digital tachograph (although this was extended to 1 May 2006 in the UK because of concerns about industry support of the new standard). The digital units record information to a driver smart card and also hold the information in the vehicle unit. The vehicle unit holds driving information for a 12-month period. Drivers participating in the Safe and Fuel Efficient Driving (SAFED) standard training procedure (see Transport Energy, 2005) were used. In this training, drivers complete a baseline drive to establish their current performance level while being observed from the passenger seat of the vehicle by a SAFED-trained instructor. The instructor also counts the number of gear changes that the driver makes over the course of their drive and makes a subjective assessment of the driver's performance on 17 different criteria, such as hazard perception and prioritisation, the use of mirrors, driver attitude and speed. The driven route encompasses a variety of road environments, and the drive duration is about an hour.

Having completed the baseline drive, the trainee is taken to a classroom and given feedback on their performance as well as instructions on how to drive more safely and more fuel-efficiently. The trainee is then given the opportunity to demonstrate what they have been taught by driving the same route again. In this second drive, the trainee is also given tips by the instructor, who is again sitting alongside the driver in the passenger seat. The trainee is again given a subjective assessment on the same 17 criteria and the number of gear changes, while the fuel used and the time taken to complete the route are recorded, with the aim of reducing the number of gear changes and fuel used without sacrificing any time in completing the route. Case

studies of companies that have sent drivers for training have observed fuel efficiency savings of between 2 and 12%, with reductions in driver stress and improved awareness of safety issues (see Freight Best Practice, 2006).

The data from drivers participating in SAFED training were selected for use in this study for two specific reasons. First, a number of factors are held constant between drive 1 and drive 2. The same driver completes the same route in the same vehicle. This reduces the amount of variation that could be attributed to such factors. Second, since drivers have been trained in fuel-efficient driving techniques, there should be changes in fuel efficiency between drive 1 and drive 2 resulting from improved driving behaviour. Given the results observed in previous experiments, it should therefore be possible to observe changes in the variation in vehicle acceleration between drives 1 and 2 related to the changes in fuel usage.

Method

All trainees were professional drivers employed by Carlsberg UK and based at the Carlsberg National Distribution Centre in Swan Valley, Northampton. Carlsberg UK kindly permitted data from the SAFED training of their employees to be used as part of this study. To ensure data protection guidelines were followed, no information was given as to the identity of the drivers responsible for the driving data.

A telematics system was installed in the training vehicle to record fuel consumption and the gear changes made by the driver. The telematics system was also capable of recording the vehicle speed at 1 Hz. Consequently, there was no need to use the data recorded by the digital tachograph itself, since the telematics system was able to report the same information in a single file. Pegasus Logistics Engineering were contracted to fit the telematics equipment to the training vehicle and deliver the resultant data from the system.

The vehicle to which the telematics equipment was fitted and which was used for training by the drivers from Carlsberg UK was a MAN TGA 4×2 tractor unit with curtain-sided trailer that had a gross vehicle weight of 21,000 kg, 12 forward gears and one reverse gear. The engine is compliant with the Euro IV emission standards and uses Exhaust Gas Recirculation (EGR) to reduce nitrogen oxide and nitrogen dioxide emissions.

The data from each training drive were delivered as a file in Microsoft Excel format at a frequency of 1 Hz, with columns for the time stamp, speed (measured in km/h), fuel (measured in ten-thousandths of a litre), current gear (−1 (reverse) to 12) and distance travelled (metres).

Results

The SAFED training schedule operated by Carlsberg resulted in data recorded for the two runs completed as part of SAFED training by five drivers. Data were also recorded for the second run completed by one further driver, but a technical fault resulted in data loss from their first run. The volume of data acquired was therefore significantly less than had been anticipated (original contract stated data would be provided for 20 drivers) and is therefore only likely to show indicative rather than

statistically robust relationships. Non-parametric Spearman's rho correlation coefficients were calculated for six factors that could be linked to fuel usage. The strongest correlation was observed between time taken and fuel used ($n = 10$; $\rho = -0.793$; $p = 0.006$). A strong negative correlation indicates that slower drivers used less fuel. The second strongest correlation was between fuel used and the SD of vehicle acceleration ($n = 10$; $\rho = 0.564$; $p = 0.090$), but this does not quite reach statistical significance. The correlation is in the expected direction, whereby drivers showing greater variation in vehicle acceleration use more fuel. The Spearman's rho correlation between fuel used and the number of gear changes also nears significance ($n = 10$; $\rho = 0.564$; $p = 0.090$). This identical result indicates that the number of gear changes, like the SD of acceleration, also decreased for every driver between drives 1 and 2. The correlations between fuel used and mean speed, SD of speed and mean acceleration do not reach significance.

Figure 7 shows a scatter plot of the SD of vehicle acceleration against fuel used for all Carlsberg drivers for whom full data were collected.

Figure 7 Graph to show the SD of vehicle acceleration against fuel used for Carlsberg drivers completing SAFED training

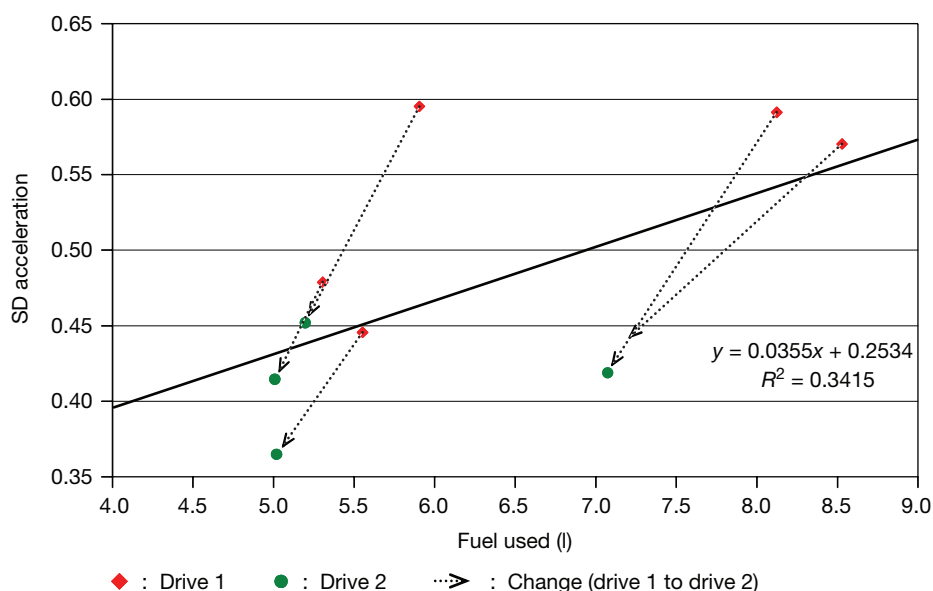


Figure 7 shows that the reductions in fuel usage are associated with reductions in SD of acceleration. However, if the relationship were perfect, the arrows would be nearer and parallel to the trend line. The observed arrows are much steeper in gradient than the trend line. Although the results are based on a very limited sample of drivers, it would appear that conditions were different for the two drivers whose data appear to the right of the graph. Although they achieved a similar SD of acceleration as the other drivers in drive 2, their fuel use is considerably higher. This is reminiscent of Figure 5, where driver factors caused the relationship between the SD of acceleration and fuel usage to change on one axis, and vehicle configuration factors caused the fuel usage to change independent to the SD of acceleration. Further investigation revealed that, for the drives showing the highest fuel usage, the training vehicle was indeed part-loaded. It is therefore unsurprising to find such differences and suggests that the relationship between the SD of acceleration and fuel usage is, in fact, stronger than the trend line shown in Figure 7.

Conclusions

The aim of this project was to investigate how changes in vehicle behaviour were linked to variation in fuel efficiency, with a view to determining whether there were identifiable behaviours that could distinguish fuel-efficient driving. The study began by using TruckSim as a tool to provide highly accurate driving data in conditions where many factors, such as traffic, weather and route, could be held precisely constant. The correlation with fuel used observed in the studies conducted in TruckSim suggested that the variation in vehicle acceleration has the potential to be a useful diagnostic tool for the assessment of drivers' fuel efficiency. It was of particular interest to observe the results of experiment 4, where the variation in vehicle acceleration was evaluated for a number of stylised drives. The results suggested that the variation in vehicle acceleration would still be a robust measure of driver fuel efficiency, even though the fuel consumption may be affected by vehicle load or vehicle type.

Experiment 5 investigated how the results observed in the simulator might transfer to data recorded from real vehicles. Data from drivers undergoing SAFED training were used, as this had many distinct advantages. Trainees completed their driving along consistent routes, and the training should have caused a noticeable change in drivers' fuel efficiency as a result of the SAFED training. The failure to acquire sufficient real-world data in experiment 5 in order to conduct reasonable statistical analyses was disappointing, particularly since the small amount of data received indicated that there was a relationship between fuel use and the variation in vehicle acceleration consistent with that observed in the simulator-based experiments. From the data available, however, the relationship initially appeared rather unconvincing. Although all drivers showed an improvement in fuel efficiency, demonstrated by a reduction in variation in vehicle acceleration, there were significant differences in the fuel usage for a given value of acceleration variation. However, the discovery that the training vehicle was part-loaded for the apparently anomalous values gave a tangible explanation to this discrepancy and suggested that the relationship between variation in acceleration and fuel usage was sound. It is hoped that more data shall still be recorded over the coming months, allowing a fuller analysis to be completed. Any follow-up study focusing only on real-world data collection should seek more involvement in the research process from the organisation submitting drivers for training, as there are benefits for them in understanding the behaviour of their drivers from the analyses performed.

Having observed a link between variation in vehicle acceleration and fuel efficiency in the controlled conditions of the simulator and SAFED training, it would now be of interest to study how this relationship withstands more varied conditions. Ideally, data would be available from a fleet of vehicles over a period of time, so that variations in load, time of day, traffic conditions, route and weather conditions can be investigated. It would also be very interesting to study whether driving style with regard to variation in vehicle acceleration has any link with accident risk. af Wahlberg has published a number of papers indicating that rapid accelerations and decelerations observed for bus drivers are linked to higher accident rates (see af Wahlberg 2004 and 2006 for examples). If this future research were to discover that variation in vehicle acceleration is a reliable tool for diagnosing the fuel efficiency and safety risk of individual drivers, then work could be done to investigate the

possibility of developing an on- or off-line system to give feedback based on this measure.

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An economic evaluation of the Kerbcraft child pedestrian training pilot project

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Introduction

The evaluation of the National Child Pedestrian Training Pilot Project (Kerbcraft) was conducted between August 2003 and March 2007 across English local authorities and Scottish unitary authorities in areas of high deprivation and high child pedestrian casualty rates. The Kerbcraft practical child pedestrian skills training programme, developed by Thomson (Thomson, 1997, Thomson *et al.*, 2002) in Glasgow and piloted in the deprived Drumchapel community in the city (Thomson and Whelan, 1997), was implemented in a wide range of different settings (Whelan *et al.*, 2008).

The overall aims of the evaluation project were to assess the impact of the national pilot project in both England and Scotland on children's pedestrian safety, and to identify the most effective ways of establishing and sustaining practical child pedestrian training schemes at the local level. The objectives of the evaluation project related to the:

- impact on child pedestrian skills;
- impact on school communities and volunteers;
- cost-effectiveness of schemes;
- factors for success and failure;
- setting up, management and maintenance; and
- sustainability of schemes.

This paper reports on the third of these objectives: to determine the cost-effectiveness of Kerbcraft in terms of local authority spending and children's behaviour change. The objectives of the economic evaluation are:

- (a) to undertake a comparative economic evaluation of seven local authority Kerbcraft schemes in terms of their cost-effectiveness; and
- (b) to undertake a comparative economic evaluation of children's behaviour change scores after Kerbcraft training at the school level.

Background

The Kerbcraft programme is based on learning theories and educational evidence of how children acquire practical pedestrian skills. The programme is designed to enhance three pedestrian skills in 5–7-year-old children:

- recognising safe versus dangerous crossing places;
- crossing safely at parked cars; and
- crossing safely near junctions.

The whole package is implemented over a period of 12–18 weeks (Thomson *et al.*, 2002). An important component of the programme is practical training, conducted by local volunteers, in the streets surrounding children's schools. The training involves both child-led problem-solving at the roadside with indirect adult support, where required, and behavioural modelling. The training is progressive, with each skill building on earlier ones. The volunteers are recruited, trained and supported by co-ordinators based in the local authority's road safety department. Table 1 shows the number of schemes which were funded in three tranches of funding in England and Scotland, and the number of children trained in all tranches

Table 1 Number of schemes and children trained per tranche across the National Network in England and Scotland from 2002 to 2007

	Total no. of schemes	English schemes	Scottish schemes	Total number of children trained
Tranche 1 (2002–05)	41	38	3	31,641
Tranche 2 (2003–06)	42	39	3	28,349
Tranche 3 (2004–07)	32	26	6	22,453
Total	115	103	12	82,443

Methods

The pilot trial involved a range of different methods, which included surveys of volunteers, a skills assessment exercise of children's behaviour at the roadside, case studies of a selection of schools, co-ordinator and Road Safety Officer surveys, a survey of head teachers, interviews with management and support staff from MVA (the research consultancy group which managed the implementation of the Kerbcraft programme), and an analysis of cost-effectiveness.

For objective (a), seven local authority Kerbcraft schemes were selected at random from the schemes conducted during tranches 2 and 3. The schemes were selected to be representative of a range of factors: rurality; ethnicity; deprivation; and large and small local authority areas (metropolitan versus non-metropolitan authorities). Data used in the analysis were obtained from MVA, as part of their management and monitoring of the network of schemes. Data included the annual budget of different schemes and the number of children trained on Kerbcraft courses.

For objective (b), the behaviour change data collected in the skills assessment exercise were used. Thirteen schools across England were selected for the skills assessment exercise, so that a broad geographical spread across tranche 2 schools could be obtained. Schools with high and low levels of deprivation, high and low levels of black and minority ethnic (BME) groups, different types of schools, and different geographical areas, such as inner-city and sub-urban, were selected. The pedestrian skills of the children were assessed before training (188 children), immediately post-training (150 children post-test 1), and two to four months after training (73 post-test 2).

Results

Objective (a)

Seven Kerbcraft schemes were selected for the comparative economic evaluation of Kerbcraft. Table 2 shows the annual budgets and the number of children on Kerbcraft courses in these schemes. In addition, the numbers of volunteers who conducted the Kerbcraft training and the percentage of BME groups in each local authority were calculated.

Table 2 Local authorities and Kerbcraft delivery

Local authority type	Number of volunteers	Annual Budget (£)	% BME groups	Number of children on Kerbcraft courses
(A) Rural local authority Tranche 3	84	23,325	0.84	612
(B) Local authority with high socio-economic deprivation Tranche 2	54	28,540	21.41	906
(C) Local authority with low socio-economic deprivation Tranche 3	77	29,209	4.81	805
(D) Local authority with high levels of BME groups Tranche 3	86	28,644	77.31	770
(E) Local authority with a high level of BME groups Tranche 3	54	30,315	73.71	1,101
(F) Metropolitan local authority Tranche 2	24	23,564	65.76	240
(G) Non-metropolitan local authority Tranche 2	40	27,978	67.32	962

The budgets and the number of children receiving Kerbcraft training within each scheme from Table 2 were compared and costs per child were calculated. These are presented in Table 3 and are all less than £100 per child per scheme, with costs lying in the range £28–99 per child. The cost of Kerbcraft in six of the schemes is less than £40, with only one local authority more than £40 per child. This can be partially explained by the absence of a Kerbcraft co-ordinator in the first six months of the scheme, which had the effect of reducing coverage of the schools and the number of children trained.

Table 3 Cost of Kerbcraft delivery in local authorities

Local authority type	Number of children on courses	Annual budget (£)	No. of schools	Cost per child (£)
(E) Local authority with high levels of BME groups Tranche 3	1,101	30,315	7 of 7	27.53
(G) Non-metropolitan local authority Tranche 2	962	27,978	5 of 12	29.08
(B) Local authority with high socio-economic deprivation Tranche 2	906	28,540	10 of 15	31.50
(C) Local authority with low socio-economic deprivation Tranche 3	805	29,209	7 of 9	36.28
(D) Local authority with high levels of BME groups Tranche 3	770	28,644	5 of 7	37.20
(A) Rural local authority Tranche 3	612	23,325	10 of 10	38.11
(F) Metropolitan local authority Tranche 2	240	23,564	3 of 12	98.18

Objective (b)

Table 4 presents a second analysis showing change in behaviour scores. School-level data on the change in Safe Places skills were used. These represent the proportion of ‘safe’ behaviours averaged across all children tested in each school at pre-test, post-test 1 and post-test 2.

Table 5 shows the analysis of the improvement in children’s roadside performance and associated costs over time. This table contains incremental ‘change data’ or ‘improvement data’ for both costs and outcomes. The local authority Kerbcraft budget was used. Costs were compared with the outcome data at school level for improvement in Safe Places behaviour scores for the actual number of trained children in each school. The figures in column four represent the added cost in pounds of making a 1% improvement in the Safe Places behaviour test scores for all of the trained children involved in Kerbcraft in a local authority area. The figures in column five represent the longer-term added cost in pounds of making a 1% improvement in the Safe Places behaviour scores for all of the trained children involved in Kerbcraft in a local authority area.

Table 4 Changes in Safe Places behaviour scores across Kerbcraft schools

School in local authority	Change in proportion of safe scores from pre-test to post-test 1	Change in proportion of safe scores from post-test 1 to post-test 2
School 1	0.04	0.29
School 2	0.27	0.07
School 3	-0.06	Not sampled*
School 4	0.20	Not sampled*
School 5	0.17	0.14
School 6	0.10	Not sampled*
School 7	0.26	0.06
School 8	0.03	Not sampled*
School 9	0.04	Not sampled*
School 10	0.13	Not sampled*
School 11	0.09	0.22
School 12	-0.07	Not sampled*
School 13	18	Not sampled*

* Not sampled because the sample size was too small.

Table 5 Costs and behaviour change

A school in a local authority	% ethnicity	Mean Index of Multiple Deprivation	Additional cost (£s) of basic improvement across all schools in local authority*	Additional cost (£s) of training robustness across all schools in local authority†
School 2	4.9	36.71	919	-164
School 7	3.9	29.95	763	63
School 4	No data	39.01	1,052	Not sampled
School 5	7.7	36.79	1,373	5
School 13	11.1	57.04	1,308	77
School 10	18.5	55.58	1,534	Not sampled
School 6	No data	60.9	2,472	Not sampled
School 11	4.03	37.24	2,680	99
School 1	6.7	53.21	3,211	56
School 8	5.9	57.76	5,999	Not sampled
School 9	75.2	50.01	4,966	Not sampled
School 12	87.4	57.04	Not cost-effective	Not sampled
School 3	No data	43.03	Not cost-effective	Not sampled

* Additional cost (£) of improving by 1% the safe places behaviour scores between pre-training and post-training across all the trained children involved in Kerbcraft in the local authority area.

† Additional cost (£) of improving by 1% the safe places behaviour scores between post-training and 2 month post-training follow-up across all the trained children involved in Kerbcraft in the local authority area.

Discussion

Some local authorities in the inner-cities appear to have performed well in terms of rolling out the Kerbcraft scheme and the coverage they have managed across their nominated schools. One of the inner-city local authorities included in this economic evaluation did not have a high level of volunteer support for Kerbcraft, but had managed to cover all its nominated schools and to enrol large numbers of children into the Kerbcraft programme, spreading the cost widely. Local authorities with a greater than 65% representation from BME groups were not affected in terms of cost-effectiveness either. It seems that the Kerbcraft scheme had managed to reach and be run cost-effectively in local authorities with high representation from BME groups and high levels of socio-economic deprivation. This should have longer-term impacts on child pedestrian accident rates in the future. There is no clear pattern of cost-effectiveness in terms of the rurality or the size of a local authority from this data.

Kelly *et al.* (2005), in discussing the economic appraisal of public health interventions, suggest that:

The variability in effectiveness and the likelihood of success of interventions are crucially filtered through two sets of mediating factors which are, to some extent, independent of the mechanics of the intervention itself. These are the enthusiasm, expertise and engagement of the staff carrying out the intervention; and the local delivery infrastructure.

The evaluation of the Kerbcraft pilot projects provides a good illustration of this process.

Conclusions

The findings of this cost-effectiveness analysis suggest that the scheme is robust and has medium-term benefits that occur after the Kerbcraft scheme has ended. Kerbcraft may also have long-term benefits as well. However, the dramatic fall in the cost per change in safe behaviours test scores suggests that investment in Kerbcraft would pay back benefits and value in terms of safe behaviours long after its implementation.

The overall evaluation of the National Child Pedestrian Training Pilot Project (Kerbcraft) investigated its impact on children's pedestrian behaviour and on schools and volunteers across English local authorities and Scottish unitary authorities in areas of high deprivation and high child pedestrian casualty rates. The most effective ways of establishing and sustaining practical child pedestrian schemes at a local level were identified. The field trial showed that the programme could be implemented in a variety of settings, taking specific account of the effects of rurality, ethnicity and social deprivation. The outcomes of the skills assessment component confirm the earlier findings of the Drumchapel pilot scheme (Thomson and Whelan, 1997), but this time in a larger and more disparate sample.

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Influences on pedestrian risk-taking in young adolescents: the conflicting role of parents and peers

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Introduction

The available evidence suggests that, generally speaking, on tests ranging from the choice of crossing routes to the use of designated crossings, children first approach adult levels of pedestrian skill around the age of 10–12 years (Thomson *et al.*, 1996; Tolmie *et al.*, 2003). The peak age for pedestrian accidents in the UK occurs **after** this, however, between 12 and 15 years (Sentinella and Keigan, 2004; Department for Transport, 2005).

Why should older children remain so vulnerable when their underlying pedestrian skills and competences have improved? One possibility is that past skills testing has presented an incomplete picture with respect to the development of pedestrian competences, and that, in fact, adolescents suffer from limitations or lacunae that place them at greater risk. Alternatively, it may be that additional factors emerge around this age to undermine the progress that has been made in skill development. Whichever is the case, it is clear that, without a better understanding of the factors at

work and how these operate, it is hard to discern what steps might be taken to improve pedestrian vulnerability in this age group.

Potential factors and possible hypotheses

As far as skills are concerned, there are clear indications that the transition to secondary school in the UK results in increased demands on children's abilities. Secondary schools are typically located in busier areas than primary schools, and children often have longer journeys to and from school, increasing their exposure to these more demanding environments. Moreover, these changes occur at exactly the time when they start to insist on – and are generally allowed – greater independence (Lynam and Harland, 1992; Platt, 1998; Platt *et al.*, 2003). Some evidence of the possible impact of the conjunction of these influences is provided by the fact that the increase in accidents post-transition to secondary school is primarily on busy roads (Harland *et al.*, 1996). The implication is that, while adolescents' pedestrian skills may have reached the level at which they are competent to deal with quieter traffic environments, their competences are not yet adequate to meet the demands of busier ones and require a period of further honing. If this is the case, the nature of the skills gap needs to be clarified as a matter of urgency.

At the same time, it is also well established that young adolescents typically regard road safety concerns as 'childish', regardless of whether or not their skills are fully developed. Both focus group and interview data suggest that they accord such issues a low priority, and see road safety as something they 'did at primary school' (Tolmie and Thomson, 2003; Lupton and Bayley, 2001). The shift from the dominance of parental to peer-group influence that happens at this age (Steinberg, 1988) may serve to reinforce these perceptions by granting them the appearance of a consensual view. In addition, the growth of a bias towards norm-breaking, as part of the effort to develop an independent identity distinct from that of parents (see Erikson (1968; 1972) on the importance of this) may lead deliberate risk-taking to become more highly valued for some adolescents (Arnett, 1995). This may feed through, in turn, to pedestrian behaviour (cf. West *et al.*, 1998). Again, then, the crucial task must be to identify the precise factors at work.

While these different influences have been framed as alternatives, there is in fact no reason to suppose that they are mutually exclusive, and, indeed, that there are various ways in which they might interact with each other. Putting them together, the following hypotheses about the sources of adolescents' vulnerability as pedestrians emerge as possibilities:

1. Young adolescents overestimate their abilities in more challenging road environments because they are less used to these, i.e. their **perception** of their competence has been shaped in less difficult conditions and therefore fails to match their **actual** competence in the circumstances to which they are now routinely exposed.
2. They pay inadequate attention to the effectiveness of their judgements, because they simply assume (with peer support) that they are able to cope.

3. The increased influence from the peer group and reaction against parental standards results in a growing perception that riskier behaviours are the accepted norm, and a feeling that it is childish to behave carefully. The net effect of this is less careful road-crossing behaviour and a more general espousal of risk-taking as part of self-identity.

The starting position for the present research was that it may be the **combined** effect of these processes that underlies the higher accident rate among young adolescents relative to primary-age children, by leading them to make poor or marginal decisions that remain uncorrected by feedback. Two studies were conducted to address this possibility.

Study 1

The first study was designed to test the hypothesis of the emergence of a discrepancy between perceived and actual pedestrian skills following the transition to secondary school. The key goals were to:

- a) assess the **actual** pedestrian skills of adolescents aged 11–15 years;
- b) compare these with measures of their **perceived** pedestrian skills;
- c) consider how the relationship between actual and perceived skill changes, especially across the transition from primary to secondary school; and
- d) examine how this relationship compares with that found among adults.

If the emergent discrepancy hypothesis is correct, 12–15-year-olds (i.e. post-transition to secondary school in Scotland) should regard decisions in all skill areas as easier, relative to their actual performance, than either 11-year-olds or adults. Since this discrepancy is argued to be sustained by lower levels of attention to feedback, 12–15-year-olds should also show a tendency not to revise their estimates of difficulty after completing problems to the same extent as primary school children or adults, even if they perform poorly. Finally, since the discrepancy hypothesis is founded on the notion that adolescents assume their performance is better than it actually is, and thus that there is room for improvement, 12–15-year-olds should show skill levels that are clearly poorer than those of adults.

Methodology

A sample of 169 participants, balanced for gender and covering a representative range of social backgrounds, took part in the study. This sample consisted of children from the last year of primary school (Primary or P7; 11–12-year-olds), young adolescents from the first three years of secondary school (Secondary or S1 to S3; 12–15-year-olds), and adult postgraduate students. The non-adult sample was drawn from four schools in West Central Scotland, two secondaries and two of their feeder primaries.

All participants were assessed via computer-based tasks on four pedestrian skills:

- **safe route planning** – the perception of dangers posed by aspects of the road layout and the adjustment of crossing routes to deal with these;
- **visual timing** – the coordination of road crossing with vehicle movement;
- **use of designated crossings** – perception of cues from traffic and crossing type and the use of an appropriate crossing strategy; and
- **perception of drivers' intentions** – awareness of cues to drivers' future actions (i.e. vehicle movements), and the need to adjust road crossing decisions to fit.

Each skill was tested in six problem contexts, which required participants to make judgements pertinent to the skill being tested and, on the basis of these, to direct the road-crossing of an on-screen character. In view of the possibility that previous assessments had overestimated older children's pedestrian skills by focusing on more basic situations, the six contexts were chosen to include a number of more complex and challenging problems, of the kind that adolescents in urban areas would be likely to face.

As well as gauging actual performance, the computer tasks required participants to judge the difficulty of making a safe decision in the different problem contexts, first of all before tackling them (but having viewed the basic conditions) and then again after having done so. This made it possible to compare relative perceptions of difficulty with relative levels of performance, and to examine how far these perceptions were adjusted in the light of the feedback generated by experience.

Past research (e.g. Tolmie *et al.*, 2005; Tolmie *et al.*, 2002; Chinn *et al.*, 2004) has established the effectiveness of computer simulations for both training and assessing pedestrian performance in a controlled fashion. However, to permit further cross-validation of measures in the present setting, data on selected skills were also collected at the roadside from a sub-sample of P7, S2 and adult participants.

Results

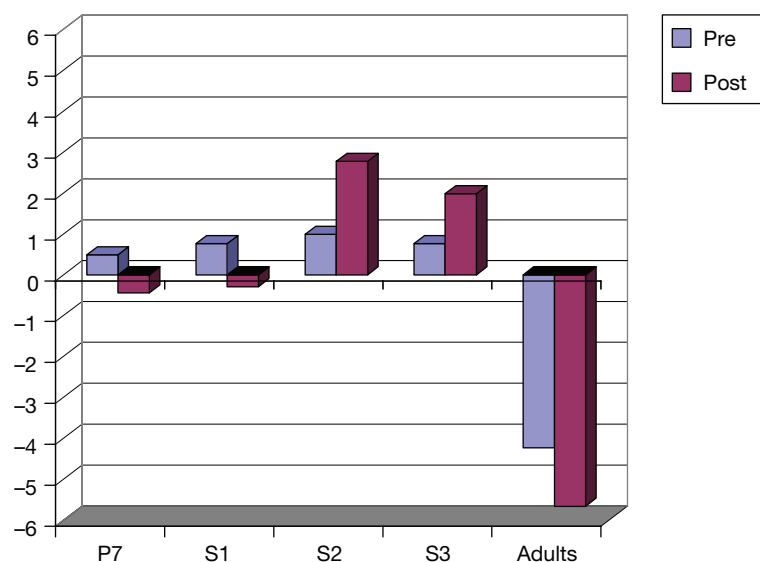
Preliminary analysis showed that performance at the roadside and on the computer simulations was well related on key shared indices. Individuals' scores on these, relative to each other, were roughly equivalent across the two settings, confirming that the computer tasks accurately estimated actual roadside skills. Having established this, attention turned to the extent to which participants exhibited improvements in skill with increasing age, and how far adolescents' performance was comparable to that of adults.

Taken overall, the pattern of age-related change in skill levels varied across area, but the general trend was one of modest improvement from 11 to 15 years and a greater shift between adolescents and adults. The adults were no better than the secondary school groups on safe route planning, and were only better than the S1 pupils on visual timing. However, they performed better than the majority of secondary school pupils on the use of designated crossings and perception of drivers' intentions. In

contrast, the secondary school sample did not differ more than marginally from the P7 pupils in any of the four skill areas.

Despite this, secondary school pupils (the 13–15-year-olds in particular) tended to rate the problems in all four skill areas as easier, relative to their actual skill levels, than either 11-year-olds or adults, and only adults showed any sign of revising their estimates of difficulty upwards post-performance, acknowledging that problems might, on occasion, be harder than anticipated. A clear picture of the size of the mismatches between performance and perceived difficulty in these age groups emerges when the measures are converted to a common scale, so that performance scores can be treated as an index of what the difficulty rating **should** have been for a given skill level. It is then possible to look at the differences between this predicted difficulty rating and those that were actually given, with positive discrepancies indicating underestimates of difficulty (the actual rating was less than the predicted) and negative differences indicating an overestimate. The outcome is shown in Figure 1.

Figure 1 Mean discrepancy between predicted and actual difficulty ratings, pre- and post-performance, by age group



As can be seen, relative to their performance level, adults substantially overestimated the difficulty of the problems in comparison with the younger age groups, indicating a considerable degree of caution on their part about their competence. Discrepancies hovered around zero for the P7 and S1 age groups, but shifted towards overestimates of difficulty post-performance, suggesting that, on balance, they had some awareness of their skill levels. In contrast, the S2 and S3 age groups consistently underestimated problem difficulty relative to their performance, and they were, moreover, the only groups to show a shift towards **greater** underestimation post-performance. These effects held regardless of gender.

Conclusions

As anticipated, then, young adolescents showed only slightly better pedestrian skills than 11-year-olds on more demanding tests, and were notably poorer than adults in most important respects. They were also much more likely to underestimate the difficulty of crossing-related judgements relative to their skill levels, especially post-performance. However, this characteristic was most marked in the second and third years of secondary school, suggesting it was not simply a function of the transition to secondary school but of some shift in perceptions post-transition, perhaps as a result of peer-influenced inattention to, or disregard of, risk.

Study 2

While suggestive, the Study 1 data do not demonstrate, however, that the overestimation of ability and lack of attention among young adolescents actively led to hazardous behaviour, and thus to the observed increase with age in accident rates. Moreover, they provide no direct information about the precise process that produces this shift in perceptions, and whether it is linked in some fashion to peer attitudes and norms with regard to pedestrian behaviour or to some more deep-seated individual bias towards risk-taking.

In order to investigate both the source of adolescents' misperceptions of ability and the relative impact of these and attitude or identity factors on pedestrian decision-making, Study 2 collected data from a single sample of 12–15-year-olds on all these various potential influences. Measures of each were then analysed for their relation to subsequent individual self-reports of actual behaviour.

Methodology

A sample of 307 pupils, drawn from the first three years (S1 to S3) of four secondary schools in West Central Scotland, participated in the study. The sample was balanced for gender and covered a full range of social backgrounds. Over the course of three sessions of computer-based testing, data were collected from each participant as laid out below:

- **Session 1:**
 - skills and perceptions of difficulty in the four areas focused on by Study 1.
- **Session 2:**
 - attitudes towards 11 pedestrian behaviours, some cautious (e.g. waiting for the green man) and some risky (e.g. running through a tight gap in the traffic);
 - perceptions of how far each behaviour was approved of by others (subjective norm) and perceived behavioural control;
 - the extent to which parents and peers were thought to perform each behaviour (i.e. parent and peer **norms**);

- how far each behaviour was seen as part of personal identity;
 - intention to perform each behaviour; and
 - general orientation towards risk-taking (Q-sort task on 40 potentially self-descriptive adjectives, rating each for applicability to the self, plus a modified version of the Attitudes Towards Risks Questionnaire, devised by Franken *et al.* (1992)).
- **Session 3:**
 - the frequency with each behaviour was carried out over the two-week period since Session 2; and
 - accident and recent near-miss history.

Results and conclusions

The use of standardised indices of measurement made it possible to make direct comparisons of the profile of participants' responses across different questions. Young adolescents' attitudes were, on balance, positive towards cautious pedestrian behaviour and negative towards risky actions, though the balance shifted slightly with age towards being less negative about risk. Perceived approval/disapproval of the different behaviours followed a similar profile, albeit without the drift towards risk. Parental norms were similar in pattern to approval, although adolescents reported parental behaviour as being a little less biased towards caution overall. Peers, in contrast, were seen as substantially more likely to engage in risky behaviour than parents, especially by 15-year-olds: this age group reported peers as being marginally more likely to engage in risky behaviour than in cautious behaviour.

Participants' risk-taking profile (as indexed by a composite measure derived following factor analysis of the Q-sort and questionnaire data) lay between parent and peer norms, being less cautious than the former, but more so than the latter. There was, however, a gradual drift towards greater espousal of risk-taking among older participants, reflecting the shift in attitudes and, more particularly, in peer norms. Reported intentions and actual behaviours reflected the more general orientation towards risk-taking. Thus they again favoured caution over risk-taking on balance, but both exhibited the same drift towards risk, and reported behaviour tended to be less cautious than had been intended, suggesting that additional influences may be at work when it comes to actual road-crossing.

These general trends masked considerable individual variability, which made it possible to use hierarchical regression analyses to establish which factors influenced intention to perform each of the 11 target behaviours, and the extent to which each behaviour was subsequently carried out. Separate analyses were conducted for intention and behaviour for each of the 11 target actions, with variables being entered in the following order:

- demographics;
- intention (prediction of behaviour only);

- TPB variables;
- skill;
- perceived difficulty;
- parent and peer norms; and
- self-identity/risk-taking.

These analyses produced highly consistent results, with the regression models accounting for large proportions of variance in responses (adjusted $R^2 = 0.28$ to 0.69 for intentions, 0.17 to 0.43 for behaviour).

As far as intentions were concerned, attitudes and perceived approval were weak to modest predictors (final beta = 0.07 to 0.30 and 0.02 to 0.18 , respectively). Approval was a stronger predictor of **cautious** intentions when first entered (beta = 0.09 to 0.35), but values fell when parent and peer norms were included, indicating shared variance with one or both of these variables. Peer norms initially had a modest influence on intention to perform risky behaviours (beta = 0.22 to 0.30), while parent norms weakly predicted cautious intentions (beta = 0.04 to 0.17). The strongest predictor of intention was participants' self-identity and risk-taking profile (final beta = 0.20 to 0.65), and the influence of peer norms dropped when this was included. Parents' behaviour was associated with perceived approval (beta = 0.09 to 0.35) and peers' behaviour with self-identity/risk-taking profile (beta = 0.08 to 0.37). These associations, taken together with the pattern of effects on intention, indicate that the influence of parent and peer norms was partially indirect, and was mediated by approval and identity respectively.

However, intention was, at best, only a moderate influence on actual behaviour (final beta = 0.05 to 0.20 , non-significant in some cases). Peer norms had a direct influence on carrying out risky behaviours (final beta = 0.03 to 0.23), and parent norms on acting in cautious manner (final beta = 0.07 to 0.26). There is an implication that risky behaviours involve an element of 'sheep-following' (hence the disparity with intention), while cautious behaviours tend to be the product of established habit (the only evident means of parental behaviour having an influence on adolescents' unaccompanied journeys). Consistent with the pattern of direct influence, self-identity/risk-taking was only a modest influence on behaviour, and not for all of the instances being examined (beta = 0.01 to 0.28). Self-reports of carrying out risky behaviour were related to near-miss history (beta = 0.11 to 0.34) and thence to accidents ($r = 0.24$), indicating that such actions have a tangible impact. Misperceptions of ability were rife here, as in Study 1, but were associated with self-identity ($r = 0.14$) rather than actual behaviour (average $r = 0.03$). Better skills, especially in the area of safe route planning, were associated with more cautious behaviour (beta = 0.09 to 0.15). Although boys exhibited riskier intentions and behaviour, the pattern of effects leading to increases in risk was identical for males and females.

General implications and conclusions

Few adolescents show markedly positive attitudes to risky pedestrian behaviour, but they are pulled towards riskier intentions and actions by the perceived presence of an element of risk in peer behaviour and the attempt to be like them. Misperceptions of skill are associated with the same pull towards risk, suggesting they are a symptom of this influence. Parental behaviour appears to provide an equivalent pull in the opposite direction, however, acting through the modelling of safe habits and the creation of a sense of approval for cautious behaviour.

Adolescents seem more likely to behave in risky fashion as pedestrians, and thus to suffer more near-misses and accidents, where parental influence is weakened. Support for the parental modelling of safe pedestrian behaviour during the primary school years appears likely, then, to be a productive arena for intervention. Skills training within the same period is also likely to have benefits, since higher skill levels were associated with safer behaviour and thus appear to exert a further degree of protective influence.

This does not mean that attempts to intervene more directly with adolescents should be abandoned, but, given their perception of road safety concerns as childish, direct training is likely to be regarded negatively, and might even be counterproductive. Getting adolescents to contribute to the skills **training** of younger children, thus promoting circumstances under which they are known to behave more responsibly (Lupton and Bayley, 2001), might serve instead to increase their sensitivity to the gaps in their own performance.

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Understanding inappropriate high speed: qualitative results from the HUSSAR project

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Introduction

Project HUSSAR is a research project concerned with High UnSafe Speed Accident Reduction. Components include a review of the English-language literature (both published and 'grey') on speed and speeding for the period 1995 to 2006, a national survey of self-reported attitudes and behaviour regarding speed choice, and a focus group study. The principal aim of the latter was to elicit driver experiences and perceptions regarding speed choice and speeding behaviour with a view to analysing the implications for the content of – and potential target groups for – speed-related media safety campaigns. This paper will report on that study and its results.

Method

Participants

Four focus groups were held between 22 and 24 February 2006, with nine participants in each group. One group was of professional drivers, two groups were of drivers on a speed-awareness course and there was one group of motorcyclists. Overall there were 9 female participants and 27 male, with an age range from 18 to 50 years. All held a full driving licence. They were each paid £50 for their participation.

Procedure

The same procedure was used for all groups. Each was audio-taped throughout their entire discussion period, which typically lasted about one hour and forty-five minutes. Groups began with the facilitator introducing the topic in general and requesting the participants to exchange their views and opinions. It was emphasised that a consensus was not a goal of discussion, and participants were encouraged to expand on topics through the use of open questions and prompts. Emerging themes were reflected back to the group at intervals to check on accuracy and completeness, and to provide an opportunity for clarification and expansion.

The facilitator was guided by a semi-structured framework that covered broad themes, previously compiled and agreed by the research team (see Table 1).

Table 1 Themes for focus group discussion	
Speeding adjectives	Speed and legal issues
Attitudes to speeding	Bike/car issues
Factors influencing speed	Causes of speeding
Speed reduction influences	Causes of slowing
Factors relating to speed limit compliance	Speeding stereotypes
Control and loss of control	Consequences of speeding
Road traffic accidents/collisions	Spontaneous recommendations from group
Speed choice	General driving behaviours influencing speed

Data analysis

Transcripts were initially generated from each audio recording, and meaning units were identified by four researchers. Emergent categories were then cross-checked. In the next stage, thematic clusters were identified and subsequently organised in terms of the concepts of the task-difficulty homeostasis model (Fuller, 2005). These two steps were carried out by two researchers independently and the results compared. Any discrepancies were resolved through discussion.

The Task-difficulty homeostasis model

In the context of speed choice, task-difficulty homeostasis basically refers to the process where drivers adjust their speed so that the perceived difficulty of the driving task falls within a range of difficulty that the driver is prepared to accept. Perceived task difficulty arises out of the interacting interface between perceived task demand and perceived capability (see Figure 1), hence the original name of task-capability interface model (Fuller and Santos, 2002). Speed directly affects task demand (Fuller et al., 2007a). Research also shows that, in the driving task, difficulty and feelings of risk covary, enabling us to refer to the upper level of difficulty a driver is prepared to accept as the driver’s risk threshold (see Figure 1).

From distal to proximal determining factors, perceived capability arises out of the driver's basic physiological competence, from which starting point the combined effects of education, training and experience produce the individual's competence as a driver. However, this competence may be undermined to varying extents by human-factor variables such as drowsiness, stress and emotional state, resulting in the driver's actual available capability and the driver's perception of this (see pathway to 'perceived capability' in Figure 2).

Perceived task demand arises out of the handling and other operating characteristics of the driver's vehicle, driving route, time of day, the physical road environment (in particular, visibility level, road alignment and road surface characteristics), and the presence and behaviour of other road users. It also critically involves the speed at which the driver is travelling (see pathways to 'perceived task demand' in Figure 2).

The driver's range of acceptable task difficulty (and its upper level defined as the risk threshold) is partly determined by the driver's perception of current capability. It is also determined in part by the distal and more immediate goals of the journey, the degree of effort the driver is prepared to invest in the task, and the driver's disposition to adopt a particular range of task difficulty and its related risk threshold. Beyond this dispositional characteristic, there may also be more immediate influences on risk threshold, such as an acute feeling of anger (see pathways to 'range of acceptable task difficulty and risk threshold' in Figure 2).

Finally, the result of the influence of all of these components may determine a driver's speed choice that exceeds the posted speed limit. Thus we need to include some representation of the driver's disposition to comply with the speed limit and also more immediate influences on compliance (see pathways to 'decision and response' in Figure 2).

Figure 1 Core of task-difficulty homeostasis model

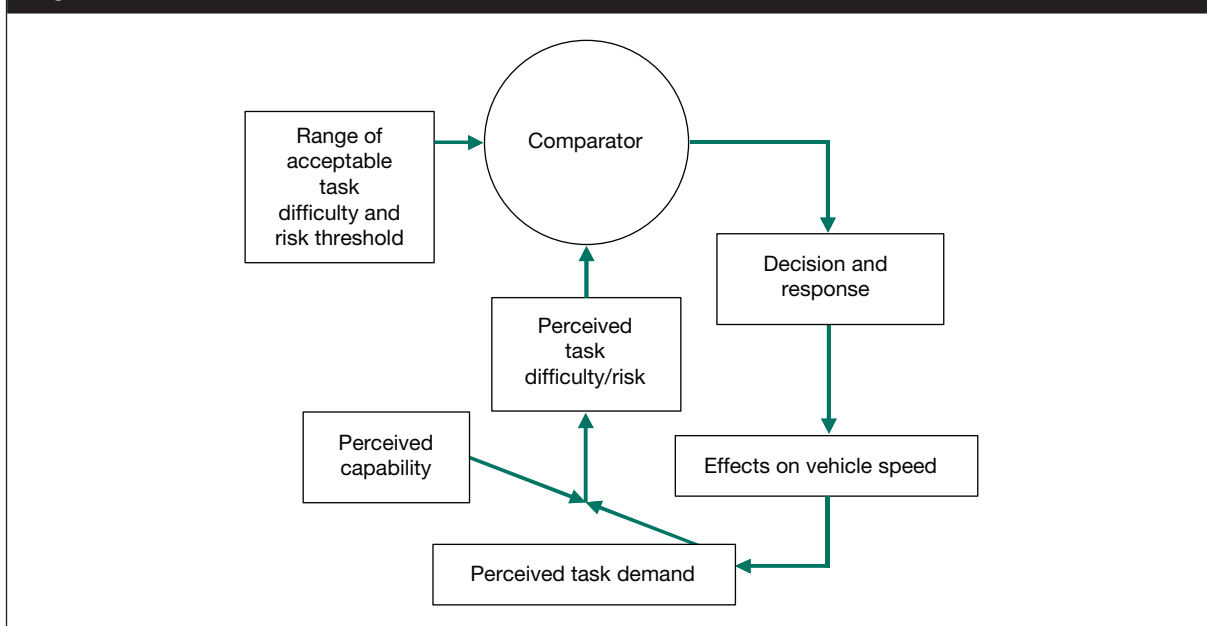
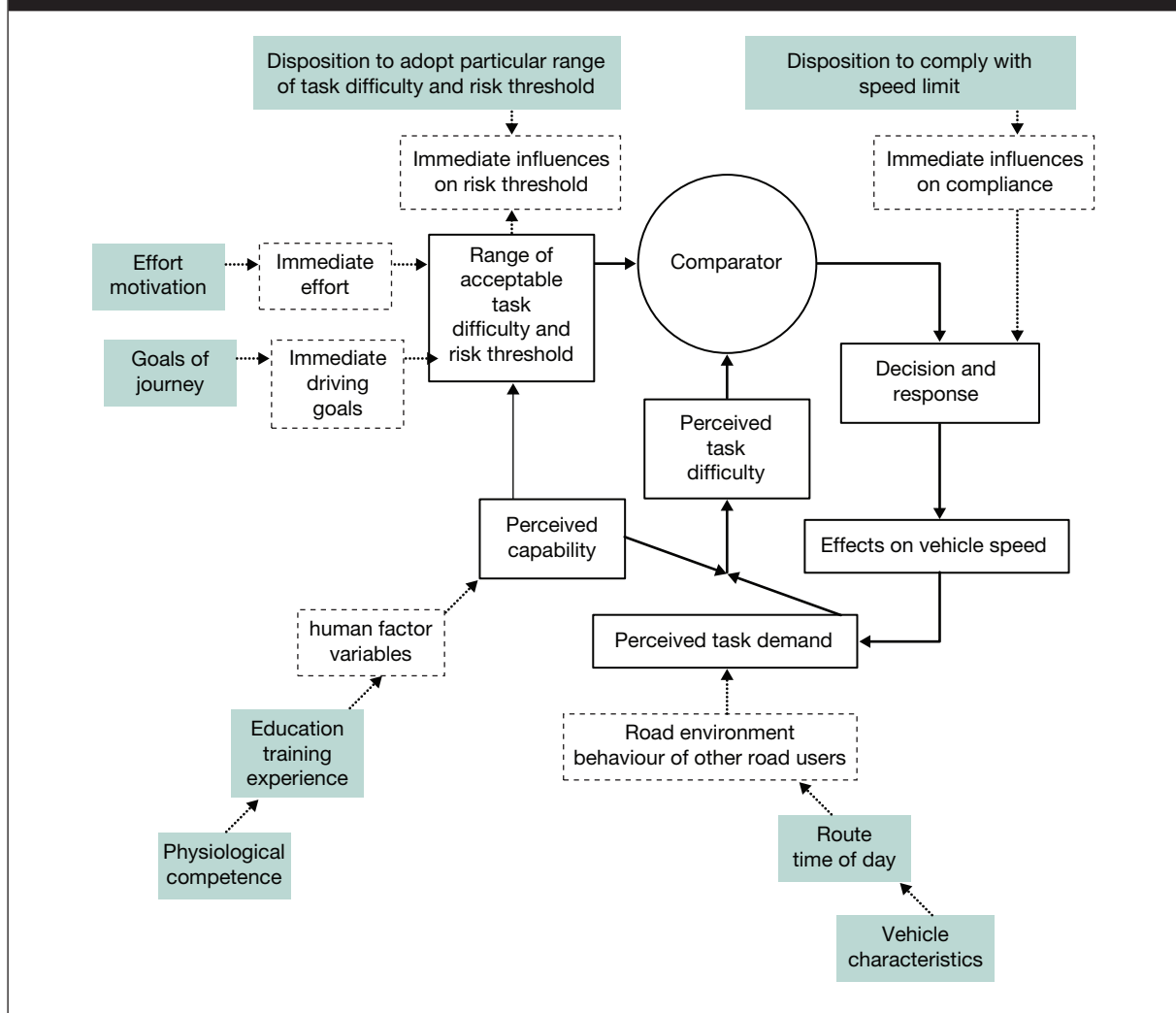


Figure 2 Expanded representation of the task-difficulty homeostasis model



Results and discussion

Complete results from the study are reported in Fuller *et al.* (2007b). Here an illustrative sample will be presented in order to demonstrate the relationship between focus group themes and the components of the task-difficulty homeostasis model.

Task-difficulty homeostasis

All focus groups identified the need for a sense of control and identified the need to reduce speed when task difficulty was perceived to increase. This is illustrated by the comment of a biker (B) stating that the safety margin is up to him:

'Well, I could control the safety margins with the speed, I feel quite happy doing 80–85, but if something, if the weath[er] ... , if conditions got worse, if the rain gets heavier, then I would slow down, I would kinda back.'

Factors which influence perceived capability

Few themes that related to factors influencing perceived capability emerged spontaneously from the groups. They included, from bikers, that they may ride faster after a break and that concentration may suffer under certain conditions, and from professional drivers that stress can be a distractor and that older drivers need to drive more slowly to compensate for impaired capability. In addition, a professional driver (P) nicely illustrated the effects of experience:

'I think the longer you've been driving, the more ... um ... apt you feel and you tend to take more risks because you feel as if you're more aware of what's around you, so you tend to say "aah 30 now, it's too slow, I've got the ability to be able to cope at a higher speed".'

Factors that influence perceived task demand

All groups indicated the importance of road characteristics, traffic conditions and vehicle-handling characteristics as elements that could affect perceived task demand. Weather conditions and the behaviour of other road users were also mentioned in two groups, as was the effect of mobile-phone use by one of the driver groups on the speed awareness course. Both professional drivers and bikers identified increased familiarity with the road as a factor that made the task appear easier:

'If you travel on the same road day in and day out you think "I know this road, I know where the bends are, so I know that I've done that bend at 40 or 50, you know". Because you know the road. But every day can be different, you don't know what's coming the opposite way, but a lot of people, because they get stuck, go "It's the same road. I ken this road. I do this week in and week out. I know what speed I can go here". And that's why people put the foot down.' (P)

Factors that affect the range of acceptable task difficulty

The pressure of being late, seeing how fast the vehicle could go and keeping with the traffic flow (see quotations below) were all mentioned in all the groups and may be identified as factors influencing journey and immediate driving goals. Speed-awareness course participants also referred to beating their estimated journey time and demonstrating their driving skill. Professional drivers spoke about various manoeuvres, such as the need to overtake. Both these groups also mentioned the motive of 'get-home-itis' (see quotation below).

Pressure of being late:

'Part of the business is, if you are trying to get to somewhere for a certain specific time, and you have been held up or whatever, its like, yeah, I am going to try and get there, ummm, not always a sensible decision, but it happens, so

you may have the pressures of making an appointment, or whatever, and I'll, you know, drive faster than I probably really want to.' (B)

Seeing how fast the vehicle could go:

'Do you not think though as well, if we're that concerned about speed and safety, that car manufacturers and the Government could do more to control the performance of vehicles? What's the point of being able to buy a Ferrari that's able to do 200 mph when you're only ever supposed to go at 70 on our roads in this country? Why have that facility? Because if you provide a facility for someone to be able to drive at 200 mph, they're going to find out about that 200 mph at some point.' (P)

Keeping with traffic flow:

'... but certainly at the bottom end of the M1 or something, in a car, everybody, and someone was saying just now, is doing 85, 90 miles an hour, in a, like a train, and if you do less then you are getting in everybody's way. And it is, in my mind, becoming more dangerous. I wouldn't actually want to be on a bike in that sort of a train, because I would feel that if anything went wrong I am meat in a sandwich.' (B)

Get-home-itis:

'If you've got a job and it's job and finish, you know it's like delivering whatever and it's like "hang on a minute if I can get all them delivered by 2 o'clock, I away home – but really I paid till ... whatever". You know it's like, but I can be away, it's job and finish. What you going to do? You're not going to say "I'll go down this street at 20 mph, and I'm not going to go home till 4 o'clock". Whereas if I go down this road at 35 mph, I'll be home at 2 o'clock.' (P)

With regard to the disposition to adopt a particular range of task difficulty and risk threshold, it is interesting that, for the most part, participants mentioned considerations that **lower** the range and the threshold. All groups referred to high speed as being dangerous and scary, and that they had a fear of crashing:

'For me it's actually fear. I don't like actually going too fast, I don't want to crash so, basically, when I do realise I'm actually speeding, I slow down.' (P)

'I went about 120 [mph] then I started feeling that I wasn't in control, a sort of feeling "anything could happen here" that sort of scared me.' (P)

Bikers mentioned, in particular, that they chose a speed to keep braking to a minimum. Speed-awareness course participants (C) referred to the fact that the time opportunity to respond is less at higher speeds. However, along with the professional drivers, they considered that driving at a speed less than the speed limit (e.g. 20 mph in a 30 mph zone) when this was unnecessary was actually **wrong**. More immediate influences on risk threshold identified by all groups were the experience of frustration/annoyance or to get pleasure, described by some as an adrenaline rush:

'You do get a buzz ... you do get a buzz out of speeding.' (C)

'... [speeding] gets the adrenaline pumping and I must admit when I was younger I probably got that the first time doing 70, 80. Christ, mind you, 80 mph isn't as fast these days cos we didn't have the roads. But there was this fighting with it, and braking and taking about half a mile to stop. I don't think there's any problem with somebody with a proper vehicle and proper roads doing 90 or 100 mph.' (P)

'Yeah, it is, it's a great feeling. Your head feels empty, you're just scooting along and your going "this is the business". You know a bit of speed and the first time you do it, wo-ho, look at me! You know.' (B)

Professional drivers and the drivers on a speed-awareness course both mentioned a range of other influences on risk threshold, including pressure from others in the car, norms of aggressive driving, competitiveness, anger, retaliation, fast music and a feeling of power:

'Just the sheer feeling of power. I mean you get somebody high-size [indicates somebody short in stature], everybody else in the world is bigger than you, stronger and all the rest of it. Suddenly you've got 5-litre car capable of 150 mph, you put them in their place. It's a fact of life. You know it doesn't matter how stupid or how thick you are as long as you've got that driving licence and you've got enough pounds to put on the counter. There's not many people who can, you know. You can get there quicker, you can get there faster, you can do this, you can do that, you can do it. I'm not saying that it's ... even people are aware of that. It makes everybody ... not even a level playing field ... because the person with a bigger and faster car can go even faster.' (P)

Bikers and professional drivers also mentioned that their reaction to outside influences often depended on their mood, on the 'mood of the day', as some put it. Perhaps not surprisingly, all groups said that seeing an accident or flowers on the roadside had an immediate influence on lowering their speeds (or, in other words, lowering their risk threshold).

Factors affecting disposition to comply with speed limits

Factors positively affecting a disposition to comply with speed limits included, for all groups, a legal obligation, the influence of enforcement and the sense that non-compliance is dangerous:

'... well I think we'd all agree with and accept, is that there are bad drivers on the road and everyone is a bad driver at some point in their career [general agreement] ... so everybody goes through bad patches of driving. But if you can appreciate that there are bad drivers on the road, can't you appreciate that if you're going a little bit faster than you should be, any accidents that may happen, you're gonna make them worse than if you were going at the speed limit.' (C)

On the other hand, a range of influences opposing compliance were identified, including the notion from participants on the speed-awareness course that the margin

above the limit permitted by police ‘authorises’ the violation, that some were taught this in training, and that there is no shame in going marginally above the limit. Professional drivers noted that violations are more acceptable on motorways and that speeding can be useful in an emergency. All groups supported the view that non-compliance is not necessarily unsafe and that an immediate influence supporting non-compliance is that the speed limit is too low:

‘Well it can be safe at times, can’t it? To break the speed limit?’ (C) Five group members immediately agreed.

‘If they expect you to slow down using your common sense, why not go faster using your common sense?’ (C)

‘... when it was busy, 40 limit, past road-works ... even when maybe there weren’t many people working there, most people were respecting the speed limit. Seven o’clock at night, quiet, not much traffic, nobody around, everybody was thinking, “what the hell are we doing 40 for?”, and they are all doing 50, and it was perfectly safe. Umm ... people were prepared to take the chance [of not being caught] because they thought that at that time of night it was most unlikely that there would be anyone standing there with a “hairdryer” [speed gun].’ (B)

Dynamic narratives

In addition, the focus group method enabled capture of the narration of dynamic episodes, in contrast to the unitary responses typical of questionnaire surveys. For example, consider this narrative about ‘putting down’ other motorcyclists:

‘I can think of two or three friends, I’m not actually a good enough driver to do this very much I don’t think, but I certainly got two friends who got old, old and British bikes, and trigger for them is someone with something newer, faster, bigger, more modern, and they go “ah, look at that”; and especially if it is someone who has fairly obviously recently just passed their direct test, and got a big sporty bike and you can just see that they are a little bit wobbly on the corners. It’s “let’s just show them what they have wasted seven or eight thousand pounds on”. And it’s not clinical speeding; this will tend to be, single track roads ... ummm and you can just see them [the two friends] disappear into the distance, and you see them 15 miles away with a big smirk on their face, and I’ll kinda try and maybe stay with these bikes but, but they will be determined to overtake, and wave goodbye to them. That’s just a statement of fact, which is kind of childish but [looking around] there is a lot of smirking going on in this room.’ (B)

Also consider this exchange concerning an aggressive response to another driver’s behaviour:

‘... he was winding me up, like ... annoying me, flashing me, and like eventually, actually, I ended up behind him, so I kind of flashed him ... well, I put my full beam on for about five minutes, you know just to ...’

Facilitator: *‘You what?’*

'I put my full beam on, like slapped it on, just to irritate him.'

Facilitator: *'But how does that help? You know ... '*

'Makes you feel better!' [laughs]

Other group member: *'It works well, doesn't it?!'* [laughs]

'It does, it does' [four others nod agreement]

'Turn it off and he thinks "pew" – and then turn it back on again!' [laughs]

Others: *'Yeah!'* (C)

Overall it was readily possible to map focus group themes onto the conceptual framework provided by the task-difficulty homeostasis model, and no theme could not be fitted to the model. All groups reported using their speed in order to control safety margins and obtain a 'comfortable' state. Capability was regarded as being affected by experience, stress, age, concentration and fatigue. Task demand was seen to be influenced by road and traffic conditions, including familiarity with the road, vehicle characteristics, weather conditions, the behaviour of other road users and secondary tasks, such as the use of a mobile phone. Through their effects on risk (feeling) threshold, very high speeds were avoided. There was an awareness that high speeds reduced the time available to deal with contingencies, and bikers in particular wanted to keep braking to a minimum to avoid loss of control.

Influences that raised speed (and therefore risk threshold) were seeking pleasure, an adrenaline rush and a feeling of power. Drivers/riders also wanted to see how fast their vehicle could go. Speed increases could be triggered by frustration, pressure from others, both inside and outside the vehicle, competitiveness and to express annoyance. Drivers indicated that there was a norm of increased aggression on the roads and admitted that feelings of anger and feelings of aggression, triggered by the behaviour of other road users, could drive speed up. Listening to fast music could also be a speed-inducing experience.

Higher speeds were seen as more acceptable when driving alone, but in general depended, to an extent, on the driver's/rider's mood. A universal motive was the pressure of being late. An associated motive was that of 'get-home-itis'. Participants also mentioned that they increased speed to beat estimated journey time, to test their skill and to keep up with the speed of the traffic flow.

Non-compliance with the speed limit was generally regarded as potentially dangerous, but not necessarily so, for example on motorways or where road and traffic conditions permitted. The margin above the limit, allegedly taught to some drivers and 'permitted' by enforcing agencies, authorises minor levels of infringement, and there is no shame felt in engaging in this behaviour. It was suggested by many participants that going over the limit can easily happen unintentionally because of a low level of prevailing task demand and when signs are not detected. Compliance is much easier when the speed limit makes sense. Some said that it can be difficult to recalibrate speed when entering a lower speed zone and the distraction of frequent checking of the speedometer can be dangerous. Hence being given feedback about one's speed can be helpful in inducing compliance.

Enforcement is commonly regarded as being a powerful motivator for compliance. Nevertheless, there are times when other motives take over and drivers lose sight of the possible consequences.

Conclusions

What are the implications for possible media campaigns of these attitudes and values, experiences and behaviours shared with us by the 36 participants of the four focus groups? One conclusion is that there appears to be no great knowledge gap that a media campaign might aim to influence. Participants were generally aware:

- of the relationship between vehicle speed and the statistical risk of collision and severity of consequences;
- that many factors can increase task difficulty or decrease their capability;
- that there are many conditions that can raise their risk thresholds, as well as lower them; and
- of influences on their disposition to conform to speed limits.

On the other hand, the admission of the role of mood state in influencing decision-making would suggest that a media campaign might target this issue, with a particular emphasis on how to manage emotions and remove their influence on decision-making. Second, the focus groups identified an inappropriate bias in perceived norms regarding speeding and aggressive driving that is an echo of findings already apparent in the research literature (e.g. Gerrard *et al.*, 1996; Åberg *et al.*, 1997). A media campaign addressing these distorted perceptions may help reduce their deleterious influence on driver behaviour. Third, time pressure emerged as a common factor influencing speeding decisions. Constructive guidance regarding effective time-management may be a further useful intervention broadcast through a media campaign. Finally, several descriptions and motives for anti-social behaviour on the road emerged. These included:

- evidence of temporary skirmishes between drivers and riders;
- recollections of social pressures influencing behaviour;
- expressions of the inability to communicate with other road users;
- awareness of the deindividuating nature of being an anonymous driver or rider; and
- risky driving to enhance status among peers.

A campaign that focused on inculcating more socially-acceptable behaviour might be one useful method of beginning to induce a shift in driving culture, a shift to one that is characterised by more courtesy, care and consideration for others.

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A typology of speeding drivers: extent of, and motives for, exceeding the speed limit

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Introduction

Speed is important because it determines the duration of the time-window of opportunity for the driver to detect, decide on and react to impending hazards (Aarts and van Schagen, 2006). Inappropriate high speeds (IHS) are associated with increases in crash probability and severity. Level of speed is associated with crash frequency, as either a power function (Maycock *et al.*, 1998; Quimby *et al.*, 1999) or an exponential function (Fildes *et al.*, 1991; Kloeden *et al.*, 1997, 2001). Those who drive fast are more likely to have been recently crash-involved (Lassarre and Stradling, 2005; Stradling, 2007). The level of speed is associated with crash severity, which tends to increase exponentially with vehicle speed (Federal Highway Administration, 1998).

An understanding of why car crashes happen and who crashes them is needed to craft appropriate interventions. For the Department for Transport funded project on High UnSafe Speed Accident Reduction (HUSSAR), a literature review was undertaken (Fuller *et al.*, 2006; 2007a), focus group discussions were analysed (see paper 17; Fuller *et al.*, 2007b), and a national survey of speed-related attitudes, behaviour and experience of UK drivers was carried out. Some results from the survey are reported here.

From the review, Fuller *et al.* (2006) concluded that evidence in the past decade was suggestive of four driver types, identified as **high-risk threshold**, **low-risk threshold**, **opportunistic** and **reactive**.

High-risk threshold drivers drive faster. They are more likely to be involved in a collision (Abdel-Aty *et al.*, 1999; McKnight and McKnight, 2003; Blows *et al.*, 2005) and are mainly, but not exclusively, young, male and inexperienced (e.g. Musselwhite, 2006). Their behaviour is associated with particular attitudes (Ulleberg and Rundmo, 2002; Iversen and Rundmo, 2004), which may be supported by a particular lifestyle and culture of driving, including the use of a car simply for pleasure and self-expression as opposed to transport (Moller, 2004; Chliaoutakis *et al.*, 2005). They may be poorly ‘calibrated’, in the sense that there are important discrepancies between their perceived and actual levels of capability and between assessed and actual levels of driving task demand (Gregersen and Bjurulf, 1996; Deery, 1999).

A **low-risk threshold driver** type, characterised by a relatively low frequency of unsafe behaviours, emerged clearly in a study by Musselwhite (2006). These drivers were the most likely to reduce their speed if they realised they were travelling faster than they thought in a 30 mph zone and were the least likely to vary their driving behaviour, even if there was an external motive to raise their risk threshold, such as being in a hurry.

Opportunistic drivers are more situation-focused and consider it to be more important to adjust their speed to that of faster others or to the physical road environment than to comply with the speed limit (Larsen, 1995). They are quite likely to use a different lane from other traffic going in the same direction to avoid being held up and to go faster than the 30 mph limit if it feels safe (Musselwhite, 2006).

Reactive drivers are more internally-focused and readily respond to motives to drive faster, such as being under time pressure or to ‘escape’ from a tailgater (Musselwhite, 2006). Their driving behaviour also appears to be strongly influenced by emotional state: such drivers are prepared to exceed the speed limit if feeling angry or annoyed (see, for example, Sümer, 2003; Dahlen *et al.*, 2005) – though not if they feel this reactive driving is unsafe.

Sample

MORI (Scotland) interviewed 1,005 UK drivers. Nine hundred and twenty-eight of these were **current drivers** who held a UK driving licence, had driven 500 miles or more in the previous 12 months, drove more often than ‘a few times a year’, and had driven more often than ‘rarely’ within the previous three months. The sample was evenly divided between male (52%) and female drivers. Male drivers tended to drive larger-engined cars for higher annual mileages. Ages ranged from 17 to 91 years. The proportion reporting being ‘involved in an RTA [road traffic accident] as a driver in the past three years’ (overall 17%) fell as age rose. Around a half of these admitted they were mainly to blame (31%) or partially to blame (16%) for their most recent collision.

Results

Extent of exceeding speed limits

Drivers indicated how often they had:

- ‘driven in a built-up area (where there is a 30 mph limit)’ at 35 mph, 40 mph and 50 mph;
- ‘driven on a single-carriageway A road (where there is a 60 mph limit)’ at 70 mph and 80 mph; and
- ‘driven on a dual carriageway (where there is a 70 mph limit)’ at 80 mph and 90 mph.

Responses were made on six-point scales from 1 ‘most days’ to 6 ‘never’. Six hundred and eighty-six respondents had driven on all three road types within the previous three months, and their response are reported in the following analyses.

Figure 1 shows the percentage of each of seven age groups reporting they ‘never’ broke the speed limit on the three road types.

As well as varying with age, proclivity to exceed the speed limit on these three road types varied with gender ($M > F$), reported annual mileage, with more high-mileage drivers reporting breaches and, on the faster roads but not the 30 mph road in a built-up area, with engine size, as shown in Table 1.

Responses to these seven scenarios were cluster-analysed, using K-means clustering set to three clusters. Table 2 shows the item means for each cluster, with the associated F and p values for subsequent one-way ANOVAs. Table 3 gives the proportions of each cluster who say they ‘rarely’ or ‘never’ undertake each speeding behaviour.

Figure 1 Percentage of each age group of drivers reporting never speeding on 30, 60 and 70 mph limit roads

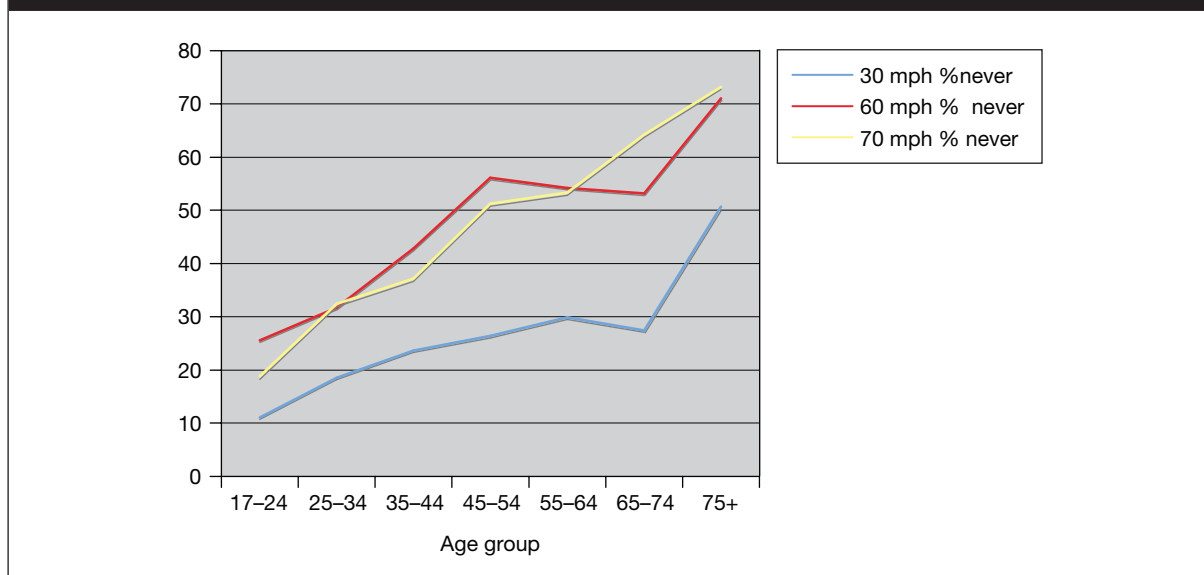


Table 1 Relationship between reporting never breaking the limit on 60 mph and 70 mph

Engine size	% never breaking 60 mph single-carriageway limit	% never breaking 70 mph dual-carriageway limit
<1.0 litre	64	74
1.1–1.6 litre	54	53
>1.6 litre	38	40

Table 2 Means for three clusters on seven items indexing frequency of speed-limit breaches

'Within the last three months, how often have you ...'	C1	C2	C3	F	p
% of sample	52%	33%	14%		
Driven at 35 [mph] in a 30 limit	5.13	2.24	1.63	920.016	0.000
Driven at 40 in a 30 limit	5.87	4.57	2.76	378.628	0.000
Driven at 50 or more in a 30 limit	5.95	5.79	4.90	99.034	0.000
Driven at 70 on a single-carriageway A road	5.44	4.59	2.24	321.741	0.000
Driven at 80 or more on a single-carriageway A road	5.89	5.72	4.07	258.396	0.000
Driven at 80 on a dual carriageway	5.41	4.52	2.40	232.356	0.000
Driven at 90 or more on a dual carriageway	5.90	5.73	4.02	246.910	0.000
No. of speed limit exceeds in town (of 3)	0.77	1.89	2.51	330.545	0.000
No. of exceeds on single-carriageway A road (of 2)	0.44	0.94	1.82	187.737	0.000
No. of exceeds on dual carriageway (of 2)	0.41	0.91	1.77	180.481	0.000
No. of exceeds out of town (of 4)	0.85	1.86	3.59	265.321	0.000
Total no. of exceeds (of 7)	1.62	3.76	6.09	436.642	0.000

Table 3 Per cent reporting 'rarely' or 'never' exceeding speed limits

'Within the last three months, how often have you ...' [% rarely or never]	C1	C2	C3
Driven at 35 in a 30 limit	80.7	1.7	3.0
Driven at 40 in a 30 limit	99.7	67.2	22.3
Driven at 50 or more in a 30 limit	96.6	97.8	75.7
Driven at 70 on a single-carriageway A road	88.3	62.0	5.0
Driven at 80 or more on a single-carriageway A road	98.3	96.1	51.5
Driven at 80 on a dual carriageway	87.7	60.3	8.1
Driven at 90 or more on a dual carriageway	98.6	96.5	49.5

The three clusters differentiate between self-reported low, moderate and excessive speeders. Half the respondents (52%) fell in cluster 1. This cluster are **speed limit compliant**, with few reporting exceeding the limit by any amount and even fewer (1–3%) reporting excessive speed (> 20 mph above the limit). They correspond to the **low-risk threshold** group.

One-third (33%) of these respondents who had recently driven on all three road types fell in cluster 2. This cluster are in-town **moderate speeders**, with all, save

2%, reporting having driven at 35 mph in a 30 mph limit. One-third or more (33–40%) of these also report 40 mph in a 30 mph area, 70 mph on a 60 mph single-carriageway A road, and 80 mph on a 70 mph dual carriageway, but hardly any (2–4%) report excess speed. This cluster are the most likely to include the **default speeders** identified in the literature review (Fuller *et al.*, 2007a).

One in seven (14%) of respondents fell in cluster 3. These are the **excessive speeders** and may be so because of a **high-risk threshold**. Only 3% have not driven at 35 mph in a 30 mph limit. Eighty per cent have driven at 40 mph and 25% at 50 mph in a 30 mph limit. Only 5% have not driven at 70 mph on a 60 mph single-carriageway A road and half (49%) have driven at 80 mph here. Only 8% have not driven at 80 mph and, again, half (51%) have driven at 90 mph on a 70 mph dual carriageway. These are the most likely to be **inappropriate high speeders** and to include the sub-group of socially deviant speeders referred to in Fuller *et al.* (2006; 2007a).

Motives for exceeding speed limits

Respondents were also asked how likely they were to break the speed limit in a range of circumstances. These responses were submitted to principal components analysis (KMO = 0.898; Bartlett Test of Sphericity significant at $p = 0.000$). Two factors were extracted and rotated to varimax solution. Factor loadings are given in Table 4, which also shows the percentage recording themselves as very or quite likely to break the speed limit in each circumstance.

Table 4 Per cent likely to break the speed limit under each circumstance and item loadings

'How likely are you to break the speed limit in the following circumstances?' $n = 567$	% very + quite likely	F1	F2
On an empty road, in the daytime	39%	0.821	
On an empty road, at night	40%	0.808	
When I am running late	41%	0.750	0.341
When overtaking	63%	0.723	
Just to keep up with traffic	45%	0.678	
When my passenger is running late	19%	0.668	0.382
When I thought the limit was too low for the road	24%	0.585	0.460
When I am feeling stressed	14%		0.781
When I am feeling angry	15%		0.768
In order to stay awake	2%		0.768
When trying to see what my car can do	7%		0.635
When someone is driving close behind me	15%		0.521

Reported incidence ranged from the two-thirds of respondents (63%), who said they were likely to break the speed limit when overtaking, to 2% who would do so 'in order to stay awake'. Factor 1 was labelled external circumstances and fits the profile of the **opportunistic speeder**. Factor 2 was labelled internal circumstances and fits the profile of the **reactive speeder**. Three items loaded on both factors,

suggesting that breaking the speed limit when you or your passenger are running late, or when the driver thinks the speed limit is too low for the road, are driven by both external and internal factors.

Scores were computed using those variables that loaded on just one factor. Thus, the opportunistic scale combined 'On an empty road, in the daytime', 'On an empty road, at night', 'When overtaking' and 'Just to keep up with traffic'. The reactive scale combined 'When I am feeling stressed', 'When I am feeling angry', 'In order to stay awake', 'When trying to see what my car can do' and 'When someone is driving close behind me'. The former gave a Cronbach's alpha reliability coefficient of 0.843, the latter of 0.810. These two scales were then divided at the scale midpoint to give binary variables: those low and high on taking external opportunities to break the speed limit, and those low and high on reacting to internal prompts to break the speed limit. On these binary measures, 55% were opportunistic speeders and 9% were reactive speeders.

A typology combining amount and motives for breaking the speed limit

These two measures, one of extent of speed-limit breaches and one of reasons for speed-limit breaches, were cross-tabulated (Table 5), separating out those who are opportunistic only, reactive only, both and neither. Hardly any ($n = 4$) respondents were, on these measures, reactive speeders only.

Table 5 Numbers of respondents in each typology cell

Count ($n = 661$)	Speed limit compliant	Moderate speeders	Excessive speeders
Neither	248	47	6
Opportunistic speeders only	90	157	56
Reactive speeders only	1	2	1
Both	7	15	31

Table 6 recasts these figures as column percentages: the proportions of each 'amount of speeding behaviour' group with each 'type of motive' for speeding.

Table 6 Percentage of each speeder group who are opportunistic and reactive speeders, separately and in combination

Column % ($n = 661$)	Speed-limit compliant	Moderate speeders	Excessive speeders
Neither	71.7	21.3	6.4
Opportunistic speeders only	26.0	71.0	59.6
Reactive speeders only	0.3	0.9	1.1
Both	2.0	6.8	33.0

Of those in the compliant cluster, a quarter ($28\% = 26.0 + 2.0$) said they would take opportunities to speed – on empty roads, when overtaking, or taking a lead from the prevailing traffic flow. Conversely, three-quarters of this group eschew such

opportunities, despite the open road or the pressing traffic. Only 2.3% (2.0 + 0.3) of those in cluster 1 owned up to reactive speeding – when stressed or angry, tailgated, needing to stay awake, or in order to test the advertised acceleration and top speed of their vehicle.

Two-thirds of the moderate speeders (78%) and almost all (93%) of the excessive speeders took opportunities to speed. However, while only 1 in 12 (8%) of the moderate speeders counted as reactive speeders, one-third (34%) of the excessive speeders were reactive speeders. Conversely, further analysis examining row percentages shows a majority (58%) of the reactive speeders are excessive speeders.

Table 7 Typology group as a percentage of the number of respondents who had driven on all three road types in the last three months

Total % (<i>n</i> = 661)	Speed-limit compliant	Moderate speeders	Excessive speeders
Neither	38	7	1
Opportunistic speeders only	14	24	9
Reactive speeders only	<1	<1	<1
Both	1	2	5

Table 7 gives, as rounded percentages, the proportion of this sample of drivers who had driven on all three road types within the last three months and who fell into each cell. Above a third (38%) reported they did not speed and had no motive to speed. A quarter (24%) exceeded speed limits somewhat and appeared to do so solely on an opportunistic basis ('On an empty road, in the daytime', 'On an empty road, at night', 'When overtaking' and 'Just to keep up with traffic'). One in twenty (5%) exceeded speed limits excessively and appear to do so on both an opportunistic and a reactive basis ('When I am feeling stressed', 'When I am feeling angry', 'In order to stay awake', 'When trying to see what my car can do', 'When someone is driving close behind me'). However, 1 in 11 (9%) report excessive speeding simply on the basis of there being opportunity to do so.

Road traffic accident involvement of the typology groups

Further analyses were undertaken to examine potential differences among denizens of the seven cells of the 12-cell typology matrix that had at least 15 respondents. Table 8 gives the proportion of drivers in each of these cells who reported being involved in a road traffic accident as a driver within the previous three years, plus the marginal percentages.

The comparison of the opportunistic-only, both opportunistic and reactive, and neither groups was significant on chi-square ($p = 0.012$), and comparison between the excessive speeders and the other two clusters was significant on Fisher's Exact Test, one-sided, at $p < 0.10$.

Table 8 Percentage of road traffic accident involvement as a driver in the last three years

n = 651/676 Overall: 19.8%	Speed-limit compliant	Moderate speeders	Excess speeders	p = 0.012
Neither	17.1	14.9	—*	16.7
Opportunistic speeders only	23.0	18.7	18.2	19.9
Opportunistic and reactive	—*	28.6	38.7	35.6
[1+2 v 3: Fisher's Exact Test, p = 0.087 1-sided]	18.6	18.5	25.6	

* Not computed due to low cell size ($n < 16$).

Excessive speeders who speed for both opportunistic and reactive reasons had double the level of recent road traffic accident involvement (38.7%) compared with the average for this sub-sample (19.8%).

Road traffic accident-involved respondents had indicated whether they considered, for their most recent crash, that they were wholly, partially or not to blame. Table 9 gives the cell and marginal percentages of those who reported themselves wholly or partially to blame for their most recent road traffic accident within the past three years.

Table 9 Per cent reporting 'wholly or partially to blame' road traffic accident involvement as a driver in the last three years

n = 644/657/854 Overall: 9.6%/9.9%/8.7%	Speed-limit compliant	Moderate speeders	Excess speeders	F(2,851) = 3.30; p = 0.037
Neither	5.6	10.0		7.1 _a
Opportunistic speeders only	12.8	8.9	13.3	8.8 _a
Opportunistic and reactive		16.1	25.8	18.2 _b
F(2,654) = 4.65; p = 0.01	7.2 _a	10.0 _a	19.4 _b	

Means with different subscripts differ at $p < 0.05$ on Student-Newman-Keuls post-hoc tests.

Excessive speeders who speed for both opportunistic and reactive reasons had around two-and-a-half times the level of recent 'to blame' road traffic accident involvement (25.8%) compared with the average for this sub-sample (9.6%).

Further characteristics of the typology groups

Table 10 gives the percentage in the seven cells who were male.

The proportion of males rises with the extent of speeding behaviour, from compliant through moderate to excessive, and, with motivation to speed, from neither through opportunistic-only to both opportunistic and reactive.

Table 10 Percentage of each speeder group who are male

Overall %, M = 55.5	Speed-limit compliant	Moderate speeders	Excessive speeders	
Neither	46.8	43.5		46.3
Opportunistic speeders only	50.0	59.9	82.1	61.1
Opportunistic and reactive		46.7	93.5	78.3
	47.8	56.6	84.8	n = 643

Table 11 shows how broad age groups are distributed across the seven cells.

Table 11 Age distribution across typology groups

% within age bands		Age bands							Total
		17–24	25–34	35–44	45–54	55–64	65–74	75+	n = 644
Speeder cluster	Opportunistic or reactive								
Compliant	Neither	8	29	29	39	42	56	78	38.5%
	Opportunistic only	8	8	15	17	15	21	9	14.0%
Moderate	Neither	–	10	8	7	8	6	4	7.3%
	Opportunistic only	36	24	32	21	28	14	9	24.4%
	Opportunistic and reactive	8	3	3	2	2	2	–	2.3%
Excessive	Opportunistic only	8	16	10	12	5	2	–	8.7%
	Opportunistic and reactive	32	11	4	3	2	–	–	4.8%

One in twelve (8%) of the youngest age group (17–24-year-olds) and three-quarters (78%) of the oldest age group (75 or more) reported themselves fully compliant and neither opportunistic nor reactive. A third (32%) of the youngest group and none of the oldest group were excessive speeders, with both opportunistic and reactive tendencies. How these proportions increase (the fully compliant) and decrease (the excessive speeders) with age and experience should be a focus of future research.

When asked ‘When driving, I sometimes behave in a way which I would not normally do outside of the vehicle’, overall 18% of drivers agreed. This proportion did not differ between male and female drivers, but older drivers were much less likely than young drivers to report this. Three-quarters (71%) of those who change when driving reported more aggressive behaviours (Stradling *et al.* (2007) gives details). Male drivers aged 17–54 were the most likely to report such change.

Table 12 shows that, as with the full sample, 18.5% of those drivers in the sub-sample who had lately driven on all three road types, and thus contributed to the typology, reported that ‘When driving, I sometimes behave in a way which I would not normally do outside the vehicle’. One in nine (11%) of the fully compliant group said they sometimes changed behind the wheel and 42% of the excessive opportunistic and reactive speeders did so.

While, overall, 13% reported sometimes becoming more aggressive behind the wheel, a third (32%) of the **excessive** opportunistic and reactive speeders did so.

Table 12 Agreement with behaviour change behind the wheel items

Speeder cluster	All	Compliant		Moderate			Excessive	
Opportunistic or reactive			Opportunistic only		Opportunistic only	Both	Opportunistic only	Both
	<i>n</i> = 644	Neither		Neither				
Reports behaviour change when driving	19	11	12	28	21	27	30	42
Reports becoming more aggressive when driving	13	9	8	13	15	20	21	32

Respondents were shown a photograph (Figure 2) of an open country road, running downhill, intended to evince excited anticipation in those who like to speed and nervous anticipation in those who do not. Drivers were asked on a road like this ‘What speed would you normally be doing?’ (reported range: 5 mph to 100 mph) and ‘What speed do you feel is the fastest you could go here that would put you right at the edge of your safety margins?’ (reported range: 5 mph to 140 mph).

Figure 2 Road scene used to elicit speed preference



Source: Pathetic Motorways <http://pathetic.org.uk/>

Table 13 shows the mean normal speed reported by each group, Table 14 the mean fastest speed and Table 15 the mean ratio between these two speeds.

Table 13 Mean normal speed in the scenario shown in Figure 2

Overall mean 53.34 mph	Speed-limit compliant	Moderate speeders	Excess speeders	$F(2,632) = 56.04$; $p < 0.001$
Neither	48.39	51.13		48.83 _a
Opportunistic speeders only	55.17	55.96	60.54	56.58 _b
Opportunistic and reactive		57.50	61.94	60.56 _c
$F(2,632) = 42.90$; $p < 0.001$	50.20 _a	55.01 _b	61.03 _c	$n = 635$
Means with different subscripts differ at $p < 0.05$ on Student-Newman-Keuls post-hoc tests.				

Mean nominated normal speeds increased significantly from compliant to excess cluster and from neither opportunistic nor reactive to both.

Table 14 Mean fastest and edge of safety limits speed in the scenario shown in Figure 2

Overall mean 63.33 mph	Speed-limit compliant	Moderate speeders	Excess speeders	$F(2,631) = 49.50$; $p < 0.001$
Neither	56.74	60.57		57.37 _a
Opportunistic speeders only	62.47	67.85	73.13	67.24 _b
Opportunistic and reactive		68.47	78.71	75.37 _c
$F(2,631) = 51.97$; $p < 0.001$	58.28 _a	66.31 _b	73.11 _c	$n = 634$
Means with different subscripts differ at $p < 0.05$ on Student-Newman-Keuls post-hoc tests.				

Mean nominated fastest speeds increased significantly from compliant to excess cluster and from neither opportunistic nor reactive to both.

Table 15 Mean normal speed here/fastest and still feel safe speed mph in the scenario shown in Figure 2

Mean 0.88	Speed-limit compliant	Moderate speeders	Excess speeders	[ns]
Neither	0.87	0.85		0.88
Opportunistic speeders only	1.00	0.84	0.85	0.88
Opportunistic and reactive		0.83	0.80	0.81
[ns]	0.90	0.84	0.89	

Intriguingly, however, even as nominated normal and fastest speeds increased, the ratio between them did not differ significantly and may thus be treated as remaining constant. Compliant, moderate, excessive, opportunistic and reactive speeders retained, on average, a constant ratio between the two speeds, with their reported normal speed at around 88% of what they reported as the speed that would put them at the edge of their safety margin. For most of the time on the road, drivers choose a speed that maintains a margin between perceived task demand and perceived capability, and this margin seems not to differ significantly across the typology.

Respondents were asked if they had recently reduced, or intended to reduce, their usual driving speed both in town and out of town. Table 16 gives the results for each typology group for in town and Table 17 for out of town slowing down. Approaching two-thirds of the excessive speeders, whether opportunistic-only (64%) or both opportunistic and reactive (65%), indicated action or intention to reduce their driving speed in town, suggesting they have some insight into their driving behaviour and the need for change. Out of town, slightly fewer, but still substantial numbers, of excessive speeders indicated that they recognised the need to slow down, whether opportunistic-only (44%) or opportunistic and reactive (51%).

Speeder cluster	All	Compliant		Moderate			Excessive	
Opportunistic or reactive								
	<i>n</i> = 577	Neither	Opportunistic only	Neither	Opportunistic only	Both	Opportunistic only	Both
I don't see a need to reduce my driving speed in town and do not intend to	63	80	78	59	50	33	36	35
I have recently reduced my usual driving speed in town	30	18	22	32	37	47	51	55
I am thinking of reducing my driving speed in town, but I have not yet changed my behaviour	4	1		2	9	7	9	7
Over the past 12 months, I have tried to reduce my driving speed in town, but have now given up trying	3	2		7	4	13	4	3

Speeder cluster	All	Compliant		Moderate			Excessive	
Opportunistic or reactive								
	<i>n</i> = 571	Neither	Opportunistic only	Neither	Opportunistic only	Both	Opportunistic only	Both
I don't see a need to reduce my driving speed out of town and do not intend to	68	82	72	57	56	57	57	48
I have recently reduced my usual driving speed out of town	24	15	21	31	31	29	28	41
I am thinking of reducing my driving speed out of town, but I have not yet changed my behaviour	5	2	5	7	9	7	8	10
Over the past 12 months, I have tried to reduce my driving speed out of town, but have now given up trying	3	1	1	5	5	7	8	

Respondents were also asked about a number of their attitudes to speed and speed limits. Table 18 gives the level of agreement of the typology groups to some of these.

Table 18 Agreement with attitude items

Speeder cluster	All	Compliant		Moderate			Excessive	
Opportunistic or reactive								
	<i>n</i> = 638–644	Neither	Opportunistic only	Neither	Opportunistic only	Both	Opportunistic only	Both
[% strongly agree + agree]								
I really enjoy driving fast	20	9	19	13	21	67	48	39
I think it will always be difficult for me to keep to the speed limit (i.e., difficult not to drive faster)	20	5	12	13	28	53	38	78
[% very frequently + frequently]								
On a typical journey in town I have to brake hard	3	3	2	4	4	7	2	7
On a typical journey out of town I have to brake hard	3	1	2	4	3	7	2	13
[% very frequently + frequently + sometimes]								
When driving I feel at risk	26	29	26	28	26	20	16	29
When driving I like to feel at risk	3	1	2	4	3	7	2	16
[% strongly agree + agree]								
	<i>n</i> = 598–639							
Fast moving vehicles are more likely to crash than slow moving vehicles	60	63	53	64	65	53	46	45
Driving faster than surrounding traffic increases the risk of a crash	90	91	93	95	93	80	82	81
The sort of driver who speeds often is more likely to crash	70	78	66	82	80	60	36	63
It is more dangerous to drive faster on minor roads than major roads	79	83	81	70	80	80	75	68
When speed of traffic goes up on a road, the number of crashes goes up	48	58	43	53	42	36	36	28

Around a quarter of all types (16–29%) feel at risk when driving some of the time, but it is only among the opportunistic and reactive excessive speeders that any appreciable number (16%) say they like to feel at risk. This group also has an elevated score on having to brake hard out of town, but not in town; and they, plus the opportunistic moderate speeders, have elevated scores on ‘I really enjoy driving fast’ and ‘I think it will always be difficult for me to keep to the speed limit’.

However, that leaves appreciable proportions of the excessive speeder group who, apparently, while speeding excessively, don't enjoy driving fast and don't like to feel at risk. They are speeding despite, rather than because of, the thrill (and see Broughton and Stradling (2005) for a discussion of parallel findings on the motivation of motorcyclists).

While knowledge of the speed/accident relationship is generally lower for the higher risk groups (excessive speeders plus moderate opportunistic and reactive speeders), it is a long way from zero. It is not clear from these data that remedying their understanding of aspects of the speed/accident relationship will remediate their speeding behaviour.

Conclusions

Recent research in driver behaviour, noted here and reviewed more fully in Fuller *et al.* (2006), concluded that evidence in the past decade was suggestive of four driver types, identified as **low risk threshold**, **high risk threshold**, **opportunistic** and **reactive**. From the UK survey for the Department for Transport HUSSAR project, a typology has been constructed by combining responses to questions on 'How much do you speed?' and 'Why do you speed?', which finds support for this suggestion. Cluster analysis of the 'extent of speeding' variables found three clusters: half the respondents (52%) fell in cluster 1, the **speed-limit compliant**, with few reporting exceeding the limit by any amount and even fewer (1–3%) reporting excessive speed (> 20 mph above the limit). They correspond to the **low-risk threshold** group.

A third (33%) fell in cluster 2, the **moderate speeders**, where all, save 2%, reported having driven at 35 mph in a 30 mph limit. A third or more (33–40%) of these also report 40 mph in a 30 mph area, 70 mph on a 60 mph single-carriageway A road and 80 mph on a 70 mph dual carriageway, but hardly any (2–4%) report speeds in excess of these.

One in seven (14%) of the respondents fell in cluster 3, the **excessive speeders** or **high-risk threshold** group. Only 3% had **not** driven at 35 mph in a 30 mph limit. Eighty per cent had driven at 40 mph and 25% at 50 mph in a 30 mph limit. Only 5% had not driven at 70 mph on a 60 mph single-carriageway A road and half (49%) had driven at 80 mph here. Only 8% had not driven at 80 mph and, again, half (51%) had driven at 90 mph on a 70 mph dual carriageway.

Factor analysis of 'reasons for exceeding the speed limit' identified two factors: **opportunistic speeders** who will break the speed limit 'On an empty road, in the daytime', 'On an empty road, at night', 'When overtaking' and 'Just to keep up with traffic'; and **reactive speeders** who will break the speed limit 'When I am feeling stressed', 'When I am feeling angry', 'In order to stay awake', 'When trying to see what my car can do' and 'When someone is driving close behind me'. On these measures, 55% were opportunistic speeders and 9% were reactive speeders.

Cross-tabulation yielded seven populated cells in a 4×3 typology matrix. It was of interest that almost all those who reported they would break the speed limit would

do so solely for opportunistic reasons, or for both opportunistic and reactive reasons, but not solely for reactive reasons. This pattern merits further investigation. That reactive reasons for speeding were strongly associated with more excessive breaches of speed limits corroborates the key role of mood state reported by Fuller *et al.* (2007b) in the companion HUSSAR qualitative analysis of focus group discussions of speeding.

Those at the more risky bottom-right corner of the two variable matrix comprising the typology were more likely to be male, more likely to be young, more likely to say their behaviour changes and becomes more aggressive when they are behind the wheel, nominated higher normal and maximum speeds on an open road and were more likely to have recent road traffic accident involvement and – even more strongly – to have been recently involved in ‘to blame’ road traffic accidents.

They did, though, show the same relationship between nominated normal and maximum speeds as other drivers, with, on average, normal speed being 88% of maximum speed, also meriting further investigation. Also, substantial proportions of them indicated recent action or future intention to reduce their driving speed, both in town and out of town, suggesting that they recognised the need to slow down.

More, but still only a few (16%), of the **opportunistic and reactive excessive speeders** say they like to feel at risk while driving. This group also has an elevated score on having to brake hard out of town, but not in town; and they, plus the opportunistic moderate speeders, have elevated scores on ‘I really enjoy driving fast’ and ‘I think it will always be difficult for me to keep to the speed limit’. However, that leaves appreciable proportions of the excessive speeder group who, apparently, while speeding excessively, do not enjoy driving fast and do not like to feel at risk. They are speeding despite, rather than because of, the thrill: driven when driving.

Finally, while knowledge of the speed/accident relationship is generally lower for the higher-risk groups, it is a long way from zero. It is not clear from these data that remedying these groups’ understanding of aspects of the speed/accident relationship will remediate their speeding behaviour.

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Did we need a long-term study of driving with Intelligent Speed Adaptation or would the earlier short-term studies have been sufficient?

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Introduction

Research on Intelligent Speed Adaptation (ISA) – the system that brings information on speed limit into the vehicle and then uses that information to inform or warn the driver and, in some versions of the system, to intervene in vehicle control so as to discourage or prevent the driver from speeding – started at the Institute for Transport Studies in 1995 and has been under way continuously since then. The major focus of the work has been on driver behaviour with ISA and on user attitudes towards the system. As a result of the continuity of this work, it is possible to compare results obtained across the projects. This paper compares the behavioural and attitudinal results obtained in the on-road trials conducted in 1999 as part of the External Vehicle Speed Control (EVSC) project with those obtained in 2004 to 2006 from the Intelligent Speed Adaptation (ISA-UK) project. Each driver's experience of ISA in the EVSC project consisted only of two drives along a fixed route, whereas in ISA-UK the drivers had an equipped car for six months, of which the middle four months were with the system activated. Thus it is possible, in comparing the results from the two projects, to ask the question of whether there was any additional benefit to the much more detailed and costly investigation of long-term behaviour in the later project, or whether the findings were generally predictable in the light of the very short-term investigation in the earlier project.

Field operational tests

At a European level, there is currently a focus on the need to demonstrate the concrete benefits of Advanced Driver Assistance Systems (ADAS) and Cooperative Vehicle Highways Systems (CVHS) through so-called Field Operational Tests (FOTs). Such tests are intended to prove the real-world impacts of using various systems by conducting rigorous large-scale trials using participants who drive the vehicles in their everyday driving. Equipping the vehicles can either be done by adding the relevant system to the participant's or the fleet's vehicles, but is more typically done by loaning equipped vehicles to the participants. Such FOTs have been quite common in recent years in North America, with examples being a trial of Adaptive Cruise Control (Fancher *et al.*, 1998) and a trial of Forward Collision Warning (University of Michigan Transportation Research Institute and General Motors Research and Development Center, 2005). However, with the notable exception of trials of ISA, they have been much less common in Europe. The resulting lack of solid, empirical evidence on the impacts of new technologies has been identified as a critical weakness by a report from the eSafety Forum, setting out the research priorities for the European Seventh Framework Programme (FP7):

There 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.

Field Operational Tests (FOTs) have during later years developed as a powerful tool to gain insight into how new functions and systems suit the user when operated in the real context under sufficiently long time to reach the 'daily operational and behaviour level'.

FOTs for ICT based traffic safety and efficiency functions and systems are viewed as very important for understanding the users' ability to use these and to make cost/benefit assessments as well as to evaluate the impact on safety, traffic efficiency, environmental aspects and the behaviour of drivers and other road users. FOTs are also important in the technical development since they can provide valuable feedback regarding the performance and improvement of the technical system. (eSafety Forum, 2006; p. 27)

Intelligent speed adaptation as a test of the value of long-term trials

The succession of national research projects on ISA can serve as a test of the added value of FOTs. With the results from the two major projects, EVSC and ISA-UK, it is possible to compare user attitudes and behaviour between the earlier short-term trials and the later long-term trials. It can therefore be deduced whether the FOT merely confirmed the previous results or whether it provided valuable additional insights.

The on-road trials in the EVSC project

The on-road trials in the EVSC project were conducted in 1999, using a single modified vehicle, a Ford Escort 1.6, driven by participants along a fixed route. The vehicle could be driven in three states: with no ISA, with a mandatory (non-overridable ISA) and with a voluntary intervening ISA that was termed ‘driver select’. Details of the trials can be found in Comte (1999).

The ISA system used a simple digital map that incorporated each change in speed limit. Position was obtained with a differential GPS. The intervening ISA interfered in vehicle fuelling, so that when it was enabled it was not possible to exceed the speed limit except by a small amount (approximately 10%). The route was approximately 42 miles long and each drive took nearly two hours. The in-vehicle display showed both the speed limit and the state of the ISA system, i.e. whether maximum speed was being controlled. There was a look-ahead function such that drivers were notified of changes of speed limit in advance; with ISA active, failure of the driver to slow the vehicle down would result in a mild activation of the vehicle’s brakes by the system. In the mandatory situation, ISA was always enabled. In the driver-select situation, ISA was by default disabled. Drivers could activate it by means of a green button on the steering wheel. Once it was active, they could choose to deactivate it at any time by means of a red button, also on the steering wheel. The drivers were reminded through a beep of changes in speed limit. To keep ISA on, they had to re-enable it at every speed-limit change.

Twenty-four drivers participated. They were split into three groups. Eight drove three times without ISA (baseline condition). Eight drove the first time without ISA and then had two subsequent drives with the mandatory ISA (mandatory condition). Eight drove the first time without ISA and then had two subsequent drives with the driver-select ISA (voluntary condition). Speeds and position along the route were recorded at 1 Hz. The results used here are only those from the voluntary condition, since the driver-select system equates most closely to the type of ISA tested in the ISA-UK field trials.

The ISA-UK field trials

In the ISA-UK project, four successive field trials were conducted with 20 participants in each (one participant in the last trial did not complete, so that there were 79 participants with complete data). The trials were conducted in the period 2004 to 2006. Each trial covered six months of driving, and an ABA experimental design was used, such that the initial month was with ISA disabled, next there were four months of driving with ISA, and finally there was another month in which ISA was once again disabled. The last month was intended to reveal whether there were any carry-over effects of experience with ISA on participants’ attitudes and behaviour.

The vehicles were a fleet of modified Skoda Fabias and were given to the participants to use for their normal driving. Each vehicle had a positioning system supplied by Navteq, which used a combination of GPS, dead reckoning and map matching to identify the road on which the vehicle was travelling as well as the direction of travel and the current position. The on-board map had speed limit encoded as a link attribute. Speed-limit information was available for national roads

and all local roads in the trial area. The ISA system compared driver-desired speed to legal maximum speed. If desired speed was greater than the limit, then additional throttle was disallowed. Speed limit and ISA system status were displayed on the dashboard, and auditory signals were provided at changes of speed limit and when system status changed, for example if the driver switched to a road for which the speed limit was unknown. Automatic mild braking was applied if, with the ISA enabled, the car began to speed excessively, for example when travelling downhill. To discourage the driver from flooring the throttle, a vibrating motor, fitted to the accelerator pedal, was activated when the driver demand exceeded the calculated maximum throttle demand by 40%. This gave the driver tactile feedback indicating that the throttle demand requested was in excess of that required to maintain the vehicle at the current speed limit. Because of system hysteresis, it was possible when ISA was engaged for the vehicle to reach a speed 10% in excess of the limit.

The ISA system was a voluntary one. In contrast with the EVSC trials, it was engaged by default. However, it could be overridden either through a kickdown on the throttle or by means of a red button on the steering wheel. A green button on the steering wheel acted as an ISA-resume control. ISA was also automatically re-enabled following an override when the vehicle was subsequently brought below the speed limit (e.g. following an overtaking manoeuvre) or at the next change in speed limit. Data, covering speed and position, were recorded at 10 Hz. During Phase 2 of the trials, i.e. the four months when ISA was active, the ISA system state was also recorded. Overall, 355,000 miles of driving with the speed limit known were recorded, of which 219,000 miles were with ISA.

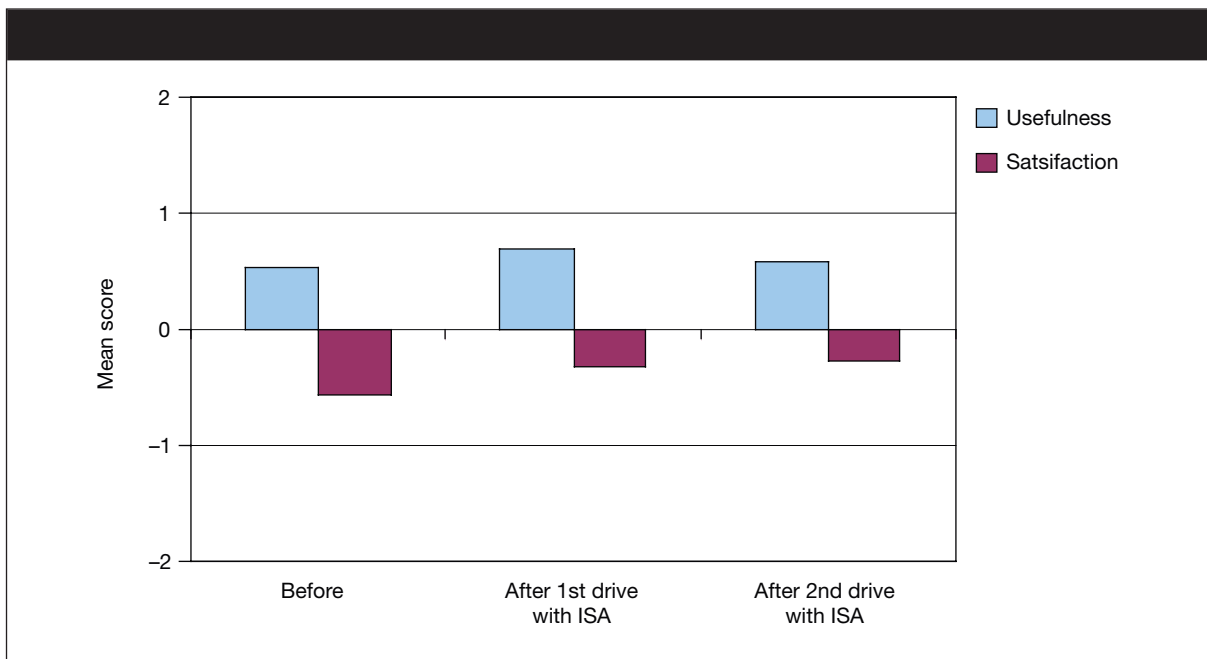
The four trials were as follows:

- Trial 1 was conducted in the Leeds area, which is mainly urban, with private motorists.
- Trial 2 was conducted in the Leeds area with fleet motorists.
- Trial 3 was conducted in south-west Leicestershire, which is mainly rural, with private motorists.
- Trial 3 was conducted in south-west Leicestershire with fleet motorists.

Comparison of attitudinal results

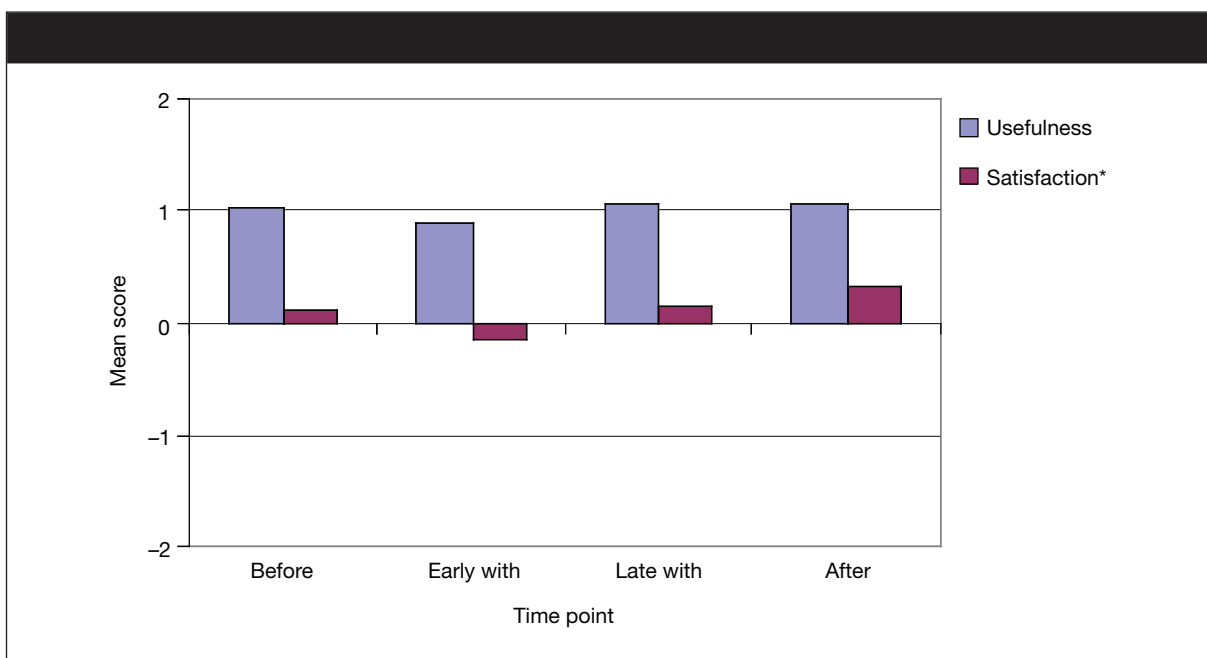
Drivers' ratings of the acceptability of the ISA system were ascertained in the EVSC project using the questionnaire of Van der Laan *et al.* (1997). The results are shown in Figure 1 for the two dimensions of usefulness and satisfaction. Usefulness was rated somewhat positively, indicating that drivers could perceive the general benefits of ISA. Personal satisfaction with ISA was, however, rated negatively, although the mean score became less negative following acquaintance with ISA.

The same questionnaire was used in the ISA-UK project. Drivers' ratings of ISA were collected in the initial month of driving (before ISA was switched on), early in the ISA phase, late in the ISA phase, and finally during the last month of driving



when the ISA system was once again disabled. The results are shown in Figure 2. It can be seen that, as in EVSC, the dimension of usefulness was consistently positive, and that the scores were somewhat higher than in EVSC. Satisfaction was by no means as negative as in EVSC: it went from slightly negative before acquaintance with ISA to slightly positive later in the trials, with the highest score being following the withdrawal of ISA.

Thus there are some broad similarities between these two set of results, with usefulness being rated consistently more positively than satisfaction. The drivers appear to consider ISA good for traffic in general, but less personally satisfying. However, the more recent drivers are more positive in terms of satisfaction. It is only possible to speculate about the reasons for this. Part of the explanation may lie in the far more sophisticated design of the ISA system in the large-scale trial. The drivers



may also have been influenced by media campaigns against speeding and by the growing enforcement from speed cameras, so that they had less wish to speed than the earlier drivers.

Figure 3 shows the questionnaire results on subjective workload from the EVSC project. Workload was ascertained using raw NASA-TLX (Byers *et al.*, 1989). Compared to baseline, drivers reported increased time-pressure and frustration after their first drive with ISA. This effect did not, however, persist into the second drive with ISA (run 3).

Figure 3 EVSC project – workload (NASA-TLX)

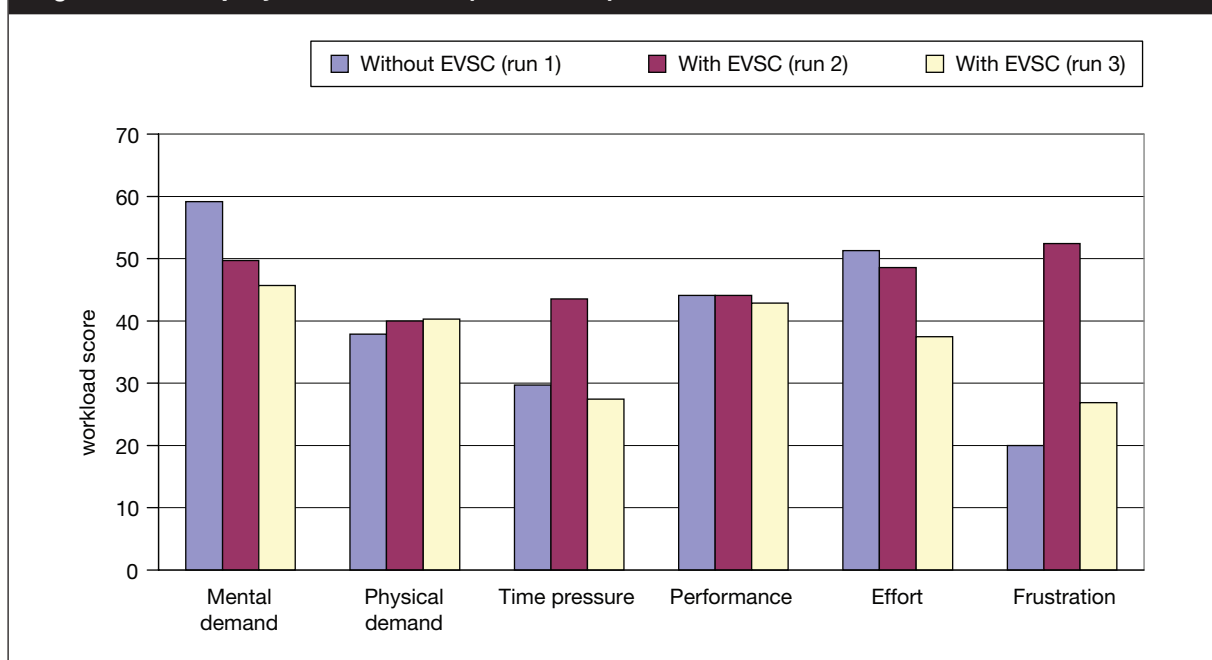
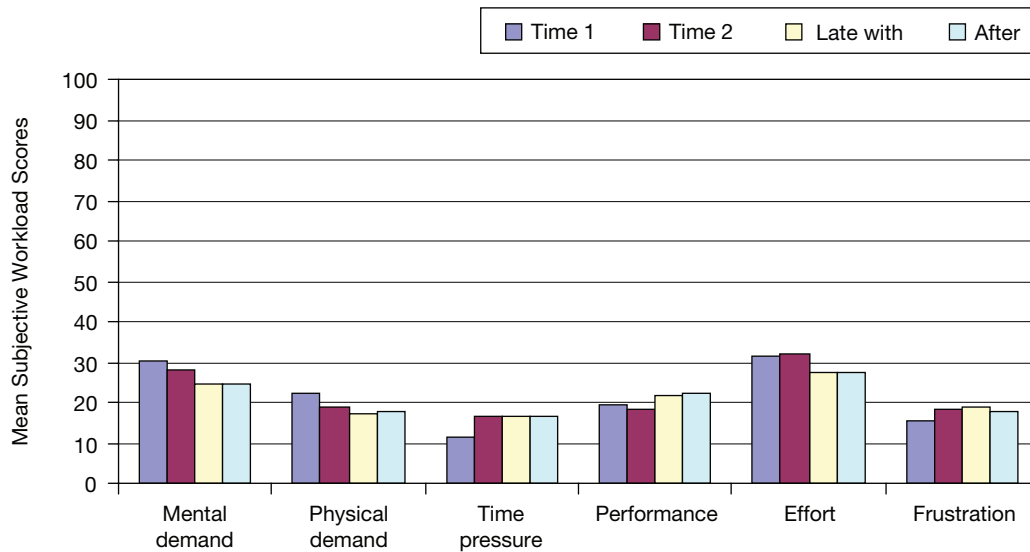


Figure 4 shows comparable data from the ISA-UK project. It can be seen that there is little overall impact of ISA on any dimension of subjective workload. So here it can be argued that the results from the two projects are broadly similar: once drivers are somewhat acquainted with a voluntary ISA, they rate the system as having little impact on workload.

Comparison of behavioural results

Figures 5 and 6 compare the amount of speeding in the two sets of trials. Figure 5 shows the percentage of time along various sections in the EVSC route that the drivers spent above the speed limit. The ISA system did not reduce speeding on all the road sections. The strongest effects of the system were on one of the sections (A) of 40 mph road and one of the sections (A) of 60 mph road. There was remarkably little impact of the ISA in the 30 mph village and not much effect on the motorway. Overall, the 'default-off' voluntary ISA had comparatively little impact in reducing speeding.

Figure 4 ISA-UK project – workload (NASA-TLX)



These results can be contrasted with those shown in Figure 6 from the ISA-UK project. Here the data are shown in terms of the percentage of distance speeding, which gives a lower weighting to periods when stationary or moving slowly than does analysis by time. The voluntary ISA substantially reduced speeding on all road categories except 20 mph (where drivers probably choose to speed between physical traffic-calming measures) and 60 mph (where there was very little speeding in the baseline situation).

Thus it can be argued that there was a greater impact of voluntary ISA on speeding in the large-scale trials. A potential explanation might lie in changes in drivers' propensity to override the system as time progressed. Perhaps they became more accepting of the ISA control following an initial period of resistance? This

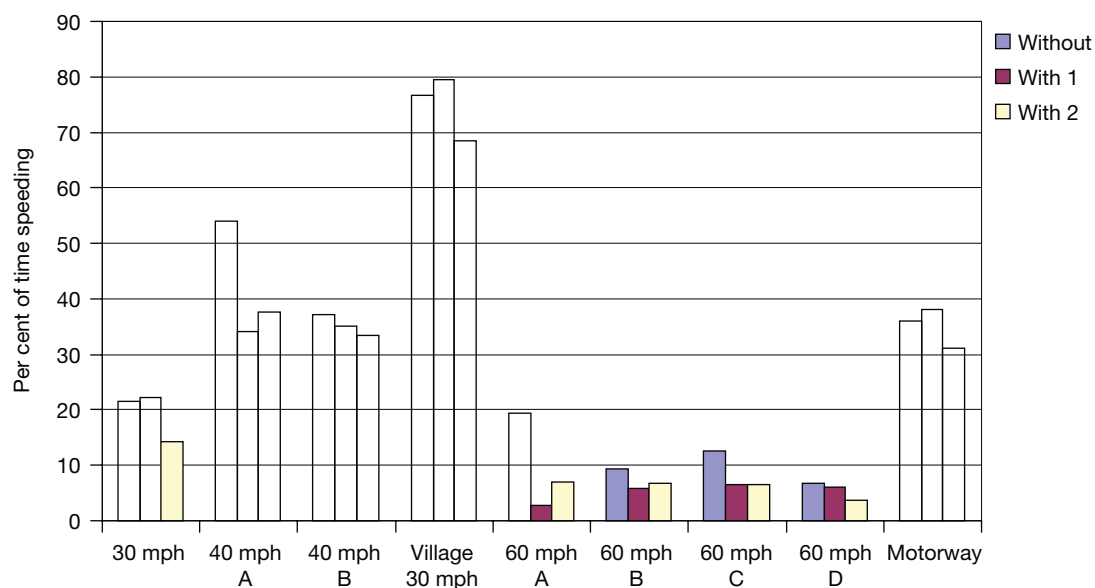
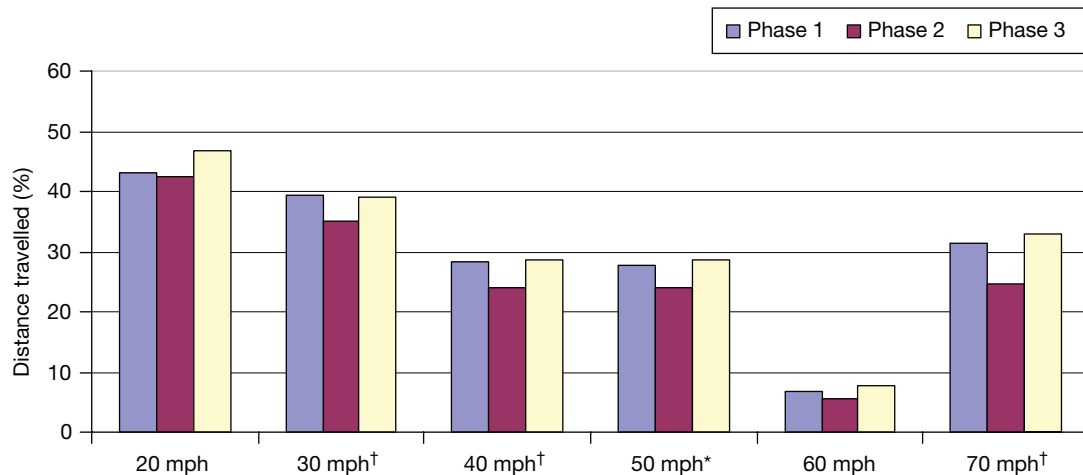


Figure 6 ISA-UK project – percentage of distance speeding

* Denotes the difference is significant at the 0.05 level

† Denotes the difference is significant at the 0.01 level

suggestion is not borne out by analysis of the frequency of drivers' overriding of the ISA system, shown in Figures 7 and 8. If anything, these indicate a tendency to override the system (opt out of ISA control) more as time progresses, at least for some of the drivers.

Those same figures also demonstrate that it is very hard, from these data, to identify a point at which drivers' behaviour towards the system stabilises. There is no evident point at which acculturation to ISA stops and behaviour reaches a kind of plateau.

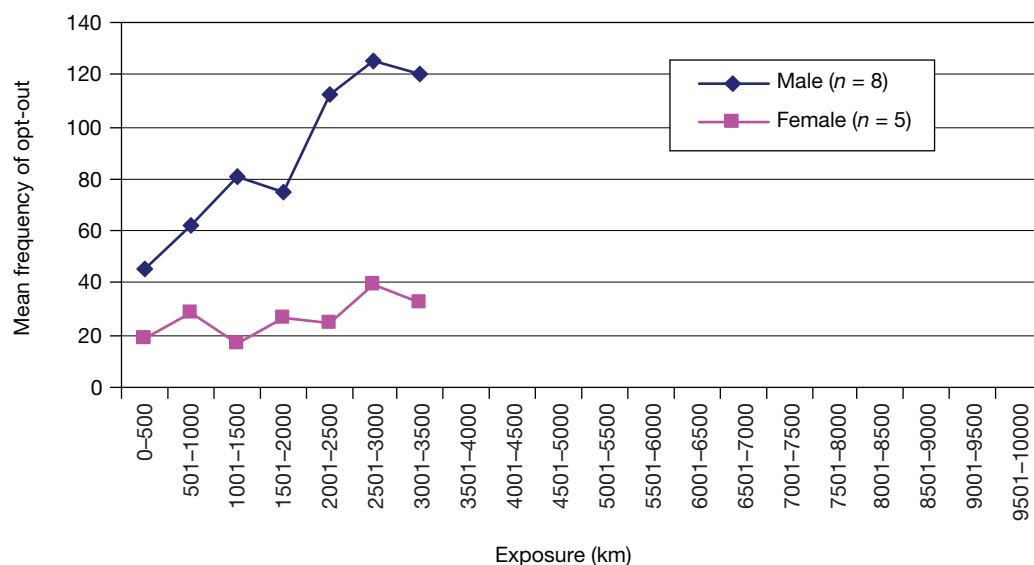
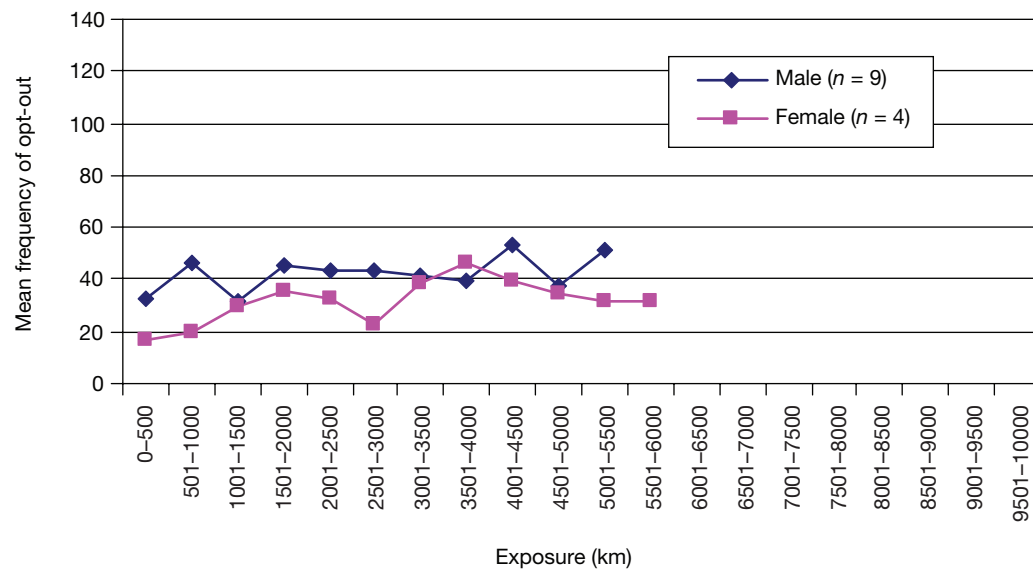
Figure 7 ISA-UK project – frequency of override (opt-out) by cumulative distance travelled for participants who drove 3000–3999 km

Figure 8 ISA-UK project – frequency of override (opt-out) by cumulative distance travelled for participants who drove 5000–5999 km



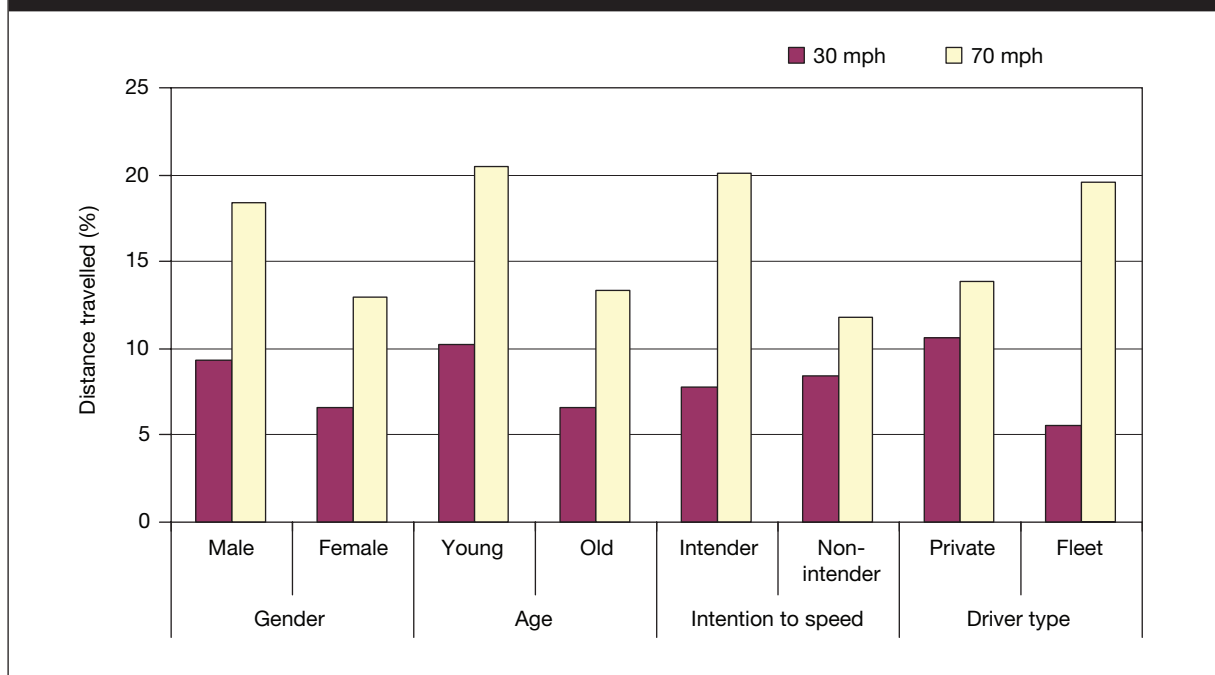
So what, then, explains the greater effectiveness of the ISA-UK system? Perhaps this can be attributed in part to the design of the ISA itself – the systems were not identical in that in the EVSC project the voluntary ISA defaulted to being off, whereas in ISA-UK project it defaulted to being on. But perhaps some of the explanation lies in the greater enforcement of speeding and, in particular, the increased deployment of speed cameras in the period since 1999.

What additional information can the long-term trials provide?

Perhaps rather obviously, the long-term trials provide a capability to examine between-group differences in a way that was not possible in the much smaller short-term trials. Figure 9 shows the substantial differences in propensity to override the ISA between various groups of participants in the ISA-UK project. Males overrode the system more than females, and young drivers (aged 25 to 40) overrode the system more than older drivers (aged 41 to 60). This was true both on 30 mph urban roads and on 70 mph roads (mainly motorways). Intenders to speed were distinguished from non-intenders by a questionnaire applying the Theory of Planned Behaviour (Ajzen, 1988). This distinction was made prior to driving with ISA, but did not prove as predictive of speeding behaviour as age or gender. Intenders did speed more on 70 mph roads, but actually sped slightly less on 30 mph roads.

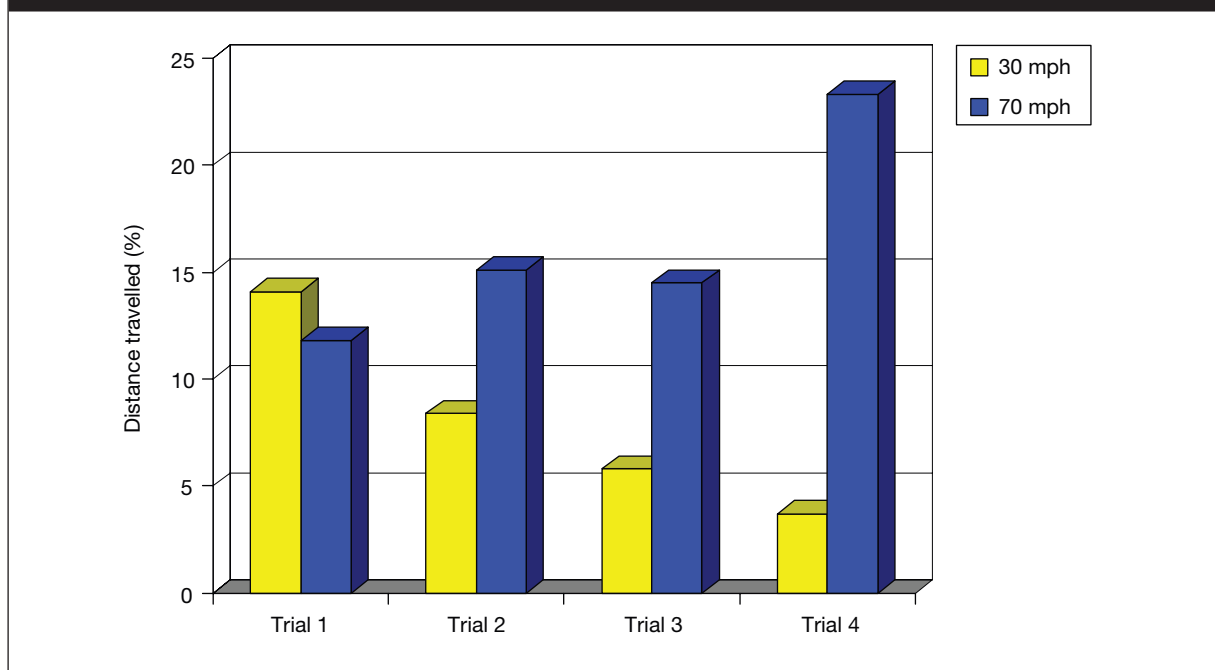
There were also substantial differences between the private and the fleet drivers. The private motorists tended to speed more on the 30 mph roads, whereas the fleet motorists sped very little on the 30 mph roads but sped far more on the 70 mph roads. Perhaps this can be attributed to a safety culture in the fleets, which emphasises the anti-social nature of speeding on urban roads but which pays less

Figure 9 ISA-UK project – overriding of system on 30 mph and 70 mph roads



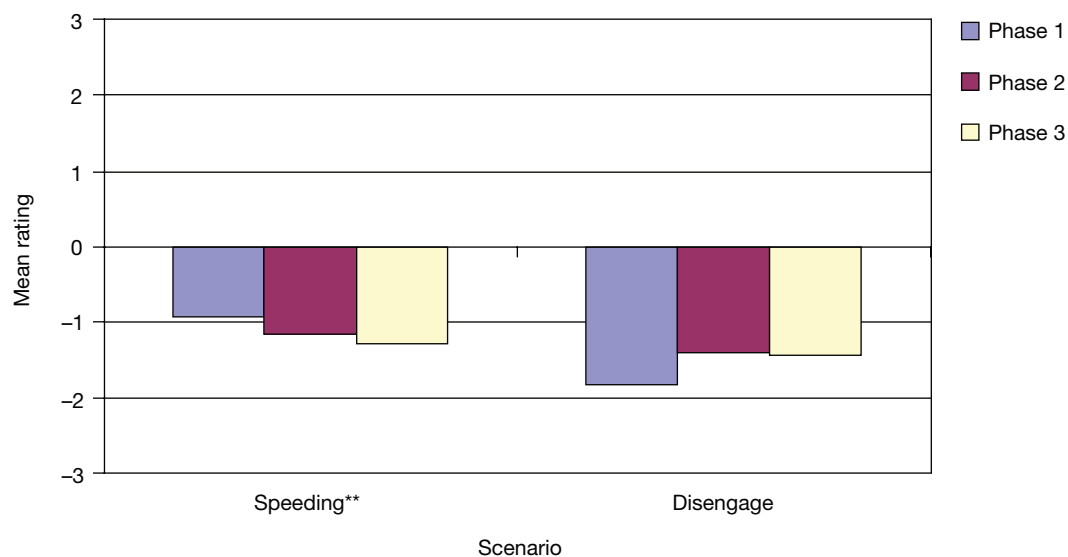
attention to speeding on motorways. Figure 10 shows that the distinction between private and fleet situations was consistent across the trials. It can be seen when comparing the private drivers in Trial 1 in Leeds with their fleet counterparts in Trial 2. Equally, it can be seen when comparing the private drivers in Trial 3 in rural south-west Leicestershire with their fleet counterparts in Trial 4.

Figure 10 ISA-UK project – overriding of system by trial



Finally, the long-term trials permitted the tracking of attitudes over time. Figure 11 shows how intention to speed, as measured by the Theory of Planned Behaviour questionnaires, changed over time. Intention to speed was negative, even prior to driving with ISA in Phase 1, but became more negative when driving with ISA in Phase 2 and was most negative following the withdrawal of ISA in Phase 3. Thus it can be argued that ISA had a calming effect on attitudes towards speed and that this effect persisted beyond the period of ISA driving.

Figure 11 ISA-UK – effect of ISA on intention to speed



Changes can also be observed in the correlations between intention and actual speeding behaviour. The correlation between Phase 1 (prior to ISA) intention and behaviour during Phase 2 (with ISA) was 0.24. The correlation between Phase 2 intentions and Phase 3 (after ISA) behaviour was 0.15. This indicates a disjuncture in Phase 3 between intentions and behaviour. The explanation may lie in the fact that the withdrawal of ISA made it harder for the drivers to carry out their intentions, in part because it is simply easier not to speed with ISA and in part because not having ISA leads to more unintentional speeding.

Conclusions

Overall, there are some quite significant similarities between the findings from the two sets of trials, particularly with regard to acceptance of the ISA system. The drivers in the more recent trials were more favourable towards ISA, perhaps because the system was better designed, but the broad trend of attitudes tending to grow more positive with increased experience was already identifiable in the earlier study. However, it is also true that the short-term trials had some limitations. They did not allow the investigation of trends in interaction with the system, such as the use of the buttons or kickdown. They did not permit the very interesting investigation of the link between participant type – for example whether a driver was a private or fleet

motorist – and speeding behaviour. Also, they could not be used to study the link between behaviour and attitudes, and the effect of ISA usage on intention to speed. FOTs can serve as an important stage in gaining an insight into driver behaviour with new in-vehicle systems and, hence, provide evidence of system impacts in large-scale deployment. Therefore they are a critical stage in providing evidence to policy-makers when they consider whether to promote the adoption of these systems.

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Do attitudes and intentions change across a speed awareness workshop?

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Introduction

It is fairly clear that there is a straightforward relationship between speed and crash involvement (Aarts and van Schagen, 2006; Finch *et al.*, 1994; Richter *et al.*, 2006) such that, as the average speed goes up, so also does the crash involvement, and vice versa. It would appear, therefore, that public safety would benefit from measures that reduce speed. Clearly, then, the enforcement of speed limits would naturally be a significant part of the process of reducing speed. In England and Wales the primary method by which this enforcement is achieved is through automated safety cameras. In fact, 91% of speeding offences are detected through cameras (Fiti and Murry, 2006). While cameras are effective in reducing speed and crash involvement (Gains *et al.*, 2005; Hirst *et al.*, 2005), they have received considerable adverse publicity in the media.

For legislation and enforcement to have its full effect, compliance is a key factor. For example, the effectiveness of a speed limit in reducing casualties will be a function of the proportion of the population who obey that limit. It is clear that compliance with speed limits is far from perfect, though it is improving. However, the fact that a substantial proportion of the population break speed limits presents some problems. What mandate do authorities have when a significant proportion of the population break the law? McKenna (2007) has argued that the perceived legitimacy of action and intervention is a key feature in these situations. Several actions of the authorities can be seen in this light. For example, the move to advertise, pre-warn and make the presence of cameras very salient can be seen as a measure designed to improve the perceived legitimacy of enforcement. The aim is to avoid the perception that enforcement is a 'speed trap'. Rather, the emphasis is on deterrence, to ensure that drivers are aware that they should slow down because they are driving in an area with a crash history.

The introduction of speed awareness courses as an alternative to the awarding of points can also be seen as a measure designed to improve the perceived legitimacy of enforcement. The aim here is to improve the acceptability of enforcement by replacing punishment with education and persuasion. A question then arises as to whether these speed awareness courses do change attitudes and intentions.

The aim of the present study is to determine whether a speed awareness programme does change attitudes and intentions. It was decided to take a fairly eclectic view of the measures that might change. A number of theories emphasise the role of intentions. Within the Theory of Planned Behaviour (Ajzen, 1991), for example, intentions are a function of three factors:

- **attitude**, which is formed from an overall evaluation of the behaviour;
- **subjective norm**, which reflects perceived social pressure; and
- **perceived behavioural control**, which reflects confidence that the behaviour can be performed.

The role of these measures has been well researched (e.g. Armitage and Conner, 2001). Additional constructs, such as the role of affect, have been emphasised by a number of authors (Manstead and Parker, 1995; French *et al.*, 2005). The affective component refers to the emotions experienced while engaging in the behaviour. In a factor analysis of why drivers break the speed limit, Gabany *et al.* (1997) found that thrill was a key component. As a result, an affective component was included in the present study.

The majority of speed awareness courses are offered to drivers who have broken the speed limit by a limited margin rather than a large margin. Indeed, several government campaigns have been designed to persuade drivers that apparently small differences in speed over the limit can make a large difference to the outcome of a crash. For example, one campaign presented the message that at 35 mph one is twice as likely to kill a pedestrian as at 30 mph. This specific attitude was assessed because it maps quite directly on to most drivers' offence.

A final factor included in the assessment was that of perceived legitimacy. McKenna (2007) has argued that, for many mass action programmes, perceived legitimacy is a key factor. In the case of road safety, McKenna argued that enough is known about the main factors in crash involvement to prompt action. The question, then, is whether the public at large considers that interventions are legitimate and, for authorities, the question is whether they will risk a public backlash. For example, Delaney *et al.* (2005) noted that, following lobbying by interest groups, an automated speed enforcement scheme in British Columbia was terminated.

Although a wide range of measures were assessed, it should be noted that the intervention did not specifically target all of these constructs. The intervention consisted of two parts. The first was a tailored software assessment and delivery of specific safety messages. The second part consisted of a group discussion with a trainer. In this intervention there was no explicit goal to change the subjective norm. That said, the software feedback did not contain any messages that would sanction speeding. Similarly, in the discussion with the trainer, it is likely that drivers who voiced concerns about speeding would have ample opportunity to do so. In other

words, while the subjective norm was not directly targeted, there may be some indirect effects. Likewise, there was no direct targeting of the role of affect, but the consideration of the negative consequences that can arise from speeding could counteract any positive affect associated with speeding.

The factors that were directly targeted in the intervention were attitudes to speeding, perceived behavioural control, intentions and perceived legitimacy. According to the elaboration likelihood model, self-relevance is one method of increasing the systematic assessment of relevant information. Messages were made personally relevant by delivering tailored feedback on drivers' attitudes and abilities. Cambell and Quintiliani (2006) argue that tailored messages are more thoroughly processed, better remembered and promote behavioural change. Although the term 'tailored message' is used here, it does not strictly conform to the definition offered by Kreuter and Skinner (2000) who, in a paper devoted to providing a definition, offer the following:

Any combination of information or change strategies **intended to reach one specific person**, based on characteristics that are unique to that person, related to the outcome of interest, and have **been derived from an individual assessment**.

(Kreuter and Skinner, 2000, p. 1; original emphasis retained)

The system used in the present study is designed to be specific to a person and is derived from an individual assessment, but it is not based on the characteristics that are unique to the individual. Indeed, it is not clear that the system that Kreuter and colleagues employ conforms to their own definition. They indicate that one system they used could generate almost 400,000 communications. Of course, that means that all communications greater than 400,000 would necessarily not be unique. This is not intended to be the pedantic point that it might appear. In order to engage the positive aspects of feedback, it is not at all clear that the message needs to be based on characteristics that are unique to the individual. If I receive feedback that indicates that I am vulnerable to a heart attack, would I consider it less self-relevant or less important to find that other people were also vulnerable for the same reason?

Feedback has a number of features over and above stimulating involvement. There is potential value in the information per se. McKenna (in press) has noted that only 4% of drivers attending these courses consider themselves less skilful than average. It has been noted by several authors that this type of perception is hardly conducive to safety. The feedback that many drivers receive will conflict with their, at best, complacent perceptions of themselves.

The fact that drivers have, over the years, formed a fairly positive view of their driving skills and safety may make them resistant to any message that might contradict this comfortable picture. It is often noted that driving is a field in which everyone perceives themselves as an expert. This position offers a potential problem for those attempting to produce attitude change. In other words, it is possible that participants may resist the effects of the message. This resistance could be conceptualised in at least two ways. It is possible, for example, that prior criticism from the proverbial back-seat driver has inoculated the driver against subsequent challenge (see McGuire, 1964, for a discussion of inoculation effects). Tormala and Petty (2002) offer a different conceptualisation in which they contradict the

generally held view that, when resistance has occurred, there is essentially no effect on the original attitude. By contrast, they propose and find that, when resistance occurs, people became more certain of their initial attitude. In essence, those designing persuasive communications, such as speed awareness courses, must open themselves up to the possibility that they may produce the opposite effect to that intended.

One additional factor that might operate against finding an attitude change is that of forewarning. Wood and Quinn (2003) found that being forewarned that a persuasive appeal will be made can enable people to galvanise their defences and resist the influence attempt. It is certainly clear that those attending speed awareness course are well and truly forewarned that an attempt will be made to change their attitudes and, as a result, there may be resistance. It is also of note that the majority of people who are caught speeding are middle-aged, contrary to the popular belief that it is the young driver who gets caught speeding. (It is likely that the middle-aged are more inclined to get caught speeding by virtue of the fact that they drive so much more and are thus more exposed to detection.) The significance of the middle-age group is that this is the age group who are found to be most resistant to attitude change (Visser and Krosnick, 1998). It is also of note that, while men tend to engage more in risk-taking (Byrnes *et al.*, 1999), there is some evidence that men are more resistant to attitude change attempts (Helander, 1984; Rossiter and Thornton, 2004).

The overall experience of enforcement will have different components that may have different impacts on the individual. For example, the very fact of receiving a formal communication from the police, providing a notification of intended prosecution, may by itself have an impact on drivers' attitudes and intentions. The aim of the present work is to determine the effects of one specific component, namely the attendance at a speed awareness workshop. Attitudes and intentions were sampled either at the beginning of the workshop or at the end of the workshop. In this way we can isolate the effect of the workshop from other components, such as the formal communication from the police. It was decided to employ a design that might minimise demand characteristics. One disadvantage of assessing the same participants at the beginning and end of the workshop is that being presented with a repetition of the questions is likely to signal to the participant that a change is anticipated. By assessing participants only once, either at the beginning or the end of the workshop, the role of demand characteristics should be diminished. The fact that all responses are anonymous should also diminish the role of demand characteristics.

Method

Participants

A total of 6,401 drivers attending speed awareness courses at eight different venues across the UK were assessed. The Perception and Performance software randomly assigned drivers to receive the evaluation questions either at the beginning of the workshop or at the end. As a result of the randomisation, a total of 3,279 drivers had their attitudes and intentions assessed at the beginning of the workshop and 3,122 at the end of the workshop. Of those attending, 41.2% were women with a modal age

in the range 41–45. For men the corresponding percentage was, of course, 58.8%, with a modal age in the range 41–45.

Procedure

The first session consisted of the computer-based assessment and tailored feedback. The system was designed to be used by people who had little or no experience of computers. All participants were informed that their responses were anonymous and that no questions would be used to identify an individual. This was reinforced by the fact that drivers could choose their own computer and no unique identification was requested. They were informed that they would receive feedback and that the accuracy of the feedback was dependent on the accuracy of their answers. The Perception and Performance Driver Risk Profile provided assessment on a range of risk factors, including self-report speed, driving violations, fatigue susceptibility, using the vehicle as an emotional outlet and attention/distractibility. Digitised video tests assessed speed choice, close following and hazard perception. The reliability for the video tests was previously assessed by Cronbach's alpha and found to be 0.87 for speed, 0.94 for close following and 0.89 for hazard perception. At the end of the session, drivers received a five-page printout providing:

- feedback on their attitudes and ability; and
- safety messages tailored to their personal responses.

The feedback and tailored safety messages were on key driver risk factors, including speed, close following, fatigue and hazard perception. The overall session took about 40 minutes, with a maximum of one hour permitted.

The next session was with a trainer who involved all participants in the discussion, which was designed to cover both perceived barriers to speeding and how speed is connected with accident involvement. The latter is illustrated through examining the personal speed choices of the participants and the potential consequences of their personal choices. For example, in reconstructing an actual crash, it was shown how their personal speed choices would have involved them in an injury crash. The motives of the authorities when considering enforcement were considered. The allocation of police resources to driving was considered in the light of the number of deaths associated with crime versus road crashes.

Evaluation consisted of a series of questions that were presented to one group at the beginning of the workshop and to the other group at the end of the workshop. The software was programmed to alternate the order of these questions on alternate days. Over time, this meant that factors such as time of day, day of week and weather were either controlled or randomised. Evaluation of the following statements was employed:

1. For me, keeping to the speed limit in the next year would be wise.
2. Most people who are important to me think that I should keep to the speed limit over the next year.
3. I am confident that I can avoid breaking the speed limit in the next year.

4. Speed limits should be more strictly enforced.
5. For me, breaking the speed limit in the next year would be enjoyable.
6. The police should be catching real criminals and not people speeding.
7. Driving at 35 mph in a 30 mph limit is quite safe.
8. For me, keeping to the speed limit in the next year would be boring.
9. I would find it difficult to drive within the speed limit in the next year.
10. Most people whose views I value would want me to keep to the speed limit in the next year.
11. Keeping to the speed limit in the next year would be good for me.

The scale used was a 1–7 scale with the following labels: agree very strongly; agree strongly; agree; neither; disagree; disagree strongly; and disagree very strongly.

Results

Table 1 presents the before and after assessment of those measures specifically associated with the theory of planned behaviour. The means for attitude, subjective norm and perceived control were calculated by averaging and, where necessary, reversing the scale of the relevant items.

Table 1 The effect of the workshop on attitude, subjective norm and behavioural control for men and women

		Attitude	Subjective norm	Behavioural control
Men	Before	2.3	2.5	3.2
	After	2.1	2.4	2.7
Women	Before	2.0	2.4	2.7
	After	1.8	2.1	2.3

A 2 (before vs after) \times 2 (men vs women) analysis of variance ANOVA was carried out for each of the measures. Given the large sample size, it is clear that there is adequate power to detect differences where they existed. Cohen's d was employed as a measure of effect size.

Attitude

For attitudes to speeding it was found that there was a highly significant improvement in attitudes following the intervention of the workshop – $F(1,6389) = 58.46$, $p < 0.001$, $d = 0.19$ (see Table 1). There was a highly significant gender effect indicating that women had a more negative attitude towards speeding – $F(1,6389) =$

207.1, $p < 0.001$, $d = 0.32$. There was no significant interaction between gender and the intervention – $F(1,6389) = 0.48$, ns.

Subjective norm

Following the intervention of the workshop there was a highly significant increase in the perceived social pressure to obey the speed limit – $F(1,6388) = 27.74$, $p < 0.001$, $d = 0.13$ (see Table 1). There was a highly significant gender effect indicating that women felt more social pressure to conform to the speed limit – $F(1,6388) = 69.39$, $p < 0.001$, $d = 0.21$. There was no significant interaction between gender and the intervention – $F(1,6388) = 2.47$, ns.

Perceived behavioural control

Following the intervention of the workshop there was a highly significant increase in drivers' confidence that they could keep to the speed limit – $F(1, 6386) = 268.7$, $p < 0.001$, $d = .41$ (see Table 1). There was a highly significant gender effect indicating that women felt more confident that they could keep to the speed limit in the future – $F(1,6386) = 246.8$, $p < 0.001$, $d = 0.45$. There was no significant interaction between gender and the intervention – $F(1,6386) = 0.11$, ns.

Affect

Following the intervention of the workshop there was a highly significant increase in the tendency for drivers to disagree with the proposal that breaking the speed limit is enjoyable – $F(1,6385) = 73.80$, $p < 0.001$, $d = 0.21$ (see Table 2). There was a highly significant gender effect indicating that women felt less positive affect associated with breaking the speed limit – $F(1,6385) = 227.4$, $p < 0.001$, $d = 0.38$. There was no significant interaction between gender and the intervention – $F(1,6385) = 1.5$, ns.

Perceived legitimacy

Following the intervention of the workshop there was a highly significant increase in the perceived legitimacy of enforcement – $F(1,6385) = 230.78$, $p < 0.001$, $d = 0.38$ (see Table 2). There was a highly significant gender effect indicating that women felt that enforcement was more legitimate – $F(1,6385) = 165.75$, $p < 0.001$, $d = 0.31$. There was no significant interaction between gender and the intervention – $F(1,6385) = 0.03$, ns.

Table 2 The effect of the workshop on affect and perceived legitimacy for men and women

		Affect	Legitimacy
Men	Before	5.4	3.6
	After	5.6	3.3
Women	Before	5.8	3.2
	After	6.1	2.9

Driving at 35 mph in a 30 mph is safe

The specific attitude ‘Driving at 35 mph in a 30 mph limit is quite safe’ was evaluated. Following the intervention of the workshop there was a highly significant increase in disagreement with this belief – $F(1,6385) = 1124.6, p < 0.001, d = 0.76$. There was a highly significant gender effect indicating that women disagreed more with this statement – $F(1,6385) = 104.1, p < 0.001, d = 0.24$. There was a significant interaction between gender and the intervention – $F(1,6385) = 6.48, p < 0.05$ – indicating that, while the intervention had a large effect for men, it had an even larger effect for women.

An alternative method of analysis is to perform a logistic regression using the workshop intervention to predict whether drivers agree or disagree with this particular attitude. It is found that, following the workshop, drivers are 4.4 times more likely to disagree that driving at 35 mph in a 30 mph limit is safe (CI 3.8–5.0).

Intentions to break the speed limit in the future

In order to analyse drivers’ speed intentions, a series of logistic regressions were carried out to determine if the intervention could predict whether drivers intended to break the speed limit or not. Table 3 presents the results separately for each of the speed limits: 30 mph, 40 mph, 60 mph and 70 mph.

Table 3 The odds of intending to keep to the speed limit at the end of the workshop relative to the beginning of the workshop (with 95% confidence intervals CI)				
	30 mph	40 mph	60 mph	70 mph
Intervention	5.6 (CI 3.9–8.0)	4.1 (CI 2.9–5.8)	4.2 (CI 3.3–5.3)	3.1 (CI 2.7–3.5)

It can be seen from Table 3 that, following the workshop intervention, drivers are 5.6 times more likely to intend to keep to the 30 mph speed limit. Similarly, following the workshop intervention, drivers were 4.1 times more likely to intend to keep to the 40 mph limit, 4.2 times more likely to keep to the 60 mph limit and 3.1 times more likely to intend to keep to the 70 mph limit.

Discussion

It is clear that, despite the potential problems of resistance to attitude change and the problem of assessing an age group who are most resistant to attitude change, it was found that a number of key attitudes did change. That said, on the global dimension of attitude to speeding, the effect size was small. This should be understood in the context of where people are on the scale. By the time they get to the workshop, they

already agree strongly that speeding is not a good idea. Whether this has been a function of the formal communication from the police or was pre-existing is not clear.

Drivers do report social pressure to conform to the speed limit and, following the workshop, this social pressure increases. Again the effect size is small and, again, drivers come into the workshop with some agreement that there is some social pressure to obey the speed limit.

For perceived behavioural control, the effect of the workshop is to increase drivers' confidence that they can keep to the speed limit. From an examination of the means, it is clear that there may be further room for improvement.

While it is possible that breaking the speed limit is perceived as enjoyable, there was not much evidence that people agreed with this either before or after the workshop. In other words drivers, on average, disagreed that breaking the speed limit was enjoyable, and this was even more true after the workshop. While thrill-seeking and pleasure are often cited as a reason for speeding (Gabany *et al.*, 1997), there is not much evidence to support this view from people who have actually been speeding. McKenna (2005) reported that 96% of those who had been caught speeding reported that enjoying speed was of little importance in their offence. Of course, it is possible that, for most people who attend speed awareness course, they are not breaking the speed limit by a large enough margin to generate positive affect. In a separate analysis carried out for the purposes of the present paper, the author examined the responses of 578 drivers who had broken the speed limit by a large margin. It was found that 73% indicated that enjoying speed had little influence on their speeding offence. Only 4% reported that enjoying speed was a very important factor in their speeding offence.

There are a number of media reports that question the legitimacy of speed enforcement, particularly via cameras. As noted in the introduction, one speed enforcement campaign was terminated following lobbying by interest groups. It is interesting, therefore, to consider the perception of the legitimacy of those groups who are most affected by cameras, namely those who are caught speeding. Those responding at the start of the workshop are close to the centre of the scale – that is, they tend neither to agree nor disagree with the legitimacy of speed control. Following the workshop, they are considerably more likely to agree that speed control is legitimate. However, it would appear that there is more work to be done to convince people of the legitimacy of speed control. Given that the technology is available to control the speed of the car, a key issue for the future will be the perceived legitimacy of doing so.

The workshop did attempt to address one very specific attitude that was linked to the offence committed by most of the drivers. This attitude considered whether driving at 35 mph in a 30 mph limit was safe. This particular attitude has been the subject of government campaigns. The significance of this particular attitude may well go beyond this particular limit. In urban areas many authorities are attempting to protect vulnerable road users by changing 30 mph limits to 20 mph limits. If it turns out that it is difficult to persuade drivers of the significance of the 30 mph limit, then clearly a major challenge lies ahead for attitudes to breaking the 20 mph limit. Completing the workshop was associated with a large positive shift in attitudes to the safety of driving at 35 mph in a 30 mph limit.

The speed awareness workshop was associated with a clear shift in intentions to break speed limits. At the end of the workshop, drivers were approximately four times less likely to intend to break speed limits.

Sex differences were observed such that women had more negative attitudes to speeding – they felt more social pressure to avoid speeding and felt more confident that they could keep to the speed limit. In addition, they experienced less positive affect from speeding and regarded speed control as more legitimate. On the issue of perceived legitimacy, there was some evidence that the workshop produced more improvements for women than men, which was consistent with other work (Helander, 1984; Rossiter and Thornton, 2004). It is possible that the present work diminished the sex difference because a tailored intervention was employed in which men, given their more dangerous attitudes, would receive corresponding feedback with stronger signals for the need for change.

Conclusion

The speed awareness workshop was shown to produce small to medium differences in drivers' attitudes to speeding, their perceived social pressure against speeding and their perceptions that they could control their speeding in the future. The workshop diminished the belief that speeding is enjoyable and increased the perceived legitimacy of speed control. At the end of the workshop, drivers were more than four times more likely to disagree that driving at 35 mph in a 30 mph limit is safe. There were also clear differences in speeding intentions. For example, drivers at the end of the workshop were more than five times more likely to intend to keep to the 30 mph limit.

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