



**ROAD SAFETY AND IN-VEHICLE
MONITORING (BLACK BOX)
TECHNOLOGY**

POLICY PAPER

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EXECUTIVE SUMMARY

In-vehicle monitoring (black box) technology is rapidly increasing in the UK, with many different forms of this technology now available. Essentially it monitors how, when and where a vehicle is being driven, records the data and provide an analysis as feedback to the driver and/or other parties. Some also provide in-vehicle alerts if pre-set parameters are exceeded (for example, hard acceleration).

The driving behaviours that are monitored are ones that influence the likelihood of the driver crashing (for example, speed) or the severity of the crash (for example, seat belt use). These are proxies for crash and injury risk, and monitoring a driver's propensity to indulge in such behaviours enables the technology to calculate a risk rating for that driver. It also, potentially, enables measures to be identified that may reduce the driver's crash risk.

In-vehicle monitoring technology has the potential to provide a wide range of safety benefits, including:

- relatively inexpensive and continuous measurement of driving behaviour and vehicle use, which is otherwise difficult to observe
- more accurate and objective data about driving than, for example, responses to self-reported questionnaires or the short (one-hour) snapshot pictures gained from driving tests and assessments
- a tool for employers to monitor and assess their staff who drive for work, improve safety, reduce crash rates and operational costs, meet their legal obligations and reduce the risk of prosecution or civil action
- a way to help young, novice drivers, parents and licensing authorities to monitor and improve the driving of young, novice drivers
- a method for insurance companies to differentiate between drivers based on their risk, rather than just by gender or age, and to tailor their insurance premiums accordingly
- a powerful research tool to enable the collection of large amounts of real-life, natural driving behaviour and the effectiveness of safety interventions on that behaviour
- a tool to inform further training and guidance needs
- data to help highway authorities to identify problem locations on their road network.

Currently, the technology is principally used by two groups: motor insurers and the (young) drivers they insure, and employers and their staff who drive for work.

Young Drivers

Several studies show that in-vehicle monitoring can significantly reduce risky behaviours, especially among the most risk-prone young drivers. However, the published literature does not yet quantify the reduction in crash or insurance claims rates for young novice drivers. The research does show that young drivers are more likely to improve their driving when the feedback is being viewed by their parents. However, some studies found that only around half of parents actually do view the feedback.

Attitudinal studies have found that parents want to monitor their children's driving, especially during their initial high risk period and think this technology could help them do so. However, they also want to respect their children's privacy and are concerned about how the technology could affect their relationship with them. Parents and young drivers are also concerned about how the data could be used by other agencies, and that information stored online could be hacked or stolen.

Reflecting the findings in the behavioural studies that many parents do not access the feedback about their children's driving, the attitudinal studies suggest potential reasons for this: many parents do not understand the data or how to use it, and are concerned about having to confront their son or daughter about their driving. They feel they need guidance on how to give feedback and what to do when the feedback indicates unsafe driving.

Attitudinal studies found that young drivers often do not like the idea of monitoring devices, but recognise that their parents might do so. They recognise that the technology could improve their driving and help them to correct "small errors", restrain their tendency to drive too fast, and help them to resist being negatively influenced by their peers. They feel it could improve their self confidence by giving them positive feedback on their driving, based on "objective" data rather than parental opinions.

But they feel the technology does not address important factors such as keeping a safe distance or avoiding hazards, and that the feedback needs to provide answers not just highlight problems. They want feedback to cover what they see as "real" safety issues and offer opportunities to discuss what took place and explain the circumstances. Young drivers think a system that requires internet or email use might prove difficult for their parents and that the cost would be prohibitive for their parents.

It should be remembered that most of the studies included in this review took place in countries where the young driver/parent relationship may be different than in the UK because these countries permit people to drive at a younger age and have graduated driver licensing systems which already impose some post-test restrictions on new drivers.

Delivering the Technology

Retro-fitted Device

Until recently, in-vehicle monitoring required a telematics device (a black box') to be retrofitted in the vehicle, which is expensive due to the cost of the physical device and fitting it into the vehicle. This level of cost makes it more difficult for insurers to introduce telematics-based insurance policies, with the result that they tend to be targeted at young drivers with high premiums. The logistics of installing the device in the vehicle (and possibly needing to remove it at a later date) can also be a barrier for insurers, young drivers and employers.

Smartphone App

Recent developments in which the monitoring technology is provided as an app on a smartphone reduce the cost because it does not require a physical device to be installed in a vehicle. As well as delivering the telematics software, apps can also deliver the feedback about the driving recorded by the software. They may also be a way of identifying the driver as they will be the owner of the smartphone, although this is not foolproof as the phone could be loaned to another driver.

However, delivering the telematics function with an app requires the phone to be switched on while the vehicle is being driven, which may tempt some drivers to use it for other purposes while driving. This risk can be mitigated by making it clear to the driver that they should not use the phone while driving and making sure they understand that the monitoring technology will detect if they do so, and report this to the insurer. A driver may choose not to take the phone with them on journeys where they feel their driving may be a lower standard than normal, or to switch it on when they are being carried as a passenger in a vehicle driven by someone else, so the app would record the other person's driving.

Insurers will need to develop technological solutions that prevent the phone being used for other purposes, and methods to detect if the telematics function is being used for selected journeys only or when someone else is driving the vehicle.

Original Equipment

The most reliable method of delivering the telematics technology would be for it to be built into vehicles as original equipment at the point of manufacture, either voluntarily by vehicle manufacturers or compulsorily required by regulations. It will be mandatory for Event Data Recorders (EDRs) to be fitted in cars and light vehicles sold in the USA from September 2013, although most US vehicles are already fitted with them. EDRs record technical vehicle and occupant-based information for a few seconds before, during and after a crash, and so are fundamentally different to the type of black box being introduced by UK insurers.

In Europe, E-Call (a technology that automatically sends the location of the vehicle to the emergency services in the event of a crash) will become mandatory on all new vehicles by 2015, but there are no current plans to introduce mandatory in-vehicle monitoring as original equipment in European cars. Nor does the USA EDR regulation amount to a mandatory US requirement to record data on the driver's behaviour and performance.

At-Work Drivers

Telematics is used by a growing number of employers, perhaps mostly in vans and large vehicles, but also in cars. Employers can use the resulting data to identify management approaches to reducing risk and/or improving efficiency, such as changing schedules and routes, providing driver training, and if necessary, instigating disciplinary action.

Several studies show that in-vehicle monitoring can help employers and at-work drivers to reduce their crash rates when driving for work. Some studies have found that accident rates for vehicles fitted with a monitoring device reduced by 20%, others found a reduction of 38% in accidents and the rate of specific unsafe driving behaviours reduced by up to 82% in one case. However, the effects have varied between fleets with most showing a reduction in accident rates, but some showing a small (but not statistically significant) increase in accidents.

Trials in America with in-vehicle monitoring devices fitted into ambulances found a dramatic and sustained improvement in driver performance, without any increase in response times. Savings in vehicle maintenance costs alone more than paid for the monitoring equipment, without taking into account other cost savings, such as fewer accidents. Surveys of commercial truck and bus safety management in the USA concluded that in-vehicle monitoring technology was underused given its safety potential. A major obstacle was driver acceptance; other challenges were handling and analysing the data and ensuring the technology was not used just to focus on negative assessments and punitive actions.

A range of published case studies of the experience of various companies that have used telematics show positive results in reducing accidents, accident costs, vehicle and fuel costs and risky driving behaviours. However, these case studies have not been published in research reports and case studies showing less favourable results may not be published.

Feedback

The most prominent issue that emerges from the research is the importance of feedback about the driving behavior monitored by the technology. Much of the research shows that driving behavior improves once the driver and/or a third party begin to receive feedback, but provides little detail about the content and nature of the feedback.

Feedback is provided in a number of different ways, mainly immediate in-vehicle feedback to the driver and/or retrospective feedback (to the driver and/or a third party, such as a parent or a manager in the driver's company) after a journey has ended. Given the evidence that many parents do not view the feedback about their children's driving, and the lack of detail about the exact nature of the feedback and how it is used, more research is needed to identify the most effective ways of designing, developing and delivering feedback, to encourage drivers and others to:

- Regularly view the feedback
- Understand what the feedback means
- Use the feedback to improve the driver's behavior and reduce their risk

Other Groups of Drivers

Although the research into, and use of, in-vehicle monitoring technology has so far been almost entirely restricted to young, novice drivers and to at-work drivers, it has the potential to be used by, and to improve the safety of, all drivers. Specific groups for whom this technology may be especially useful include older drivers and offenders.

Data Privacy/Access

Concerns about data security and who can access the data and for what purposes still need to be resolved as these concerns appear to be a significant barrier to the wider acceptance of the use of in-vehicle monitoring technology.

Data Ownership and Portability

Issues around data ownership and data portability need to be clarified. In particular, drivers would find it very useful to be able to use the data collected about their driving when seeking competitive insurance quotes from different insurance companies, or when applying for jobs that involve driving. The latter would also help employers to manage their occupational road risk by enabling them to assess driving ability and risk during recruitment.

This would be much easier if there were common data standards used across the insurance industry, which is not the case at the moment.

Driver identification for Multi-Driver Vehicles

It is important that any in-vehicle monitoring system is able to identify who is driving the vehicle, so that the driving behavior data it produces can be correctly assigned to the specific driver who was driving the vehicle at the time. This is particularly important in the case of young drivers driving a car that other family members also drive, and for employers with fleet vehicles that are driven by more than one member of staff.

Cost

Cost concerns could be addressed by keeping initial costs to a minimum and, and helping potential users to understand how any costs will be more than covered by savings in insurance premiums, fuel, damage, running costs and accident costs.

INTRODUCTION

This policy paper explores the rapidly developing use of in-vehicle telematics to monitor and analyse real-life driving behaviour, and its potential road safety advantages and disadvantages. The paper primarily focuses on this technology by two groups:

- motor insurers and the (young) drivers they insure
- employers and their staff who drive for work.

On 21 December 2012, the European Court of Justice (ECJ)'s gender ruling¹ (commonly called the Gender Directive) came into effect, making it illegal for insurers to take gender into account when calculating premiums. Previously, gender was a major factor in determining a driver's, especially a young driver's, level of premium, with female drivers generally receiving substantially lower premiums than males because male drivers crash more often than females, and so make more motor insurance claims. This is one of the major reasons from the growth of telematics-based motor insurance.

Potentially, this technology provides a powerful tool to improve driving standards and reduce crash rates, by:

- helping drivers to recognise their 'real' driving styles and how particular types of driving (for example, exceeding speed limits, hard acceleration, etc) increase the risk of crashing, as well as cost more in fuel use and vehicle wear and tear
- incentivising drivers to avoid these types of driving behaviour, and so reduce their risk
- helping those in a position to influence drivers (parents, trainers, employers, insurers, etc) to identify riskier drivers and their training needs or other ways of reducing their risk (an employer changing journey schedules, for example).

However, in-vehicle telematics also raises privacy issues and the risk that the data will be mis-interpreted, leading to inappropriate responses.

The use of telematics (black boxes) to monitor real-life driving behaviour, and to incentivise better, safer driving, is increasing rapidly, mainly with two groups of drivers: young drivers and at-work drivers.

Young, Novice Drivers

Young, novice drivers face very high motor insurance premiums in their first few years of driving after gaining a full driving licence, which can often amount to £3,000 to £5,000 a year. This is because young, novice drivers are involved in more crashes than other drivers, and so are more likely to make insurance claims, which also tend to be much more expensive than claims made by other groups of drivers. Many insurance companies in the UK now have, or are developing, motor insurance policies that include a black box that records how the policyholder is driving. The insurance company sends the driver feedback based on the data from the black box, and may adjust their premium accordingly, or even withdraw their insurance if the policyholder's driving does not improve.

At-work Drivers

In-vehicle telematics (of various sorts) are used by a growing number of employers for their fleets, perhaps more commonly for vans and large vehicles, but also for cars. Typically, they monitor fuel use, mileage and location with many also being used to monitor speed, harsh braking, cornering and acceleration. Employers can use the resulting data to identify driver training needs, change schedules and routes, and if necessary, instigate disciplinary action.

IN-VEHICLE MONITORING TECHNOLOGY

Many in-vehicle monitoring devices are essentially “black boxes” with in-built accelerometers, GPS and other features. Broadly speaking, there are two types: Journey Data Recorders (JDRs) and Event Data Recorders (EDRs), although they have many different names.

Event Data Recorders (also known as crash data recorders or accident data recorders) monitor the way a vehicle is being driven throughout a journey but only record the data when an event (for example, a collision, sharp braking, etc) exceeds pre-set parameters. They typically record several seconds before, during and after the event. An analysis of the data is provided to the driver, and/or a third party, after the journey, usually by some form of website or app. Some also provide real-time visual or audible alerts to the driver during the journey. In the USA, the law EDRs requires EDRs, which are voluntarily fitted in most new vehicles, to record 15 data elements from September 2013. It is likely that a new regulation will make EDRs mandatory on all new cars and light vehicles sold in the USA from September 2013.

Journey Data Recorders (also known as in-vehicle data recorders or in-vehicle monitoring devices) monitor the way a vehicle is being driven, typically at 1 second intervals, throughout a journey. The data for the whole journey is recorded and an analysis is provided to the driver, and/or a third party, after the journey, usually by some form of website or app. Some also provide real-time visual or audible alerts to the driver during the journey.

With both EDRs and JDRs, the driving behaviour of the driver is constantly monitored throughout a journey, but with Event Data Recorders, only a small amount of the data is recorded and so can be analysed, whereas with Journey Data Recorders, all of the data for the whole journey is recorded and so can be analysed.

The advantage of telematics for motor insurers is that it provides data to show when, where and how a vehicle is being driven. This enables the insurer to calculate the risk of an individual policyholder based on their driving, rather than on their membership of a group (ie, gender or age). When an insurance claim is submitted, it also provides a more accurate picture of what actually happened in the crash, which helps the insurer to establish blame and settle claims, and to reduce fraudulent claims.

Telematics-based insurance enables insurers to provide personalised, tailored, insurance premiums, and it is rapidly developing in the UK.

Until recently, the monitoring technology has been contained in a small device (a ‘black box’) fitted in the vehicle, or in software embedded in another device, such as a SatNav. A more recent development is for the technology to be delivered by an app downloaded into a smart mobile phone, which must then be switched on in the vehicle. While this is a less expensive, because it avoids the cost of producing and installing a physical box in the vehicle, it may raise the risk of the phone being used for other purposes while driving, and there is more chance that a driver may not always take the phone in the vehicle which means the data may be less complete.

The most reliable method of delivering the telematics technology would be for it to be built into vehicles as original equipment at the point of manufacture, either voluntarily by vehicle manufacturers or compulsorily required by regulations. It will be mandatory for EDRs to be fitted in cars and light vehicles sold in the USA from September 2013. In Europe, E-Call will become mandatory on all new vehicles by 2015, but there are no current plans to introduce mandatory in-vehicle monitoring as original equipment in European cars.

The driving behaviours that are monitored by in-vehicle telematics are behaviours that influence the likelihood of the driver crashing (for example, speed) or that influence the severity of the crash (for example, seat belt use). They are proxies for crash and injury risk, and monitoring an individual driver's propensity to indulge in such behaviours enables the technology to calculate a risk rating for that driver. It also, potentially, enables measures to be identified that may reduce the driver's risk.

Reviews^{2,3} have identified a wide range of in-vehicle monitoring devices, which vary in terms of what they measure, how and for what purpose(s). The most common forms of driving behaviour that tend to be monitored and measured are:

- Journey start and finish times
- Vehicle speed
- Vehicle location
- Acceleration
- Braking
- Cornering
- Seat belt use
- Fuel consumption.

Some systems also provide video of the external road and traffic environment and/or inside the vehicle itself, to provide contextual details about the driving and an indication of what the driver is doing (not wearing a seat belt, using a mobile phone).

The devices use customised algorithms to determine whether or not safety-relevant events have occurred or whether pre-set parameters have been exceeded. These algorithms are as varied as the devices themselves.

The monitoring devices also vary in terms of how obvious they are to the driver, with some completely hidden from view and others positioned within the field of view of the driver to provide them with performance feedback or warnings while they are driving.

Most monitoring systems provide feedback directly to the driver, either in the vehicle in real-time while they are driving and/or retrospectively once a trip had ended, usually in some form of online report. Some of the systems also provide feedback to, or through, a third party, such as a parent or a line manager.

The effectiveness of this feedback can be influenced by a number of factors related to the individual driver, the organisation or third party, as well as the nature of the feedback itself. While many of the published studies show that feedback influences driver behaviour, they provide little detail on the nature of the feedback or how it influences behaviour.

This technology enables accurate information about a person's driving to be collected, and enables the driving behaviour of individual or groups of drivers to be analysed to identify strengths and weaknesses, crash risk and to create personalised feedback. Sometimes the mere presence of the device can impact behaviour, even in the absence of any feedback (i.e., a Hawthorne effect).

In-vehicle telematics have the potential to provide:

- relatively inexpensive and continuous measurement of driving behaviour and vehicle use, which is otherwise difficult to observe
- more accurate and objective data about driving than, for example, responses to self-reported questionnaires or the short (one-hour) snapshot pictures gained from driving tests and assessments
- a tool for employers to monitor and assess their staff who drive for work, improve safety, reduce crash rates and operational costs, meet their legal obligations and reduce the risk of prosecution or civil action
- a way to help young, novice drivers, parents and licensing authorities to monitor and improve the driving of young, novice drivers
- a method for insurance companies to differentiate between drivers based on their risk, rather than just by gender or age, and to tailor their insurance premiums accordingly
- a powerful research tool to enable large amounts of real-life, natural driving behaviour and the effectiveness of safety interventions on that behaviour
- a tool to inform further training and guidance needs
- data to help highway authorities to identify problem locations on their road network.

The fastest growing area in the use of in-vehicle technology is by motor insurance companies, most of who have developed, or are developing, insurance policies in which the policyholder has a monitoring device (a black box or an app on a smart phone) in their vehicle. As an example, of how much this type of motor insurance is developing, the first national television advert in Great Britain to promote an insurance policy using in-vehicle monitoring technology was aired in August 2012.⁴ Adverts and articles on this topic now appear regularly in the national media.

YOUNG DRIVERS AND PARENTS

Several studies suggest that in-vehicle monitoring can significantly reduce risky behaviours, especially among the most risk-prone young drivers.

A Dutch study⁵ tested whether Pay-As-You-Drive (PAYD) car insurance is effective in reducing speed violations by young drivers, and to what extent a financial incentive (a discount on the insurance premium) in combination with feedback to the drivers affects their actual driving speed. In 2007, approximately 6,000 policyholders of five Dutch insurance companies were asked to complete an online questionnaire on PAYD, of whom 706 did so and 337 volunteered to participate in a field experiment. 228 of the drivers were randomly selected to participate, of whom 141 completed the field experiment. Over half (60%) were men, with an average age of 24 years and on average they had held a driver's licence for 4.5 years.

The participants were randomly assigned to one of three groups: a gain-incentive group, a loss-incentive group or a control group, and between November 2007 and June 2008, their cars were equipped with GPS devices that monitored where they were driving, and their speed, time, and distance.

The experiment comprised four phases, each lasting two months. During the first and final phases, the participants' driving was monitored, but it had no financial consequences. During the intervention phases, the 50 participants in the gain-incentive group could gain up to 50 Euros discount each month if they drove safely; the 50 Participants in the loss-incentive group started each month with 50 Euros discount, and could lose up to 50 Euros a month if they failed to drive safely; and the 41 participants in the control group were told that they would receive the maximum discount at the end of the experiment, irrespective of their driving behaviour. The monthly discount comprised 30 Euros for keeping to the speed limit, 15 Euros for reduced mileage, and 5 Euros for not driving at night during the weekend.

Participants in the two incentive groups could track their performance during the intervention phases on a website that provided detailed feedback on their speed violations, mileage, and night-time driving, and showed how much discount they would receive at the end of the month if they continued to drive in the same way. Participants in the control group did not receive feedback on their driving behaviour.

Both the incentive groups reduced their speeding after the financial incentive was introduced, but increased it when the financial incentive was removed. However, there was no difference between the gain- and loss-incentive groups. The control group did not reduce their speeding. The distance travelled in excess of speed limits fell by 6%, from 20.5% to 17.6%. Therefore, PAYD was estimated to have reduced illegal speeding by 14%.

This PAYD trial was more effective at reducing speeding on 50, 80 and 100 km/h roads, than on 30 and 120 km/h roads. The authors thought this may be because it is easy to inadvertently exceed the speed limit on 30 kph roads, irrespective of financial incentives to reduce speeds, and that speed violations on 120 km/h roads are infrequent, so a financial incentive may not reduce it much further. As most fatal car accidents in the Netherlands occur on single-carriageway, two-lane rural roads, of which 80 and 100 km/h roads are typical examples, the report concluded that PAYD was especially effective on the most dangerous roads.

The PAYD trial did not reduce mileage or weekend night time driving, perhaps because the participants knew that most of the monthly discount could be earned by driving within speed limits, and only a small part by reducing mileage and avoiding driving at night on the weekend. A small sample of the participants was interviewed and most indicated that reducing mileage and avoiding driving at night was very difficult.

In an American study,⁶ the vehicles of twenty-six 16 and 17 year old drivers (12 males and 14 females with driving experience ranging from 3 months to over a year) from a rural high school, were equipped with an event triggered video recording system. This continuously captured audio-video data including views of the road ahead and the vehicle's interior, and recorded acceleration, date, and time, but only saved the data (10 seconds before and 10 seconds after) if an event exceeded a set threshold. An LED light flashed during an event so the driver knew the data was being recorded. The study included three phases: during Phase 1 the drivers received no feedback; in Phase 2, the driver received immediate feedback from the system (e.g., blinking LED) and their parents could access their driving data, and in phase 3, the driver received no feedback in the vehicle and the parents received no information about them.

During Phase 1, the participants drove 43,401 miles (individual mileage varied greatly from 795 miles to 3,406 miles) and their devices were triggered over 1,000 times, of which 376 were safety-relevant events that would have required parental feedback in the form of a discussion about what happened. The 376 safety-relevant events translated into an average of 8.6 events per 1000 miles for all the drivers. However, one group of 18 drivers averaged 2.5 events per 1000 miles, and another the other group of 7 drivers averaged 23.4 events per 1000 miles, almost ten times the rate of the first group.

Drivers' actions resulted in 246 incidents (including three near-catastrophic crashes and one airbag crash), which translated to an average of 5.7 incidents per 1000 miles driven. The 'low frequency' group averaged 2.0 incidents per 1000 miles while the 'high frequency' group averaged 14.7 incidents per 1000 miles. The drivers in the near-crashes and the crash were from the 'high frequency' group. In these 246 incidents, the most common faults were taking a 90-degree turn too fast, cutting a corner during a turn, or braking abruptly. The 'high frequency' group triggered the device 26 times while negotiating a bend, while the 'low frequency' group registered no such triggers. The high frequency group also triggered the device almost four times more often than the low frequency group while making 90-degree junction turns. The groups also differed significantly in the number of abrupt braking events.

During the second phase, the participants received visual feedback from a blinking LED light when they triggered an event, a weekly summary of their performance relative to their peer group and video clips of all safety-relevant events. During this phase, they covered more than 249,790 miles, during which there was a significant reduction in the number of safety-relevant events. In the first nine weeks, the drivers reduced their rate of safety-relevant events from an average of 8.6 events per 1000 miles to 3.6 events per 1000 miles – a 58% reduction. They further reduced the rate of events to 2.1 per 1000 miles in the following nine weeks, achieving a 76% reduction from the baseline. This drop from 8.6 to 2.1 events per 1000 miles driven was statistically significant.

Most of the overall reduction was due to a change in the behaviour of the higher risk subgroup. The 18 'low frequency' drivers did not change their behaviour significantly. However, the seven 'high frequency' drivers showed a dramatic 72% reduction, from an average of 23.4 to 6.4 safety-relevant events per 1000 miles in the first nine weeks of the intervention. After an additional nine weeks, they further dropped their safety-relevant events by 89% from the baseline, averaging 2.6 events per 1000 miles. They maintained an average of 3.0 events per 1000 miles for the remainder of the intervention, only slightly higher than the other group.

A similar pattern emerged for the incidents (including near-crashes and crashes), with the seven 'high frequency' drivers reducing their higher rates to almost the level of their 'low frequency' peers after 18 weeks of receiving feedback about their driving.

A study⁷ in Israel fitted in-Vehicle Data Recorders (IVDRs) in 62 vehicles driven by newly qualified 17 year old drivers (36 males and 26 females) and their parents (the IVDR could identify who was driving). Israel has a Graduated Driver Licensing System in which young people can start learning to drive at 16.5 years and take their driving test from 17 years. For the first three months after passing the test, they can only drive when accompanied by experienced driver, but can drive unsupervised thereafter, although there are restrictions on the number of passengers they can carry for the first two years of driving.

The IVDR recorded trip start and end times, speeds and manoeuvres such as braking and accelerating, turning, lane handling and speeding, and provided online feedback to the drivers. Monthly risk ratings were calculated for the novice driver and the other family members driving the same vehicle.

Initially, only minimal information was provided to the drivers about the purpose and the capabilities of the IVDR, and no feedback was provided. After about 4 months, they were given additional information about the IVDR and could access a website to see the data collected by the IVDR and their risk ratings. The access times of the family members to the website were monitored.

During the 12-month period, the 36 male and 26 female young drivers were monitored over almost 8,000 driving hours in which they recorded over 41,000 manoeuvres with intermediate or high severity ratings. Their parents recorded about 10,000 driving hours and 30,000 intermediate or high severity manoeuvres. Overall, male novice drivers had higher average risk ratings than females, but all the novice drivers had higher risk rates than their parents.

After feedback was provided for the first time, the average risk ratings of the young drivers decreased substantially. In the following period, while the risk ratings increased back again for the male drivers, but the decrease was sustained for the female drivers. The average risk ratings of the parents did not change during the study period, indicating that their driving styles were well established.

Feedback was available to the novice drivers and their families for 236 household-months during the study, but was accessed in only 162 of those household-months. Surprisingly, in half (49%) of the cases, only the parents accessed the feedback, in one quarter (22%) of the cases only the young drivers consulted their driving data and in 28% of the cases both the novice drivers and parents did so.

Access to feedback affected the risk ratings of the young drivers - their risk rates decreased when their parents monitored their driving behaviour, but increased, although not significantly, when they checked their own driving records. Young drivers whose driving records were not consulted by parents did not modify their behaviour. Most probably, parents who consulted the feedback tended to monitor their young drivers more carefully, but these findings indicate that parents should be encouraged to monitor the behaviour of their young drivers, and tailor family policies about their use of the car to discourage risky behaviours.

A few years later about half of the drivers participated in a follow up study⁸ to evaluate how their driving had changed after three to four years of driving. In-Vehicle Data Recorders were re-installed in the cars of 32 of the young drivers (21 males and 11 females). Their average age was now 20.5 years and they had held a licence for 3 1/2 to 4 years on average. In general, there were no significant differences between the event rates in the first year and fourth year studies, but again the transition to feedback had a noticeable effect as the events rate in situations where the events frequency was relatively high (such as weekend driving) were significantly reduced.

A study⁹ to determine if teenage driving behaviour improves when a monitoring and feedback device is installed in their vehicle was conducted by fitting a shoebox-size monitoring device (including a GPS device and a small speaker) in the cars or light trucks of 85 16 and 17 year old drivers (38 males and 46 females), each with between with 0 and 15 months driving experience. This detected sudden braking and acceleration, non-use of seat belts, and speeding (10mph above the limit) and issued an audible alert whenever an event occurred. Descriptions were posted on a website for the young drivers' parents to access.

The participants were assigned randomly to one of four groups:

- Group 1: In-vehicle alert and immediate website notification (alert and web)
- Group 2: In-vehicle alert and conditional (if the behaviour was not corrected within 20 seconds) website notification (alert then web)
- Group 3: Website notification but no in-vehicle alert (web only)
- Group 4: No in-vehicle alert and no website access (control group).

To establish a baseline of driving behaviour, no in-vehicle alerts were given and no data was sent to the parent websites for the first two weeks after the devices were installed. Following this period, the drivers (except those in the control group) received in-vehicle alerts and data was sent to the parent website. After 20 weeks, the in-vehicle alerts and parent website were disabled, but monitoring data continued to be collected for a further two weeks, after which the devices were removed from the vehicles. Following the trial, the young drivers and parents were interviewed separately about the perceived effectiveness of the device, parents' use of the monitoring features, and overall satisfaction.

The total number of miles driven during the study by each participant varied from 338 to 10,345. The number of sudden braking/acceleration, seat belt non-use, and speeding violations also varied. Seven participants had no sudden braking/acceleration notifications during the 24 weeks of the study, whereas one participant had 145 notifications.

Braking/Acceleration Rates

For drivers in group 1 (alert and web), the rate of sudden braking/acceleration fell from 0.64 events per 100 miles during the first week without any feedback to 0.40 (43% lower) during the 20 weeks when they and their parents received feedback and the final two weeks when the feedback was switched off. The trend for group 2 (alert then web) was 31% lower, except that behaviour improved further during the final two weeks without feedback. For group 3 (web only) the reduction was 12%.

Seat Belts

The rates for not wearing a seat belt were analysed as miles driven without a seat belt. Overall, seat belt use ranged from 25% to 100% of the miles driven, but it was high for most drivers. Thirteen of the 71 drivers with reliable seat belt sensors used belts all the time, and another 53 used belts at least 90% of the time.

Drivers in group 1 (alert and web) drove unbelted for 3.69% of their miles during the initial no feedback phase, 0.09% during the feedback phase (a 90% reduction), but increased significantly to 3.03% during the second no-feedback phase. Non seat belt use by drivers in group 2 (alert then web) declined as well, but as their rates already were extremely low, the changes were not statistically significant. For drivers in group 3 (web only) failure to wear a seat belt fell by 61% during the feedback phase, and remained low in the second, no feedback phase. Drivers in the control group were less likely to use seat belts during the feedback phase than during the first no feedback period.

Speeding

For most groups, the percentage of miles driven more than 10 mph above the speed limit increased between the initial no feedback period and feedback phase, with the only exception being drivers in group 2 (alert then web) whose speeding rate declined during the feedback phase, but increased again afterwards; this group were speeding for 14% of their miles during the no feedback period, 10% during the feedback phase, and 12% during the second no feedback phase.

Parents Access to Feedback

During the early stages of the study, it was noticed that the parents were rarely visiting the websites to view the analysis of their children's driving, so after the devices had been installed in the first 31 vehicles, the parents, except those in the control group, were sent a brief email every 2 to 3 weeks, stating how many times during the previous week the teenager's vehicle had exceeded the speed limit by more than 10 mph and prompted the parent to visit the website for more information.

Most of the 24 families involved before these email notifications began made few visits to the websites; one family made no visits during the 20-week period, while 21 families made between 1 and 30 visits each. The remaining two families accounted for 63% of all website visits, with 118 and 159 visits respectively. In total there were 440 visits to the websites, averaging only 18 visits per family over a 20 week period (less than once a week). Surprisingly, the families who began receiving email alerts made even fewer visits to the website: 420 visits to the websites were made by these 39 families. Seven of these families made no visits at all during the 20 week feedback period, while the rest made between 1 and 47 visits each.

The parent websites were used very little, and emailing report cards to parents did not increase website visits. The report cards may have been too brief to engage parents' interest, or they may have provided enough information for them to feel they did not need the website. The lack of parent involvement may have been due to lack of time or other priorities. Parents did not pay for the monitoring device, so they may not have felt compelled to get their money's worth. They also knew that the researchers were monitoring driver behaviour and perhaps trusted that they would be informed of any serious problems.

In summary, this study found that in-vehicle alerts were somewhat effective in reducing the risk-taking behaviour of recently licensed 16 and 17 year old drivers, and although the drivers found them annoying they felt it helped them become better drivers. However, young drivers may learn to tune out the alerts over time, so reinforcement from parents appears necessary to sustain good behaviour. Surprisingly, access to a website detailing their child's behaviour was not enough motivation for parents to actually visit the website. Emailing report cards to parents was more effective than website access, but it could be that the website contained more information than most parents wanted to receive. Close and continuous monitoring by parents is a key factor in improving young driver behaviour, but it is not yet clear how best to encourage such parent participation in the monitoring process.

A driver simulator study¹⁰ involving 29 (7 male and 9 female) 18 – 21 year old drivers and 13 (7 male and 6 female) 35 – 55 year old driver explored the effectiveness of feedback in reducing the time they spend on a secondary (non-driving) activity while driving. The participants completed several drives (each approximately 7 min) on simulated two-lane rural roads with oncoming traffic, and were instructed to drive at a comfortable speed that was not above the speed limit of 45 mph and to follow a lead vehicle that periodically braked. Some of the participants performed a secondary task that simulated the visual, motor and cognitive distractions typical of scanning an MP3 playlist. A visual alert appeared on the dashboard if the driver glanced away from the road for more than 2 seconds and a more prominent visual alert if the glance was more than 2.5 seconds.

Not surprisingly, the secondary task impaired driving performance, resulting in less stable steering control and slower braking when the vehicle in front braked. The visual feedback resulted in less frequent driver glances to the MP3 display and longer glances to the road ahead, but it did not affect braking times or steering. The visual feedback did not result in longer glances to the feedback display, so did not impose any additional distraction. Subjectively, the drivers believed the visual feedback enhanced their driving performance.

A second, similar driving simulator study¹¹ was conducted to assess whether combining real-time feedback with retrospective feedback provided any additional benefits. 48 participants (23 females and 25 males) aged 18 to 21 years, all of whom had at least one year of driving experience completed the same driving and secondary distraction task as in the first simulator study. One group (17 participants) received retrospective feedback in the form of a trip report after each drive, the second group (14 participants) received both retrospective and immediate in-vehicle feedback, and the third group (17 participants) received no feedback.

Incidents occurred in 40 of the 68 drives by drivers who received the retrospective feedback and in 38 of the 56 drives by drivers who received the combined feedback. Driving performance improved from the first to last drive for all the drivers, but more so for the drivers who received feedback (both retrospective only and combined) than for those who received no feedback, suggesting a learning effect, which was enhanced by feedback.

For the last drive, when drivers had already been exposed to feedback several times, both feedback types resulted in significantly faster reactions to the lead vehicle braking. Drivers who received retrospective feedback reacted 0.34 seconds faster, and those who received combined feedback, 0.41 seconds faster, than the drivers who received no feedback. There were no significant differences between the two feedback types: both retrospective and combined feedback enhanced driving performance.

However, drivers who received the combined feedback had longer on-road glances (by 0.46 second on average) than those who received no feedback, which suggest that combined feedback provides the benefits of retrospective feedback and immediate feedback, i.e., faster reaction times and longer glances to the road, respectively.

Most of the participants felt the secondary task impaired their driving performance, but the feedback (retrospective only and combined) enhanced their driving performance. Drivers also seemed to accept the feedback, finding the trip-report useful. Drivers who received no feedback, perceived more risk and also had worse driving performance than the drivers who received feedback.

Young Drivers' and Parents' Attitudes to Black Box Technology

A wide ranging USA review¹² of monitoring systems included three focus groups with young drivers and three with parents to gather views on the role of parents in monitoring young drivers, and their reactions to in-vehicle technology options.

Parents' Views

Parents were interested in this technology because they wanted to monitor their children's driving behaviour, especially during their initial probationary licensing phase, and thought the devices could be a useful learning tool to help modify and improve driver behaviour. They were most in favour of monitoring whether their children were speeding, drinking and driving, using seat belts, and using mobile phones. However, they also respected their children's privacy, and did not want to spy on them. They were concerned about how monitoring technology could affect the level of trust in their relationship with their child, and how the data could be used by insurance companies and law enforcement agencies, or used against them or their children in court. They had varying opinions about real-time tracking systems, with some believing it would be too intrusive and would not teach correct behaviour.

Parents were interested in paper reports or reports available by downloading from the device using a USB drive, but many were concerned that information on the internet could be hacked or stolen. They anticipated reviewing the reports often at first and then slowly tapering off as the child's driving improved. They generally supported the use of summary reports, but were less interested in video recordings, primarily due to concerns that it would further distract the young driver. Some thought that it was unnecessary, although others thought that it would add context to the other recorded information. They did not like the idea of a professional driver trainer reviewing the clips, although some would be willing to try such a system for free. Parents were also worried that audible alerts would cause further distractions in an already difficult driving environment.

Parents would prefer to rent a device rather than purchase it because they felt it should only be used for a limited time while young drivers are still learning good driving, and wanted to be able to stop using it if they felt that it was not suitable for them. They thought that young drivers would accept the use of such devices more easily if they were required by law.

Young Drivers' Views

The young drivers initially did not like the idea of monitoring devices in their vehicles, and did not favour technology that tracks and notifies parents about the vehicle's location, although they recognised that their parents might appreciate such a system. They thought a system which allows real time location of the young driver was extremely undesirable, and that real-time information would not be useful since parents do not have time to constantly monitor their children. They also raised the issue of trust.

Young drivers did not want driving reports to go to parents, but if they did, they wanted them to represent what the young drivers see as "real" safety issues and offer opportunities to discuss what took place and explain the circumstances. They believed their parents would be interested in information on seat belt use, speeding, and unsafe driving, and that their parents' reactions to the information would include discussions, nagging, questions, no fuel money, suspension of driving privileges, and requiring more driving practice.

The young drivers thought that any system that requires internet or email use might prove difficult as their parents are not computer-literate, and the effort of logging onto a website and reviewing the data would be too cumbersome for their parents. They also believed that the feedback reports should not be issued so frequently as to be annoying. They did not like the idea of video recordings, but some admitted that their parents may be interested in them, and they considered audio recordings an even greater infringement on their privacy and felt that they would serve no purpose. They did not see commentary by a professional driver trainer as useful since they could interpret the data themselves. They thought that real time driver feedback in the form of audible alerts would be problematic, as the sounds might be both startling and easily ignored.

They also thought that the cost of the systems would be prohibitive and so the parents would not be interested.

A phone survey of parents of young drivers¹³ known to a road safety organisation in Israel interviewed 200 parents of young drivers (ages 17 to 24) who were still learning but had not passed their test, 358 parents of young drivers who had held a driver's licence for up to three months (and so could only drive when accompanied by an experienced driver), and 348 parents of young drivers with a driving licence between three and six months and so could drive unsupervised.

The vast majority (85%) of parents said they would like to know how their young driver was driving; only 6% said they were not interested. Approximately 30% of the parents said they were not concerned or only slightly concerned about their son or daughter's driving, about 34% said they were moderately concerned, and 40% reported being either "very" or "extremely" concerned. More mothers expressed concern than fathers.

Most (80%) said they would be willing to install the technology in the vehicles driven by their children, but if there was a cost, the number decreased, although approximately half still said they would be willing to do so. However, nearly a fifth (19%) said they were certain they would not install the technology if there was a cost, and 8% said they did not know. If there was a cost to using the technology more parents of male young drivers said they would be "certainly" willing (25.6%) than parents of females (17.4%). Parents who were more concerned about their son's or daughter's driving were more likely to be willing to install the technology, even if there was a cost.

Most parents (69%) thought installing the technology would increase the need for parents to be involved in their son's or daughter's driving, because they would be exposed to "*what is going on*" and consequently they would:

- not be able to ignore the information but would feel obligated to react to it
- receive objective information based on facts and data rather than on opinion
- be able to see a larger picture of the young driver's driving and things about their driving that they could not have known before
- need to attend to the issue over time and on a regular basis.

Parents listed three main factors that would encourage parents to install the technology:

- it can serve as a 'monitor'
- it can help the parent–young driver relationship
- it can enhance the driving safety of the young driver and of others.

The concerns about installing the technology were that it would:

- infringe the young driver's privacy and erode their self-confidence
- prevent parents from "learning to let go" or giving their son or daughter the independence they need
- create a lack of trust in the parent–young driver relationship
- diminish parental confidence in their son/daughter
- be unnecessary if there is understanding and trust between parents and young drivers
- reduce parents' obligations
- not address important factors that can distract young drivers
- not be used by parents.

About half of the parents said that cost would be a barrier "to a large extent" (22%) or "very large extent" (32%) to installing such technology. Almost half 42% were very concerned about outside sources getting the information to a great extent (24%) or a very great extent (17.7%). About a quarter expressed concerns about infringement of privacy or surveillance of the young driver. Additional concerns included needing to use the internet to receive the feedback, learning things about their son or daughter, having to confront them, or that their son or daughter will want to find out how they themselves have been driving.

Most (86%) parents thought both parents and the young driver should have access to the young driver's data. Only 8% thought only the young driver should, and 3% that only the parents should. Parents who thought that only the young driver should get the feedback said it would encourage the development of personal responsibility, independence, and self confidence, and would help them learn from their own mistakes, promote safer driving habits through internal commitment rather than external pressure, and not infringe their privacy.

Parents who thought that parents should also get the data thought that it was their responsibility to know about their child's driving and to influence him or her to avoid endangering lives. They also felt young drivers could not be completely trusted and might not tell them if something dangerous happened.

When the telematics device detected that a young driver is driving unsafely, over half (60.6%) of parents thought that parents should be informed, over one third (37%) said that the young driver should be warned first and if no change took place, then parents should be informed, and 2% thought parents should not be informed.

About half (52%) of the parents said that the whole family should see the parents' driving data, 27% said only the parents should see it, and 17% said both the parents and the young driver should see it.

This study found a difference in attitudes between parents who supported the technology and those who opposed it. Those who opposed it said parents need to enable their child to have responsibility and independence, that it would erode their confidence and that parents need to let them make their own mistakes. Those who supported the technology believed it should be installed as part of parental obligations and that it would serve as a trigger for better communication between parents and the young drivers. However, the concern and dilemma about infringing the young drivers' privacy was shared by most parents.

An interesting finding was the depiction of parents as purposely "ignorant" about their child's driving as a way to avoid thinking about the risks. They said the technology would force parents not to be oblivious and to be more realistic and proactive. The report recommended that resources to help parents communicate better with their young driver about their driving should be developed.

Another interesting finding was that most parents were willing to have their own driving data available to the young driver, indicating that the technology could improve the parents' driving as well. This could have important implications because young drivers' driving practices have been found to be influenced by their parents' driving.

Another study¹⁴ of parents and young drivers who had used In-Vehicle Data Recorders in their cars were interviewed about their experiences. Interviews were also conducted with parents who had originally agreed to install the technology but then did not do so.

Both parents and young drivers saw the technology as a tool that could improve the young driver's skills by helping them to learn about their patterns of driving behaviour. Young drivers thought that it could be a tool for checking themselves and to help correct what they called "small errors."

Both parents and young drivers believed the technology could help restrain their tendency to drive too fast, reduce reckless driving, and help young drivers resist being influenced by their peers. Some young drivers said that without the technology they might have driven more wildly, and some said that it helped them to cope with temptations to drive less carefully. Parents thought the technology helped to reduce the potential negative influence of peer pressure when other young people are in the vehicle.

Although the technology could create tensions in the young driver-parent relationship, both parents and young drivers viewed it as a means to improve communication. Parents said it presented an opportunity to open a dialogue with their children about driving. Some young drivers said the technology could enable young drivers to show their parents how they drive.

A recurring theme from both parents and young drivers was that the feedback from the technology provided "objective" data about the young driver's driving, and so could reduce friction that may arise from differing opinions about how the young driver is driving. Parents saw it as a means to support their pleas for the young driver to drive more safely, whereas young drivers saw it as a means to prove they drive safely and can be trusted.

The main advantage given by parents was that it enabled them to know how the young driver is driving when they begin to drive independently. Some said that once the period in which the young driver must, by law, be accompanied, is over, they felt a lack of opportunity to teach their children more about driving, and the technology could virtually extend the accompanied driving period. However, parents emphasised it would be wrong to use the technology as a tool to check when their children came home, so its potential use as a monitor was also seen as a disadvantage.

Young drivers thought the technology could improve their self confidence by giving them positive feedback on their driving, especially when given in "real time" when the driver is driving alone. They also said that the technology enables them to get positive feedback and reinforcement from their parents, and helps them feel their parents can trust them as drivers.

The connection of the feedback with computer technology was considered a great advantage by most of the young drivers, but they also suggested it would be useful to receive the feedback via other media, such as text messages or even graphs to their mobile phone (not while driving).

Both parents and young drivers felt that privacy was a major drawback of installing the technology, but young drivers were much more emphatic about it. Among the young drivers there was a strong feeling of ambivalence about the technology, even when they noted its advantages. Some perceived it as putting them under constant supervision, while some said they did not mind being monitored.

Both parents and young drivers were concerned about erosion of trust and tensions associated with using of the technology. Some parents said that although they installed the technology they did not want to use it because they believed it would sabotage the relationship between them and the young driver. Young drivers said installing the technology can suggest to them that their parents do not trust them. They noted that tensions emerged when the technology was perceived as a means to supervise young drivers, especially in families where there was not much trust between the parents and their children. It may be that such tensions could be reduced or avoided if the technology was introduced as part of the young driver's motor insurance.

Both parents and young drivers felt that the technology was limited in the kind of safety-factors it measured, and that it did not address important factors such as keeping a safe distance or avoiding hazards. This might mean that parents and young drivers limit their discussion to the parameters measured by the technology. Some young drivers thought the technology's feedback did not provide answers but only highlighted problems.

Some young drivers and their parents said that they had "figured out" how to drive in a manner that prevented the technology from detecting that they drove in a way that was not considered to be safe. In other words, they learned how to circumvent some of its parameters. Some said they would attempt to try to circumvent it for their own amusement, and gave examples how they did it without being 'caught.' However, the report did not provide any details about how they had done so.

Some parents said that they often did not check the data because it required logging on to a computer, and some of them would have preferred getting the feedback through other channels and in other formats, such as verbal summaries.

Parents felt that they were unable to use the technology effectively as a means to improve the driving skills of the young driver because either they did not adequately understand the data or did not know how to use it to improve their child's driving. They felt that they needed guidance before the technology is installed and throughout the monitoring period. Some did not know how to give feedback that would actually impact on the young driver's driving safety. A recurring concern was what to do when the feedback indicated unsafe driving, with some parents choosing not to confront the young driver with the data.

Some young drivers said they got different, sometimes contradictory, feedback from each parent about their driving. Some suggested that parents who check the feedback all the time could get "paranoid." Some young drivers reported their parents "rarely" checked the feedback, or when they did, it was superficially. In some families discussions about the feedback were limited or took place long after the incidents took place. Both parents and young drivers reported that by the time they bothered to check, the feedback was no longer relevant because it was related to events that occurred months before.

Parents who did not install the technology

There were two main reasons for not installing the technology: practicality in that it was not convenient to do so, or they were concerned it might harm the vehicle, and strong objections from the young driver.

In interviews following one of the trials the study⁷, most of the parents involved felt the monitoring system improved the teenager's driving and almost all (98%) would recommend the device to parents of another teenage driver. When asked how they felt about having the device in their vehicle, more than half of the young drivers who had audible in-vehicle alerts described the alerts as "annoying." Those with website notification only were only slightly happier, but 83% of teenagers with in-vehicle alerts and 81% of those with website notification only thought the device was effective at improving their driving.

Interviews in 2006 with 923 parents of 16 and 17 year old teenagers who were taking their driving test¹⁵ in three American States with differing Graduated Driver Licensing systems found that almost all the parents planned to supervise their teenager's driving after they had gained their driving licence, usually by accompanying them on drives and requiring them to gain permission to use the car. Many also planned to impose restrictions on night-time driving and on carrying passengers. Parents most wanted to know whether their child was speeding, driving while distracted or inattentive or using a mobile phone while driving.

Depending on the State, 37% to 59% of the parents had heard about in-vehicle monitoring devices, but only 2% - 6% knew someone who had installed such a device. The main reason they would consider using one was to know what was happening in the vehicle (54% - 78%). Only a few parents (2% - 13%) said it was because the devices would improve the young drivers' driving. The most frequent reason for parents saying that they would not use in-vehicle monitoring devices was that they trusted their young driver (49%-77%) or that it would be an invasion of their privacy (3%-65%). Cost was another concern.

They were less in favour of devices that included cameras than computer chip devices or cell phone GPS devices, and when asked which type of device they would install, cell phone GPS was the most favoured, followed by computer chip and video cameras.

Summary of Young Drivers and Black Box Technology Research

Effect on Driving Behaviour

Several studies have found various positive effects on driving behaviour.

Pay-As-You-Drive insurance with a financial incentive and feedback on driving reduced speeding by young drivers by 14%. It was more effective at reducing speeding on 50, 80 and 100 km/h roads, which are the roads with the highest fatality rates.

An Event Data Recorder in the cars of young drivers with in-vehicle alerts and website feedback to parents, resulted in a 76% reduction in the rate of safety-relevant events. Most of the improvement was among the higher risk young drivers.

In-Vehicle Data Recorders (IVDRs) which provided data to a website for young drivers and their parents to access, resulted in a substantial decrease in average risk ratings of the young drivers, but the risk ratings of the young male drivers (not the female drivers) increased back again once the feedback ceased. Only half of parents and just over one quarter of young drivers accessed the feedback. Young drivers' risk ratings fell when their parents monitored their driving behaviour, but increased, although not significantly, when they checked their own driving records.

Rates of sharp braking and acceleration of 16 and 17 year old drivers reduced by 12% to 43% by a monitoring device, with in-vehicle alerts and immediate or conditional website notifications to their parents. Failure to wear a seat belt fell by up to 90%, but speeding was not reduced. Parents rarely visited the websites to view the analysis of their children's driving, and email prompts to do so did not increase visits, but did provide some of the information the parents would have seen on the website.

A visual in-vehicle alert resulted in less frequent driver glances to an MP3 display and longer glances to the road ahead, but did not affect braking times or steering. A visual alert and a report after the drive, resulted in faster reaction times and longer on-road glances.

In-vehicle alerts and online feedback reduced the risk rates of the young drivers, but only when their parents accessed the driving reports and discussed them with their children. Only half of parents accessed the web analysis and only one quarter of the young drivers did so.

Attitudes to the Technology

Parents

- want to monitor their children's driving, especially during their initial high risk period
- think the technology could help them do so and to improve their children's driving
- are most in favour of monitoring speeding, drinking and driving, using seat belts, and using mobile phones
- think the technology would increase their involvement in their children's driving
- think it is helpful that the driving information is based on facts and data
- would be willing to install the technology in vehicles driven by their children, but less so if there is a cost
- but respect their children's privacy and are concerned about how the technology could affect their relationship with their child, that it might erode their self-confidence and prevent parents from "learning to let go" or to give their child independence
- are concerned about how the data could be used by insurance companies and law enforcement agencies, and that information on the internet could be hacked or stolen
- are worried that audible alerts would distract the driver

- anticipate reviewing the reports often at first and then less so as the child's driving improves
- may not check the data if it requires logging on to a computer, but generally support summary reports, and are less interested in video recordings
- think they should be informed when the device detects a young driver is driving unsafely, although some think the young driver should be warned first and only if no change took place, should the parents be informed
- feel unable to use the technology effectively to improve the driving of the young driver because they do not understand the data or know how to use it, and are concerned about having to confront their son or daughter
- feel they need guidance on how to give feedback and what to do when the feedback indicates unsafe driving.
- may be concerned that their children will want to find out how they, the parents, are driving
- would prefer to rent a device rather than purchase it.

Young Drivers

- often do not like the idea of monitoring devices, but recognise that their parents might
- feel the technology could improve their driving and help them check themselves and correct "small errors."
- help restrain their tendency to drive too fast, reduce reckless driving, and help them resist being influenced by their peers
- feel the devices could improve their self confidence by giving them positive feedback on their driving, especially when given in "real time" when they are driving alone
- believe the devices could enable them to get positive feedback and reinforcement from their parents, and help them feel their parents can trust them as drivers
- think the "objective" data about their driving could reduce friction about the way they drive
- believe their parents would be interested in information on seat belt use, speeding, and unsafe driving
- do not want driving reports to go to parents, but if they do, want them to represent what they see as "real" safety issues and offer opportunities to discuss what took place and explain the circumstances.
- believe their parents' reactions would include discussions, nagging, questions, no fuel money, suspension of driving privileges, and requiring more driving practice.
- Sometimes receive different, even contradictory, feedback from each parent about their driving
- think a system that requires internet or email use might prove difficult for their parents
- think audible alerts can be both distracting and easily ignored.
- think the cost of the systems would be prohibitive and so the parents would not be interested
- feel the technology does not address important factors such as keeping a safe distance or avoiding hazards, and might limit discussions to the parameters measured by the technology
- think the technology's feedback needs to provide answers not just highlight problems, and that it would be useful to receive it via other media, such as text messages or even graphs to their mobile phone (not while driving).

EMPLOYERS AND AT-WORK DRIVERS

In-vehicle telematics are used by a growing number of employers for their fleet vehicles, perhaps more commonly for vans and large vehicles, but also for cars. Typically, they monitor fuel use, mileage and location with many also being used to monitor speed, harsh braking, cornering and acceleration. Some also use the technology to monitor efficiency issues, such as whether an engine is left running while the vehicle has stopped to make a delivery. Employers can use the data to identify management approaches to reducing risk and/or improving efficiency, such as changing schedules and routes, providing driver training, and if necessary, instigating disciplinary action.

Several, but not all, studies suggest that in-vehicle monitoring can help employers and at-work drivers to reduce their crash rates when driving for work.

A major study¹⁶ involving 840 vehicles, 270 of which were fitted with either an Accident Data Recorder (ADR) or a Journey Data Recorder (JDR), in 11 different fleets assessed whether this improved driving behaviour and reduced accident risk. The drivers were told if a recorder was fitted in their vehicle and that its prime purpose was to help them to adapt their driving behaviour. Drivers in vehicles fitted with a recorder were compared with drivers in similar vehicles not so equipped. Accident data for the 12 month period before the equipment was installed was compared to the data during the period that the recorders were installed. The vehicles were divided into 7 groups (A to G) with vehicles fitted with a recorder being matched with one or more control groups.

During the study period, the 840 vehicles, 270 of which were fitted with monitoring devices were involved in 1,836 road accidents. The effects of the monitoring devices varied between the groups.

Group A was 110 heavy trucks in an international transport company fitted with ADRs and matched with 50 similar trucks in the company and 105 similar vehicles from another similar company that were not fitted with an ADR. Accident rates for vehicles fitted with an ADR increased by 13%, although this was not statistically significant.

Group B was 25 medium and heavy trucks from two distribution companies fitted with ADRs and matched with 188 trucks from the same companies and 76 from other companies that were not fitted with an ADR. Accident rates for vehicles fitted with an ADR reduced by 17%, although this was not statistically significant.

Group C was 25 coaches from three different fleets owned by a tour operator fitted with JDRs and matched with 50 coaches from another company that were not fitted with a JDR. Accident rates of the vehicles fitted with a JDR reduced by 42%, which was statistically significant.

Group D was 54 taxis and vans fitted with ADRs and matched with 66 taxis and vans from another company not fitted with an ADR. The accident rates for the taxis and vans fitted with an ADR increased by 54%, although this was not statistically significant.

Group E was 23 company cars from an insurance company fitted with ADRs and matched with 21 private cars without an ADR used for work purposes in the same company. Accident rates for the cars fitted with an ADR reduced by 3%, although this was not statistically significant.

Group F was 23 coaches of a tour operator fitted with ADRs and matched with 9 coaches without an ADR from the same company. The accident rates of the coaches fitted with an ADR reduced by a statistically significant 72%.

Group G was 10 taxis operating in a large city fitted with ADRs and matched with 5 taxis without an ADR operating in the same city. Accident rates were not given in the report.

Overall, when adjusting for confounding factors, the accident rate for vehicles fitted with a monitoring device reduced by 20%. When compared to vehicles without ADRs in their own company, the overall accident reduction for ADR vehicles was 31%. When compared to vehicles without ADRs in their matched external company, the overall accident reduction for ADR vehicles was 12%, not statistically significant. The study did not examine the feedback provided by managers to the drivers, so it is not possible to say whether the feedback itself had any effect.

One study¹⁷ investigated how information from in-vehicle monitoring technology can be used to analyse the behaviour of a single, individual driver, "David", who worked as a technician in a large commercial company, driving a company car to customer locations to install or repair communication equipment. All the vehicles in the fleet were fitted with an in-vehicle feedback and monitoring technology designed to provide drivers and managers with feedback on their driving behaviour. It provided real-time monitoring of extreme braking and accelerating, sharp turning and sudden lane changes. A web application provided feedback about these driving events to drivers and safety officers.

The monitoring device was installed in David's car for 1,054 days from 13 September 2006 to 1 August 2009, during which he used the car on 877 days for 5,704 trips, 126,443 driving minutes; he committed 6,878 undesirable driving events during this period. Feedback was not provided during a baseline period of September to December 2006, but was provided from the beginning of 2007.

David's driving improved over time. At the beginning of 2007, his event rate for an average trip was 1.293, but had reduced by a statistically significant 82% by the beginning of 2008. The rate for the average trip by the beginning of 2009 was -0.640 fewer than in 2008.

As David was a company car driver, his behaviour during and outside working hours was compared. His event rate was 26% lower on weekends and 29% lower when driving in leisure time, possibly because his work-time driving was in more difficult conditions (e.g. more traffic and time pressures during work hours).

A review of case studies¹⁸ of companies that have used Accident Data Recorders found that:

- A school bus operator in the United States fitted half of its school bus fleet with a black box and compared it with the other half of the fleet that were not fitted with a black box. The buses without a black box accounted for 72% of the fleet's accidents over a six month period. The authors concluded that 19 accidents were prevented by the use of the black boxes, which resulted in a saving of \$76,000 in vehicle repair costs.
- A 1997 German study based on information from 42 real accidents involving vehicles fitted with an Accident Data Recorder showed the ADRs increased the degree of certainty in identifying what had caused the accidents to as much as 100%, compared with traditional sources of information when investigating accidents.

- After Berlin Police fitted ADRs to 62 squad cars in 1996 the number of accidents due to the driver's own fault fell by 20% and by 36% on emergency-trips. Costs savings were approximately 25%. Berlin Police subsequently fitted more than 400 of their squad cars with ADRs.
- WKD Pinkerton Security GmbH fitted approximately 100 pool company cars with ADRs, following which their accidents decreased by 30%, minor damage accidents by 60% and led to considerable savings in insurance premiums.
- A German bus operator fitted ADRs in 123 buses, following which the number of accidents decreased by between 15% and 20%.
- Nine vehicle fleets in Great Britain, the Netherlands and Belgium with a total of 341 vehicles were fitted with data recording equipment as part of the SAMOVAR (Safety Assessment Monitoring on Vehicles with Automatic Recording) Project. Over a 12 month period the accident rate decreased by 28%.

Two trials were conducted in America to test whether an in-vehicle monitoring device improved the driving of ambulance drivers. Both found that there was a dramatic and sustained improvement in driver performance, without any increase in response times. Costs savings more than paid for the monitoring equipment.

In the first trial,¹⁹ a metropolitan Emergency Medical Services (EMS) group installed an in-vehicle monitoring device, which monitored speed, hard acceleration and braking, cornering, use of emergency lights and sirens, use of front seat belts, indicators and the hand brake, in 36 ambulances. It provided real time auditory feedback to the driver with warning 'growls' when pre-set parameters were approached and penalty tones when they were exceeded. Penalty counts were recorded when drivers exceeded certain parameters and downloaded daily for analysis. Electronic reports were generated for the drivers and their managers.

In phase I (3 months) of the study, initial data was collected but no auditory feedback was given to the drivers and drivers were not identified; in Phase II (3 months), auditory feedback was given to the drivers, but individual drivers were not identified; in Phase III (12 months) auditory feedback was given to the drivers and drivers used electronic key fobs so the system could identify which driver was driving the ambulance.

Over the 18 month period, the ambulances covered over 1.9 million miles, during which seatbelt violations dropped from 13,500 in April 2003 to 4 violations in August 2003 by which time the audible alerts were being used, and were sustained at low rates to June 2004, a 3,375 fold reduction in seat belt violations. Similar trends were seen with speeding events.

The number of violations increased in the second month of phase 1, probably because at the start of the study the drivers were initially very aware about the monitoring device and so drove more carefully, but during the second month, with the device remaining silent, they became less attuned to its presence, and their driving performance deteriorated, showing a large peak in violations in all the parameters measured. Once the audible tones were switched on in phase II, there was a dramatic improvement in safety performance. The maximum improvement occurred in Phase III, when driver identification via the key fobs was implemented.

Overall driving performance improved from a baseline of 0.018 miles between penalty counts (>56 counts/mile) to a high of 15.8 miles between penalty counts, an 878 fold safety proxy improvement.

There were two steep declines in performance, the first of which was due to one driver who had been identified as performing poorly, and was reassigned, and the second was attributed to an additional parameter being introduced into the data captured and the vehicles also being driven by mechanics.

There was only one minor vehicle accident in over 1.9 million miles of driving, and fewer and less severe crashes than in the preceding similar time periods. The detailed data captured in this crash enabled the company to refute an allegation that the ambulance had made an unscheduled stop on the way to the hospital.

There was a 20% cost saving in vehicle maintenance in the first six months, with 10% to 20% less brake and tyre wear and reduced oil consumption. This cost saving alone, not including any savings in accident costs, decreased vehicle damage, and reduced staff time investigating accidents, covered the cost of implementing the system.

The second trial²⁰ was almost identical to first one, but took place in a different area of America and with a different ambulance service. In this trial, in-vehicle monitoring recorders were installed in 20 ambulances over a 24 month period. The same three phases were used as in the first trial: Phase I (5 months) in which data was captured but no auditory feedback given to the drivers and no driver identification, Phase II (13 months) during which auditory feedback was given to the drivers, but drivers were not identified and Phase III (8 months) in which the system was fully operational with auditory feedback and driver identification. The speed and seat belt tolerances were more stringent than the previous trial meaning they triggered penalty counts sooner.

In this trial, the 20 ambulances covered over 950,000 miles, during which overall driver performance improved dramatically from high rates of speed infringements, and high rates of not using seat belts. The most dramatic improvement was the reduction in speeding penalty counts, with a reduction from 14.94 penalties/mile in Phase I to 0.00003 penalties/mile in Phase III.

Seatbelt violations dropped from 4.72 violations per mile in Phase I to 0.001 violations per mile in Phase III and continued to be sustained thereafter, a 4,000 fold reduction in seat belt violations.

There were 19 vehicle incidents in the whole of 2004 (the monitoring devices were not installed until November 2004), 11 in 2005 and no major vehicle crashes during the fully implemented phase of the study period. Savings in vehicle expenses amounted to almost quarter of a million dollars a year, and as in the first trial, more than covered the cost of installing and using the monitoring devices. There were also cost savings from fewer crashes, decreased vehicle damage, reduced accident investigation costs and insurance savings.

Both trials found a sustained and dramatic improvement in safety performance and safety proxies with the use of this type of onboard driver monitoring and feedback system. Once the audible tones were switched on, there was a dramatic improvement in safety performance, and introducing driver identification resulted in the maximum improvements.

In both studies, before the devices were installed, extensive consultation was conducted with staff to explain the technology and the rationale and potential benefit of its implementation, The system was well received by the staff, and there was no interference with, or damage to, the systems or the monitoring or feedback equipment.

Both reports stated that in other regions in the USA where this technology had been implemented there were claims of up to 90% reductions in crash rates, but did not provide references for these reports.

A study²¹ in which an IVDR was installed in 191 small vans in a single company concluded that initial exposure to the feedback caused a substantial reduction in driver risk ratings, which is further enhanced if drivers continue to access the feedback over time. In this study, the company vans were driven by staff who were not employed as professional drivers but whose job required them to drive significant mileages to service locations. The drivers, 189 males and 2 females, were aged 25 to 68 years, with an average age of 41 years.

During the first 8 weeks of the study, immediately after the IVDR was installed, the drivers were told about the device, but did not receive any feedback about their driving, and were told that the data would not be used by their managers. At the end of this period, the drivers were called to a meeting in which they learned more about the IVDR, received initial feedback on their own driving, and access to a website where they could view their own data and average data for the whole fleet. Real-time feedback in the vehicle was not provided.

After the IVDRs were installed, crash rates per 10,000 driving hours fell by a statistically significant 38% (from 6.30 per 10,000 hours driving to 3.91). However, at fault crash rates only fell by about 5% (from 3.26 per 10,000 hours driving to 3.10), possibly because there were only a small number of at-fault crashes in total. Crash rates for all company vehicles (about 1,200) fell by about 19% over the same period.

Driver risk ratings fell by 33% in the first month that drivers received feedback from the IVDR, and then stayed at similar levels for the rest of the seven month feedback period.

A project²² to evaluate a commercially available onboard safety monitoring (OBSM) system among truck drivers, involved the installation of two video cameras and three accelerometers for 17 consecutive weeks during which the drivers made their normal deliveries. During a four week baseline phase, the device recorded safety-related events, but the feedback light on the device was disabled and safety managers did not have access to the recorded safety-related events to provide feedback to drivers. During the 13-week intervention phase, the feedback light on the OBSM device was activated and safety managers had access to the data and followed the coaching protocol with drivers (when necessary).

Carrier A significantly reduced their mean rate of recorded safety-related events/10,000 miles travelled by a statically significant 37%. Carrier B significantly reduced the mean rate of recorded safety-related events/10,000 miles travelled by 52%. The authors concluded that these results suggest the combination of video monitoring and behavioural coaching was responsible for the reduction in the rate of safety-related events.

A 2003 summary of current practice in commercial truck and bus safety management techniques,²³ including a literature review and a survey of 139 commercial vehicle safety managers and 57 other experts, concluded that in-vehicle monitoring technology was underused in truck and bus transport given its safety potential.

The survey gathered information on the use of, and views about, both in-vehicle monitoring devices (with management feedback to the drivers) and Event Data Recorders that only recorded the data if an 'event' occurred. Only 36% of safety managers in the survey reported using in-vehicle monitoring technology, and they rated its effectiveness compared with other methods as relatively low, Safety managers rated it 18th of 28 possible solutions, and the other experts rated it 16th. Ironically, they rated the overall practice of crash, incident, and violation tracking as highly effective, but did not highly value this particular method.

Only 24% of safety manager respondents used EDRs in their fleets, and gave them relatively low ratings for effectiveness. Again, it was ironic that 83% of safety managers practised conventional crash and incident investigation and rated it highly in effectiveness.

The authors concluded that a major obstacle to more widespread use of the technology is driver acceptance. They suggested one way to address driver privacy concerns would be to give drivers greater control over the handling and disposition of the data. An approach might be to make the driver the sole “owner” of the monitoring data; by providing feedback to the driver without management review to encourage the drivers to adopt self-management methods to improve their safety performance levels. They also recommended emphasising positive feedback and rewards (including financial rewards) for safe driving behaviours rather than punishments for unsafe behaviours. For example, the data could be used to exonerate a driver following an incident, and systems that include vehicle tracking provide extra security, with some including a “panic button” for drivers to alert dispatchers if necessary.

Other challenges identified in the survey were data archiving, downloading, reduction, and analysis, which is often difficult. If not done frequently, the data becomes “stale” and less useful. Another weakness was that poor safety performance (e.g., speeding) may be more apparent in the data than good performance, which might bias the process toward negative assessments and punitive actions toward drivers.

A literature review²⁴ suggested that there are several benefits of in-vehicle data recorders for commercial fleet operations, including:

- documenting specific behaviours that might lead to crashes, incidents, or traffic violations and thereby provide an opportunity for proactive corrective feedback
- providing objective, timely, and frequent feedback to drivers and managers
- drivers receiving positive feedback and rewards for good behaviours (possibly structured to reinforce group or fleet-level achievements)
- setting benchmarks for driving behaviours to establish company expectations
- replacing time consuming ride-along observations
- improving productivity and efficiency, as well as compliance with regulations
- identifying situations where liability is a concern.

However, the review concluded that further research and development was needed to:

- identify and validate the driving behaviours that may be precursors to crashes or injuries
- identify the most effective ways to provide feedback that encourages safe behaviour and discourages unsafe behaviour
- establish management and driver acceptance of the technology.

The authors noted that organisations can also benefit by using the aggregated data from multiple drivers and vehicles to, for example, inform route planning and scheduling at a corporate level.

The review noted that several studies have found positive effects from the use of in-vehicle monitoring devices, but some had also found that the effects were not sustained. It recommended that strategies to promote continued engagement in the use of the technology be developed. It also noted some evidence that sub-groups of drivers might account for the majority of triggering events and that these sub-groups would benefit the most from these types of monitoring systems.

Case Studies

Case studies of the use of telematic technology by various companies are published online. Although they have not been validated and published in research reports, they show positive benefits of using in-vehicle monitoring technology. However, case studies with unfavourable results may be less likely to be published.

A mobile phone company²⁵ installed 'black box' technology in 20 vehicles in 2005, and in a further 250 company cars in 2006. Immediate feedback was given to the driver through a dashboard-mounted display or by optional SMS or Email messaging, and drivers were also encouraged to log on to their individual website to analyse reports of their driving. A "Safety Stars" incentive points-based programme rewarded employees for improving the way they drive.

This resulted in a marked change in driver behaviour in the first 6 months of 2007 with an 18% reduction in road traffic accidents and a cost reduction of 23%. The trial more than paid for itself, with a £417,000 saving in vehicle damage costs and a 3% (£20,000) reduction in fuel costs in a 12 month period. In addition, there were improvements to staff sickness rates and a significant reduction in the administrative work associated with processing road crash information. Overall, the company achieved a 49% reduction in vehicle repair costs in 2007 in comparison with 2006. Crash rates fell by 20% over the same period. There was evidence that employees had modified their driving behaviour as the rate of "unsafe manoeuvres" per 10 hours of driving fell from 81 in 2006 to 41 in 2007.

A transport company,²⁶ fitted 'on-board computers' to its vehicles found that it resulted in a significant reduction in the cost of motor vehicle accidents, a 14% improvement in fuel efficiency, a 14% decrease in insurance premiums in 2010 and another 14% in 2011. Vehicle downtime was "greatly" reduced, and driver turnover fell considerably.

A company²⁷ fitted a telematics product to 360 vehicles in the UK and Ireland to enhance defensive driving techniques and road safety. Results showed a 15% increase in MPG across, a 13% reduction in risky driving incidents and a 14% reduction on its insurance premium for 2011.

A major bus operator,²⁸ fitted telematics to 9,000 buses in the UK and Ireland, after a trial showed a significant decrease in emissions and unnecessary driving manoeuvres. They experienced a 70% decrease in unnecessary driving manoeuvres, a 5% improvement in fuel-efficiency, 8.4% reduction in passenger injuries and a 6.3% reduction in collisions.

In 2008, a large company²⁹ that had fitted telematics to its vehicles experienced a two-thirds drop in risky manoeuvres in three months.

Another company³⁰ experienced a 72% reduction in driver risk and a 49% reduction in accidents and a 10% reduction in fuel costs, following the introduction of telematics in its fleet.

A passenger transport company³¹ found that 75% of its participating operators showed measurable improvements, reducing their fleet risk by 77%, with a 71% reduction in risky driving and a 100% conversion of high-risk drivers to "medium" or "low" risk.

A bus and coach operator³² with a fleet of 37 buses and coaches providing local services, school trips, private hire and continental travel, started using telematics in 2010. This boosted fuel economy by 11%, reduced insurance claims by 50% and reduced by excessive manoeuvres by 60%.

An online delivery company³³ experienced a 10% fuel saving in a pilot of black box technology fitted to their vans to improve Road Safety and improve fuel efficiency.

Some case studies report reactions to the introduction of the technology rather than accident or financial results.

The Fleet Management Unit of a Local Authority³⁴ decided to procure a telematics system and consulted its "user stakeholders", who generally saw benefits to them of such a system. However, these mainly revolved around the ability to track vehicles locations, rather than to monitor and improve driving standards. The anticipated benefits included being able to:

- Allocate jobs to the nearest driver, saving fuel and time.
- Improve Health and Safety, especially for lone workers.
- Improve customer service, with more accurate Estimated Time of Arrival
- Analyse routes, resulting in fuel and time savings.
- Lower insurance premiums
- Resolve disputes about illegal parking.

A fire safety services company³⁵ found a positive reaction to the introduction of telematics from its drivers with most drivers seeing it as an important training aid.

Summary of At-Work Drivers and Black Box Technology Research

In-vehicle telematics are used by a growing number of employers for their fleet vehicles, perhaps more commonly for vans and large vehicles, but also for cars. Several, but not all, studies suggest that in-vehicle monitoring can help employers and at-work drivers to reduce their crash rates when driving for work.

A major study involving hundreds of vehicles in 11 different fleets found that overall the accident rate for vehicles fitted with a monitoring device reduced by 20%. However, the effects varied between the fleets with four fleets showing a statistically significant reduction in accident rates, three showing a reduction that was not statistically significant and three showing an increase in accident rates that was not statistically significant.

A study following a single, individual driver who had a monitoring device fitted in his vehicle and access to feedback about his driving, that his event rate for an average trip reduced by a statistically significant 82%.

A review of case studies of companies that used Accident Data Recorders found that:

- IVDRs in a USA school bus fleet prevented 62 accidents over a six month period, and saved \$76,000 in vehicle repair costs.
- A German study of 42 real accidents showed that ADRs increased the degree of certainty in identifying what had caused the accidents to as much as 100%.
- Accidents involving police cars due to the driver's own fault fell by 20% and by 36% on emergency-trips. Costs savings were approximately 25%.
- ADRs fitted to company pool cars resulted in a 30% decrease in accidents and a 60% decrease in damage only accidents.

- Accidents in German bus fleet decreased by between 15% and 20%.
- Over a 12 month period, the accident rate decreased in nine vehicle fleets in Great Britain, the Netherlands and Belgium fell by 28%.

Two trials in America found that installing in-vehicle monitoring devices into ambulances resulted in a dramatic and sustained improvement in driver performance, without any increase in response times. A 20% saving in vehicle maintenance costs in the first six months more than paid for the monitoring equipment.

In the first trial, there was a 3,375 fold reduction in seat belt violations, and a similar trend with speeding. Once the audible alerts were switched on in the vehicle there was a dramatic improvement in safety performance and an even greater improvement when a driver identification system was used.

The second, almost identical, trial in a different area of America and with a different ambulance service found very similar results. The most dramatic performance improvement was the reduction in speeding, and a 4,000 fold reduction in seat belt violations.

After the IVDRs were installed in a fleet of small vans, crash rates fell by a statistically significant 38%. However, at fault crash rates only fell by about 5%, possibly because there were only a small number of at-fault crashes in total. Driver risk ratings fell by 33%.

A study to evaluate a commercially available onboard safety monitoring system in two truck fleets found that the rate of recorded safety-related events/10,000 miles in the first company fell by a statically significant 37%, and in the second company by a statically significant 52%.

A USA summary commercial truck and bus safety management techniques concluded that in-vehicle monitoring technology was underused given its safety potential. A major obstacle was driver acceptance; other challenges were handling and analysing the data and ensuring the technology was not used just to focus on negative assessments and punitive actions.

A range of published case studies of the experience of various companies that have used telematics show positive results in reducing accidents, accident costs, vehicle and fuel costs and risky driving behaviours. However, these case studies have not been published in research reports and case studies showing less favourable results may not be published.

Notes about the Research

Much of the research about the use of this technology with young drivers was conducted in countries, such as the USA, Israel and Australia, with significantly different driver licensing systems than the UK. These countries have varying forms of graduated driver licensing systems (which impose restrictions on unaccompanied driving after the driving test) and often permit young people to drive at earlier ages than in the UK. This may mean that parents are able to exert a greater influence on their children's first years of driving than is possible for UK parents.

It should also be noted that the in-vehicle monitoring systems used in some of the studies were specifically produced for the study in question and were not commercially available systems.

In common with much road safety education and training research, few of the published reports had rigorous experimental designs.

DISCUSSION: KEY ISSUES

Feedback

The most prominent issue that emerges from the research is the importance of feedback about the driving behavior monitored by the technology. Feedback is designed to raise awareness of the real way someone is driving (which they may not fully realise) and to highlight particular types of driving behavior that may increase risk, so the driver can reduce the number of times they commit such infringements, and/or be helped by others to do so. As drivers often overestimate their ability, feedback can help to calibrate their perceived performance (i.e., how safe they think they drive) with their actual performance.

Much of the research shows that driving behavior improves once the driver and/or a third party begin to receive feedback. However, the research provides little detail about the content and nature of the feedback, making it more difficult to assess the most effective ways of using this feedback.

Feedback is provided in a number of different ways, which can be broadly divided into immediate in-vehicle feedback to the driver and retrospective feedback, after a journey has ended, to the driver and/or a third party, such as a parent or a manager in the driver's company.

Immediate (real-time) in-vehicle feedback has the advantage of being able to alert a driver that they are driving in a way that is exceeding safety parameters (speeding, for example) and give them the opportunity to change the way they are driving and so reduce the risk of being involved in an accident during that journey. It can be provided in various ways, the most common of which are audible alerts and visual displays. Other, less common, methods include head-up displays and tactile feedback, such as vibrations in the steering wheel.

However, feedback in real-time must not increase risk by distracting or confusing the driver, especially when they may already be driving poorly or in difficult circumstances. In-vehicle visual displays (information on a screen or flashing LED lights) should be designed to avoid the risk of distracting the driver's attention away from the road (some of the research studies have found that simple visual alerts do not distract the driver). Audible alerts could startle or annoy drivers, if for example, they are too loud and abrupt, and so need to be designed to avoid this risk. Conversely, they still need to be prominent enough not to be missed or easily ignored by the driver.

Retrospective feedback is most often provided in the form of reports which can be accessed on a website or through other online media, such as emails or a mobile phone app. It may refresh the memory of critical incidents during the trip, or draw the driver's attention to something they did not even realize they were doing. It can encourage self-reflection and understanding of the degree to which particular types of driving increases their risk, and in the case of Pay As You Drive type insurance policies, increase the cost of their motor insurance premiums.

Very often, in addition to the driver, other people have access to the feedback, especially parents and managers. Many of the research studies that examine the role of feedback have found that simply providing access to feedback about a driver's driving behavior is not enough in itself to ensure that the driver, and especially the parents of young drivers, view and consider it. Some studies have found that less than half of parents view the data and analysis about their child's driving, even though they are concerned about the risks their child faces.

Therefore, to obtain the best safety benefits from in-vehicle monitoring technology, it will be important to design and develop feedback delivery mechanisms that encourage the drivers and relevant other people to view and use the feedback. Several surveys have identified concerns about the security of this type of individual driver data online, with fears that it might be stolen or hacked. Some have also found that the process of logging onto a website discourages some parents from doing so regularly, and many young drivers in the studies believe that using online communication methods is too cumbersome for their parents.

Aside from the issue of how often the feedback is accessed, the published literature rarely provides much detail about the content and nature of the feedback itself – the level of detail given, how it is presented and what advice is given to help the driver or other person to understand it. Some of the studies do suggest that a balance is needed between how much information is provided – too little and it is not useful, but too much and it is daunting. The literature also identifies that guidance is needed, especially for the parents of young drivers, on how to use the feedback. Interviews with parents who have had in-vehicle monitoring devices fitted in vehicles driven by their children have found that many do not know what to do with the feedback, how to communicate with their child about it and are concerned about having to confront their child about some aspects of their driving. One study even identified that some parents prefer to remain ‘purposefully ignorant’ about their child’s driving to avoid conflicts with them.

The research literature about both young drivers and at-work drivers is almost entirely absent of any details about actions taken as a result of the feedback about driver behavior. One of the USA trials with ambulances resulted in one poorly performing driver being assigned to other duties, and some of the young driver studies indicate that parents may restrict driving privileges, although this is in countries that have graduated driver licensing schemes and which allow people to drive at younger ages than in the UK, so it may not be as feasible for UK parents.

However, there is potential for a much wider range of responses to be based on the feedback. For example, employers might change the driving task (amend journey schedules) or provide tailored driver education or training that focuses on the specific issues raised by the data for each individual driver. Young drivers and parents might take extra driving practice or professional lessons that focus on the specific issues raised by the data for the individual driver.

Research is needed to identify the most effective ways of designing, developing and delivering feedback about the driving data produced by the telematic devices, to:

- Encourage drivers and other to regularly view the feedback
- Understand what the feedback means
- Use the feedback to improve the driver’s behavior and reduce their risk

The retention of feedback also needs further investigation. It has been suggested that one way to enhance the retention of feedback may be to provide cumulative feedback, in the form of a comprehensive summary of past driving performance and driver behaviour.³⁶ This may help drivers to assess their overall driving performance by highlighting persistent behaviours that lead to errors.

Cost

Cost is an issue for both the insurer and the policyholder (and parents in the case of young drivers).

In addition to the normal costs of providing motor insurance, an insurer must be able to cover the cost of providing the telematics service to a policyholder and still make a profit on the insurance policy. The costs usually include:

- The device itself
- Installing the device in the vehicle
- The method of providing feedback (for example, a website)
- Providing a discount on the insurance premium
- Removing the device from the vehicle when it is no longer wanted, or possibly switching it to another vehicle if the policy holder swaps vehicles.

It is difficult for insurers to be able to cover the additional costs of the telematics service for most drivers, who pay annual motor insurance premiums of a few hundred pounds, and still make a profit on the insurance premium. However, for young, novice drivers, who pay annual motor insurance premiums of thousands of pounds, it is more likely that insurers can cover the cost of the telematics service, offer an attractive discount on the premium (for those drivers who merit it) and still make a profit. This is one of the reasons (in addition to the fact that young drivers make more claims, and more expensive claims) for telematics insurance in the UK being largely targeted at young drivers.

However, several studies have found that even when the advantages of using this type of technology are accepted, the cost of installing and using it deters some parents and employers from doing so. Such concerns could be addressed by keeping any initial costs to a minimum and, and helping potential users to understand how any costs will be more than covered by reducing other costs, such as insurance premiums, fuel, damage and accident costs, and so there would be a financial benefit to them. It may be that as the technology improves and becomes more widespread, the cost will reduce.

One study found that some parents would prefer to be able to rent an in-vehicle monitoring device, rather than purchase it, because this would give them more flexibility to stop using it if they felt it was no longer necessary or that it was not helping them or their young driver.

Data Privacy/Access

A common concern about the use of in-vehicle monitoring technology is data privacy, with all the key groups (young drivers, parents and at-work drivers) being concerned about who might have access to their driving data and how they may use the data. A particular concern is the risk of the data being used against the driver, in court, for example. Other concerns include that too many agencies may be able to access the data and use it for their own purposes.

Data Ownership and Portability

There are issues around data ownership and data portability that need to be clarified. For example, drivers may find it very useful to be able to use the data collected about their driving when seeking competitive insurance quotes from a range of different insurance companies. This would be much easier if there were common data standards used across the insurance industry, but at the moment there are no agreed industry standards (except for raw GPS data).³⁷

This is a contentious issue within the insurance industry due, in part, to the tension between insurance companies who wish to retain their customers rather than make it easier for them to switch to another insurer and insurance aggregators (eg, price comparison websites) who want to help customers compare insurance deals and switch between companies.³⁸ Those opposing data standards argue that it is too early to set standards and more experience of the use of telematics, with many more drivers over a longer time period, is needed first.

Another potential advantage of data portability is the possibility that a person could use the description of their driving and risk rating produced by the telematics software when applying for jobs that involve driving. This would help employers to assess driving ability and risk during recruitment and provide an advantage to job applicants who were able to provide objective evidence of their safe driving.

What to Monitor

Most of the devices monitor similar types of driving behaviour, which are associated with increased crash risk. Typically, these are:

- Journey start and finish times
- Vehicle speed
- Vehicle location
- Acceleration
- Braking
- Cornering
- Seat belt use
- Fuel consumption.

Some systems also provide video of the external road and traffic environment and/or inside the vehicle itself, to provide contextual details surrounding the driving and an indication of what the driver is doing (not wearing a seat belt, using a mobile phone).

Delivering the Technology

Retro-fitted Device (Black Box)

Until recently, in-vehicle monitoring required a telematics device (a 'black box') to be retrofitted in the policy holder's vehicle, which meant that the insurer had to cover the cost of the telematics software, the physical device which housed it, and fitting the device into the vehicle (and possibly removing it later). These costs are in addition to the cost of developing the insurance product itself and the substantial investment in new IT systems to collect, store and analyse the driving data from the device, and the customer service costs of providing feedback to the policy holder. The logistics of installing the device in the vehicle can also be a barrier for insurers, young drivers and employers.

Smartphone Ap

Several insurance policies now use smartphones, rather than a 'black box', to deliver the telematics capability. This is considerably less expensive for the insurer because it removes the need for, and so the cost of, a physical device being retro-fitted into the driver's vehicle. This lower cost may make it easier for insurance companies to offer telematics-based motor insurance to all drivers, not just young ones.

As well as delivering the telematics software, apps can also deliver the feedback about the driving recorded by the software. They may also be a way of identifying the driver as they will be the owner of the smartphone, although this is not foolproof as the phone could be loaned to another driver.

However, there are some clear dis-advantages. Firstly, it requires the driver to own a smartphone in the first place, although the ownership and use of smartphones is increasing massively. Secondly, it requires the phone to be switched on while the driver is driving, which may increase the risk of the driver using the phone for other purposes, which would distract the driver and increase their risk of crashing. Thirdly, drivers may try to cheat the system by, for example, not switching the telematics function on for journeys where they think their driving may be worse than normal (eg, if they are late) or switching it on when they are a passenger being driven by a more experienced driver (eg, a parent) to 'fool' the system into thinking that they are driving (this would actually be insurance fraud).

Insurers will need to carefully monitor the use of smartphones for telematics insurance and develop safeguards against mis-use and unintended consequences that actually increase risk. These risks may be mitigated by making it clear to the driver that they should not use the phone while driving and making sure they understand that the monitoring technology will detect if they do so, and report this in the feedback.

Policies that use smartphones have clear rules about not using the phone for other purposes while driving, and always using the telematics function when driving. The driving data should indicate if a driver is being distracted by using the phone for other purposes because the distraction will affect their driving. The data may also be able to show if a different driver is driving because the driving pattern will be different. However, insurers may need to develop technological solutions that prevent the phone being used for other purposes and/or which more clearly identify the driver.

Original Equipment

The most reliable method of delivering the telematics technology would be for it to be built into vehicles as original equipment at the point of manufacture, either voluntarily by vehicle manufacturers or compulsorily required by regulations.

In 2006, the National Highway Traffic Safety Administration (NHTSA) introduced a regulation standardizing the data collected by EDRs, which are voluntarily fitted in most new vehicles, from September 2013. This required the EDRs to record 15 data elements for the seconds immediately before and during a crash, including vehicle speed and deceleration, driver seatbelt use, and whether the brakes were applied. The NHTSA is expected to introduce a regulation to make EDRs mandatory on all new cars and light vehicles sold in the USA from September 2013, although most US vehicles are already fitted with them. EDRs record technical vehicle and occupant-based information for a few seconds before, during and after a crash, and so are fundamentally different to the type of black box being introduced by UK insurers.

In Europe, E-Call (a technology that automatically sends the location of the vehicle to the emergency services in the event of a crash) will become mandatory on all new vehicles by 2015.³⁹ In a crash, an eCall-equipped car automatically calls the emergency services, resulting in quicker medical care for the victims, which it is estimated will save hundreds of lives. This uses much of the same technology as telematic devices, but it only sends a signal in the event of a crash, to alert the emergency services and direct them to the vehicle's location. There are no current plans to introduce mandatory in-vehicle monitoring as original equipment in European cars.

Driver identification for Multi-Driver Vehicles

It is important that any in-vehicle monitoring system is able to identify who is driving the vehicle, so that the driving behavior data it produces can be correctly assigned to the specific driver who was driving the vehicle at the time. This is particularly important in the case of young drivers driving a car that other family members also drive, and for employers with fleet vehicles that are driven by more than one member of staff.

It is possible that where the telematics function is being provided via a smartphone app, the phone could be a way of identifying the driver as they will be the owner of the smartphone, although this is not foolproof as the phone could be loaned to another driver.

Other Groups of Drivers

Although the research into, and the use of, in-vehicle monitoring technology has so far almost entirely been restricted to young, novice drivers and to at-work drivers, it has the potential to be used by, and improve the safety of, all drivers. Specific groups for whom this technology may be especially useful include older drivers and offenders.

Socio-Economic Issues

It is well established that people from lower socio-economic groups face a disproportionately higher risk on the road, and one of the reasons for this is that they are less able to afford newer, safer products. This disadvantage may also apply to the adoption of in-vehicle monitoring technology, especially if it requires ownership of a smartphone. Conversely, if telematics motor insurance results in discounted insurance premiums, such policies may become more affordable for drivers on lower incomes.

Research Tool

Although it is outside the remit of this paper, a common use of in-vehicle monitoring technology is to record and analyse the real-life driving of particular groups of drivers for research purposes. The USA "100-Car Naturalistic Driving Study"⁴⁰ is a good example of this.

Road Safety Engineering

Another potential advantage of this technology is that large amounts of (anonymised) data produced from its widespread use could help road safety engineers to identify locations on their road networks which are more likely to suffer accidents, and so enable them to take remedial measures.

Effect on higher risk drivers

A particularly interesting finding from some of the research studies is that most of the driving risk created by a particular group of drivers (for example, young novice drivers) may be created by a small sub-group, who are much higher risk than the rest of the group. When drivers in a higher risk sub-group use in-vehicle monitoring technology, they improve their driving and reduce their risk to such an extent that their risk levels come down to that of their lower risk counterparts.

CONCLUSION

In-vehicle monitoring (black box) technology is rapidly increasing in the UK, with many different forms of this technology now available. Essentially they monitor how, when and where a vehicle is being driven, record the data and provide an analysis of it as feedback to the driver and/or other parties. Some also provide in-vehicle alerts if pre-set parameters are exceeded (for example, hard acceleration).

The driving behaviours that are monitored are ones which influence the likelihood of the driver crashing (for example, speed) or the severity of the crash (for example, seat belt use). These are proxies for crash and injury risk, and monitoring a driver's propensity to indulge in such behaviours enables the technology to calculate a risk rating for that driver. It also, potentially, enables measures to be identified that may reduce the driver's crash risk.

In-vehicle monitoring technology has the potential to provide a wide range of safety benefits, including:

- relatively inexpensive and continuous measurement of driving behaviour and vehicle use, which is otherwise difficult to observe
- significantly more accurate and objective data about driving than, for example, responses to self-reported questionnaires
- a tool for employers to monitor and assess their staff who drive for work, improve safety, reduce crash rates and operational costs, meet their legal obligations and reduce the risk of prosecution or civil action
- a way to help young, novice drivers, parents and licensing authorities to monitor and improve the driving of young, novice drivers
- a method for insurance companies to differentiate between drivers based on their risk, rather than just by gender or age, and to tailor their insurance premiums accordingly
- a powerful research tool to enable large amounts of real-life, natural driving behaviour and the effectiveness of safety interventions on that behaviour
- a tool to inform further training and guidance needs
- data to help highway authorities to identify problem locations on their road network.

Until recently, the monitoring technology has been contained in a small device (a 'black box') fitted in the vehicle, or in software embedded in another device, such as a SatNav. A more recent development is for the technology to be provided via smart phones, which must then be switched on in the vehicle. While this is less expensive, because it avoids the cost of producing and installing a physical box in the vehicle, it may raise the risk of the phone being used for other purposes while driving, and the data may not be as accurate if the phone is left behind for some journeys.

The technology is principally used by two groups: motor insurers and the (young) drivers they insure, and employers and their staff who drive for work.

Young Drivers and Black Box Technology

Several studies show that in-vehicle monitoring can significantly reduce risky behaviours, especially among the most risk-prone young drivers. However, the published literature does not yet quantify the reduction in crash or insurance claims rates for young novice drivers. The research does show that young drivers are more likely to improve their driving when the feedback from the monitoring technology is being viewed by their parents. However, some studies found that only around half of parents actually do view the feedback.

Attitudinal studies have found that parents want to monitor their children's driving, especially during their initial high risk period and think this technology could help them do so. However, they also want to respect their children's privacy and are concerned about how the technology could affect their relationship. They are also concerned about how the data could be used by other agencies, and that information stored online could be hacked or stolen.

Reflecting the findings in the behavioural studies that many parents do not access the feedback about their children's driving, the attitudinal studies indicate reasons for this: many parents do not understand the data or how to use it, and are concerned about having to confront their son or daughter about their driving. They feel they need guidance on how to give feedback and what to do when the feedback indicates unsafe driving.

Attitudinal studies found that young drivers often do not like the idea of monitoring devices, but recognise that their parents might do so. They recognise that the technology could improve their driving and help them to correct "small errors", restrain their tendency to drive too fast, and help them to resist being negatively influenced by their peers. They feel it could improve their self confidence by giving them positive feedback on their driving, based on "objective" data rather than parental opinions.

But they feel the technology does not address important factors such as keeping a safe distance or avoiding hazards, and that the feedback needs to provide answers not just highlight problems. They want feedback to cover what they see as "real" safety issues and offer opportunities to discuss what took place and explain the circumstances. Young drivers think a system that requires internet or email use might prove difficult for their parents and that the cost would be prohibitive for their parents.

It should be remembered that most of these studies took place in countries where the young driver/parent relationship may be different than in the UK because these countries permit people to drive at a younger age and have graduated driver licensing systems which already impose some post-test restrictions on new drivers.

At-Work Drivers

Telematics is used by a growing number of employers, perhaps mostly in vans and large vehicles, but also in cars. Employers can use the resulting data to identify management approaches to reducing risk and/or improving efficiency, such as changing schedules and routes, providing driver training, and if necessary, instigating disciplinary action.

Several studies suggest that in-vehicle monitoring can help employers and at-work drivers to reduce their crash rates when driving for work. Some studies have found that accident rates for vehicles fitted with a monitoring device reduced by 20%, others found a reduction of 38% in accidents and the rate of specific unsafe driving behaviours reduced by up to 82% in one case. However, the effects have varied between fleets with most showing a reduction in accident rates, but some showing a small (but not statistically significant) increase.

Trials in America with in-vehicle monitoring devices fitted into ambulances found a dramatic and sustained improvement in driver performance, without any increase in response times. Savings in vehicle maintenance costs alone more than paid for the monitoring equipment, without taking into account other cost savings, such as fewer accidents. Surveys of commercial truck and bus safety management in the USA concluded that in-vehicle monitoring technology was underused given its safety potential. A major obstacle was driver acceptance; other challenges were handling and analysing the data and ensuring the technology was not used just to focus on negative assessments and punitive actions.

Feedback

The most prominent issue that emerges from the research is the importance of feedback about the driving behavior monitored by the technology. Much of the research shows that driving behavior improves once the driver and/or a third party begin to receive feedback, but provides little detail about the content and nature of the feedback.

Feedback is provided in a number of different ways, mainly immediate in-vehicle feedback to the driver and/or retrospective feedback (to the driver and/or a third party, such as a parent or a manager in the driver's company) after a journey has ended. Given the evidence that many parents do not view the feedback about their children's driving, and the lack of detail about the exact nature of the feedback and how it is used, more research is needed to identify the most effective ways of designing, developing and delivering feedback, to encourage drivers and others to:

- Regularly view the feedback
- Understand what the feedback means
- Use the feedback to improve the driver's behavior and reduce their risk

Other Groups of Drivers

Although the research into, and use of, in-vehicle monitoring technology has so far been almost entirely restricted to young, novice drivers and to at-work drivers, it has the potential to be used by, and improve the safety of, all drivers. Specific groups for whom this technology may be especially useful include older drivers and offenders.

Data Privacy/Access

Concerns about data security and who can access the data and for what purposes still need to be resolved as these concerns appear to be a significant barrier to the wider acceptance of the use of in-vehicle monitoring technology.

Data Ownership and Portability

Issues around data ownership and data portability need to be clarified. In particular, drivers would find it very useful to be able to use the data collected about their driving when seeking competitive insurance quotes from different insurance companies, or when applying for jobs that involve driving. The latter would also help employers to manage their occupational road risk by enabling them to assess driving ability and risk during recruitment.

This would be much easier if there were common data standards used across the insurance industry, which is not the case at the moment.

Driver identification for Multi-Driver Vehicles

It is important that any in-vehicle monitoring system is able to identify who is driving the vehicle, so that the driving behavior data it produces can be correctly assigned to the specific driver who was driving the vehicle at the time. This is particularly important in the case of young drivers driving a car that have other family members also drive, and for employers with fleet vehicles that are driven by more than one member of staff.

Cost

Cost is another barrier to the acceptance of in-vehicle monitoring technology. Such concerns could be addressed by keeping any initial costs to a minimum and, and helping potential users to understand how any costs will be more than covered by reducing other costs, such as insurance premiums, fuel, damage and accident costs, and so there would be a financial benefit to them. It may be that as the technology improves and becomes more widespread, the cost will reduce.

Delivering the Technology

Until recently, in-vehicle monitoring required a device (a black box') to be retrofitted in the policy holder's vehicle, which meant that the insurer had to cover the cost of the telematics software, the physical device which housed it, and fitting the device into the vehicle, in addition to the cost of developing the insurance product itself and the substantial investment in new IT systems to collect, store and analyse the driving data from the device, and the customer service costs of providing feedback to the policy holder. This level of cost makes it more difficult for insurers to introduce telematics-based insurance policies, with the result that they tend to be targeted at young drivers with high premiums. The logistics of installing the device in the vehicle can also be a barrier for insurers, young drivers and employers.

Recent developments in which the monitoring technology is provided as a downloaded app in a smart mobile phone reduce the cost of using the technology because it does not require a physical device to be installed (and possibly taken out later) in a vehicle. However, this means that the phone needs to be left switched on while the vehicle is being driven, which may tempt some drivers to use it as a phone. This risk can be mitigated by making it clear to the driver that they should not use the phone while driving and making sure they understand that the monitoring technology will detect if they do so, and report this in the feedback. Insurers need to develop solutions that prevent the phone being used for other purpose and/or which more clearly identify the driver.

The most reliable method of delivering the telematics technology would be for it to be built into vehicles as original equipment at the point of manufacture, either voluntarily by vehicle manufacturers or compulsorily required by regulations. It will be mandatory for EDRs to be fitted in cars and light vehicles sold in the USA from September 2013, and in Europe, E-Call will become mandatory on all new vehicles by 2015. However, neither of these devices record driving behaviour on an ongoing basis, and there are no current plans to introduce mandatory in-vehicle monitoring as original equipment in European cars.

Socio-Economic Issues

In a related issue to cost, consideration needs to be given to reducing the likelihood of certain groups, for example, people from lower socio-economic groups, being unable to benefit from in-vehicle monitoring technology.

Final Summary

The use of in-vehicle monitoring technology is increasing very rapidly in the UK. It has great potential to significantly improve driving standards and reduce crash and casualty rates. Currently, it is largely restricted to two groups, young, novice drivers and at-work drivers, but could also be used with other groups of drivers, and perhaps eventually be standard technology in all vehicles. There are knowledge gaps that need to be filled in order to achieve the maximum road safety benefits from this technology. These include identifying the most effective:

- type of feedback to provide to drivers and those who influence them
- ways of delivering that feedback
- ways to use the feedback to help drivers further reduce the risks they face and create on the road.

Practical issues also need to be resolved, in particular, the:

- development of common data standards, data access, privacy and portability
- cost of providing the monitoring technology
- the implications of providing the technology via smartphones.

RECOMMENDATIONS

Feedback

Research and development should be conducted to identify the most effective ways of providing feedback to drivers, and others, such as parents and employers. This should address:

- Immediate in-vehicle feedback to the driver in ways that the driver will notice and easily understand, without being distracted.
- Retrospective feedback to the driver in ways that the driver can easily understand.
- Retrospective feedback to third parties, such as a parent or a manager in the driver's company, in ways that they can easily understand.
- How best to deliver retrospective feedback to drivers, parents and employers, such as emails, apps, web reports.
- How best to encourage drivers, parents and employers to regularly access retrospective feedback when it is provided.
- The most effective content and nature of retrospective feedback, including the level of content, language and the inclusion of positive advice, rather than just warnings about poor driving.
- How best to enhance the retention of feedback, for example by providing cumulative feedback, in the form of a comprehensive summary of past driving performance and driver behaviour.

Actions Based on the Driving Data

Research and development should be conducted to identify the most effective ways of using the driving data to design methods of helping drivers to improve their driving, and other methods of reducing their driving risk. This should address:

- Guidance and tools for parents to help them use the driving data and analysis to discuss the issues it raises with their children and to help them to improve their driving.
- Guidance and training for employers to help them interpret and use the driving data and analysis to address any issues it raises with their drivers and to help them to improve their driving.
- Guidance and training for employers to help them to implement management solutions, such as a change to journey schedules or vehicles.

Delivering the Technology

Research should be conducted to identify the most effective methods of delivering in-vehicle monitoring technology to different groups of drivers. This should address:

- How best to reduce the costs and logistical dis-advantages of fitting (and where necessary, later removing) retro-fitted devices.
- The relative advantages and dis-advantages of using smartphone apps to deliver the telematics capability, including the reliability of the driving data.
- The possibility of the technology being fitted in vehicles at the point of manufacture, either voluntarily by vehicle manufacturers or required by regulations should be investigated.
- Insurers should carefully monitor the use of smartphones for telematics insurance and develop safeguards against mis-use and unintended consequences.

Data

- Concerns about data privacy (i.e., who might have access to the driving data and how they may use it) need to be addressed to reassure potential users.
- Issues around data ownership and data portability need to be clarified. For example, drivers should be able to use the data collected about their driving when seeking competitive insurance quotes from a range of different insurance companies, or when applying for jobs that involve driving.
- Common data standards should be developed across the insurance and telematics industries.

Driver identification for Multi-Driver Vehicles

- Telematics providers should ensure that their in-vehicle monitoring systems are able to identify who is driving the vehicle, so that the driving behavior data can be correctly assigned to the specific driver who was driving the vehicle at the time.

Other Groups of Drivers

- Research and development should be conducted into the use of in-vehicle monitoring technology for other groups of drivers, and ultimately for all drivers. Specific groups for whom this technology may be especially useful include older drivers and offenders.
- Further research should be conducted into the findings from some early studies that higher risk drivers are likely to benefit the most from the use of telematics and may reduce their risk to the levels of lower risk drivers.
- The ability of drivers from lower socio-economic groups to access the telematics should be investigated, to ensure that drivers who may already face disproportionately higher risk on the road, are not excluded, and so further dis-advantaged.

Road Safety Engineering

- The potential advantages of this technology to help road safety engineers to identify higher risk parts of their road networks should be investigated.

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