

Road Safety Research Report No. 95

**Scoping Study of Driver
Distraction**

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October 2008

Department for Transport: London

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ISBN 978 1 906581 24 4

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EXECUTIVE SUMMARY

Driver distraction is an increasing phenomenon which is not completely understood. This report was commissioned to understand the state of knowledge on driver distraction and lay some groundwork for future distraction research efforts, with the strategic aim of improving safety through policy interventions. The main objectives of the project were:

- to prepare a definition of driver distraction and secure at least UK agreement on its adoption;
- to summarise and critically review research on driver distraction from sources both within and outside the vehicle and to identify gaps in knowledge; and
- to provide recommendations for future research and for monitoring changes in the impact of driver distraction.

A core and wider reference group of scientists who are research-active in the area of driver distraction were identified at the beginning of the project to review the work and participate in workshops. A distraction definition discussion document was then produced, along with a distraction review document. These were circulated among the reference groups and discussed during two workshops. The first workshop resulted in an agreement on the definition shown in Box 1.

Box 1: Definition of driver distraction

Diversion of attention away from activities required for safe driving due to some event, activity, object or person, within or outside the vehicle.

Note 1: safe driving requires monitoring of the road and traffic environment (which includes pedestrians and other road users) and control of the vehicle.

Note 2: safe driving also requires an appropriate degree of attention and vehicle control to maintain a reasonable safety margin allowing for unexpected events.

Note 3: types of distraction may be visual, auditory, biomechanical or cognitive, or combinations thereof.

A distraction review was compiled to provide some background information and references on humans as information processors, the concept of attention, theories of driving, and metrics and methods used to assess distracted driving performance. The review then broadly categorises observation-based, experimental and opinion-based research. The review concluded the following:

- Estimates of the role of driver distraction in accident causation can vary widely due to the lack of a standardised definition and inconsistencies in accident reporting. Nevertheless, a study of naturalistic driving behaviour found that inattention contributed to 78% of accidents (Neale *et al.*, 2005).
- External distractions (e.g. from outside persons, objects, events) are the most frequently reported cause of distraction-related accidents (Stutts *et al.*, 2001). Nevertheless, research on the effects of distraction by sources external to the vehicle and passengers within the vehicle appears to be scarce.
- Driving performance decrements have been shown as a result of distraction by mobile phones, in-vehicle information systems (IVIS), in-car entertainment (ICE) and email systems, as well as advertising billboards, variable message signs (VMS) and other distractors.
- Study results indicate that drivers themselves are poor judges of their performance decrements while driving (Horrey *et al.*, 2007).
- The lack of a standardised assessment methodology or baseline against which to compare distracted driving performance leads to difficulties in making relative judgements without designing an experiment to include all variables of interest.
- The current state of knowledge is not sufficient to confidently identify ‘high-risk’ groups for driver distraction; however, age and gender differences have been found when examining distracted driving performance.
- Research has been conducted on drivers’ attitudes towards engagement with distractors. For example, the results of a Canadian survey (Insurance Bureau of Canada, 2006) suggested that 89% of Canadians were very or somewhat concerned about driver distraction; but 60% of drivers would not agree to stop using their mobile phones while driving. Nevertheless, attitudes can change with time and periodic monitoring may be beneficial.

The research gaps identified through the process of reviewing distraction-related literature were discussed during the second workshop. These were:

- measuring driving performance degradations, and the impact of these on crash risk, from specific distractors outside of the vehicle;
- measuring driving performance degradations caused by people and other non-technological distractors within the vehicle, in real situations;
- the relative effects on driving performance and interaction effects of in- and extra-vehicle distractors, including current and emerging technologies;
- measuring the effects of different IVIS interface designs on driving performance (including modality/multi-modality, layout, menu complexity, etc.);
- the cumulative and interactive distracting effects of a combination of in-vehicle

technologies (including IVIS, ICE, Advanced Driver Assistance Systems, etc.) and the ‘cost’ of task-switching;

- the frequency and duration of drivers’ actual use of the different functions of in-vehicle technologies (e.g. texting, the internet, email functions of mobile phones) and of multiple functions or technologies, and the impact of this on risk during real-world driving;
- understanding the distinction between sensory and perceptual distractors (e.g. ‘looked but failed to see’ accidents);
- identification of high-risk groups for distraction (e.g. elderly drivers, business drivers, younger drivers) and the effects of distractors on these groups;
- drivers’ knowledge of the effects of distracted driving, their attitudes towards engagement with distractors and factors which would motivate drivers or different groups of driver to change their behaviour;
- the relationship between the findings of experiments (in terms of driving performance degradations) and actual near-miss or crash rates due to distractors;
- quantification of the role of distraction (or individual distractors) in accident causation based on existing crash data, hence the cost to society of distracted driving and related crashes;
- the development of a standard, meaningful, objective and reliable test procedure and baseline to identify ‘unacceptable’ levels of visual distraction (potentially in real time);
- the development of a standard, meaningful, objective and reliable test procedure and baseline to identify ‘unacceptable’ levels of cognitive and auditory distraction (potentially in real time); and
- the identification of best practice to monitor the effects of distracted driving (e.g. accident rates, driver behaviour and attitudes) over time.

This workshop concluded that:

- research gaps could be grouped in terms of methodology, and multiple gaps could potentially be tackled at once (see Appendix 1);
- initially, the nature of the problem could be characterised – this could be done from accident studies and surveys/focus groups on perceptions and attitudes;
- as well as gathering information on the current effects of distraction, it is important to identify, at an early stage, developments in the driving environment and form a strategy to tackle the potential effects of these;
- opportunities exist to collaborate in European-level projects (e.g. naturalistic driving studies), and many of these are starting in summer 2008; and

- European projects draw on expertise across EU countries and share the cost of the research across member states. Often this enables European projects to be of a larger scale and to make greater scientific advances than may be feasible with the resources of an individual state. Thus, contribution to a large-scale European naturalistic driving study would enable some of the research gaps identified during this project to be filled in a cost-effective way.

1 INTRODUCTION

In early 2007, the Department for Transport held a workshop on driver distraction. The workshop concluded that driver distraction is an increasing and developing global phenomenon which is not completely understood nor documented. The workshop recommended a comprehensive and co-ordinated approach to tackling the problem of driver distraction (Sampson, 2007).

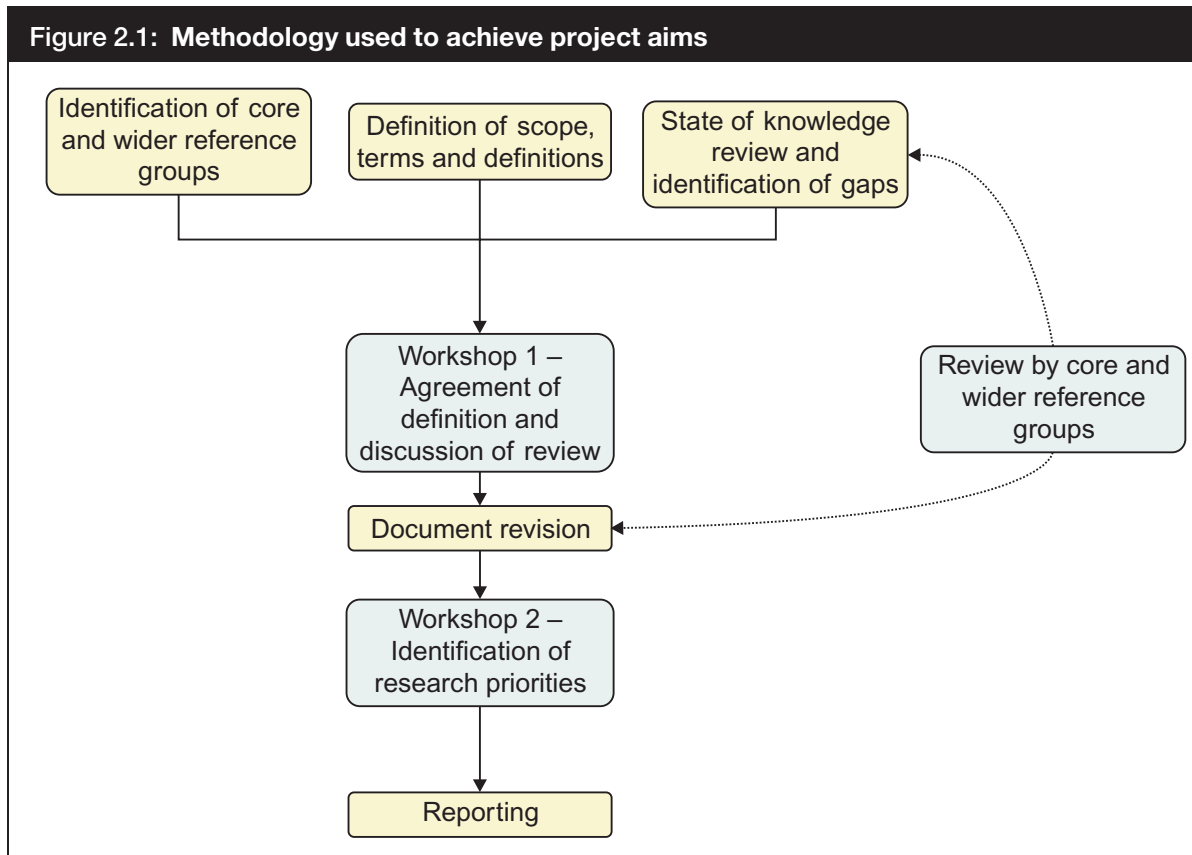
The work described here follows from this and was commissioned to capture the state of knowledge on driver distraction with the strategic aim of improving safety through policy interventions. The main objectives of the project were:

- to prepare a definition of driver distraction and secure at least UK agreement on its adoption;
- to summarise and critically review research on driver distraction both within and outside the vehicle;
- to identify gaps in knowledge;
- to provide recommendations on ways to monitor changes in the impact of driver distraction on road traffic accidents; and
- to propose a programme of future research.

Section 2 of this report summarises the methods used to achieve these aims. Section 3 provides a high level background to distraction-related concepts and broadly summarises research in the area of driver distraction. Section 4 then presents the conclusions of an expert workshop and the agreed definition of driver distraction. Sections 5 and 6 summarise research gaps in the field of driver distraction and the outcomes of a further workshop which aimed to prioritise these research gaps.

2 METHODOLOGY

Figure 2.1 outlines the methodology and approach taken towards achieving the aims set out above.



2.1 Identification of core and wider reference groups

In order to secure wide agreement on the adoption of a definition of driver distraction and to propose research priorities, influential professionals working in this area were consulted.

The core group comprised six of the most influential UK experts (later joined by Professor Mike Regan who has recently edited an international book on driver distraction) who were selected as being research-active in the scientific area of driver distraction:

- Professor Oliver Carsten, Leeds University;
- Professor Andrew Parkes, TRL;
- Associate Professor Mike Regan, MONASH University;
- Dr Alan Stevens, TRL;

- Dr Terry Lansdown, Heriot-Watt University;
- Dr Gary Burnett, Nottingham University; and
- Mr Mark Fowkes, MIRA.

These experts acted as an external reference group in order to validate the work and supplement it with additional suggestions and perspectives. They also attended the workshops and contributed to the project deliverables. Dr Alan Stevens acted as expert moderator during the sessions.

A wider reference group was also given the opportunity to remotely review and comment on outputs from the project. These included:

- Professor Neville Stanton, Brunel University;
- Professor John Groeger, Surrey University;
- Professor Geoff Underwood, Nottingham University;
- Mr John Richardson, Loughborough University;
- Professor John Lee, University of Iowa, USA;
- Dr Helen Dudfield, Qinetiq;
- Mr Rob Gifford, PACTS;
- Dr Joanne Harbluk, Transport Canada;
- Professor Hirano Kawashima, Keio University, Japan;
- Dr Peter Burns, Transport Canada;
- Dr Michael Pettitt, University of Nottingham;
- Dr Johan Engstrom, Volvo, Sweden; and
- Dr Trent Victor, Volvo, Sweden.

2.2 Definition of scope, terms and definitions

Initially, a document was produced by TRL which outlined a number of discussion points which were thought to be key in the process of defining driver distraction. A definition was proposed at the end of the document which was then sent to members of the core and wider reference groups for comments. Their feedback was collected and discussed in the first workshop (see Section 2.4).

2.3 State of knowledge review and identification of research gaps

The aim of the distraction review was to summarise research on driver distraction and to identify gaps in knowledge. The review was not intended to be comprehensive in terms of depth but rather to provide a broad categorisation of what is well researched, and to suggest where there are obvious gaps.

A first draft of the review document was sent to members of the core and wider reference groups for comments, and a revised version was re-circulated after Workshop 1. This review is presented in Section 3 of this report.

2.4 Workshop 1: agreement of definition and discussion of review

A workshop was held at the Department for Transport premises at Great Minster House with key members of the TRL project team, the core reference group and Department for Transport representatives. The aims of the workshop were:

- to clarify the scope of the work;
- to explore and understand different perspectives;
- to discuss the terms and definitions and the state of knowledge review;
- to reach agreement, where possible, on key concepts, terms and definitions; and
- to get contributors' support for the project.

The definitions discussion document (see Section 2.2) formed the basis for the workshop. Each discussion point was raised in turn, and a member of the TRL project team was responsible for putting forward the views of the wider reference group. The agreements reached in the workshop and the finalised definition are presented in Section 4.

2.5 Workshop 2: identification of research priorities

A second workshop took place towards the end of the study. Its aim was to:

- resolve any outstanding issues;
- confirm that the reference group is content that the important research gaps have been identified;
- discuss specific research needs, projects and priorities; and
- formulate recommendations for a programme of future research and ways to monitor changes in the impact of driver distraction on road traffic accidents.

In advance of the second workshop, the research gaps identified in the distraction review document were categorised and refined into 14 main research gaps. These formed the basis of an exercise in which members of the core and wider reference groups were asked to allocate a budget of 500 ‘research points’ to these research gaps with the strategic aim of reducing distraction-related accidents.

This helped to produce a list of research gaps in order of ‘research point’ allocation, and formed the basis of the discussion in the second workshop. Notes from this workshop were produced and circulated, and form the basis for the summary in Section 6.

3 LITERATURE REVIEW

3.1 Introduction

The aim of this review is to provide an overview of research in the area of driver distraction and related concepts. It does not aim to be comprehensive in terms of depth but to provide a broad categorisation of what is well researched, and suggest where there are obvious gaps.

In terms of scope, the technical focus is on:

- sources of distraction; and
- risk and impact of distraction on accidents.

To some extent, causes and mechanisms of distraction are covered but this is to a lesser degree of detail, in recognition of the strategic aim of improving safety through policy interventions.

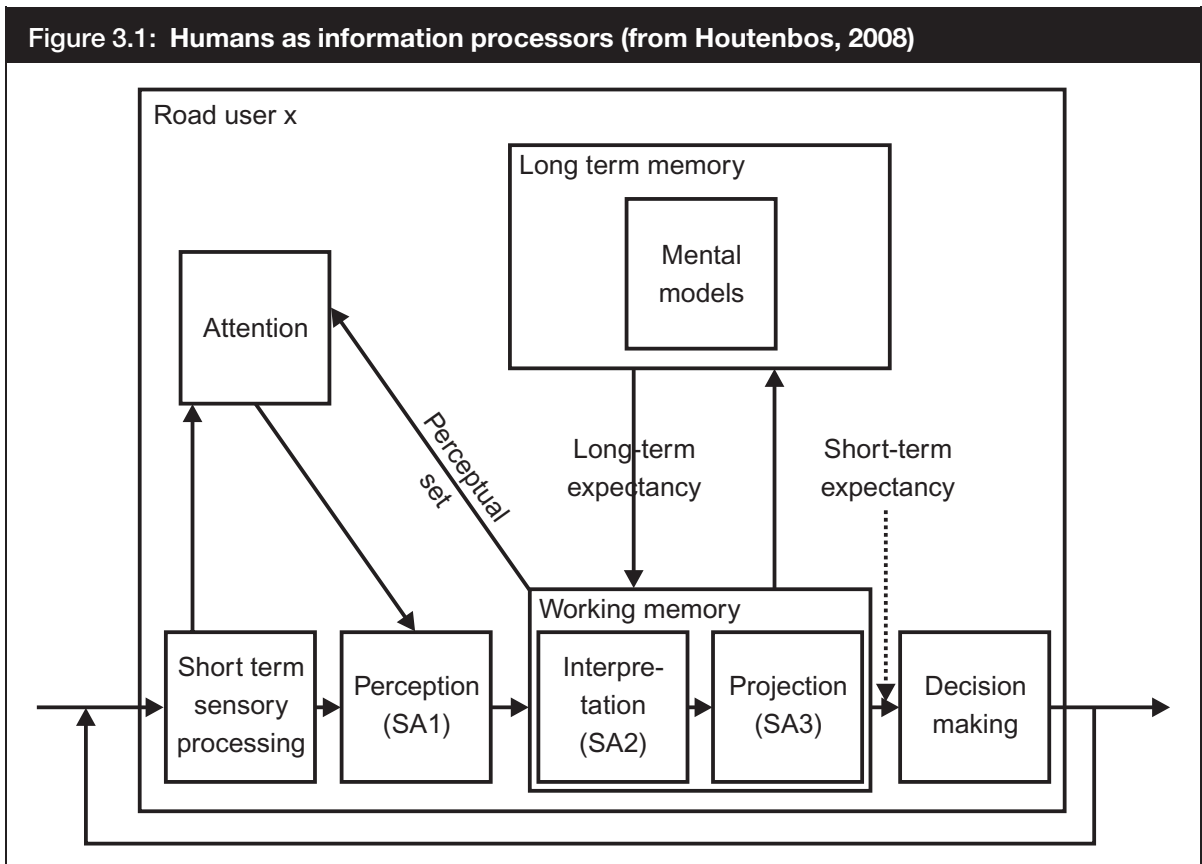
Essentially, there are three relevant scientific approaches:

- observation – for example, an epidemiological approach to accident data and passive observation of driver behaviour;
- experiment – i.e. studies of driver performance in laboratory, simulator and instrumented vehicles where external variables are modified to study effects; and
- opinion-based research (sometimes by stakeholder group).

Reviews of distraction have been conducted elsewhere (for example, Pettitt, 2007; Young *et al.*, 2003; Kircher, 2007; Lee *et al.*, 2008). In the interests of economy, this review will be based on these where possible, covering material on observational, experimental and opinion-based research. A brief discussion of concepts related to distraction will be followed by an overview of metrics and methods. A broad analysis of distraction research will then be presented prior to the identification of research gaps. In summary, this report will demonstrate what is known about driver distraction and then suggest what is unknown.

3.2 Information processing, attention and driving

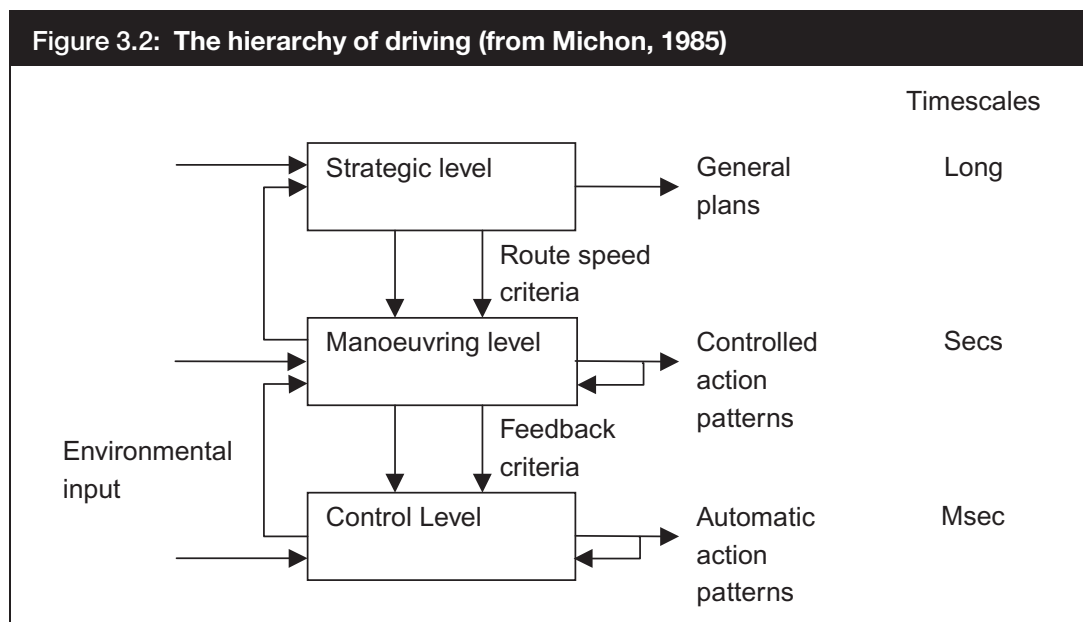
Driver distraction occurs in the context of the driving task, information processing and attentional allocation – a basic grasp of these concepts is useful if the problem of distraction is to be understood. This section draws on research in the fields of cognitive psychology and driver behaviour to give the reader a brief explanation of the processes which underlie these concepts. Figure 3.1 depicts human information processing in the context of the driving task.



At a simple level, humans take in information about their environment, then process (some of) this information (see Figure 3.1), and as an outcome may produce a response (Eysenck, 2000). However, human beings do not respond to everything in their environment at the same time. Everyday experience would suggest that people are not fully aware of everything in their environment. Even if one is aware of certain stimuli, there may be a delay in responding to one stimulus if another is being responded to simultaneously. While the precise constraints on human information processing have been subject to much debate (see debates on early and late selection/filtering in Haberlandt (1994) and Eysenck (2000)), it is generally accepted that there is an issue of ‘available resources’, and that some information is filtered out, at some point, from the process depicted above (Haberlandt, 1994).

The process of attention (see Figure 3.1) helps to concentrate one’s ‘available resources’ on a portion of the environment, assisting when stimuli are difficult to perceive, in the execution of simultaneous tasks, and when people are overloaded with information (Haberlandt, 1994). Attention can either be directed voluntarily (endogenous attention) or drawn by external stimuli (exogenous attention) (Driver and Spence, 1999). For example, when driving, expectations can guide visual attention as can sudden changes in the environment. Attention can also be focused (e.g. only listening to music) or divided (e.g. listening to music while driving) (Eysenck, 2000).

Driving is made up of a number of tasks to which the driver must allocate attention. Michon (1985) suggests that these can be depicted in a hierarchy (see Figure 3.2). At the strategic level, the trip goal, route and modal choice are planned. The outcomes from this level impose certain performance criteria on the lower levels. At the manoeuvring level, the driver negotiates obstacles, curves, junctions, etc., by undertaking common driving manoeuvres. These manoeuvres require a certain level of performance at the control level, but performance at the manoeuvring level can also lead to a re-evaluation of strategic level activities. At the control level, the driver executes automatic actions (over-learned sequences of actions which require little attention, see ‘automatic processes’ below) including steering, braking and gear changes. Again, performance at this level can lead to a re-evaluation of criteria set at the higher levels. Figure 3.2 also indicates that the timescales for activities decrease towards the lower levels, with individual processes at the control level typically taking milliseconds.



The Contextual Control Model (COCOM) of driving (Hollnagel, 1993) focuses on human performance rather than information processing. The cycle of human action presupposes constructs, which are essentially the driver’s knowledge of, and assumptions about, a situation. Based on these constructs, drivers will execute an action (based on their competences), thereby invoking an event and gaining feedback on their action. The event and environmental disturbances then influence the constructs, and the cycle continues.

This model of driving highlights the role of situational awareness in forming constructs. Situational awareness in the driving task can be described as follows (Endsley, 1995):

- the perception of elements in the current driving situation (see ‘SA1’ in Figure 3.1);

- the comprehension of the current driving situation (see ‘SA2’); and
- the projection of future characteristics of the driving situation (see ‘SA3’).

In essence, drivers must sample information from their environment through ‘attention’, process the information to comprehend the situation and predict how it might change, and respond through control inputs to the vehicle. Senders *et al.* (1967) and Wierwille (1993) argue that drivers share their attention between tasks, and sample the roadway when their uncertainty about the roadway reaches a certain threshold.

Indeed, it is possible to give attention to some things at the same time (e.g. changing gear and looking for an acceptable gap in traffic) and perform well if there are sufficient resources to cope with the requirements of the tasks. The following theories have attempted to explain human capacity and resources:

- Single Resource Theory (Kahneman, 1973; Norman & Bobrow, 1975) – a single pool of limited capacity is available for all tasks. Task performance depends upon whether sufficient capacity from this pool is allocated to it. Allocation is somewhat influenced by the person’s strategy, personal characteristics and motivations.
- Multiple Resource Theory (Wickens, 1984) – there are separate pools of resources for spatial and verbal information processing codes, different modalities (e.g. visual, auditory, etc.), stages of information processing (encoding, central processing and responding), and motor versus verbal response. Task demands may lead to these resources being utilised independently or jointly.
- Malleable Attentional Resource Theory (Young and Stanton, 2002) – there are separate pools of resources available for information processing; however, the size of these varies positively with mental workload up to a certain limit. Thus, large reductions in mental workload lead to a temporary shrinkage in capacity.
- Connectionist/Control Architecture (Schneider and Detweiler, 1988) – a common resource can be shared more effectively between two competing tasks through practice of the two tasks either concurrently or individually. Thus, a driver’s experience of using a system can influence its effects on their driving performance.

Eysenck (2000) comes to the conclusion that when attention is divided between two tasks, performance on the tasks is dependent on:

- task similarity – two tasks interfere with each other if they utilise the same stimulus modality (e.g. visual), if they make use of the same stages of processing or if they rely on related memory codes;

- task difficulty – it is more difficult to perform two difficult or complex tasks together than two simple tasks; and
- practice – practice can greatly improve dual task performance, but is unlikely to completely eradicate interference.

The idea that practice can improve dual task performance is linked to the concepts of controlled and automatic processes (Schneider and Shiffrin, 1977):

- Automatic processes – these are used to carry out highly practised tasks that require little or no thought. They are created by extracting and storing patterns and linked sequences, and place minimal demand on human information processing. They may, however, place demands on sensory and motor functions.
- Controlled processes – these are needed for novel situations. Tasks must be carried out in serial, so for two tasks to be completed in a short space of time one must switch between the two. This type of processing is powerful but slow and effortful.

It can be argued that elements of the driving task became automatic with practice (Young and Stanton, 1998). Learner drivers often have to carefully plan and execute every action, carefully monitoring the position of the vehicle and other road users. They are often only able to complete a single task smoothly at any given time. Gradually, as drivers become experienced, tasks become integrated and fluid. Most tasks are carried out with little conscious control, and attention can be shared with secondary tasks. Nevertheless, Michon's (1985) model suggests that some elements of the driving task may require more resources than others. For example, driving is a visually demanding task. Navigation in unfamiliar areas can be both visually and cognitively demanding.

It has been mentioned that attention can be divided between tasks, and that task performance depends on whether the resources available meet task demands. In certain driving situations, drivers make use of their 'spare capacity' by voluntarily allocating some attention to secondary tasks. In other situations, their attention may be drawn away from the driving task or an element of the driving task by an external stimulus. In either case, the driver is said to be distracted from tasks necessary for safe driving. If the driving situation suddenly requires the resources which the driver has allocated to the distracting task or stimulus, drivers may become unable to perform the driving task to a sufficiently high standard.

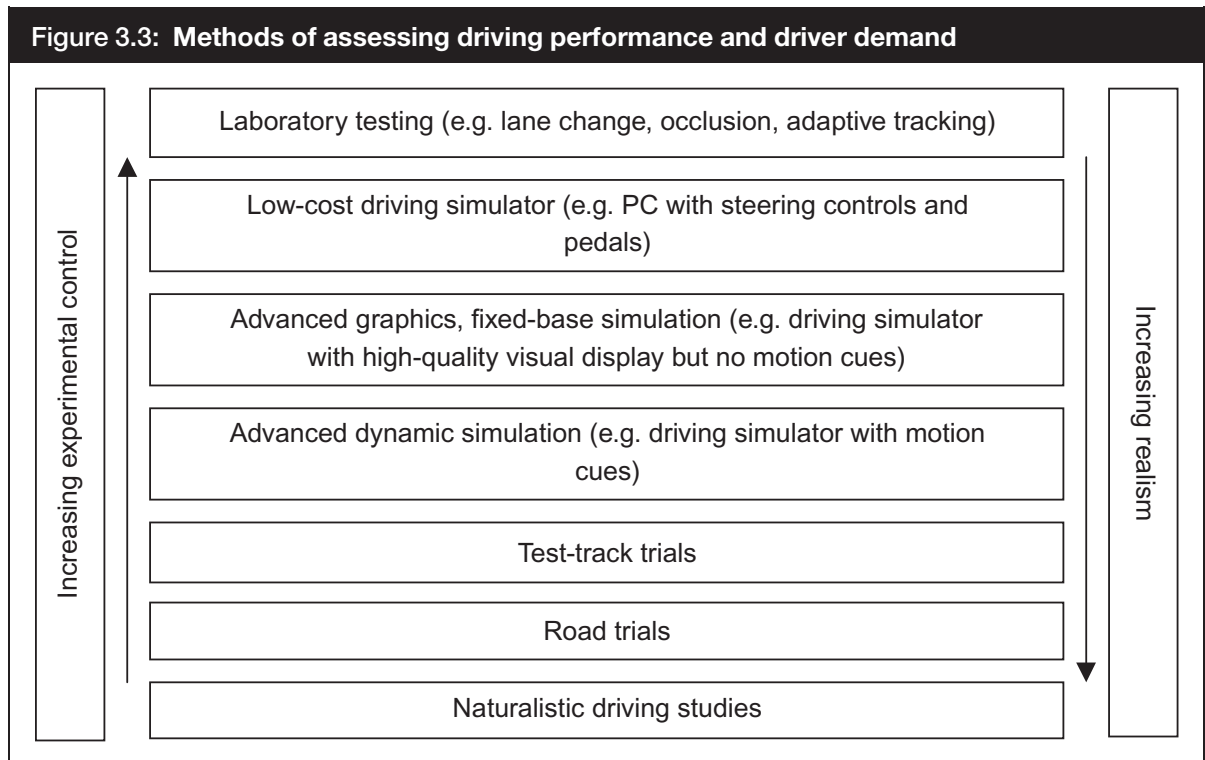
This section has aimed to provide a very brief introduction to a range of concepts underlying driver distraction. For further information, the reader is referred to the following sources:

- for human information processing, introductory psychology books such as Eysenck's (2000) *Psychology: A Student's Handbook*;

- for attention, Chapter 3 of Haberlandt’s (1994) *Cognitive Psychology*;
- for situational awareness, Mica Endsley’s (1995) ‘Measurement of situation awareness in dynamic systems’; and
- for mental workload, Chapter 18 of Wilson and Corlett’s (2005) *Evaluation of Human Work*.

3.3 Metrics and methods

Distraction research has utilised a wide range of methods for assessing driving performance. A categorisation of these methods is given in Figure 3.3. These methods exist on a continuum with naturalistic driving most realistically representing the driving task, and lab testing offering the largest amount of experimental control.



Driving performance has been largely evaluated using instrumented vehicles on the test track or road (e.g. Crundall *et al.*, 2006; Burnett, 2004) and driving simulators (e.g. Lansdown, 2002; Horberry *et al.*, 2006; Jamson and Merat, 2005). One of the most prominent studies of naturalistic driving recorded the movements of 100 drivers and their vehicles for over 2,000,000 vehicle miles (Neale *et al.*, 2005).

It is common for distracted driving performance to be compared to a baseline in which additional distractions are not presented. If the distraction is a secondary task, two main approaches are taken:

- loading tasks are designed such that the driver must maintain a certain level of performance on the secondary task, and decrements in driving performance are measured; and
- subsidiary tasks are carried out using drivers' spare capacity, as drivers are asked to maintain their performance on the driving task.

While many studies have specified their own secondary task for use during the study (e.g. inputting specific destination details into an off-the-shelf navigation system), reference tasks also exist which aim to standardise the assessment of certain types of distractor and certain types of distraction. For example, under the European HASTE (Human machine interface And the Safety of Traffic in Europe) project, two different reference tasks were designed. One of these was a cognitive task which had no visual component, and the other was a visual task (Roskam et al., 2002; Östlund *et al.*, 2004). Others are being developed for ISO standardisation.

There is a wide variety of measures of driving performance, driver behaviour, task performance and demand. The measures, which are listed in Table 3.1, are not measures of driver distraction; however, the precise experimental setup could allow the inference that reduced driving performance is a result of driver distraction.

Table 3.1: Examples of driving performance measures

		Measure used	Description
Primary task performance	Longitudinal control	Speed	Reductions in speed could indicate task difficulty compensation. Speed variability can be attributed to increased task demand. Non-compliance with speed limit signs could, depending on the situation, suggest that the driver is unaware of the speed limits or unaware of the speed of their vehicle
		Time headway	The maximum time available for the following vehicle to match the deceleration of a leading vehicle. Keeping a low time headway is a risky driving behaviour and may indicate high task demand. High time headway may indicate task difficulty compensation
		Time to collision	The time required for the following vehicle to collide with the lead vehicle if their relative velocities were maintained. Keeping a low time to collision is a risky driving behaviour and may indicate high task demand
	Lateral control	Steering input frequency	A lower frequency of steering inputs may indicate that the driver is not responding to the driving environment frequently. This may indicate high task demand
		Steering wheel position	Increased variation in steering wheel position can mean that the driver is making larger corrective steering wheel inputs. This may suggest that the driver is reacting only to larger deviations in lane position
		Time to line crossing	The amount of time it would take to cross the lane marking if no speed or steering adjustments were made. Lower times to line crossing could indicate high task demand
		Lane position	High variability in lane position can indicate poor tracking ability and high task demand
		Lane excursions	These are situations in which the driver crosses the lane markings. A larger number of excursions, particularly when a driver is instructed to maintain a central lane position, can indicate high task demand or a fatigued driver
			<i>(continued)</i>

Table 3.1. (continued)			
		Measure used	Description
	Reaction time	Braking response time	Longer reaction times to braking lead vehicles, crossing pedestrians, changing speed limits, etc., suggest that the driver is less able to respond to a hazard in a timely manner. This can indicate that the driver is experiencing high task demand
Driver Behaviour	Gap acceptance	Time available to cross	When turning right (on UK roads) across a stream of oncoming traffic, if drivers accept gaps which are very small, and particularly if this leads to collisions or near misses, this may be a result of poor judgement due to high task demand. If drivers fail to turn when the gap is sufficiently large, then it is also possible to infer that the driver's judgements are impaired
		Glance frequency	The frequency with which the driver looks at something (e.g. secondary task/distractor). The more frequently the driver's visual attention is drawn away from the primary task of driving, the higher the likelihood that important changes in the driving environment are not sensed, and cannot be responded to
		Total glance time	The total amount of time spent looking at something (e.g. distractor). The longer the driver spends looking away from the primary visual task, the higher the chance of an incident occurring to which the driver can not respond swiftly
		Maximum glance duration	The longest period spent looking at something (e.g. secondary task/distractor) without glancing away. Larger glances away from the tasks required for safe driving increase the chance that the driver will fail to detect changes in the driving environment and respond swiftly
		Total eyes off road time	The larger the amount of time the driver spends looking away from the road, the higher the chance of a crash. High cognitive demand can cause the driver to fixate primarily on the road ahead and carry out fewer mirror and instrument checks
	Anticipation	Pedal release/cover	Pre-emptive actions, such as accelerator release and covering the brakes, are indicative of higher order processes rather than automatic actions. Failure to adopt pre-emptive actions could indicate high task demand
Secondary task performance	Secondary task success	Task completion/ response time Input errors	If a driver can complete a secondary task swiftly, this could indicate sufficient capacity to carry out the task If the driver makes a larger number of errors on the secondary task, this may indicate that the driver has insufficient capacity to carry out the task while driving
Physiological measures	Arousal/ stress response	Respiration frequency	An increased rate of breathing can indicate a stress response, which can occur as a result of high task demand
		Respiration duration	The duration for which the rate of respiration is elevated may indicate the length of time for which the stress response is physically experienced. A longer duration would indicate prolonged higher task demand
		Background EEG	Electroencephalography (EEG) is the measure of the electrical activity produced in the brain. Increased activity in an area of the brain would indicate increased task demand
		Pupil diameter	Pupil dilation occurs as a response to stress, and could indicate high task demand
		Blink rate	An increased blink rate may be an indication of high task demand

(continued)

Table 3.1. (continued)

		Measure used	Description
		Galvanic skin response	Increases in the conduction of the skin indicates a state of arousal. It may be possible to infer that this is due to increased task demand
		Heart rate	Increases in a driver's heart rate or in the variability of their heart rate indicate a state of arousal, and may be considered to show an increase in task demand
		Speed	Reductions in speed could indicate task difficulty compensation. Speed variability can be attributed to increased task demand. Non-compliance with speed limit signs could, depending on the situation, suggest that the driver is unaware of the speed limits or unaware of the speed of their vehicle

The Wiener Fahrprobe (Viennese Driving Test (Risser, 1985)) utilises two observers within the driven vehicle. One of these evaluates standardised driving performance measures such as speed choice, while the other monitors hazards and conflicts with other road users. In addition to measuring driver performance, some methods exist to elicit drivers' own opinions of their driving and mental effort. Such self-report methods include:

- uni-dimensional scales (e.g. Rating Scale Mental Effort);
- multidimensional scales (e.g. Subjective Workload Analysis Technique and NASA TLX); and
- the Manchester Driver Behaviour Questionnaire.

Laboratory-based methods have also proven to be successful in measuring driving performance or demand, including the following:

- Peripheral detection tasks (e.g. Olsson and Burns, 2000) present targets in the driver's peripheral view to which they must respond. With increasing visual and cognitive demand, drivers become less responsive to these targets.
- The occlusion technique (e.g. Horberry *et al.*, 2007) utilises a set of goggles with shutters that open and close at short intervals. Periods when the shutter is closed represent glances at the road scene, and periods when the shutter is open are used to perform a secondary task. If the secondary task can be completed effectively, it is said to be 'chunkable' and therefore more acceptable for in-vehicle use.
- Adaptive tracking (e.g. Parkes *et al.*, 2001) requires participants to use a joystick to move a circle which is presented on a screen so that it remains around a moving target dot. The task becomes increasingly difficult if the participant is able to accurately track the movements of the circle.
- Choice reaction time tests (e.g. Parkes and Hooijmeijer, 2000) present the participant with a range of different stimuli and require a distinct response for each.

- The lane change task (e.g. Harbluk *et al.*, 2007) utilises a desktop computer which repeatedly prompts drivers (using road signs) to perform lane changes. The quality of these lane changes are then compared as an indicator of driving performance and task demand. A normative model of single-task performance also exists against which ‘distracted’ performance can be compared.

While these metrics are useful in the assessment of distracted driving performance, Angell *et al.* (2006) found that no single metric is able to show the complete effects of the secondary task on driving.

This section has aimed to provide a broad overview, with suitable examples, of methods of assessing distracted driving performance, ranging from laboratory-based methods, which offer high experimental control but low realism, to naturalistic driving, which offer high realism but low experimental control. A brief explanation of measures of driving performance and task demand has also been presented. For further information, the reader is referred to:

- Östlund *et al.* (2005), *Driving Performance Assessment – Methods and Metrics*;
- Victor (2005), *Keeping Eye and Mind on the Road*;
- Angell *et al.* (2006), *Driver Workload Metrics Task 2 Final Report*; and
- Burnett (2008), ‘Designing and evaluating in-car user-interfaces’.

3.4 Observation-based approach

The review by Pettitt (2007) examines the relationship between driver distraction and accident statistics. This section is based on this review, and focuses specifically on studies which analysed accident data and passively observed driver behaviour through naturalistic driving and other observational techniques.

3.4.1 *Distraction as a factor in accident causation*

It can be difficult to estimate the role of distraction in accident causation because of several factors, including the lack of a standard definition of distraction and inconsistent accident reporting (Stevens and Minton, 2001). Furthermore, more serious accidents are usually recorded in more detail, and there is a possibility that distraction is more common in less serious accidents and, thus, underrepresented in accident statistics. Finally, in fatal accidents it may be difficult to judge whether driver distraction was a contributing factor, as it may be impossible to tell if the driver was distracted or not (Stevens and Minton, 2001).

3.4.1.1 Results from around the world

The U.S. National Highways Traffic Safety Administration (NHTSA) estimates that driver inattention is a causal factor in approximately 25% of police-reported crashes in the USA (see Table 3.2), although other sources estimate that this figure is between 35% and 50% (Stutts *et al.*, 2001). Based on data from 1995–99 in the Crashworthiness Data System (CDS) and weighting the data to reflect national results, 12.9% of drivers involved in accidents were identified as distracted. However, Stutts *et al.* (2001) feel that this is an underestimate of the percentage of actual crashes involving driver distraction, due to difficulties in determining accident cause and the types of accidents sampled. Further results from naturalistic driving studies are reported in Section 3.4.3.

3.4.1.2 Results from the UK

In-vehicle distraction was shown to be a contributory factor in 2% of fatal accidents between the years 1985 and 1995 (Stevens and Minton, 2001). The greatest source of internal distraction was passengers, followed by entertainment systems, and eating and drinking. However, the distraction levels caused by passengers may be underestimated as fewer than half of the accidents examined involved multi-occupant vehicles.

Stevens and Minton (2001) found that internal distraction accounts for 2% of distraction-related accidents, which is much lower than the figures given in studies based on the CDS. This may be caused by the following differences in the USA data: it was from a different time period, it did not include accidents involving vehicles with professional drivers, but did include non-fatal accidents and distraction from sources external to the vehicle. If these are indeed the reasons for the difference between the study results, this may imply that distraction from sources external to the vehicle may account for a large portion of distraction-related accidents or that distraction is less often identified as a causal factor in accidents involving professional drivers and in fatal accidents. Furthermore, the difference may also arise because the data used by Stevens and Minton (2001) spans a period from the mid-1980s to the mid-1990s, when there were fewer sources of in-vehicle distraction (the CDS data were from 1995 to 1999). The authors argue that a figure of 2% is likely to be a conservative estimate (Stevens and Minton, 2001) due to the reasons discussed in Section 3.4.1.

A study using data of work-related road traffic accidents in the Midlands area of the United Kingdom by Pettitt *et al.* (2005), showed that 3.7% of accidents had distraction as a causal factor, a small figure in comparison with some other studies. This may be due to the specific characteristics of the driver population studied.

Table 3.2: Studies of accidents caused by distraction					
Source	Country	Accident data	What was classed as distraction in the study?	Percentage attributed to distraction	Authors' comment
Pettitt <i>et al.</i> (2005)	UK	Work-related road traffic accidents, 1996–2004	Distracted drivers of any of the vehicles involved in the crash	3.7% of all accidents	Distraction from passengers is likely to be less prevalent among professional drivers because they usually drive alone
Stevens and Minton (2001)	UK	STATS19, police fatal incident reports and in-depth investigations, 1985–95	Internal distraction	2% of fatal accidents	Over-representation of multi-occupant vehicles may suggest that passengers can be a source of distraction
Stutts <i>et al.</i> , 2001	USA		Distracted drivers of any of the vehicles involved in the crash	25% and 50% of police-reported crashes	
Stutts <i>et al.</i> , 2001	USA		Distracted drivers of any of the vehicles involved in the crash	12.9% of drivers involved in the incidents	Likely to be an underestimate due to difficulties in determining accident cause and the types of accidents sampled

3.4.1.3 Sources of distraction

Stutts *et al.* (2001) report that external distractions – outside persons, objects or events – are the most frequently reported source at 29.4% of distraction-related accidents, followed by making adjustments to the radio/cassette/CD player (11.4%) and other occupants in the vehicle (10.9%).

Examining in-vehicle distraction, Stevens and Minton (2001) found passengers to be the greatest single source of distraction, followed by interacting with the radio/cassette player and handling food, drink and cigarettes. Notably, some distractions expose drivers to distractions for different lengths of times, for example passengers represent a distraction for the entire period they are in the vehicle, whereas adjusting the radio is only a momentary distraction.

During a large-scale survey, when drivers were asked to report the main distractions they encountered in reference to a recent crash, McEvoy *et al.* (2006) found that

lack of concentration, adjusting in-vehicle equipment, outside people, objects or events, and talking to passengers were the most frequently reported distractions.

A study by Dibben *et al.* (2007) concentrated solely on music as a distraction from the driving task. The survey found that approximately two-thirds of drivers listen to recorded music and music radio while driving, but those who preferred silence were more likely to have 'no claims' motor insurance (i.e. had not claimed for repairs to their or another vehicle as the result of a crash) (Dibben *et al.*, 2007).

A small number of US studies have examined the effects of advertising billboards on accident rates. Although many of these studies have been correlational, a before-and-after study by Ady (1967) showed that, in some circumstances (i.e. depending on the relationship between the billboard and its surroundings), the presence of roadside advertisements did lead to an increase in accident rates.

3.4.2 *Exposure to distracting tasks*

Several studies have investigated the frequency of mobile phone use in on-road traffic (e.g. Broughton and Hill, 2005; Hill, 2005). A recent series of observation studies were enhanced by the use of electronic devices sensitive to microwave radiation (TRL 2006, 2007). Sample sizes per study included over 80,000 cars and 20,000 other vehicles, such as lorries or vans. The use of hand-held mobile phones while driving was substantially higher for 'other drivers' than for car drivers, particularly for hand-held and less so for hands-free mobile phone use at both time points. The prevalence of mobile phone use for car drivers decreased between September 2006 and August 2007 to 1.4%; for 'other drivers' the overall prevalence for the same time period decreased to 3.0%. For both driver groups, the change resulted from decreased use of hands-free and held-held phones.

3.4.3 *Naturalistic driving studies*

In an attempt to understand pre-crash causal and contributing factors, Neale *et al.* (2005) and Klauer *et al.* (2006) studied 100 instrumented vehicles over 2,000,000 miles. Complete information on 69 crashes, 761 near-crashes (conflict situations requiring rapid, severe evasive manoeuvres) and 8,295 incidents (requiring less-severe evasive manoeuvres than near-crashes) was collected. From this, four categories of driver inattention were determined:

- secondary task engagement (i.e. driver distraction);
- fatigue;
- driving-related inattention to the forward roadway; and
- non-specific eye glances.

The results showed that 78% of crashes and 65% of near-crashes were coded with one of these inattention categories as a contributing factor, with secondary task engagement the greatest source of inattention, accounting for 22% of accidents (Neale *et al.*, 2005; Klauer *et al.*, 2006). Overall, results suggest that engaging in secondary tasks while driving increases the risk of having an accident by two times that of normal baseline driving for simple tasks, and three times for complex tasks (Klauer *et al.*, 2006).

An analysis of eye glance behaviour demonstrates that glances away from the road for more than two seconds significantly increase the risk of being involved in a crash, or near-crash, while those less than two seconds do not appear to significantly increase risk beyond baseline driving (Klauer *et al.*, 2006).

3.4.4 *Individual differences*

Studies have also shown that individual differences have an effect on crash and injury risk as a result of distraction. Neyens and Boyle (2008) argue that teenage drivers have a higher crash risk, and they express concern over the opportunities for this group of driver to engage in technology-based and non-technology-based distraction. Their analysis shows that teenage drivers and their passengers are more likely to sustain severe injuries if distracted by a mobile phone or passengers than if they engage with an in-vehicle system or are inattentive. Braitman *et al.* (in press) interviewed 16-year-olds who had been involved in a non-fatal accident within eight months of passing their driving test. They found that failing to detect another vehicle was one of three main causes of crashes, and that these were caused by failing to look properly, distraction or inattention.

Drivers can also be differentiated according to their purpose or motivations for driving. A naturalistic driving study of long-haul truck drivers (Hanowski, *et al.*, 2005) monitored 41 truck drivers over 140,000 miles. Of the 2,737 critical incidents observed, 41 were attributed to driver distraction; these were near-crashes or other relevant conflicts and no crashes were recorded during the study period. The authors conclude that long-haul truck drivers do look away from the roadway even if a task does not require visual attention.

3.4.5 *Summary*

This section has presented an overview of the role of distraction in accident causation. Efforts to make comparisons between studies are hindered due to differing interpretations of driver distraction and disparity between data sources. While estimates suggest that between 25% and 50% of accidents involve some form of driver inattention, with distraction contributing to half of these (Stutts *et al.*, 2001), key studies tend to produce much more conservative estimates (Stutts *et al.*, 2001; Stevens and Minton, 2001). In contrast, a unique study of naturalistic driving behaviour found that inattention contributed to 78% of accidents, with secondary

task engagement the greatest cause of inattention (Neale *et al.*, 2005). There have been some investigations of individual differences in driver distraction, although research is particularly scarce in the area of the effects of drivers' motivations and purposes for driving on distraction-related accidents. Robust research on the effects of external signs and advertising on distraction-related accidents also appears to be scarce.

3.5 Distraction and driving performance: the experimental approach

Owing to the apparent scarcity of firm data regarding distraction and accident rates, especially when considering more novel in-car systems, a significant branch of research has focused on the impact of distraction on driving performance measures.

This section presents an overview of studies which have focused on the impact of driver distraction on driving performance. A brief literature search has uncovered a large amount of research which has looked at the effects of distractors, including mobile phone or passenger conversations, navigation systems with various input and output modalities, e-mail systems, in-car entertainment systems (radio, CD/cassette player/visual entertainment displays), eating, map reading and variable message signs (VMS). These are summarised in the following sub-sections.

3.5.1 Distractors

3.5.1.1 Mobile phones

A large proportion of studies have focused on mobile phones as a distractor, and have found that drivers display decrements in driving performance when driving while simultaneously holding a mobile phone conversation (e.g. Burns *et al.*, 2002). It has also been found that subjects' perception of their driving performance is unrelated to and, at times, in the opposite direction to actual decrements in their performance while using a mobile phone (Horrey *et al.*, 2007). This may suggest that drivers themselves are poor judges of their performance decrements while driving. A recent study has also investigated the effect of experience on using a mobile phone while driving (Shinar *et al.*, 2005). Participants' driving performance was studied during five sessions. The authors report that participants carried out three drives per session, each consisting of distinct tasks to aid the measurement of variables relating to driving performance. These drives were counterbalanced, but the authors do not state whether the drives were identical across the five sessions. The results showed that drivers display significant improvements in most measures of driving performance (Shinar *et al.*, 2005). This suggests a learning effect of driving and using a mobile phone, and that the real impact of using a mobile phone while driving may depend on the level of experience the driver has in carrying out these two tasks simultaneously.

3.5.1.2 In-vehicle information systems

There have also been a number of studies which have evaluated driving performance while using in-vehicle information systems (IVIS). Results of these studies are more complex due to the large number of independent variables which have been studied. These have included different input and output modalities as well as screen configurations, complexity and position within the vehicle.

As with the studies which evaluated driving performance while using mobile phones, studies have tended to find decrements in driving performance while using some forms of IVIS. The use of handwriting rather than keyboard input (Burnett *et al.*, 2005) and audio output (Dingus *et al.*, 1995) have been shown to have advantages in terms of driving performance. Burnett (2004) concluded that drivers made fewer but longer glances at those placed low in the centre console, and a larger number of shorter glances at those placed higher on the centre console.

While such studies are helpful in piecing together an overall picture of driving performance while using an IVIS, it is apparent that driving performance has been assessed relative to a different baseline in most of these. Furthermore, the methods used to test driving performance in each instance may have been different. As a result, it is not possible to draw concrete conclusions as to which combinations of input/output modality, placement and screen design make driving performance 'safe' or even 'safer' than other designs. This issue is further discussed in Section 3.5.2.

3.5.1.3 In-car entertainment systems

A smaller number of experiments have looked at the impact of using in-car entertainment (ICE) systems on driving performance. The precise distractors utilised in these experiments have been varied, including listening to or tuning a radio (McKnight and McKnight, 1993; Strayer *et al.*, 2003), changing a cassette (Wikman *et al.*, 1998), continuously changing a CD and selecting a track (Jenness *et al.*, 2002), listening to a radio broadcast (Jancke *et al.*, 1994), listening to audio materials from a rear-seat audio-visual display (Hatfield and Chamberlin, 2008a), or looking at a visual display in a neighbouring car (Hatfield and Chamberlin, 2008b). In general, studies have found that using an ICE system while driving degrades driving performance.

Comparative studies of navigation systems, mobile phone use and ICE systems are useful in enabling broad comparisons between these three categories of distractor. However, since each of these are multi-functional, it has not been possible to establish which of these distractors pose a greater risk to road safety and whether any of these pose an 'acceptable' level of risk.

3.5.1.4 Email systems

A small number of studies have also examined the effects of operating email systems on driving performance (for example, Jamson *et al.*, 2004; Lee *et al.*, 2001). While the studies seem to show that drivers attempt to maintain a certain level of perceived safety, the number of collisions (albeit in a simulator environment) does increase. Driving performance decrements are particularly large for complex systems which the driver cannot pace.

3.5.1.5 Distractions external to the vehicle

There are fewer published studies on distractions external to the vehicle, such as variable message signs (VMS) (Erke *et al.*, 2007), and advertising (Horberry and Edquist, in press; Crundall *et al.*, 2006; Holohan *et al.*, 1978). These studies have shown that drivers attempt to compensate for the visual demands of VMS displaying messages by driving more slowly, thereby keeping the sign in view for longer. Advertisements placed at street level appear to have a larger distracting effect in potentially hazardous situations.

3.5.1.6 Other distractors

The effects of eating (Young *et al.*, in press) and personal mp3 player use (Chisholm *et al.*, in press) on driving performance have also been evaluated by a small number of studies. Both activities led to poorer driving performance. In particular, difficult mp3 player tasks corresponded to increases in perception response time and collisions, and increased visual attention directed into the vehicle compared with the baseline. Practice improved driving performance and increased responses to hazards, but a significant decrement remained relative to the baseline (Chisholm *et al.*, in press).

3.5.2 Comparators

The studies outlined in the previous section demonstrate not only the variety of performance measures which have been used to show the effects of distractors but also the range of performance baselines, or states to which 'distracted' driving performance has been compared. Table 3.3 gives examples of these.

Table 3.3: Examples of distractors studied and comparators used		
Distractor	Comparator	Example study
Mobile phone	<p>Hand-held versus hands-free mobile phone conversation</p> <p>Dialling versus listening versus talking versus listing</p> <p>Difficult versus easy conversation on a mobile phone</p> <p>Mobile phone conversation versus conversation with a passenger versus blindfolded passenger</p> <p>Mobile phone conversation versus driving at the legal limit of alcohol intoxication</p> <p>Mobile phone versus using the radio versus climate controls</p> <p>Mobile phone versus operating a CD player</p> <p>Mobile phone versus reading directions</p> <p>Mobile phone conversation in low versus high traffic density</p>	<p>Burns <i>et al.</i>, 2002; Haigney <i>et al.</i>, 2000 Green <i>et al.</i>, 1993 STTG, 2002; Harbluk <i>et al.</i>, 2007 Crundall <i>et al.</i>, 2005</p> <p>Burns <i>et al.</i>, 2002; Strayer <i>et al.</i>, 2006 Parkes <i>et al.</i>, 2007</p> <p>Jenness <i>et al.</i>, 2002 Jenness <i>et al.</i>, 2002 Jenness <i>et al.</i>, 2002</p>
IVIS	<p>Highly-informative versus minimal information display</p> <p>Keyboard versus handwriting entry</p> <p>Use with preferred versus non-preferred hand</p> <p>Display located centrally at 10°, 20° and 30° vertical eccentricities below eye-line height</p> <p>Route guidance system versus written directions versus a paper map</p> <p>Navigation by memory versus route guidance system</p> <p>Head-down electronic route map versus paper map versus head-up turn-by-turn guidance display with head-down electronic map versus voice guidance with head-down electronic map</p> <p>Manual/visual versus speech/auditory input and output modalities</p> <p>Route guidance system versus dialling a mobile phone versus tuning a radio</p>	<p>Vashitz <i>et al.</i>, 2008 Burnett <i>et al.</i>, 2005 Burnett <i>et al.</i>, 2005 Burnett, 2004</p> <p>Dingus <i>et al.</i>, 1995</p> <p>Harms and Patten, 2003 Srinivasan and Jovanis, 1997</p> <p>Gartner <i>et al.</i>, 2002; Tijerina <i>et al.</i>, 1998; Harms and Patten 2003 Tijerina <i>et al.</i>, 1998</p>
ICE	<p>ICE versus mobile phone</p> <p>Using ICE in a simple versus complex (billboards, buildings and oncoming vehicles) environment</p>	<p>Wikman <i>et al.</i>, 1998; Reed-Jones <i>et al.</i>, in press; Horberry <i>et al.</i>, 2006 Horberry <i>et al.</i>, 2006</p>
Email	<p>System-paced versus driver paced</p> <p>No email versus simple (3-level menu) versus complex (4–7-level menu) email system</p>	<p>Jamson <i>et al.</i>, 2004 Lee <i>et al.</i>, 2001</p>
Advertising	<p>Street level versus raised level advertisements</p> <p>Primed to look for advertisements versus primed to look for hazards</p>	<p>Crundall <i>et al.</i>, 2006 Crundall <i>et al.</i>, 2006</p>
<i>(continued)</i>		

Table 3.3. (continued)		
Distractor	Comparator	Example study
Eating/ drinking	Eating/drinking versus reading directions	Jenness <i>et al.</i> , 2002
	Eating/drinking versus using a voice activated or manual dial system to make calls on a mobile phone	Jenness <i>et al.</i> , 2002
	Eating/drinking versus continuously operating a CD player	Jenness <i>et al.</i> , 2002
	Eating and drinking versus no distractor	Young <i>et al.</i> in press
Mp3 players	No distractor versus simple mp3 player task versus complex task	Chisholm <i>et al.</i> , in press
VMS	VMS with message versus without message	Erke <i>et al.</i> , 2007

3.5.3 Individual differences

Some experiments have also studied individual differences in distracted driving performance. For example, Tetzke *et al.* (2005) measured driving performance while interacting with an IVIS and also participants' interactions with an IVIS under single-task conditions (i.e. not driving). They found that elderly drivers were slower at completing the single task. Furthermore, they found that while driving, elderly participants slowed down more in an attempt to compensate for the demands of interacting with an IVIS, but this did not prevent them from crossing the lane boundaries. Although there were improvements in task performance with practice, other studies have shown that speed of information processing decreases with age, particularly for controlled processes (Jennings and Jacoby, 1997) (see automatic and controlled processes, Section 3.2).

Lesch and Hancock (2004) found gender differences in driver confidence and performance while concurrently using a mobile phone. They found that while for males driving confidence decreased as the size of distraction effects increased, for females confidence increased as their driving performance showed greater effects of distraction. When matched on confidence, older females were much slower in terms of braking response.

3.5.4 Distraction mitigation

While much research has concentrated on reducing the number of crashes as a result of distraction and other states of driver inattention (e.g. collision avoidance systems), there has been some research into distraction mitigation. Karlsson (2004) investigated the effects of presenting a blue flash in the centre of the road position or a kinaesthetic brake pulse on distraction. He found that these measures were ineffective but speculated that methodological problems may have been to blame. Donmez *et al.* (2007) used a small display within the vehicle that warned drivers that they were being distracted. A broad categorisation of distraction mitigation strategies can be found in Donmez *et al.* (2004) *A Literature Review of Distraction Mitigation Strategies*.

3.5.5 Summary

This section has broadly categorised research which, in the main, has shown driving performance decrements as a result of distractors such as mobile phones, IVIS, in-car entertainment and email systems, as well as advertising billboards, VMS and other distractors. Research on the effects of distraction by sources external to the vehicle and passengers within the vehicle appears to be scarce. While it is important to understand the relative hazards posed by the range of distractors present in the driving environment, the lack of a standardised methodology to assess distracted driving performance makes it difficult to make these comparative judgements without designing an experiment to focus on all variables which are of interest. A further observation can be made that the current state of knowledge is not sufficient to identify 'high-risk' groups for driver distraction. Finally, although driving at the legal limit for alcohol intoxication has been used to represent the borderline case between safe and unsafe driving, an analysis of the studies above shows that there is no single standard against which any observed effects of a distractor on driving performance has been compared.

3.6 Distraction and attitudes: opinion-based research

Aside from the work based on observation and experiments described in Sections 3.4 and 3.5, there has also been considerable work in the area of driver distraction which is based on the opinions of experts and drivers themselves. The sub-sections below outline drivers' and experts' opinions of how distracting certain activities are while driving, how often drivers carry out these activities and the contribution of such behaviours to crashes. Finally, respondents' opinions on distraction mitigation strategies are discussed.

3.6.1 Self-reported distraction

Patel *et al.* (in press) asked drivers to rate how risky they thought 14 distracting activities were. They found that the highest risk ratings were associated with the use of mobile phones, looking at a map or book, and grooming. The use of satellite navigation technologies and hands-free kits were given a risk rating much lower than the use of mobile phones, and the least risky activities were listening to music and talking to passengers.

In summer 2000, NHTSA hosted an internet forum on the safety implications of cellular telephones, vehicle navigation systems, wireless internet capabilities, wireless messaging and other in-vehicle technologies. Technical experts as well as the general public contributed to the forum, which drew widespread national and international participation. Contributors were able to post their comments about a particular technology, respond to the comments from others and take part in an opinion survey. Out of 1,069 respondents, 75% responded that it is not safe to talk on a mobile phone while driving, 29% (of 732 respondents) thought that it is safe to

use a mobile phone while driving under light traffic conditions, and a further 7% thought it was safe to use a mobile phone anytime while driving. Holding a conversation, dialling a number and carrying out mobile phone related tasks, such as writing down notes, were the biggest safety concerns (NHTSA, 2000).

3.6.2 *Exposure to the distractor*

The exposure of drivers to distractions is of interest as low exposure to a distraction may have more moderate effects on road safety compared with a similar distraction to which the driver is frequently exposed. Overall, research suggests that, on average, drivers engage in a distracting activity once every six minutes (McEvoy *et al.*, 2006).

The now somewhat dated survey carried out by NHTSA (2000) inquired about respondents' own mobile phone use while driving. Only 29% (of 573 respondents) responded that they do own a mobile phone but do not use it while driving. Nineteen per cent reported that they use a hand-held mobile phone, 10% said they use a hands-free kit, and 8% said that they use both hand-held and hands-free mobile phones while driving. Twenty-six per cent of respondents reported that they sometimes or frequently use a mobile phone in 'hands-free' mode while driving, and 27% reported that they sometimes or frequently receive calls while driving (NHTSA, 2000). More recent research commissioned by the Canada Safety Council (2003) also highlighted the exposure of drivers to various distracting activities. Thirty-five per cent said that they had used a mobile phone while driving, although 79% reported that they had seen another driver use their mobile phone while driving (Canada Safety Council, 2003).

3.6.3 *Effects of distraction on near-misses and crashes*

While detailed accident data would be a valuable source of information on the role of distraction in accidents, it is nevertheless useful to consider peoples' opinions on the matter. Sixty-four per cent of respondents to the NHTSA (2000) survey had witnessed or experienced a 'close call' resulting from a driver (or themselves) using a mobile phone. Sixteen per cent had witnessed or experienced a crash as a result of such behaviour. This was in comparison to 55% of respondents witnessing or experiencing a close call, and 23% witnessing or experiencing a crash resulting from a driver being distracted by something other than a mobile phone (NHTSA, 2000).

McEvoy *et al.* (2006) found that drivers reported distraction as being the cause of 21% of crashes during the last three years, involving 1 in 20 drivers. Younger drivers (18–30 years) were found to be significantly more likely to report distracting activities, to perceive distracting activities as less dangerous, and to have crashed as a result (McEvoy *et al.*, 2006).

3.6.4 *Distraction mitigation*

Eighty per cent of respondents to the NHTSA (2000) survey thought that drivers do a poor job of making decisions about when it is safe to use technology while driving or thought that drivers cannot make these judgements. This is supported by one expert contributor's (Staplin) opinion that because highly-trained drivers perceive the difficulty of the driving task as being routine, they become more susceptible to distraction as a result of not allocating full attention to the driving task (NHTSA, 2000). Despite the general agreement that drivers cannot easily judge when it is safe to use technology while driving, 35% of respondents said that they would not purchase a navigation system which prevented destination entry while the vehicle was in motion (NHTSA, 2000).

These findings are reflected in the results of a survey carried out by the Insurance Bureau of Canada (2006). The results of this survey suggested that 89% of Canadians were very or somewhat concerned about driver distraction; but 60% of drivers would not agree to stop using their mobile phones while driving, despite being told that mobile phone use made them four times more likely to be involved in a collision.

Only 25% of respondents to the NHTSA survey thought that auditory systems (input and output) could address safety concerns associated with operating in-vehicle technologies. One of the expert contributors to the forum (Lee) agreed with this result, stating that speech recognition 'would allow drivers to keep their hands on the wheel and eyes on the road; however, it would not eliminate the cognitive distractions'. Furthermore, Lee argued that imperfect systems and poorly-designed dialogue structure could potentially result in the driver making input errors. Recovering from such errors could also be distracting (NHTSA, 2000).

Only 25% of respondents to the NHTSA (2000) survey stated that they had changed how they use their mobile phone in their vehicle because of a safety tip they had heard or seen. A similar percentage thought that public education and training about the safe use of in-vehicle technologies could increase safety to a large extent. On the other hand, 43% thought that the effects of such campaigns would be minimal. Seventy-four per cent of respondents advocated a tougher approach, suggesting that states or local governments should enact laws to restrict the use of mobile phones while driving (NHTSA, 2000).

3.6.5 *Summary*

This section has shown that in 2000, 29% of respondents to an internet survey used a mobile phone while driving, with 26% responding that they did this sometimes or frequently. Seventy-five per cent agreed that it is not safe to use a mobile phone while driving. This section has also highlighted that drivers agree that they are poor judges of when it is safe to use technology while driving, and that legal implications

of using distracting technologies would be more likely to change behaviour than safety campaigns. Nevertheless, drivers' attitudes towards the use of in-vehicle technologies while driving may be different in the UK. Furthermore, attitudes change with time. Thus, there remains a lack of comprehensive research here. For more information, the reader is referred to the NHTSA (2000), Driver Distraction Internet Forum.

3.7 Summary of research

This section will attempt to bring together, broadly, the findings of this review which have been presented in Sections 3.4, 3.5 and 3.6.

The review has highlighted that there has been a considerable amount of research into the area of driver distraction. Observation-based studies have shown that:

- distraction is a causal factor for accidents and near-miss events; and
- there is a relationship between visual distraction (glances away from the road) and the risk of having a crash/near-miss.

The experimental approach has been particularly useful in showing the link between distraction and degrading driving performance. The work in this area has focused mainly on in-vehicle technologies, although some studies have also looked at performance while eating, drinking, talking to a passenger, driving along roads containing advertisements and reading maps. Studies have examined:

- the presence of visual, manual and cognitive distractions;
- standard methods of assessing visual demand;
- the relative benefits of speech/audio versus visual/manual interfaces:
 - display complexity;
 - display placement;
- task complexity;
- system pacing (versus driver pacing of tasks); and
- the difference between drivers' assessments of their distracted driving performance and their actual distracted driving performance.

Finally, the opinion-based research has highlighted, in very general terms:

- how frequently drivers are exposed to some of the distractors;
- their opinions of the effects of distraction or certain distractors on their driving, including self-reports of contribution to crash situations; and
- how people feel about mitigation strategies such as education and enforcement.

4 WORKSHOP 1: DISTRACTION DEFINITION

This section of the report summarises the discussions which took place during the workshop and presents the agreed definition of driver distraction.

4.1 Discussion point 1 – the danger of a definition

The workshop on the 7 February 2007 (Sampson, 2007) identified a key activity of agreeing the definition of driver distraction in order to ‘measure driver distraction, relate it to road safety risk and give policy advice to Ministers’. There are many definitions of distraction already available in the literature and part of the discussion concerned the purpose to which a definition would be put. Some participants were initially in favour of a rather wide definition so that the overarching objective of safety could be addressed on as broad a front as possible. A concern was noted that a definition that was too specific may imply a particular indicator of distraction (and means of measurement). It could also lead to different levels of recorded involvement in road safety and hence identification of different design and policy considerations to reduce the impacts of distraction as defined. However, the definition of specific metrics and indicators was, nevertheless, useful.

In discussion three levels of definition were identified:

- the lay-person’s definition, which is rather broad;
- a more scientific definition; and
- specific definitions of metrics or indicators of distraction.

A consensus emerged for a scientific definition that was more general than the metrics/indicators but not so broad as to be unfocused.

It was also thought beneficial to understand, perhaps by means of a concept mapping diagram, the relationship of the definition of distraction to related concepts, including, for example:

- situational awareness;
- impairment; and
- inattention.

This was noted as a future action. It was also noted that beneficial research can often take place at the interface between different concepts and that this should be borne in mind when identifying research gaps and research programmes.

4.2 Discussion point 2 – distraction, fatigue, inattention and internal thoughts

In the US naturalistic driving study, nearly 80% of crashes and 65% of near-crashes identified inattention as contributing factor (Klauer *et al.*, 2006). As noted by Lee *et al.*, (2008), the authors defined inattention as including general inattention to the road, fatigue and secondary task demand. So, inattention occurs, according to these authors, when a driver fails to give sufficient attention to activities critical for safe driving, and this includes drowsiness and fatigue.

In discussion, the workshop participants agreed to exclude issues of impairment, such as fatigue and drugs or alcohol, from the definition of distraction. It was noted that drivers who are impaired are likely to be more susceptible to distraction. It was also remarked that there is a continuum of driver ability and the susceptibility of different driver groups to distraction was an area for further research.

The participants then considered the situation where the driver is absorbed in their own thoughts, for example daydreaming or worrying about a specific past or future event. These are activities ‘internal’ to the driver’s mind. They can result in inattention but can they be regarded as distraction?

Prose accounts of accidents sometimes suggest that the drivers were momentarily ‘distracted’ by thoughts of events in their lives other than the driving task at hand. According to Beirness *et al.* (2002), the presence of a triggering event or activity distinguishes driver distraction from the broader category of driver inattention. A lack of a definable event or occurrence in an accident could be a basis to re-categorise them as having inattention (rather than distraction) as a contributory factor.

There was considerable debate about this point, both during the workshop and within the comments provided by the wider reference group of experts. The participants agreed that cognitive processes were always involved in distraction. If a driver is concentrating hard on distinguishing signage or understanding a complex message, such internal thoughts are part of distraction, and such internal thought processes are triggered by an event.

There was more of a debate concerning the discernable difference between the cognitive/perceptual processes involved in sensory distraction (e.g. interaction with navigation displays) and the cognitive/perceptual or even emotional processes involved in non-triggered events (e.g. worrying about future situations or readdressing past conversations). An example was given concerning how a driver’s ‘train of consciousness’ might progress following a triggered event:

‘... **What’s that sign trying to tell me? Oh yes, the A34 is congested** ...
OK so it’ll take me 10–20 minutes longer to get home ... so will the

Co-op be open then . . . I think it shuts early on Wednesdays . . . why do they do that? . . . not enough custom, I suppose . . . still, it's good that we've got a shop at all in the village with competition from the out of town ones . . . someone was saying that to me only last week . . . Oh yes John . . . he's still recovering from that flu, I wonder . . .'

It was agreed that beyond the cognitive tasks involved in perception and decision making, represented by the bold text, the 'train of consciousness' passes out of the realm of driver distraction.

Agreement: distraction excludes driver fatigue and impairment. These are related but distinct concepts.

Agreement: distraction requires a definable trigger and excludes daydreaming and general internal thoughts.

4.3 Discussion point 3 – distraction from what?

Prose accounts of accidents reveal that some arise as a result of drivers who are lost or unfamiliar with their location, or searching for visual cues such as road signs and street names at the time of the collision. When a driver is looking for street signs or buildings, they are assigning additional priority to their route finding task at the expense of the safe control of their vehicle.

Can such a driver be classed as 'distracted'? This depends on what is regarded as the driving task. If driving includes route finding then, logically, the driver cannot be distracted from driving by route finding.

The workshop participants agreed that the driver could be distracted by route finding and so a refined 'core' driving task was sought.

A discussion then took place concerning safe driving and it was noted that 'safe driving' is best regarded as an outcome whereas 'activities required for safe driving' is a process.

It was agreed that the 'core' driving task is 'activities required for safe driving in the road and traffic environment' and that any competing activities were potential distractions. (Note, traffic includes all other road users, e.g. pedestrians.) These activities consist of monitoring of the road and traffic environment, and control of the vehicle.

Agreement: 'activities required for safe driving' is taken as the task from which distraction occurs, with the implication that this requires lateral and longitudinal control of the vehicle in the road and traffic environment (which

includes pedestrians and other road users) such that a suitable safety margin is maintained.

4.4 Discussion point 4 – distraction as a continuous variable

Much of the literature implies that (however defined) the driver is either not distracted or distracted, i.e. a binary choice. However, the driver is usually allocating attention between a number of tasks or sub-tasks. So, it is more realistic to discuss the degree of distraction, which depends on (at least):

- the demands of the activities required for safe driving (see above);
- the demands of other tasks that the driver chooses to engage with;
- the driver's distribution of attention between those tasks; and
- the driver's overall capacity (and specific task performance ability).

It was agreed that distraction becomes important – we could say safety critical – when there is a shortfall between the demands of the tasks for safe vehicle control and the resources devoted to it by the driver. The degree of shortfall relates to the degree of distraction.

It was noted that drivers vary in their driving skill and in the resources that they need to undertake different tasks, so the degree of distraction may well be different for different drivers in the same circumstances.

Typically, there will always be some sub-optimal attention allocation. However, it is typically only called distraction when it is judged that the degree of shortfall (between the activities required for safe driving and the resources devoted to it by the driver) exceeds some safety margin. Note that there is no agreement on this safety margin.

Agreement: distraction is a continuous variable. Distraction becomes critical when there is a shortfall between the activities required for safe driving and the resources devoted to it by the driver.

4.5 Discussion point 5 – distraction and consequence

Demands can increase rapidly and unexpectedly, so a single glance away from the road could be harmless or critically important. In a recent international conference (CAA and TIRF, 2006) it was concluded that 'distractions need not produce immediate consequences such as corrective actions or crashes, but do increase the risk of these consequences'.

The workshop participants agreed with this view. Safe driving implies not only an absence of crashing into people or things but also implies that driving skill and

practice is at an acceptable level. This means driving in a reasonable way or, slightly more scientifically, driving with a reasonable safety margin to allow for unexpected events.

So, a question would be whether a driver's overall level of attention and allocation of attention was reasonable in the circumstances. This is something for which an agreed quantitative measurement does not exist but that driving examiners judge by experience and courts may need to take a view on when distinguishing between inconsiderate, careless and dangerous driving (Crown Prosecution Service, 2007).

Agreement: drivers can be too distracted and/or driving in an unsafe way even if there is no immediate adverse consequence of the behaviour, such as an actual crash. Safe driving requires more than avoiding crashes although measuring safe driving is challenging.

4.6 Discussion point 6 – distraction and chance

It was agreed that the risk of a distraction-related crash is likely to be a function of:

- **timing** (e.g. coinciding with an unexpected event is more critical than in a low workload situation, such as stopped at a traffic light);
- **intensity** (e.g. texting requires more resource than listening to the radio);
- **resumability** (the extent to which tasks can be re-started efficiently);
- **frequency** – more often repeated actions are more likely to coincide with a critical event;
- **duration of the distraction** – again increasing the probability of the distraction coinciding with a critical situation; and
- **hang-over effect** – the lingering cognitive or emotional residue beyond effective task completion.

A more sophisticated discussion can also be found in Lee *et al.* (2008). The workshop participants also noted the possible additive effects of multiple distraction sources.

Agreement: the degree of driver distraction is time varying, as are the demands of safe vehicle control, and unsafe situations can develop rapidly and unexpectedly. All other things being equal, reducing distraction improves the chance of the driver dealing appropriately with an unsafe situation.

4.7 Discussion point 7 – distraction and driver engagement

It was agreed above that when a driver allocates some of their attention to an event, activity, object or person (EAOP) that is not directly related to the activities required

for safe vehicle control, they become distracted to some degree. The EAOP can then be called ‘distracting’ or ‘a distractor’. It was agreed that the EAOP becomes distracting as a result of driver behaviour.

It was noted that drivers are individuals and some EAOPs are of more interest than others (e.g. personal grooming, reading advertising) and this varies with time. However, it is likely that there are properties of EAOPs that will make them more distracting to a broad range of drivers. One approach to reducing distraction is to change the properties of EAOPs to make drivers less willing to engage with them. This was noted as an area for future research.

In addition to EAOPs being more or less engaging according to an individual driver’s preferences, there are also some properties that will make an EAOP more or less attractive to **all** drivers. Reference was made to research on brain function and processing pathways; some object properties are likely to capture a driver’s attention automatically, such as movement or flashing lights. At this stage the driver’s individual tendencies determine whether the driver will continue to allocate attention to the EAOP. Again, reduced distraction may be achieved by regulating the use of visual properties that unconsciously compel the driver to attend to them.

Agreement: events, activities, objects and persons only become distracting as a result of a driver’s engagement with them. Their properties determine how distracting they are to a population of drivers.

4.8 Discussion point 8 – distraction and driver initiation

It was agreed that distractions inside the vehicle can be driver initiated (e.g. making a phone call) or non-driver initiated (e.g. the unpredictable actions of a passenger).

It was also agreed that external distractions are usually non-driver initiated (e.g. the unpredictable behaviour of a drunk pedestrian, a changeable advertisement) but still require the engagement of the driver, either automatic or conscious. In addition, distractions arising outside of the vehicle can also be driver initiated if one considers route-finding activities, such as searching for buildings or street names. A further example provided was a driver choosing a scenic route in order to be entertained (distracted) by their surroundings.

Agreement: distraction should be considered as arising from both driver-initiated and non-driver-initiated sources.

4.9 Discussion point 9 – types of distraction

Four types of distraction are commonly referred to in the literature: visual, cognitive, biomechanical and auditory (Ranney *et al.*, 2000). However, it was agreed that these are not mutually exclusive, for example while a device may be particularly

distracting visually, it is also likely to incorporate elements of, for example, biomechanical distraction from manipulation of the controls.

Similarly, narratives from accident investigations may record that the driver was distracted by a passenger but it may not be clear the extent to which this involved visual distraction (e.g. turning to look at them), auditory distraction (e.g. being startled by a noise), cognitive distraction (e.g. by talking to the passenger), biomechanical distraction (e.g. by passing a toy to a child) or a combination of types.

Agreement: appreciating the different types of distraction may inform future studies but our current understanding and ability to measure their role is limited.

4.10 Agreed definition of driver distraction

Diversion of attention away from activities required for safe driving due to some event, activity, object or person, within or outside the vehicle.

Note 1: safe driving requires monitoring of the road and traffic environment (which includes pedestrians and other road users) and control of the vehicle.

Note 2: safe driving also requires an appropriate degree of attention and vehicle control to maintain a reasonable safety margin allowing for unexpected events.

Note 3: types of distraction may be visual, auditory, biomechanical or cognitive, or combinations thereof.

5 IDENTIFICATION OF RESEARCH GAPS

The research described in Section 3 has contributed to a much-improved understanding of the extent of distraction and its effects on driving. There are, however, a number of research areas that do not appear to have been covered in-depth, or in which the studies may not reflect recent developments in the in-vehicle and extra-vehicle environments. The following sections categorise these potential areas of research which have been drawn from:

- an analysis of the evidence presented within this report;
- the opinions of prominent experts in the field of driver distraction who have been involved with the current project;
- reviews of documents, including:
 - the Proceedings of the International Conference on Distracted Driving (Hedlund *et al.*, 2006)
 - *An Inquiry into Driver Distraction* prepared for the Parliament of Victoria by the Victorian Automobile Chamber of Commerce (2005);
 - *Strategy on Distracted Driving* by the Canadian Council of Motor Transport Administrators (2006);
 - *Strategies for Reducing Driver Distraction from In-Vehicle Telematics Devices* by Transport Canada (2003); and
 - *Driver Distraction: A Review of the Literature* by Kircher (2007).

5.1 Distraction and the effects of distractors

- The effects of the level of exposure to distractors:
 - the actual frequency and duration of use of the different functions of in-vehicle technologies (e.g. calling, texting, internet, email functions of mobile phones, as these may result in different types of distraction);
 - the identification of groups of drivers who have high exposure to distractors (e.g. business drivers); and
 - the frequency of use of multiple in-vehicle information systems (IVIS) within the same vehicle.
- The relative effects of all known distractors, including current and emerging technologies, original and after-market fitments on the driving population and different groups of drivers:
 - the identification of high-risk groups for distraction (e.g. elderly drivers?, business drivers?, etc.); and
 - the effects of distractors on high-risk groups.
- The effects of distractions from outside the vehicle (e.g. rubbernecking, advertisements, signage, items of road geometry).

- The effects of distractions within the vehicle:
 - the distracting effects of mobile-phone tasks other than holding a conversation (e.g. SMS (short message service), etc.);
 - the cumulative and interactive distracting effects of a combination of in-vehicle technologies;
 - the distracting effects of task interfaces (including modality/multi-modality, layout, menu complexity, etc.);
 - how drivers schedule (or should schedule) in-vehicle tasks relative to external driving demands;
 - the cost of task switching; and
 - the effects of distractions caused by people within the vehicle (e.g. children) in real situations.
- The distinction between sensory and perceptual distractions (e.g. ‘looked but failed to see’ accidents).
- Distraction mitigation strategies:
 - drivers’ knowledge of the effects of distracted driving and their attitudes towards the use of in-vehicle technologies; and
 - factors which would motivate drivers or different groups of driver to change their behaviour.

5.2 Distraction measurement

- Development of a standard, meaningful, objective and reliable test procedure to identify unsafe levels of distraction:
 - review of current metrics;
 - measurement of cognitive and auditory distractions;
 - agreement on or development of a common baseline against which distracted driving performance can be compared (particularly for non-visual tasks);
 - development of an algorithm for distraction detection operating in real-time;
 - the relationship between the findings of experiments (in terms of driving performance degradations) and actual near-miss or crash rates; and
 - the study of naturally occurring distractions to verify simulator results.

5.3 The role of distraction in accident causation

- Crash risk posed by distracted driving (as a baseline figure):
 - the particular risk posed by individual distractors, including current and emerging technologies, original and after-market fitments.
- The cost to society of distracted driving and related crashes.

5.4 Long-term monitoring of the effects of distraction

- Best practice to monitor the problem of distracted driving over time:
 - changes to accident rates over time;
 - changes in driver behaviour (e.g. rate of interaction with distractors such as IVIS) and attitudes over time.

6 WORKSHOP 2: PRIORITISATION OF RESEARCH GAPS

Prior to the workshop, the research gaps presented in Section 5 were condensed into a list of 14 research gaps. These are listed below:

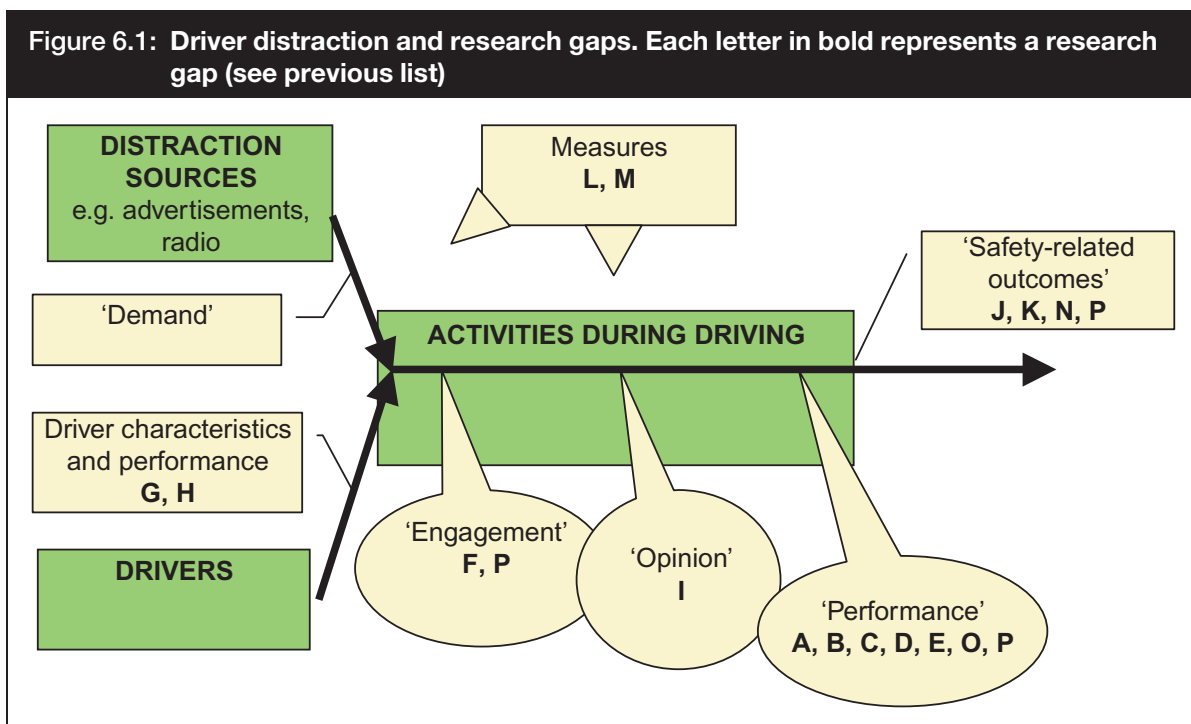
- A. Measuring driving performance degradations, and the impact of these on crash risk, from specific distractors outside of the vehicle.
- B. Measuring driving performance degradations caused by people and other non-technological distractors within the vehicle, in real situations.
- C. The relative effects on driving performance and interaction effects of in- and extra-vehicle distractors, including current and emerging technologies.
- D. Measuring the effects of different in-vehicle information system (IVIS) interface designs on driving performance (including modality/multi-modality, layout, menu complexity, etc.).
- E. The cumulative and interactive distracting effects of a combination of in-vehicle technologies (including task-switching).
- F. The frequency and duration of drivers' actual use of the different functions of in-vehicle technologies (e.g. texting, internet, email functions of mobile phones) and of multiple functions or technologies, and the impact of this on risk during real-world driving.
- G. Understanding the distinction between sensory and perceptual distractors (e.g. 'looked but failed to see' accidents).
- H. Identification of high-risk groups for distraction (e.g. elderly drivers, business drivers, younger drivers) and the effects of distractors on these groups.
- I. Drivers' knowledge of the effects of distracted driving, their attitudes towards engagement with distractors and factors which would motivate drivers or different groups of driver to change their behaviour.
- J. The relationship between the findings of experiments (in terms of driving performance degradations) and actual near-miss or crash rates due to distractors.
- K. Quantification of the role of distraction (or individual distractors) in accident causation based on existing crash data, hence the cost to society of distracted driving and related crashes.
- L. The development of a standard, meaningful, objective and reliable test procedure and baseline to identify 'unacceptable' levels of visual distraction (potentially in real time).

- M. The development of a standard, meaningful, objective and reliable test procedure and baseline to identify ‘unacceptable’ levels of cognitive and auditory distraction (potentially in real time).
- N. The identification of best practice to monitor the effects of distracted driving (e.g. accident rates, driver behaviour and attitudes) over time.

An exercise was then conducted in which members of the core and wider reference groups were asked to allocate a finite number of ‘research points’ to these areas, with the strategic aim of reducing distraction-related accidents. During the workshop, the research gaps were discussed in total research point order. For each, an attempt was made to cover:

- the potential impact of the research topic;
- suggested methodology;
- dependencies and/or collaboration needs; and
- resources and timescale required.

Figure 6.1 was presented at the beginning of the workshop to depict how the research gaps fit within the area of driver distraction.



The following section summarises the conclusions of the workshop in relation to each research gap.

6.1 Discussion of identified research gaps

Table 6.1: A. Measuring driving performance degradations, and the impact of these on crash risk, from specific distractors outside of the vehicle (e.g. rubbernecking, advertisements, signs, road furniture)	
Impact	Dependencies/collaboration needs
High Research in this area is relatively sparse, and the impacts could be large in terms of policy, particularly for signs and advertising. Some external distractions (e.g. scenery) may be difficult to mitigate	No dependencies Road and planning authorities would ideally be involved, and the advertising industry would be a key stakeholder
Methodology	Resources and timescale
Degradations can be measured in relation to each other or to other distractors A combination of an experimental approach (e.g. driving simulator) and an observational approach (naturalistic driving, incorporating epidemiological methods to calculate risk) could be sought. There may be a temptation to look at variables which are easier to measure, but the effects of change blindness and situational awareness may also be important	This would depend on the methods used, and the combinations of distractors to be assessed, but likely to be medium to high cost, with similar timescales

Table 6.2: B. Measuring driving performance degradations caused by people and other non-technological distractors within the vehicle, in real situations	
Impact	Dependencies/collaboration needs
Medium/high Potentially high impact on peer-pressure/distraction by passengers/children and related accidents	No dependencies
Methodology	Resources and timescale
Lends itself to simulator and naturalistic driving studies, but could have an initial focus group component Some privacy and ethical issues need to be addressed	Focus group and simulator research is a low-cost option, but naturalistic driving is likely to be long term and resource-intensive

Table 6.3: C. The relative effects on driving performance and interaction effects of in- and extra-vehicle distractors, including current and emerging technologies

Impact	Dependencies/collaboration needs
High The data would inform where mitigation efforts should be concentrated	Collaboration with car manufacturers and insurance companies, and possibly at a European level, would increase cost-effectiveness of a naturalistic driving study
Methodology	Resources and timescale
Would have to define which combinations would be of interest by developing a taxonomy of known distractors inside and outside the vehicle. Questionnaires and focus groups could augment this by identifying emerging technologies of interest. Products which promote inattention and cause distraction indirectly could also be included. An experimental approach could then be used to home in on the problem Naturalistic driving could be useful but would be expensive. Simulators studies are better suited to initially exploring interactive effects. Alternatives (e.g. black box with audio) could be used but would yield a poorer picture	Would depend on the scope of the project, but would be likely to range from medium to high costs and timescales

Table 6.4: D. Measuring the effects of different IVIS interface designs on driving performance (including modality/multi-modality, layout, menu complexity, etc.)

Impact	Dependencies/collaboration needs
Low This is a fairly well-researched area. There seems to be an implementation problem in that guidance exists but is not integrated into the design process of vehicles and driving-related systems At times the existing guidelines may be conflicting	Likely to be covered by industrial collaboration
Methodology	Resources and timescale
Could assist in the provision of guidelines to industry Could measure the impact of improved human-machine interface (HMI) on safety and inform consumers, or feed this back into vehicle design	Low but continuous effort

Table 6.5: E. The cumulative and interactive distracting effects of a combination of in-vehicle technologies (including task-switching)	
Impact	Dependencies/collaboration needs
High The data would inform where mitigation efforts should be concentrated	Collaboration with car manufacturers and insurance companies, and possibly at a European level, would increase the cost-effectiveness of a naturalistic driving study
Methodology	Resources and timescale
Would have to define which combinations would be of interest, initially by developing a taxonomy of technologies with potential for conflict. Questionnaires and focus groups could help with this and also in identifying emerging technologies of interest. Products which promote inattention and cause distraction indirectly could also be included. An experimental approach could then be used to home in on the problem. Naturalistic driving could be useful but would be expensive. Simulator studies allow for greater control in understanding cumulative and interactive effects. Alternatives (e.g. black box with audio) could be used but would yield a poorer picture	Would depend on the scope of the project, but would be likely to range from medium to high costs and timescales

Table 6.6: F. The frequency and duration of drivers' actual use of the different functions of in-vehicle technologies (e.g. texting, internet, email functions of mobile phones) and of multiple functions or technologies, and the impact of this on risk during real-world driving	
Impact	Dependencies/collaboration needs
High This could yield information on the frequency and duration of interaction with distractors, and task scheduling. This would help to target mitigation strategies	Naturalistic driving studies would benefit from European partners and funding to increase cost-effectiveness. Collaborating bodies would need to ensure that they use complementary methods Naturalistic driving would depend on the relevant technologies being on the market
Methodology	Resources and timescale
Could consider non-technological distractors as well. Questionnaires could target larger numbers, but results are likely to underestimate the frequency and duration of use. Roadside mobile-phone use surveys have used sensors to determine actual mobile-phone use but this may be more difficult to apply to other distractors. An experimental approach could be taken and might include verbal protocols while driving. An experimental approach could be preceded by task analysis to better understand potential real-world usage scenarios. Naturalistic driving (incorporating epidemiological methods) would be the ideal method but, if resources are scarce, could be used to monitor the behaviour of a subset of drivers identified as high risk through other methods	Survey work could be relatively short term and conducted at a relatively low cost, but naturalistic driving studies would be long term and expensive

Table 6.7: G. Understanding the distinction between sensory and perceptual distractors (e.g. ‘looked but failed to see’ accidents)

Impact	Dependencies/collaboration needs
High This area has policy implications. Understanding the mechanism would help to develop countermeasures Could yield data which may help to develop countermeasures for certain groups of drivers	May inform other research programmes
Methodology	Resources and timescale
This would lend itself to an experimental approach. Naturalistic driving data could complement this approach if the instrumented vehicles contained real-time distraction mitigation systems capable of assessing the presence of cognitive distraction	A constructive step forward is likely to be achieved with modest resources and timescales. A long-term project is required to understand the phenomena in-depth

Table 6.8: H. Identification of high-risk groups for distraction (e.g. elderly drivers, business drivers, younger drivers) and the effects of distractors on these groups

Impact	Dependencies/collaboration needs
High This would help to identify where the problems lie and design effective mitigation strategies	Potential collaboration with companies/fleet managers/insurance companies
Methodology	Resources and timescale
Analysis of accident/on the spot (OTS) data, experimental approach or naturalistic driving. Could include bus drivers, pedestrians, parents driving with children, cyclists and other road users	Could range from medium/low to high depending on the methodology employed. For example, naturalistic driving studies are likely to be costly

Table 6.9: I. Drivers’ knowledge of the effects of distracted driving, their attitudes towards engagement with distractors and factors which would motivate drivers or different groups of driver to change their behaviour

Impact	Dependencies/collaboration needs
High Would help to understand the road user and identify situations in which their perception of risk from distraction and actual risk are misaligned. Changes in society and in-vehicle environment (e.g. smoking ban, cup holders) may encourage some behaviours and change engagement patterns	May be able to access driver attitudes better if the mechanisms of distraction are well understood
Methodology	Resources and timescale
Initially it would be necessary to clearly define distraction in terms of actions rather than objects. This taxonomy is critical Then, survey work and focus groups could be used to gather data, and should include (among other distractors) food and beverage consumption, smoking and distraction from sources outside the vehicle. Alternatively, a verbal protocol could be used during driving	Easiest area to research, with a relatively low cost and timescale

Table 6.10: J. The relationship between the findings of experiments (in terms of driving performance degradations) and actual near-miss or crash rates due to distractors	
Impact	Dependencies/collaboration needs
Medium Statistics may be useful in distraction mitigation. This will not yield information about the driving context and distraction mechanisms	If in-vehicle equipment use were to be monitored (perhaps on a national rather than individual basis), manufacturers and fleet managers may be involved. The data collected may be of use to them
Methodology	Resources and timescale
Equations are needed that relate performance degradation to fatalities and injuries. Data derived from naturalistic driving studies may provide a mechanism for bridging the performance degradation/safety gap by identifying critical scenarios and events that characterise real-world crashes which can be used as assessment scenarios in simulator studies	Would require a significant commitment of resources to improve data collection

Table 6.11: K. Quantification of the role of distraction (or individual distractors) in accident causation based on existing crash data, hence the cost to society of distracted driving and related crashes	
Impact	Dependencies/collaboration needs
High Quantification is important for policy	Potentially with OTS teams/police
Methodology	Resources and timescale
<p>Accident data are not of sufficiently high quality and do not usually include exposure data that can be used to calculate crash risk. Data from epidemiological studies are required to derive risk estimates, however these rely on quality data</p> <p>To improve data it would be necessary to clearly define distraction. The development of a taxonomy of sources of distraction, deriving from this definition, is critical. For good accident data collection to occur, forms should have prompts. Training of the data collectors would be useful but may be impractical</p> <p>An alternative would be to calibrate the accident data using OTS data, although there may be shortcomings in OTS data for distraction and fatigue. The Human Factors Analysis and Classification System (HFACS) could be used to identify causal factors from accident reports, particularly human factors</p>	Medium if based on existing data, but high if new data collection techniques are designed and implemented

Table 6.12: L. The development of a standard, meaningful, objective and reliable test procedure and baseline to identify ‘unacceptable’ levels of visual distraction (potentially in real time)

Impact	Dependencies/collaboration needs
<p>High Visual distraction is a major contributor to distraction-related accidents. Research would be helpful for designing improved in- and extra-vehicle environments, and mitigation strategies</p>	<p>Possible Co-operation from vehicle designers and road engineers could be sought</p>
Methodology	Resources and timescale
<p>Developing new metrics or refining old metrics. Important not to focus on particular technologies Performance-based metrics (e.g. Helmut Zwahlen, Wierwille) would be ideal but are not straightforward. However, practical adaptive interfaces using workload managers are becoming available which use such surrogates. Product-based approaches (e.g. checklists, promotion of good design as a countermeasure) are possible Unlikely that ‘unacceptable’ levels can be defined, rather good/better/best scenarios</p>	<p>Should hold back on this area in the short term. There may be pre-emptive work to do in other areas Progress may be achievable in the long term with the performance-based approach. If the product-based approach were taken, it may also take time for products which are designed to minimise distraction to become widely available</p>

Table 6.13: M. The development of a standard, meaningful, objective and reliable test procedure and baseline to identify ‘unacceptable’ levels of cognitive and auditory distraction (potentially in real time)

Impact	Dependencies/collaboration needs
<p>High There is less research in this area than there is on visual distraction. It is an important research area and is likely to become more so as in-vehicle interfaces change</p>	<p>Possible Co-operation from vehicle designers and road engineers could be sought</p>
Methodology	Resources and timescale
<p>This lends itself to an experimental approach</p>	<p>High levels of uncertainty as this is intermingled with the issues of mood and arousal</p>

Table 6.14: N. The identification of best practice to monitor the effects of distracted driving (e.g. accident rates, driver behaviour and attitudes) over time	
Impact	Dependencies/collaboration needs
<p>Medium Important from a road authority point of view in monitoring how the problem is changing Countermeasure development is in its infancy and evaluation of these is important</p>	<p>This research gap lies in the overlap between other areas. It depends on the repeatability of other methodologies to understand changes Collaboration could be sought with LGV fleets and Transport for London (TfL) as a road authority. Collaboration at a European level would be useful to establish a methodology/analysis technique and a baseline</p>
Methodology	Resources and timescale
<p>Would require good accident data, periodic exposure surveys (through self-report questionnaires and observational studies), periodic attitude surveys and naturalistic driving studies. Company fleets could be encouraged and assisted to optimise data collection systems, given the large number of vehicle kilometres travelled for work purposes</p>	<p>This may require a large amount of resources and could be an extension of 'the quantification of the role of distraction based on existing crash data'. Costs may be offset somewhat if meta-analysis techniques were to be set up under an EC project</p>

6.2 Additional research gaps

The following additional research areas were identified during the discussions:

- the effects of distraction due to insufficient information to carry out the driving task effectively;
- developing training programmes and monitoring their effects on driver distraction;
- driver self-regulation – how drivers compensate for the current and anticipated effects of distraction;
- long-term effects of using in-vehicle systems (e.g. reliance) and distraction mitigation strategies; and
- crash configurations/accident scenarios where distraction is over-involved as a causal factor.

There are some similarities between these research gaps and the 14 listed previously. For example, the effects of insufficient information to carry out the driving task can be investigated with a similar methodology as proposed for research gaps A and B (measuring driving performance degradations from distractions from within and outside the vehicle). The effects of training on driver distraction and the long-term effects of using in-vehicle systems can be investigated by extending the scope of research gaps F and I (the frequency and duration of drivers' actual use of in-vehicle

technologies, their knowledge of the effects of distracted driving and their attitudes towards engagement). Driver self-regulation could also be investigated under research gap F. Finally, research gap J could be extended to investigate not only near-miss and crash-rates due to distractors but also crash-configurations and accident scenarios where distraction is a causal factor.

6.3 Research programme

Some time was then spent discussing how these research gaps may be turned into a research programme. The following recommendations were made:

- Research gaps could be grouped in terms of methodology, and multiple gaps could potentially be tackled at once (See Appendix 1). Additionally, it may be possible to group the research gaps in terms of which mitigation strategies they support, although at times the outcome of the research may inform the most suitable mitigation strategy.
- Initially, the nature of the problem could be characterised. This could be done from accident studies, and surveys/focus groups on perceptions and attitudes. Work could include elements of research gaps F, H and I. Focus groups could be used to inform survey questions and to explore survey results.
- The National Highway Traffic Safety Administration (NHTSA) Driver Distraction Forum is an example of a discussion/survey mechanism which reached a large audience; this format of study could be considered.
- As well as gathering information on the current effects of distraction, it is important to identify, at an early stage, developments which bring about a change in the nature and type of potential distractions (e.g. new technologies inside and outside the vehicle), and form a strategy to tackle the potential effects of these.
- Naturalistic driving studies are being planned across Europe, and many of these are starting in 2008. European projects draw upon expertise across European countries and allow research costs to be shared by member states. By contributing to this work, it may be possible to ensure that additional data are collected to fill the research gaps discussed during this workshop. It would be cost-effective to exploit these opportunities for collaborative work, and contribution to a suitable large-scale European project is likely to be more beneficial than conducting a small-scale UK naturalistic driving study.

6.4 Summary

This workshop discussed a total of 19 research gaps which had been identified during the literature review presented in Section 3, in terms of impact, methodology, resources, timescales, dependencies and collaboration needs.

In terms of mitigating against distraction, the need for clear messages to the public which are easy to understand, and a methodology for evaluating and monitoring effects, were identified.

The workshop concluded that there was some overlap between some of the research gaps in terms of scope and methodology. Furthermore, some of the research gaps will require significant investment and/or participation in larger-scale studies (e.g. naturalistic driving, at a European level). It was emphasised that exploiting opportunities to collaborate in larger pieces of work would be more beneficial in understanding the phenomenon than carrying out small-scale projects.

7 CONCLUSIONS

This project has brought together scientists and policymakers in a scoping study of driver distraction. From the process undertaken to complete this project, the following can be concluded:

- The use of a sizable, wider reference group ensured that the project outputs were seen and reviewed by an audience that is influential in distraction research.
- The use of a smaller core reference group for workshop attendance also worked well. The group of half a dozen research-active scientists was large enough to ensure that different viewpoints emerged, but small enough to ensure a constructive debate.
- The mixture of individuals at the workshops, which included policy makers as well as scientists, helped to incorporate different perspectives into the debate.
- The circulation of discussion documents prior to the first workshop and the research gaps prior to the second helped to keep the debate focused, and allowed the views of the wider reference group to be incorporated.

A number of conclusions about the nature and definition of driver distraction and research gaps have been drawn within Sections 4 and 6. Some final recommendations that can be made as a result of these discussions relate to the European naturalistic driving studies which have been planned for some time, and some of which are due to start in summer 2008. These studies are an invaluable opportunity to make advances in distraction research which may not be possible through smaller-scale studies. Therefore, these should be seen as an important step towards reducing distraction-related accidents. To this end, a concentrated effort is needed to identify:

- what projects are planned;
- when they are due to begin;
- whether they are likely to address UK research needs; and
- whether it is feasible to exploit or build on them.

This could be achieved through a brief data collection exercise and an expert workshop to share knowledge and prioritise projects. After this, decisive steps would need to be taken to ensure effective UK participation.

8 ACKNOWLEDGEMENTS

The work described in this report was carried out in the Human Factors and Simulation Group of the Transport Research Laboratory.

The authors would also like to thank members of the core and wider reference groups for their contributions to the project:

- Dr Gary Burnett;
- Dr Peter Burns;
- Professor Oliver Carsten;
- Dr Helen Dudfield;
- Dr Johan Engstrom;
- Mr Mark Fowkes;
- Mr Rob Gifford;
- Professor John Groeger;
- Dr Joanne Harbluk;
- Professor Hirano Kawashima;
- Dr Terry Lansdown;
- Professor John Lee;
- Professor Andrew Parkes;
- Dr Michael Pettitt;
- Associate Professor Mike Regan;
- Mr John Richardson;
- Professor Neville Stanton;
- Professor Geoff Underwood; and
- Dr Trent Victor.

9 REFERENCES

- Ady, R. (1967) An Investigation of the relationship between illuminated advertising signs and expressway accidents. *Traffic Safety Research Review*, 3, 9–11.
- Angell, L., Auflick, J., Austria, P. A., Kochher, D., Tijerina, L., Biever, W., Diptiman, T., Hogsett, J. and Kiger, S. (2006) *Driver Workload Metrics Task 2 Final Report*. Report No. DOT HS910 635. Washington, DC: National Highway Traffic Safety Administration.
- Beirness, D. J., Simpson, H. M. and Pak, A. (2002) *The Road Safety Monitor: Driver Distraction*. Ontario, Canada: Traffic Injury Research Foundation.
- Braitman, K. A., Kirley, B. B., McCartt, A. T. and Chaudhary, N. K. (in press) Crashes of novice teenage drivers: characteristics and contributing factors. *Journal of Safety Research*.
- Broughton, J. and Hill, J. P. (2005) Mobile Phone Use by Drivers, 2000–2003. TRL Report No. 634. Wokingham, Berkshire: Transport Research Laboratory (TRL).
- Burnett, G. E. (2004) An evaluation of different positions for an in-vehicle navigation display. *Proceedings of the International Conference of Traffic and Transport Psychology*, Nottingham, UK, 6–9 September 2004.
- Burnett, G. E. (2008) Designing and evaluating in-car user-interfaces. In J. Lumsden (ed.), *Handbook of Research on User-Interface Design and Evaluation for Mobile Technology*. Idea Group Inc.
- Burnett, G. E., Lomas, S., Mason, B., Porter, J. M. and Summerskill, S. J. (2005) Writing and driving: an assessment of handwriting recognition as a means of alphanumeric data entry in a driving context. *Advances in Transportation Studies*, 59–72.
- Burns, P. C., Parkes, A., Burton, S., Smith, R. K. and Burch, D. (2002) *How Dangerous is Driving with a Mobile Phone? Benchmarking the Impairment to Alcohol*. TRL Report No. 547. Crowthorne, Berkshire: TRL Limited.
- Canada Safety Council (2003) *Multi-Tasking While Driving ~ “Yes” Responses*. From 2003 Nerves of Steel survey, commissioned by The Steel Alliance and the Canada Safety Council.
- Canadian Automobile Association (CAA) and the Traffic Injury Research Foundation (TIRF) (2006) *International Conference on Distracted Driving – Summary of Proceedings and Recommendations*. Ottawa, Ontario: TIRF and CAA.
- Canadian Council of Motor Transport Administrators (2006). Strategy on Distracted Driving. www.ccmta.ca/english/committees/rsrp/strid-distraction/strid-distraction-strategy.cfm#public (accessed 21 December 2007).

- Chisholm, S. L., Caird, J. K. and Lockhart J. (in press) The effects of practice with MP3 players on driving performance. *Accident Analysis and Prevention*.
- Crown Prosecution Service (2007) *Policy for Prosecuting Cases of Bad Driving*. www.cps.gov.uk/publications/prosecution/pbd_policy.html (accessed 21 December 2007).
- Crundall, D., Bains, M., Chapman, P. and Underwood, G. (2005) Regulating conversation during driving: a problem for mobile telephones? *Transportation Research Part F: Traffic Psychology and Behaviour*, 8(3), 197–211.
- Crundall, D., Van Loon, E. and Underwood, G. (2006) Attraction and distraction of attention with roadside advertisements. *Accident Analysis and Prevention*, 38(4), 671–677.
- Dibben, N. and Williamson, V. J. (2007) An exploratory survey of in-vehicle music listening. *Psychology of Music*, 35(4), 571–589.
- Dingus, T., McGehee, D., Hulse, M., Jahns, S. and Manakkal, N. (1995) *Travtrek Evaluation Task C3 – Camera Car Study*. Report No. FHWA-RD-94-076. Mclean, VA: Office of Safety and Traffic Operations.
- Donmez, B., Boyle, L. N. and Lee, J. (2007) Safety implications of providing real-time feedback to distracted drivers. *Accident Analysis and Prevention*, 39(3), 581–590.
- Donmez, B., Boyle, L., Lee, J. D. and McGehee, D. V. (2004) *Safe VEHICLES using adaptive Interface Technology (Task 4). A Literature Review of Distraction Mitigation Strategies*. www.volpe.dot.gov/hf/roadway/saveit/docs/dec04/litrev_4a.pdf (accessed 6 January 2008)
- Driver, J. and Spence, C. (1999) Crossmodal links in spatial attention. In G. W. Humphreys, J. Duncan and A. Treisman (eds), *Attention Space and Action – Studies in Cognitive Neuroscience*. Oxford: Oxford University Press.
- Endsley, M. R. (1995) Measurement of situation awareness in dynamic systems. *Human Factors*, 37, 65–84.
- Erke, A., Sagberg, F. and Hagman, R. (2007) Effects of route guidance variable message signs (VMS) on driver behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour*, 10(6), 447–457.
- Eysenck, M. W. (2000) *Psychology: A Student's Handbook*. East Sussex: Psychology Press.
- Gartner, U., Konig, W. and Wittig, T. (2002) Evaluation of Manual vs. Speech Input when using a Driver Information System in Real Traffic. http://ppc.uiowa.edu/Driving-Assessment/2001/Summaries/Driving%20Assessment%20Papers/02_Gartner_Wittig.htm (accessed 6 December 2007).

- Green, P., Hoekstra, E. and Williams, M. (1993) *Further On-the-road Tests of Driver Interfaces: Examination of a Route Guidance System and Car Phone*. Report No. UMTRL-93-35. Ann Arbor, MI: University of Michigan Transportation Research Institute.
- Haberlandt, K. (1994) *Cognitive Psychology*. Boston: Allyn & Bacon.
- Haigney, D. E., Taylor, R. G. and Westerman, S. J. (2000) Concurrent mobile (cellular) phone use and driving performance task demand characteristics and compensatory processes. *Transportation Research Part F*, 3, 113–121.
- Hanowski, R.J., Perez, M.A. and Dingus, T.A. (2005). Driver distraction in long-haul truck drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, 8(6), 441-458
- Harbluk, J. L., Noy, Y. I., Trbovich, P. L. and Eizenman, M. (2007) An on-road assessment of cognitive distraction: impacts on drivers' visual behavior and braking performance. *Accident Analysis & Prevention*, 39(2), 372–379.
- Harms, L. and Patten, C. (2003) Peripheral detection as a measure of driver distraction. A study of memory-based versus system-based navigation in a built-up area. *Transportation Research Part F: Traffic Psychology and Behaviour*, 6(1), 23–36.
- Hatfield, J. and Chamberlain, T. (2008a) The effect of audio materials from a rear-seat audiovisual entertainment system or from radio on simulated driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, 11(1), 52–60.
- Hatfield, J. and Chamberlain, T. (2008b) The impact of in-car displays on drivers in neighbouring cars: survey and driving simulator experiment. *Transportation Research Part F: Traffic Psychology and Behaviour*, 11(2), 137–146.
- Hedlund, J., Simpson, H. and Mayhew, D. (2006). International Conference on Distracted Driving: Summary of Proceedings and Recommendations, Toronto, Canada, 2 – 5 October 2005, www.distracteddriving.ca/english/documents/ENGLISH-DDProceedingsandRecommendations.pdf (accessed 21 December 2007).
- Hill, J. P. (2005) *A Survey of Mobile Phone Use by Drivers, April 2004*. TRL Report No. 635. Wokingham, Berkshire: Transport Research Laboratory (TRL).
- Hollnagel, E. (1993) *Human Reliability Analysis: Context and Control*. London: Academic Press.
- Holohan, C., Culler, R. and Wilcox, B. (1978) Effects of visual distraction on reaction time in a simulated traffic environment. *Human Factors*, 20(4), 409–413.
- Horberry, T., Anderson, J., Regan, M. A., Triggs, T. J. and Brown, J. (2006) Driver distraction: the effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. *Accident Analysis & Prevention*, 38(1), 185–191.

- Horberry, T. and Edquist, J. (in press) Distractions outside the vehicle. In M. A. Regan, J. D. Lee and K. Y. Young (eds), *Driver Distraction: Theory, Effects and Mitigation*. Florida, USA: CRC Press.
- Horberry, T., Stevens, A., Cotter, S., Robbins, R and Burnett, G. (2007) *Occlusion Protocol*. Published Project Report PPR 259. Wokingham, Berkshire: Transport Research Laboratory (TRL).
- Horrey, W. J., Lesch, M. F. and Garabet, A. (2007) Awareness of performance decrements due to distraction in younger and older drivers. *Proceedings of the 4th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, Stevenson, WA.
- Houtenbos, M. (2008) *Expecting the Unexpected: A study of interactive driving behaviour at intersections*. PhD thesis. Technical University of Delft.
- Insurance Bureau of Canada (2006) Avoiding Driver Distractions. www.abc.ca/en/Car_Insurance/Road_Safety/Driver_Distraction.asp (accessed 13 December 2007).
- International Standards Organisation (2007) *ISO 16673: 2007 Road Vehicles – Ergonomic Aspects of Transport Information and Control Systems – Occlusion Method to Assess Visual Distraction due to the use of In-vehicle Systems*. ISO.
- Jamson, A. H. and Merat, N. (2005) Surrogate in-vehicle information systems and driver behaviour: effects of visual and cognitive load in simulated rural driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, 8(2), 79–96.
- Jamson, A. H., Westerman, S. J., Hockey, G. R. J. and Carsten, O. M. J. (2004) Speech-based ‘email’ and driver behavior: effects of in-vehicle message system interface. *Human Factors*, 46, 625–639.
- Jancke, L., Musial, F., Vogt, J. and Kalveram, K. T. (1994) Monitoring radio programs and time of day effect simulated car driving performance. *Perceptual Motor Skills*, 79, 484–486.
- Jenness, J. W., Lattanzio, R. J., O’Toole, M. and Taylor, N. (2002) Voice-activated dialling or eating a cheeseburger. Which is more distracting during simulated driving? *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting*, Pittsburg, PA.
- Jennings, J.M. and Jacoby, L.L. (1997). An opposition procedure for detecting age-related deficits in recollection: telling effects of repetition. *Psychology and Aging*, 12(2), 352-361.
- Kahneman, D. (1973) *Attention and Effort*. Englewood Cliffs, NJ: Prentice-Hall.
- Karlsson, R. (2004) *Evaluating Driver Distraction Countermeasures*. PhD Thesis. Linkopings Universitet, Sweden

- Kircher, K. (2007) *Driver Distraction: A Review of the Literature*. Vti (Swedish National Road and Traffic Research Institute) Rapport 594A. Linköping, Sweden: Vti.
- Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D. and Ramsey, D. J. (2006) *The Impact of Driver Inattention on Near-crash/crash risk: An Analysis using the 100-car Naturalistic Driving Study Data*. National Highway Traffic Safety Administration (NHTSA) Report No. DOT HS 810 594. Washington, DC: NHTSA.
- Lansdown, T. C. (2002) Individual differences during driver secondary task performance: verbal protocol and visual allocation findings. *Accident Analysis and Prevention*, 34(5), 655–662.
- Lee, J. D., Craven, B., Haake, S. and Brown, T. L. (2001) Speech based interaction with in-vehicle computers: the effects of speech-based E-mail on drivers' attention to the roadway. *Human Factors*, 45, 631–639.
- Lee, J. D., Young, K. L. and Regan, M. A. (2008) Defining driver distraction. In M. A. Regan, J. D. Lee and K. Y. Young (eds), *Driver Distraction: Theory, Effects and Mitigation*. Florida, USA: CRC Press.
- Lesch, M. F and Hancock, P. A. (2004) Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? *Accident Analysis and Prevention*, 36(3), 471–480.
- McEvoy, S. P., Stevenson, M. R. and Woodward, M. (2006) The impact of driver distraction on road safety: results from a representative survey in two Australian states. *Journal of Injury Prevention*, 12(4), 242–247.
- McKnight, A. J. and McKnight, A. S. (1993) The effect of cellular phone use upon driver attention. *Accident Analysis and Prevention*, 25, 259–265.
- Michon, J. A. (1985) A critical view of driver behavior models. What do we know, what should we do? In L. Evans and R. Schwing (eds), *Human Behavior and Traffic Safety*. New York: Plenum press. pp. 485–525.
- National Highway Traffic Safety Administration (NHTSA) (2000) *The Driver Distraction Internet Forum*. U.S. Department of Transport, NHTSA. www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Welcome.htm (accessed 18 December 2007).
- Neale, V. L., Dingus, T. A., Klauer, S. G., Sudweeks, J. and Goodman, M. J. (2005) *An Overview of the 100-car Naturalistic Study and Findings*. National Highway Traffic Safety Administration (NHTSA) Report No. 05-0400. Washington, DC: NHTSA.
- Neyens, D. M. and Boyle, L. N. (2008) Influence of driver distraction on the severity of injuries sustained by teenage drivers and their passengers. *Accident Analysis and Prevention*, 40(1), 254–259.

Norman, D. A. and Bobrow, D. G. (1975) On data-limited and resource limited processes. *Cognitive Psychology*, 7, 44–64.

Olsson, S. and Burns, P. C. (2000) Measuring driver visual distraction with a peripheral detection task. Available online at *The Driver Distraction Internet Forum*. U.S. Department of Transport, National Highway Traffic Safety Administration. www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Welcome.htm (accessed 23 January 2008).

Östlund, J. Carsten, O., Merat, N., Jamson, S., Janssen, W. and Brouwer, R. (2004) *Deliverable 2—HMI and safety-related driver performance. Human Machine Interface And the Safety of Traffic in Europe (HASTE) Project*. Report No. GRD1/2000/25361 S12.319626., ec.europa.eu/transport/roadsafety_library/publications/haste_d2_v1-3_small.pdf (accessed 23 January 2008).

Östlund, J., Peters, B., Thorslund, B., Engström, J., Markkula, G., Keinath, A., Horst, D., Juch, S., Mattes, S., Foehl, U. (2005). Driving Performance Assessment – Methods and Metrics. Adaptive Integrated Driver-vehicle Interface (AIDE) Project. Report No. D2.2.5., www.aide-eu.org/pdf/sp2_deliv/aide_d2-2-5.pdf (accessed 23 January 2008).

Parkes, A.M., Sexton, B., Burton, S., Hu, H.L., Shaw, J. and Daggy, B. (2001). An evaluation of the effects of an energy drink on post-lunch and early evening driving performance. International Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Colorado, August 2001, ppc.uiowa.edu/Driving-Assessment/2001/Summaries/Driving%20Assessment%20Papers/12_Parkes_Andrew.htm (accessed 18 December 2007).

Parkes, A. M. and Hooijmeijer, V. (2000) The influence of the use of mobile phones on driver situation awareness. National Highway Traffic Safety Administration (NHTSA). Internet Forum on ‘The safety impact of driver distraction using in-vehicle devices’, 5 July 2000. www.driverdistraction.org (accessed 18 December 2007).

Parkes A. M., Luke T., Burns P. C. and Lansdown T. (2007) *Conversations in Cars: The Relative Hazards of Mobile Phones*. TRL Report No. 664. Wokingham, Berkshire: Transport Research Laboratory (TRL).

Victorian Automobile Chamber of Commerce (2005). Driver Distraction Prepared for the Parliament of Victoria Road Safety Committee Inquiry www.vacc.com.au/LinkClick.aspx?fileticket=fhR8vuLSPsI%3D&tabid=2399 (accessed 6 December 2007).

Patel, J., Ball, D. J. and Jones, T. (in press) Factors influencing subjective ranking of driver distractions. *Accident Analysis and Prevention*.

Pettitt, M. (2007) *Development of an Extended Keystroke Level model for Predicting the Visual Demand of In-Vehicle Interfaces*. PhD thesis. University of Nottingham.

- Pettitt, M. A., Burnett, G. E. and Stevens, A. (2005) Defining driver distraction. *Proceedings of 12th ITS World Congress*, San Francisco, USA, ITS America.
- Ranney, T., Mazzae, E., Garrott, R., Goodman, M. J. (2000) NHTSA Driver distraction research: past, present and future. *The Driver Distraction Internet Forum*. www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Papers20233.htm#A233 (accessed 4 December 2007).
- Reed-Jones, J., Trick, L. M. and Matthews, M. (in press) Testing assumptions implicit in the use of the 15-second rule as an early predictor of whether an in-vehicle device produces unacceptable levels of distraction. *Accident Analysis and Prevention*.
- Risser, R. (1985) Behaviour in traffic conflict situations. *Accident Analysis and Prevention*, 17(2), 179–197.
- Roskam, A. J., Brookhuis, K. A., de Waard, D., Carsten, O. M. J., Read, L., Jamson, S., Östlund, J., Bolling, A., Nilsson, L., Antilla, V., Hoedemaeker, M., Janssen, W. H., Harbluk, J., Johansson, E., Tevell, M., Fowkes, M., Victor, T. and Engström, J. (2002) *Deliverable 1 – Development of Experimental Protocol*. Human Machine Interface And the Safety of Traffic in Europe (HASTE) Project GRD1/2000/25361 S12.319626.
- Sampson E. (2007) *Notes on the Driver Distraction Workshop 7 February 2007*. London: Department for Transport.
- Schneider, W. and Detweiler, M. (1988) The role of practice in dual-task performance: toward workload modeling in a connectionist/control architecture. *Human Factors*, 30(5), 539–566.
- Schneider, W. and Shiffrin, R. M. (1977) Controlled and automatic human information processing: 1. Detection, search, and attention. *Psychological Review*, 84, 1–66.
- Senders, J. W., Kristofferson, A. B., Levison, W. H., Dietrich, C. W. and Ward, J. L. (1967) The attentional demand of automobile driving. *Highway Research Record*, 195, 15–33.
- Shinar, D., Tractinsky, N. and Compton, R. (2005) Effects of practice, age, and task demands on interference from a phone task while driving. *Accident Analysis and Prevention*, 37(2), 315–326.
- Srinivasan, R. and Jovanis, P. P. (1997) Effect of in-vehicle route guidance systems on driver workload and choice of vehicle speed: findings from a driving simulator experiment. In Y. I. Noy (ed), *Ergonomics and Safety of Intelligent Driver Interfaces*. New Jersey: Lawrence Erlbaum Associates Publishers.
- Stevens, A. and Minton, R. (2001) In-vehicle distraction and fatal accidents in England and Wales. *Accident Analysis and Prevention*, 33, 539–545.

- Strayer, D. L., Crouch, D. and Drews, F. A. (2006) A comparison of the cell-phone driver and the drunk driver. *Human Factors*, 48, 381–391.
- Strayer, D. L., Drews, F. A. and Johnston, W. A. (2003) Cell phone induced failures of visual attention during simulated driving. *Journal of Experimental Psychology: Applied*, 9, 23–32.
- Stutts, J. C., Reinfurt, D. W., Staplin, L. and Rodgman, E. A. (2001) *The Role of Driver Distraction in Traffic Crashes*. Washington, DC: Foundation for Traffic Safety.
- Surface Transportation Technical Group (STTG) (2002) Effect of Cellular Telephone Use on Choice Response Time in a Simulated Driving Task and Tracking Accuracy in a Simple Tracking Task. USA: STTG.
- Tijerina, L., Parmer, E. and Goodman, M. (1998) Driver workload assessment of route guidance system destination entry while driving: a test track study. *Proceedings of the 5th ITS World Congress*, Seoul, Korea.
- Transport Canada (2003). Strategies for Reducing Driver Distraction from In-Vehicle Telematics Devices: A Discussion Document. TP 14133 E, www.tc.gc.ca/roadsafety/tp/tp14133/pdf/tp14133e.pdf (accessed 21 December 2007).
- Transport Research Laboratory (2007) *Mobile Phone Use by Drivers, 2005–2007*. TRL Report No. LF2103. Crowthorne, Berkshire: TRL.
- Transport Research Laboratory (2006) *Mobile Phone Use by Drivers, 2004–2006*. TRL Report No. LF2100. Crowthorne, Berkshire: TRL.
- Totzke, I., Hoffmann, M. and Kruger, H. P. (2005) Age, previous knowledge, and learnability of driver information systems. In G. Underwood (ed.), *Traffic and Transport Psychology – Theory and Application*. Oxford: Elsevier.
- Vashitz, G., Shinar, D. and Blum, Y. (2008) In-vehicle information systems to improve traffic safety in road tunnels. *Transportation Research Part F: Traffic Psychology and Behaviour*, 11(1), 61–74
- Victor, T. (2005) *Keeping Eye and Mind on the Road*. PhD thesis. Uppsala Universitet.
- Wickens, C. D. (1984) Processing resources in attention. In R. Parasuraman and R. Davies (eds), *Varieties of Attention*. New York: Academy Press.
- Wierwille, W. A. (1993) Visual and manual demands of in-car controls and displays. In B. Peacock and W. Karwowski (eds), *Automotive Ergonomics*. Washington, DC: Taylor & Francis. pp. 299–320.
- Wikman, A. S., Nieminen, T. and Summala, H. (1998) Driving experience and time sharing during in-car tasks on roads of different width. *Ergonomics*, 41, 358–372.
- Wilson, J. R. and Corlett, N. (2005) *Evaluation of Human Work*, third edition. London: Taylor & Francis.

Young, K., Regan, M. and Hammer, M. (2003) *Driver Distraction: A Review of the Literature*. Monash University Accident Research Centre Report No. 206. Victoria, Australia: Monash University.

Young, M. S. and Stanton, N. A. (1998) What's skill got to do with it? Vehicle automation and mental workload. In M. A. Hanson (ed.) *Contemporary Ergonomics*. London: Taylor & Francis.

Young, M. S. and Stanton, N. A. (2002) Malleable Attentional Resources Theory: a new explanation for the effects of mental underload on performance. *Human Factors*, 44(3), 365–375.

Young, M. S., Mahfoud, J. M., Walker, G. H., Jenkins, D. P. and Stanton N. A. (in press) Crash dieting: the effects of eating and drinking on driving performance. *Accident Analysis and Prevention*.

APPENDIX 1

Research gaps grouped by methodology

Research gap	Epidemiological approach	Survey/questionnaire	Focus group	Laboratory testing	Simulator study	Track/road trials	Naturalistic driving
A. Measuring driving performance degradations, and the impact of these on crash risk, from specific distractors outside of the vehicle (e.g. rubbernecking, advertisements, signs, road furniture)	✓			✓	✓	✓	✓
B. Measuring driving performance degradations caused by people and other non-technological distractors within the vehicle, in real situations			✓		✓		✓
C. The relative effects on driving performance and interaction effects of in- and extra-vehicle distractors, including current and emerging technologies		✓	✓	✓	✓	✓	✓
D. Measuring the effects of different IVIS interface designs on driving performance (including modality/multi-modality, layout, menu complexity, etc.) ¹							
E. The cumulative and interactive distracting effects of a combination of in-vehicle technologies (including task-switching)		✓	✓	✓	✓	✓	✓
<i>(continued)</i>							

¹ This was identified as being a relatively well-researched area; thus, it was thought that the focus should be on the implementation of research findings rather than the identification of a methodology for research.

Research gap	Epidemiological approach	Survey/questionnaire	Focus group	Laboratory testing	Simulator study	Track/road trials	Naturalistic driving
F. The frequency and duration of drivers' actual use of the different functions of in-vehicle technologies (e.g. texting, internet, email functions of mobile phones) and of multiple functions or technologies, and the impact of this on risk during real-world driving	✓	✓	✓			✓	✓
G. Understanding the distinction between sensory and perceptual distractors (e.g. 'looked but failed to see' accidents)				✓	✓		
H. Identification of high-risk groups for distraction (e.g. elderly drivers, business drivers, younger drivers) and the effects of distractors on these groups	✓			✓	✓		✓
I. Drivers' knowledge of the effects of distracted driving, their attitudes towards engagement with distractors and factors which would motivate drivers or different groups of driver to change their behaviour		✓	✓			✓	
J. The relationship between the findings of experiments (in terms of driving performance degradations) and actual near-miss or crash rates due to distractors	✓						
K. Quantification of the role of distraction (or individual distractors) in accident causation based on existing crash data, hence the cost to society of distracted driving and related crashes	✓						
<i>(continued)</i>							

Research gap	Epidemiological approach	Survey/questionnaire	Focus group	Laboratory testing	Simulator study	Track/road trials	Naturalistic driving
L. The development of a standard, meaningful, objective and reliable test procedure and baseline to identify 'unacceptable' levels of visual distraction (potentially in real time)				✓	✓	✓	
M. The development of a standard, meaningful, objective and reliable test procedure and baseline to identify 'unacceptable' levels of cognitive and auditory distraction (potentially in real time)				✓	✓	✓	
N. The identification of best practice to monitor the effects of distracted driving (e.g. accident rates, driver behaviour and attitudes) over time	✓	✓					✓