Driver Distraction Caused by Mobile Devices: Studying and Reducing Safety Risks

Luca Chittaro and Luca De Marco

HCI Lab, Dept. of Math and Computer Science
University of Udine
via delle Scienze 206, 33100 Udine, Italy
+39 0432 558450

chittaro@dimi.uniud.it, demarco@dimi.uniud.it

Abstract. In this paper, we survey the different topics and issues related to the study and prevention of risks associated to the in-car usage of mobile devices (such as cellular phones) and complex interfaces (such as *Advanced Traveller Information Systems* or ATIS). More specifically, we will first give a classification of the types of driver distraction, addressing some of its specific sources and the incidence on safety; then, we will illustrate the tasks carried out on mobile devices that are most likely to lead to crashes and we will give examples of the risks of using mobile devices while driving. We will then concentrate on how the safety-relevant distraction effects induced by a particular device interface can be measured and how the design of the device user interfaces can be made safer.

1 Introduction

The risks and benefits associated to the in-car usage of mobile devices (such as cellular phones) and complex interfaces (such as *Advanced Traveller Information Systems* or ATIS) are not yet well understood. It is difficult to precisely determine the effects of these technologies on the safety of the driver and her passengers, especially due to facts such as the lack of an amount of statistical data sufficient to find out the causal relationships between usage of these technologies and crash data and the need to agree on measures to assess the level of driver distraction in a practical, reliable and indicative way.

It must be noted that this field of research is constantly progressing. This paper aims thus at introducing the reader to the main issues by surveying relevant literature, inviting the reader to further study the presented topics by keeping up-to-date with the recent projects carried out in this community.

The paper is organized as follows. Section 2 provides a categorization of driver distraction types. In section 3, the *incidence of device usage* on safety and the factors that influence the driver's *willingness to engage* in a secondary task are discussed. In section 4, the mobile device tasks that are most likely to lead to crashes are presented and some studies which demonstrate the risks of device usage while driving are summarized. In section 5, the basic research needs to improve the safety and usability of existing and new in-vehicle systems are reviewed. Sections 6 and 7 list the main research needs and initiatives to reduce crash risks. In section 8, the most important and most frequently used measures to investigate the safety-relevant distraction effects induced by a particular device interface are summarized. Section 9 motivates the need to devote special attention to older drivers in the design of mobile interfaces.

2 Types of Distraction

Driver distraction can manifest itself in several ways. The first form is the withdrawal of attention, which can be divided in two types: general and selective, according to the classification by [Brown, 1994], or, correspondingly, *eyes-off-the-road* and *mind-off-the-road* according to the classification by [Green, 2000].

A *general withdrawal of attention (eyes-off-the-road)*, as described in [Tijerina, 2000], manifests itself in both degraded vehicle control and degraded object and event detection. This is due to eyelid closure (in the case of driver fatigue) or eye glances away from the road scene (in the case of visual inattention). As [Green, 2000] points out, in-vehicle tasks that are visually demanding, such as reading detailed maps or long strings of text, are likely to lead to crashes, or at least to a greater amount of this kind of visual distraction.

A *selective withdrawal of attention (mind-off-the-road)* seems to be a more insidious type of distraction. As, described in [Tijerina, 2000], vehicle control (e.g., lanekeeping, speed maintenance) remains largely unaffected but object and event detection is degraded. This is due to driver's attention to thought (e.g., daydreaming or listening to a long or complex auditory message), which can lead to a selective filtering of information based on expectations rather than the actual situation and to *looked-but-did-not-see* phenomena. This can have serious consequences on the road where, for example, a driver at a cross-road *looks* at a vehicle approaching from the right without really *seeing* it, because she is involved in a heated telephonic conversation, so she crosses the road colliding with the other vehicle.

Another form of distraction is the one referred to as *biomechanical interference* (or simply *mechanical interference*) in [Tijerina, 2000]. This refers to body shifts out of the neutral seated position, e.g., reaching a cellular telephone or leaning to see or manipulate a device. This can degrade the driver's ability to execute manoeuvres. The relevance of this effect is indicated by a series of studies summarized in [Green, 2000] (more details about these studies are presented in Section 4).

3 Incidence of Device Use

Together with task demand of in-vehicle device usage, the incidence of task execution is critical to safety evaluations and safety benefits estimation. To illustrate this point, [Tijerina, 2000] presents the example of hands-free cellular phone operation, pointing out that the perception that hands-free operation is *safe*, could induce drivers, who previously used hand-held units, to use their cellular phones more frequently, for longer conversations and over a broader range of speed regimes, road types, and driving situations (e.g., dense traffic, bad weather). In this scenario, the final result could be an increase rather than a reduction of the number of crash occurrences due to cellular phone use while driving.

This hypothesis is supported also by [Llaneras, 2000], stressing that even though hands-free (and voice recognition) technology may eliminate the associated manual and visual demands of operating a cell phone, allowing drivers to keep both hands on the wheel and eyes on the road, these technologies do not address the more insidious and potentially problematic issue of cognitive distraction. The fact that attending to a demanding cognitive task while driving produces changes in the driver's visual behaviour, vehicle control and subjective assessments of workload, safety and distraction, is illustrated also in [Harbluk, Noy and Eizenman 2002] with an on-road experiment, during which participants where asked to carry out tasks of varying cognitive complexity, and data about the dependent variables were automatically registered using the MicroDAS system (some details about this system are presented in Section 5.2).

Another important aspect to take into account is the driver's *willingness to engage* in a secondary task [Ranney et al., 2000], which is a function of a multiplicity of factors, including driver (e.g., experience), vehicle (e.g., display design), environmental (e.g., weather), situational (e.g., urgency) and task characteristics (e.g., ease of use). Thus, at any given time, a driver's decision to carry out a secondary task is based on a complex set of factors. This is one of the reasons why associating specific devices with a specific degree of risk is a very complex issue.

As [Green, 2000] mentions, motor vehicle manufacturers are well aware of the connections between usability, safety, and product liability, while the computer and electronics manufacturers have had little experience with the safety concerns so central to motor vehicle design. For this reason, caution on their part is imperative and primary attention, during the design of new in-vehicle devices and interfaces, should focus on their impact on safety.

4 Tasks that can lead to crashes

Driver inattention is one of the most common causes of traffic crashes, as demonstrated by statistical data from several studies.

Based on an analysis of NHTSA crash data [Ranney et al., 2000], the major components of inattention-related crashes reported by U.S. police include: "distraction" (attending to tasks other than driving, e.g., tuning the radio, speaking on a phone; interacting with other people or children, etc.); “looked but did not see” (e.g., situations where the driver may be lost in thought or was not fully attentive to her surroundings), and situations where the driver was drowsy or fell asleep. All together, these crashes account for approximately 25 percent of police reported crashes; distraction was most likely to be involved in rear-end collisions in which the lead vehicle was stopped and in single vehicle crashes; crashes in which the driver “looked but did not see” occurred most often at intersections and in lane-changing/merging situations [Ranney et al., 2000].

Another important study that highlights the importance of driver distraction is [Stutts et al., 2003]. In the first part of that study, 5 years of U.S. national crash data (from 1995 to 1999) were analyzed finding out that the percentage of distraction-induced crashes was equal to 13.7 percent (8.3% of drivers identified as visually distracted, 5.4% identified as *looked but did not see*) which is not as high as from NHTSA’s data, but still represents a significant percentage of crashes. Moreover, in the second part of the study, 70 volunteer test drivers were found to be engaged in some form of potentially distracting activity up to 16 percent of the time they were driving, not including any conversations they may have had with passengers.

[Green, 1998] provides a summary of the most relevant aspects emerging from a set of data collected by the *Japanese National Police Agency Traffic Planning Department* about mobile phone and navigation system related crashes (the data was obtained from post-crash interviews of drivers by the police, for a total of 59 crashes only one of which was fatal). Among this data, the most noteworthy is a 25.4 percent of crashes (15 out of 59, among which the fatal one) where the driver was operating the navigation system and not only looking at its screen. It must be noted that all 11 Japanese vehicle manufacturers comply with the *Japan Automobile Manufacturers Association (JAMA)* guidelines, which prohibit many of the in-vehicle device tasks, including destination entry while moving. Aftermarket suppliers and old OEM products may not be in compliance and approximately 63 percent of the units shipped to the date of the study were aftermarket units.

Other interesting results about the causes of crashes come from the “*Tri-Level Study*”, one of the fundamental studies in this area [Dingus, Gellatly and Reinach, 1997]. Although at the time of the study, which is quite dated (1975), in-vehicle technology was not very widespread, inattention, in-vehicle sources of distraction and evaluation errors are the principal causes of crashes. The “*Tri-Level Study*” identifies three fundamental factors which contribute to crashes: driver errors in 93% of the cases, environmental factors in 34%, vehicle-related factors in 13%. The percentage sums to more than 100, because factors are not mutually exclusive but are often co-occurring. Human errors can be divided in the following categories, with their relative percentage of incidence: 56% recognition, 52% decision, 11% execution.

A general conclusion that can be derived from the “*Tri-Level Study*”, and is confirmed by other subsequent studies, is that a major part of crashes is not caused by careless people who voluntarily infringe the rules of the road, but by well-intentioned drivers committing a series of mistakes.

In [Green, 2000], interesting data about the causal relationships between device use while driving and crashes are presented and various studies about cellular phones and navigation systems are mentioned. In the following, we summarize the most interesting facts.

4.1 Tasks Performed by Drivers with cellular phones

The tasks most often associated with crashes related to mobile phone are (in decreasing order of frequency): receiving a call, dialing and talking. The task of receiving a call is the most risky one, because mobile phones are often left in a place that is difficult to reach for the driver (e.g., in a coat or jacket pocket, on the passenger seat, in a briefcase in the back seat) and people tend to leave whatever they are doing when the phone rings (as they would do in an office or home setting) to the detriment of safe driving. The adoption of hands-free cellular phones can reduce this sort of *mechanical* effect, but cannot reduce the cognitive distraction involved in the conversation.

The following data emerge from the series of studies cited in [Green, 2000] (for a complete discussion of the research on mobile phones, see [Goodman et al., 1997]):

- The risk of a collision when using a cellular telephone is up to four times higher than when a cellular phone is not used; units that allowed the hands to be free seem to offer no safety advantage over hand-held units.

- The risk of a collision increases with the frequency of calls.
- Crashes involving phone users are more likely to be caused by inattention, unsafe speed, or being on the wrong side of the road, and are much more likely to happen in cities, a location assumed to demand more attention.
- Reaction time while using the phone increases 45 percent for non-regular phone users and 60 percent for regular phone users.
- Glance data also suggests decreases in attention to the road due to using the phone while driving.

Some other interesting considerations come from [Llaneras, 2000], who stresses that, among the three types of distraction cited in the literature, only visual and mechanical distraction can be partially reduced (but not totally removed). Indeed, visual distraction can be reduced with the increasing experience of the driver in using the interface of the system and with a good design of the interface itself, but is still inevitable for certain functions (e.g., message reading). Mechanical distraction can be even eliminated, thanks to the use of hands-free cellular phones and vocal commands. On the contrary, cognitive distraction, which seems to be the most relevant aspect for safe cell phone use while driving, does not seem to be eliminable. Even after years of talking on the land line phone, our ability to concentrate on more than one activity does not seem to improve. To realize the truth of this assertion, it is sufficient to think to the way we respond to someone who is standing in front of us trying to capture our attention while we are on the phone: often we wave them away, or interrupt our conversation on the phone to address the other person [Llaneras, 2000].

Someone may not be convinced about the risks of phone usage and claim that talking with passengers induces the same kind of distraction. Unfortunately, as [Green, 2000] points out, the conversation with passengers is much less distracting than a phone conversation, because to some degree passengers limit the complexity of what they say to match the driver's ability to process that information at the moment, while a person on the phone has no knowledge of the driving situation.

In summary, crash data indicate a significant increase in crash risk associated with using mobile phones in moving vehicles, with the increase in risk being on the order of 4 or so, with the risk increasing with frequency of phone use and cognitive distraction substantially ineliminable.

4.2 Tasks Performed by Drivers with Navigation Systems

For in-vehicle-navigation and route-guidance systems used to guide drivers to destinations, the tasks of interest are [Green, 1998]:

- entering the destination into the navigation system;
- following system guidance;
- calibration and set up.

Little research has been done on calibration and other miscellaneous navigation-system tasks, probably because they are rarely performed, while considerable work has focused on the first two tasks.

The question about the destination entry task is whether to allow drivers carrying it out in a moving vehicle or not. In [Green, 1997], several circumstances in which the availability of the destination entry function while driving would be useful and desirable, are reported. Among them:

- The driver being in a hurry and knowing the general direction to start with, enters the destination immediately after starting.
- The driver decides to change destination enroute.
- The driver entered the wrong destination.
- The driver did not know the exact destination at the beginning of the trip (e.g., the desired intersection) and therefore entered a location near the destination.

According to the already mentioned *JAMA Guidelines*, destination entry in a moving vehicle must be prohibited as being too distracting for the driver. Following other guidelines, the question to permit it or not depends on meeting certain thresholds of attention: the so called "*15-Second Rule*", for example, establishes that any navigation function that is accessible by the driver while a vehicle is in motion shall have a total task time of less than 15 seconds when operated on a *static* vehicle [SAE J2364, 2000]. In an experimental study [Green, 1999], correlations between static task performance and dynamic task performance were relatively low. The results were interpreted to suggest that the use of a static test in applying the 15-second rule could not be used to reliably predict the acceptability of a device. The rule was found to be effective in identifying the most distracting tasks, but in this regard, it did no better than would a 30- or 45-second rule. Nevertheless, the authors conclude that the rule itself and the ideas behind it may suggest areas for improving the development of objective test procedures for a variety of in-car information systems.

There are two fundamental choices about the route guidance function. The first is the presentation modality, which can be auditory or visual (or even bi-modal) and in the case of visual information can take the form of a route map or turn-by-turn instructions. The second is the level of detail and the quantity of information presented. Both aspects are to be limited to avoid the risk of introducing an excessive level of distraction due to information overload.

In [Green, 1997], a series of navigation-related crash situations (the first two involving destination entry; the second two involving route following) are presented. An example for each of the four situations is reported in the following:

- *Situation 1*. The driver is on an expressway and looking at the navigation system while entering a destination and something occurs without warning requiring an immediate response (e.g., lead vehicle brakes or another vehicle cuts in);
- *Situation 2*: The driver is in an urban area and looking at the navigation system while entering a destination, misses a stop sign or traffic light and collides with a vehicle on a crossing path. This might include never seeing the signal at all or not noticing a state change;
- *Situation 3*: The driver is on a limited-access road and receives guidance too late, either because the guidance was poorly timed or the driver missed the prepare-to-exit message. The driver hastily attempts to change lanes to get to the exit.
- *Situation 4*: The driver is in an urban area and receives a prepare-to-turn or turn message. Thinking it to be a command (and believing the computer knows all), the driver acts abruptly ignoring traffic conditions (e.g., colliding with another vehicle) or road signals (e.g., turns down a one-way street in the wrong direction).

4.3 Tasks Performed by Drivers with Internet Services

Thanks to wireless networks and technologies, mobile services such as e-mail and Web access are increasingly available to drivers.

According to [Burns and Lansdown, 2000], the availability of Internet information in the vehicle can provide wide and enduring benefits for drivers, passengers, commercial vehicle operations, service providers and transport systems managers, but there is considerable evidence that complex in-vehicle information systems can distract the driver.

The principal advantages of using *In-Vehicle Internet* systems are:

- The availability of maps updated in real time based on traffic conditions could help drivers in avoiding traffic congestions.
- The availability for passengers of commercial, entertainment and support information relative to the surrounding area (e.g., to make hotel and restaurants reservations and to check the availability of a number of services and points of interest, such as parking, gas stations, museums, theatres, etc.) could enhance the traveling experience.

The specific issues related to this kind of systems are the following:

- Drivers will have to wait an uncertain and potentially long time for the information, because loading time will depend on multiple factors, such as the quantity of information, the demand on the provider and the demand on the device loading the information. Yet every second of delay is a risk for distraction and frustration, both with potential negative consequences on safety.
- The dynamic and inconsistent nature of Internet information in structure and format and the unfamiliar and unpredictable nature of its presentation will inevitably increase the cognitive demands on the driver, which can become excessive and incompatible with driving; moreover, a mouse would be clearly unsuitable for use while driving, and users rarely browse the Web using a keypad or speech recognition.

Some possible solutions to the above-mentioned issues are:

- Reformatting of information to present data in a simplified way that is more suitable for an in-car interface (e.g., the same principles used for WAP interfaces on mobile phones might be adopted as a starting point).
- Conventional interfaces should be available only while the vehicle is stationary and be automatically turned off, at least for the driver, while the vehicle is in motion. The passengers should always have access to full functions. However, there must be some consideration about whether the passengers' (especially the front seat one's) interaction with a device will distract the driver, for example in the case that the driver is able to see the display showing moving objects or flashing banners such as advertisements.

5 Basic Research Needs for New In-Vehicle Systems

Green [1996] illustrates three fundamental directions that need to be taken into account to design and evaluate the safety and usability of existing and new systems. To provide the data necessary to reach this goal, there is the need to, firstly, gather information on how people drive at present (both normally and before crashes) and, secondly, organize this information as models of driving behavior, which developers can then apply.

5.1 Measure how people normally drive

According to [Green, 1996], baseline data are needed to examine how people drive now and determine if new systems make driving safer and easier. Using instrumented cars, data should be collected about how normal drivers (i.e., not familiar with in-vehicle devices) perform when they drive to work or go shopping. The factors of interest are:

- driver age and sex,
- type of car,
- type of road,
- traffic,
- regional differences in driving aggressiveness.

The results from this research could be used to develop standards for normal driving (e.g., *On average, an electronic map should require no more fixations than a paper map*). To conduct normative driving studies (and certify products), an agreed upon set of measures is needed (both of driver output and vehicle output), to be chosen as the most important and predictive ones (a list of them will be presented in Section 8). There is also the need for evidence linking those measures to driving difficulty. Without agreement, engineers cannot verify claims that a particular design is safer or easier to use than another.

NHTSA first major effort in this area was the *Truck Driver Workload Study*, conducted between 1992 and 1995 [Tijerina, 1996] [Tijerina et al., 1996]. An experimental study was carried out with 16 professional drivers, who drove over-the-road under a variety of conditions (reading various text messages displayed on a screen, performing manual dialing tasks, and responding to questions imposing cognitive demand to simulate wireless phone dialogue). One major conclusion of this work was that workload assessment is best considered as a relative assessment made in comparison to other tasks or baselines. Open-road driving was considered to be a baseline in terms of driving task workload, while tuning a radio was considered to be the upper boundary of acceptable workload for a secondary task since it is a well established and accepted distraction. A second conclusion of this work was the demonstration that there are some measures which can be used effectively to assess the driver's workload associated with in-vehicle devices (e.g., visual allocation measures, including glance duration, number of glances, and total glance time away from the road scene) and safety-relevant performance levels (e.g., lane-keeping measures, such as lane excursion frequency).

More recently, an important study relative to distractions in everyday driving [Stutts et al., 2003] was conducted in two phases. In phase I, 5 years (from 1995 to 1999) of national crash data were analyzed with the primary purpose to provide input for developing a taxonomy of driver distractions, identifying the major sources of distraction contributing to crashes, and the specific circumstances of these crashes (what type of road they occurred on, whether they occurred more or less often at nighttime, at what age drivers were most involved) that would guide subsequent real-world observations in drivers' vehicles. The narrative descriptions of the crashes provided by police officers who investigated them were also examined for further insight into the problem. In phase II of the study, the goal was to measure the frequency of occurrence of these various distractions in everyday driving. The consequences of the distractions on driving performance were also measured by means of video-recording equipment mounted on 70 volunteer subjects' vehicles, recording about 3 hours of videotape for each participant. Although limited in the number of subjects and driving period length, some interesting results emerge from this second part of the study. The most important ones are those pointed out in [Stutts, 2003]:

- distractions are a very common component of everyday driving (16% of subjects driving time, not including any conversations they may have had with passengers);
- there are many sources of driver distraction (cell phones, radio controls, eating or drinking, reaching for things inside their vehicle, or attending to events outside their vehicle);
- passengers can also be a source of distraction, especially babies and young children;
- descriptive data on the various distractions has been collected; for example, it took the 28 cell phone users an average of 13 seconds to dial a number, 8 seconds to answer a ringing phone, and each conversation averaged about 1 ½ minutes; to change the radio station or insert a CD or tape, drivers manipulated their audio systems about 8 times per hour of driving.
- insights about how distractions might interfere with safe driving were gained, e.g.,
    - § when drivers were dialing the cell phone or answering to it, they were looking inside the car 68% of the time vs. the 23% of the time when they were manipulating music controls;
    - § reading and writing, dialing the cell phone, manipulating vehicle controls are among the activities that were especially likely to be associated with high rates of driving with no hands on the steering wheel;
    - § reaching for objects inside the vehicle, eating or drinking, dialing or answering cell phones, and interacting with babies are the distractions associated with the highest rates of swerving or crossing into another lane.

5.2 What happens prior to real crashes?

Accident reconstruction (using skid marks and vehicle damage) is a well-accepted engineering practice [Green, 1996]. Detailed data is available from flight and voice recorders for virtually every major air transport accident, but not for automobile crashes. Knowing where drivers were looking at, what were other vehicles doing, etc., prior to crashes could be valuable in identifying the causes of accidents. Engineers will find the data on what is distracting very useful for designing safer vehicles.

A fleet of vehicles should be instrumented to record driver and vehicle performance parameters during normal driving on public roads. This idea is currently being followed by NHTSA (*National Highway Traffic Safety Administration*), which has developed a family of vehicle instrumentation systems that allow one to assess driver performance and behavior under a wide range of conditions [Ranney et al., 2000]. In particular, MicroDAS [Barickman and Goodman, 1999] is a portable data acquisition system that can be installed in any vehicle, including test participants' own vehicles, with minimal obtrusion. The system includes analog and digital event recording systems and a video event recording system, the latter capable of collecting over 22 hours of full-motion video, allowing one to conduct naturalistic studies of driving behavior.

5.3 Formulate models of driving

Normal driving data should be used to develop models of driving, which enable to compute estimates of driver performance, workload and crash risks, induced by the use of in-vehicle devices while driving.

Generally speaking, a model could be:

- a verbal description of how of a system works;
- a flow chart;
- a set of equations that provide engineering estimates;
- an exact quantitative description of a system.

A useful *model of driving* should consider road geometry, traffic, vehicle description, and driver behavior files, from which the model should generate predictions of driver behavior (e.g., glance durations and frequencies), performance (speed and lateral position), and workload over time. Using data describing typical drivers and trips for the proposed interface, designs (varying in the types of controls and displays used, etc.) could be computed.

Another important aspect to consider is that on-the-road human factors tests are conducted all over the world, using different types of roads, drivers, and vehicles. Measurements are also obtained from driving simulators, which on one side eliminate the danger of real driving conditions, but on the other side reduce the experiment realism. However, comparisons of on-the-road tests with each other are rare, and even rarer are comparisons of simulators with on-the-road tests, or simulators with each other. These comparisons are needed to determine the accuracy and reliability of data.

6 Reducing crash risks

While some people believe that safety is a driver's responsibility or that education is the answer, others propose laws to regulate the in-vehicle use of devices (in particular, someone claims that only emergency calls should be legal while the vehicle is in motion).

Nevertheless, the best way to eliminate hazards is to design them out, and [Green, 2000] proposes a three-way strategy to reduce crash risks to a minimal level. This strategy is summarized in the following three subsections.

6.1 Apply and Extend Driver Interface Regulations and Design Guidelines

Laws to regulate the use of cellular phones are different from nation to nation. Parkes and Hooijmeijer (2000) analyzed some of them, concluding that the situation is confused and continuously changing, but there seems to be a tendency towards an increasingly strict regulation, prohibiting at least the use of non-hands-free cellular phones while driving, if not even all but emergency calls.

Considering navigation system interfaces, although we are not aware of specific laws, there are many guidelines of varying authority. Among those guidelines, the most important ones at national level are:

- **JAMA** (*Japan Automobile Manufacturers' Association*) [JAMA, 2000]; although not mandatory, all 11 Japanese vehicle manufacturers comply with them and encourage their widespread adoption all over the world. They are far more restrictive than all the other guidelines. Among other things, when a vehicle is in motion, they prohibit to present the driver with:
    - § images of television broadcasts or video playback;
    - § phone numbers and addresses as guiding information;
    - § introductions to restaurants and hotels, although pictures showing their location may be presented;
    - § scrolling characters;
    - § messages longer than 31 characters, excluding punctuation and units;
    - § complex operations, like destination entry.

  However, the JAMA guidelines are lacking with respect to the following aspects:
    - § supporting documentation explaining the empirical basis for each guideline;
    - § general references to previous research;
    - § details about test data, i.e.,
        - driver's tasks (with pictures of the interfaces);
        - vehicles and streets types;
        - instructions given to subjects;
        - measures used;
        - statistical analysis;
    - § they are based on Japanese driving conditions.
- **SAE Recommended Practice J2364**, commonly known as **"***15-Second Rule***"** [SAE J2364, 2000]; it does not apply to vocal interfaces, and specifies:
    - § prohibited tasks in a moving vehicle (all navigation tasks, involving the combined use of visual and manual controls, with a total static completion time greater than 15 seconds);

- § information about the set-up of the system under investigation, which must be operational and fitted into a vehicle, buck or mock-up in the design intent location;
  - § information about test subjects:
    - how many,
    - age,
    - familiarity with the system under investigation.
- **SAE Recommended Practice J2365** [SAE J2365, 2001]; it provides a method for calculating the time required to complete navigation system-related tasks, in order to check the conformity of a system to SAE J2364. Given a step-by-step description of a driver's task, J2365 provides a method to quickly estimate total task times by means of a spreadsheet starting from available estimates for various types of keystrokes, mental activities, and other actions. The relevant advantage of J2365 is that task times can be estimated when the design is still in the early stages, and system modifications are easier to make.
- **UMTRI Guidelines** (*University of Michigan Transportation Research Institute*) [Green et al., 1993]; it is a set of extensive and research-based guidelines, developed with the support of the *U.S. Department of Transportation*. These guidelines:
  - § focus on the presentation modality of the information to drivers and on the input methods required to manipulate the interface of devices;
  - § are based on field tests (in laboratory, simulator and on-road environments) with younger and older drivers, and on driver interface design experience (literature references are also given);
  - § are well organized in categories (i.e., *principles*, *general guidelines* and *specific guidelines*) and types (*general*, *specific* and *integration oriented*), well commented and with good application examples, in order to provide a reference manual for the in-vehicle interface designer (although the authors stress the fact that they are not normative).

  However their authors also warn that:
  - § the guidelines have been explicitly developed for the american road context, so that some (minor) modifications could be necessary before they can be applied in other countries (e.g., traffic circles, which are very common in Europe, are not present in the USA);
  - § the guidelines have been explicitly developed for car vehicles, although the authors claim that they should be applicable also to light trucks, vans and mini-vans, which operates in the same conditions of cars.
  - § disabled and impaired drivers have not been explicitly considered.
- **Battelle Guidelines** (*Human Factors Transportation Center*) [Campbell, Carney and Kantowitz, 1998]; it is a set of extensive and research based guidelines, developed with the support of the *U.S. Federal Highway Administration*. Like the UMTRI guidelines, they provide a reference manual for the in-vehicle interface designer, being well organized and rich in comments, literature references and examples. Some peculiar characteristics of these guidelines are that:
  - § they address almost all aspects of in-vehicle system design (the first two chapters are introductory ones):
    - information presentation on displays (chapter 3),
    - controls selection and manipulation style (chapter 4),
    - routing and navigation (chapter 5),
    - information services (chapter 6),
    - safety and warning messages (chapter 7),
    - augmented signage information (chapter 8),
    - commercial vehicle operation (chapter 9);
  - § they use a *4-star rating system* to assess the relative contribution of empirical data and expert judgment, with the following meaning:
    - **ÜÜÜÜ**: mainly empirical data,
    - **ÜÜÜ**: empirical data, supported by expert judgment,
    - **ÜÜ**: expert judgment, supported by empirical data,
    - **Ü** : mainly expert judgment;
  - § They contain 8 *Design Tools* in the form of data-flow diagrams containing simple questions to be answered by the designer to take decisions about:

- *Trip status allocation* (e.g., pre-drive, zero speed, or in transit) of a task.
- *Sensory modality allocation* (e.g., visual, auditory, or visual and auditory) of a task.
- *Display format allocation* (e.g., text, icon, graphics, or route map) of the information to be presented.
- *Display location* (e.g., head-up or head-down).

- **HARDIE** (*Harmonization of ATT Roadside and Driver Information in Europe*) **Guidelines** [Ross et al., 1996]; it is an European set of guidelines for navigation systems, based upon more general principles than the previous ones. Like the previous ones, they provide a reference manual for the in-vehicle interface designer, so they are well organized and contain comments, literature references and examples, but they do not address all the in-vehicle system design aspects. Their focus is only on the presentation of information (not input controls) to the driver (not passengers), while the vehicle is in motion (not static).

6.2 Employ Human Factors Experts, Data, and Methods to Develop Driver Interfaces

The second direction in the strategy proposed by [Green, 2000] is to employ the following elements in designing driver interfaces:

- **Guidelines** and **Recommended Practices** (see previous subsection).
- **Task analysis**.
- **Driver testing** (perhaps the most important aspect):
  - § in static mockups;
  - § in driving simulators;
  - § on circuits and on the road.

6.3 Carry out Research on and Development of a Workload Manager

What drivers are able to do in a moving vehicle depends upon the workload of the driving situation and their capabilities that depend on their age and expertise [Tsimhoni and Green, 1998].

The final goal of the 3-way approach proposed in [Green, 2000] is to develop a *workload manager* that should be able to adjust automatically the quantity of information delivered to the driver, based on:

- workload due to driving conditions;
- availability of visual and mental resources for in-vehicle information processing;
- single tasks priority.

All the information needed by a workload manager is likely to be available in a near-term vehicle. In fact, workload depends on:

- road geometry;
- traffic conditions;
- vehicle speed;
- signs;
- weather;
- time of day;
- in-vehicle tasks.

Unfortunately, there is currently no method to compute workload from this data and research funding is minimal [Green, 2000]. Moreover, as pointed out in [Ranney et al., 2000], it is the coincidence of driver inattention and the occurrence of unanticipated events (e.g., curves in the road, vehicle cut in) that characterizes the random nature of distraction-related crashes. It follows that the dynamic nature of the circumstances across drivers, along with the random nature of distraction-related crashes, would make it difficult to associate specific devices with a specific degree of risk.

7 Safety Initiatives

In the following we provide a summary of the organizations that promote initiatives concerning safety risks involved in using devices while driving, and the main initiatives they promoted:

- *European Union* (EU): *Statement of Principles* for automotive human-machine interfaces [European Commission, 1998].
- *Alliance of Automobile Manufacturers* (AAM): very general guidelines [Alliance of Automobile Manufacturers, 2001], based on the European Union principles [European Commission, 1998].
- *Federal Highway Administration* (FHWA): sets of guidelines for in-vehicle information systems, developed by UMTRI [Green et al., 1993] and by Battelle [Campbell, Carney and Kantowitz, 1998].
- *Intelligent Transportation Society of America* (ITS-A): board level task force on driver distraction formed to present at U.S. House of Representative hearings, reported in [Green, 2001].
- *International Standards Organization* (ISO), in particular *Technical Committee 22* (TC 22), *Subcommittee 13* (SC 13), "*Working Group 8*" (WC 8): international standards for dialog management, suitability for use while driving, message priority, and accessibility while driving (draft and working draft standards), reported in [Green, 2001].
- *Japan Automobile Manufacturers Association* (JAMA): human-machine interface guidelines used by all OEMs in Japan [JAMA, 2000].
- *National Highway Traffic Safety Administration* (NHTSA), *U.S. Department of Transportation*: *Driver Distraction Internet Forum* [Llaneras, 2000]; workshops on research needs; program *CAMP* (*Crash Avoidance Metrics Partnership*), a 3-year effort to develop workload metrics.
- *Society of Automotive Engineers* (SAE): standards for accessibility while driving (SAE J2364, "the 15-second rule" [SAE J2364, 2000]), compliance calculations for SAE J2364 (SAE J2365 [SAE J2365, 2001]), and message priority (SAE J2395).

According to [Green, 2001], SAE and ISO activities proceed in parallel and there is a working group seeking to integrate the U.S. 15-second rule and the JAMA regulation into a single evaluation method suitable for broad use. That effort is hampered by a lack of data comparing the alternative evaluation methods.

Noteworthy from all of this activity is the lack of formal action on voice interfaces (although the subject is dealt with in the main guidelines cited in this work: UMTRI, Battelle and HARDIE) due to the lack of research data on specific tasks, but also to a lack of speech experts on the SAE and ISO ergonomics committees [Green, 2001].

Other possible initiatives that might be taken to limit the problem of driver distraction and facilitate effective driver-system integration are discussed in detail in [Road Safety and Motor Vehicle Regulations Directorate, 2003]. All the initiatives cited in that report need input and commitment from the stakeholders part and cooperation between the organizations previously cited to have a really effective impact. The following is a list of some of the most important initiatives extracted from [Road Safety and Motor Vehicle Regulations Directorate, 2003], which are not mutually exclusive and may be complementary:

- Public awareness campaigns, that however suffer from some limitations: they are costly, they should involve manufacturers and although they might alleviate some of the problems, effects might be only temporary.
- A voluntary *Memorandum of Understanding* between government jurisdictions and industry, that would require manufacturers to agree to follow the leading human factors guidelines for the design of in-vehicles systems and implement a design process for driver-system integration. This process would involve:
    - § the systematic application of human factors considerations in the design and development of in-vehicle devices, taking a process-oriented approach to design, in analogy to the ISO 9000 family of standards;
    - § the equipment of vehicles with event data recorders to record details on the status of in-vehicle devices at the time of collisions, to help clarifying the causes of collisions;
    - § the development of a comprehensive features database of equipment fitted to specific models of motor vehicles to help to gauge the risk of these devices.
- Regulatory initiatives, disabling access to in-vehicle devices in moving vehicles.
- Prohibition of open-architectures that would allow the use of untested after-market *plug-and-play* type applications.

Another important on-going initiative (pursued, among others, by the NHTSA [Ranney et al., 2000]) is the implementation of highly realistic driving simulators, that will offer the capability to study safety issues in a setting that does not compromise driver safety, but allows drivers to experience a wide range of demands associated with driving conditions (e.g., traffic, weather), driver state (e.g., fatigue, drugs) and tasks (e.g., cell phone, navigation). It will further provide the opportunity to assess the distraction potential associated with various in-vehicle technologies (e.g., user interfaces) under identical driving conditions, which cannot be repeated in on-road studies.

8 Device Demand Measures

As we have seen, there is an urgent need to carry out research studies about the safety of device usage while driving. Safety cannot be measured directly, but some indirect measures can be employed to investigate the safety-relevant distraction effects induced by a particular device interface.

Following [Katz et al. 1997], the first step is to establish what should be measured, how to measure it and why. For in-vehicle device interfaces, the primary issues are usefulness, safety, and ease of use (usability). Information is desired both concerning how well the interface performs with respect to those features and how the interface might be improved.

Desirable measures should be:

- *Indicative*: the measures should reflect usefulness, usability, or safety in an unambiguous way (e.g., if a navigation system allowed people to driver faster, on one side it would enhance mobility, but on the other side it would increase the risk of a serious injury in a collision).
- *Reliable*: poor reliability can affect subjective measures where the decision rules are not clear and objective measures where technology limitations lead to inconsistency.
- *Accepted by researchers and practitioners*: although there may be excellent scientific evidence supporting a particular measure, if the measure is not understood or believed by those who will be applying the results, it is of little value.
- *Easy to take and analyse*: practical constraints have a major impact on how studies are conducted; certain techniques are simply too expensive to be adopted or too time-consuming to be analyzed (eye fixations measures are a good example for both kinds of problems).

In the following we summarize the most important and most frequently used measures reported by the literature (for each measure, a list of some relevant studies in which it has been employed is cited).

8.1 Driver eye glance behaviour

Driver eye glance behaviour is a primarily relevant measure to be taken into account because of the dominant role of sight while driving (approximatively 90 percent of information comes from the visual channel while driving [Dingus, Gellatly and Reinach, 1997]). Driver eye glance behavior measures inform about the visual distraction induced by the various kinds of in-vehicle devices. The primary metrics which take into account driver eye glances towards an in-vehicle device for a certain task are:

- *Mean glance duration* ([Tsimhoni, Yoo and Green, 1999] [Brooks, Nowakowski and Green, 1998] [Chiang, Brooks and Weir, 2001] [Tijerina et al. 2000]).
- *Number of glances* ([Tsimhoni, Yoo and Green, 1999] [Brooks, Nowakowski and Green, 1998] [Chiang, Brooks and Weir, 2001] [Manes and Green, 1997]).
- *Total glance duration:* the product of *number of glances* and *mean glance duration* ([Tsimhoni, Yoo and Green, 1999] [Chiang, Brooks and Weir, 2001] [Tijerina et al. 2000]).
- *Mean time between glances* ([Tsimhoni, Yoo and Green, 1999] [Brooks, Nowakowski and Green, 1998]).
- *Glance frequency* ([Brooks, Nowakowski and Green, 1998] [Tijerina et al. 2000]).
- *Eyes-off-the-road time* ([Tsimhoni, Yoo and Green, 1999] [Manes and Green, 1997]).

As reported in [Green, 1997], the main problems of this kind of measures are:

- data reduction time is very time consuming (typically 30-40 times subject testing times), because, although automated methods are being developed, the data is currently collected by aiming a video camera at the driver's face and manually examined by playing back the tape at slow speed to determine the duration of each off-road glance and count their frequency;

- technical challenges of automated systems, as getting a magnetically-sensing head tracker to work in a magnetically-unfriendly environment (car body), counteracting the solar overload of IR-based eye trackers, and resolving the optical interference of glasses, worn by virtually all older drivers;
- norms on acceptable and unacceptable glance durations and frequencies are missing;
- finally, this kind of measures requires expensive data collection material and the installation of a working prototype inside a real vehicle (with all the safety risks involved) or inside a mockup in the context of a (expensive) drive simulation environment.

8.2 Driving performance

This category includes all vehicle control aspects. The measures are particularly relevant to safety, because they address the effect of in-vehicle device operation on driving performance, giving indirect information about the cognitive and visual distraction due to the execution of secondary tasks while the vehicle is in motion. The primary metrics reported in literature are:

- Driver control measures:
  - § *Lateral control*, in terms of mean and standard deviation of the *steering wheel angle* ([Tsimhoni, Yoo and Green, 1999] [Tsimhoni, Green and Lai, 2001] [Vollrath and Totzke, 2000]);
  - § *Longitudinal control*, in terms of mean and standard deviation of the *throttle angle* ([Tsimhoni, Yoo and Green, 1999]).
- Vehicle external behaviour:
  - § *Lateral behaviour*:
    - mean and standard deviation of the *lateral position* ([Tsimhoni, Yoo and Green, 1999] [Parkes and Hooijmeijer, 2000] [Tsimhoni, Green and Lai, 2001] [Vollrath and Totzke, 2000] [Katz et al. 1997] [Chiang, Brooks and Weir, 2001] [Manes and Green, 1997]),
    - *number of lane excursions* ([Tsimhoni, Yoo and Green, 1999] [Nowakowski and Green, 1998] [Manes and Green, 1997] [Tijerina et al. 2000]),
    - *time to line crossing* ([Tsimhoni, Yoo and Green, 1999]), where *line* stands for one the lane’s delimiting lines,
    - *lateral acceleration* ([Tsimhoni, Yoo and Green, 1999]);
  - § *Vehicle speed*:
    - mean and standard deviation of *speed* and *acceleration* ([Parkes and Hooijmeijer, 2000] [Vollrath and Totzke, 2000] [Nowakowski and Green, 1998] [Katz et al. 1997] [Manes and Green, 1997]);
  - § mean and standard deviation of the *distance from the leading vehicle* ([Vollrath and Totzke, 2000]).
- *Reaction times*:
  - § to the breaking of the leading vehicle ([Lee et al. 2000] [Martens and van Winsum, 2000]);
  - § to an unexpected obstacle ([Martens and van Winsum, 2000] [Olsson and Burns, 2000] [Parkes and Hooijmeijer, 2000]).
- *Situation awareness* ([Parkes and Hooijmeijer, 2000] [Lee et al. 2000]), defined in [Parkes and Hooijmeijer, 2000] as a person’s perception of the elements of the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future. According to [Parkes and Hooijmeijer, 2000], there are three levels of *situation awareness* (assessed by means of a set of questions to test subjects):
  - § Level 1: perception of the elements in the environment.
  - § Level 2: comprehension of the current situation.
  - § Level 3: projection of future status.
- *Time-to-collision (TTC)* ([Green, 1997] [Tijerina, 2000] [Katz et al., 1997]), defined as how long it would take for a collision to occur if all vehicles on the road retained their current velocity and acceleration tensors indefinitely. TTC is a measure of the safety cocoon around a vehicle, and consequently has considerable appeal for safety evaluations. However, devices for

measuring TTC for safety evaluations are not widely available. Additionally, driver norms for TTC (needed to assess what is safe and unsafe) are lacking and there are no plans to develop norms.

According to [Green, 1997], speed variance and lane variance measures are partially biased, because the use of the in-vehicle devices is intermittent, so obtaining differences in normal driving on straight roads is difficult. As a solution to intermittency problems, he proposes to partition each trip into sections and only examine those sections where the device use is likely (e.g., near turns for navigation systems). Nevertheless, the driving behaviour varies greatly, depending on the driver and the current situation. Moreover, levels of acceptable performance are uncertain as normative data on "plain old driving" are lacking. Until normative data will be available, [Katz et al., 1997] suggest to gather all the previously mentioned measures to be able to identify tendencies based on a large amount of data.

8.3 Secondary tasks performance

This category includes all the performance measures related to secondary task execution, namely, all tasks which involve the operation of an in-vehicle device while the vehicle is in motion. The primary measures are:

- *Task completion time*:
  - § in a *static* vehicle ([Tsimhoni, Yoo and Green, 1999] [Manes and Green, 1997] [Tijerina et al. 2000]);
  - § in a *moving* vehicle ([Tsimhoni, Yoo and Green, 1999] [Manes and Green, 1997] [Tijerina et al. 2000]).
- *Time to answer* to test questions ([Tsimhoni, Green and Lai, 2001] [Brooks et al. 1999] [Brooks and Green, 1998] [Brooks, Nowakowski and Green, 1998] [Nowakowski and Green, 1998]).
- *Percentage of errors* in answers to test questions ([Martens and van Winsum, 2000] [Olsson and Burns, 2000] [Brooks et al. 1999] [Brooks and Green, 1998] [Brooks, Nowakowski and Green, 1998] [Nowakowski and Green, 1998] [Katz et al. 1997] [Manes and Green, 1997]).
- *Number of keystrokes* ([Chiang, Brooks and Weir, 2001]).

8.4 Subjective assessments

Subjective assessments given by test participants are especially useful to find out the improvements needed by a particular interface and can highlight previously unconsidered aspects. Generally, they are gathered about the following aspects:

- Ease of use of a system ([Katz et al. 1997] [Chiang, Brooks and Weir, 2001]).
- Safety ([Tijerina et al. 2000]).
- Distraction ([Lee et al. 2000]).
- Mental workload ([Katz et al. 1997] [Lee et al. 2000] [Tsimhoni, Green and Lai, 2001]): the NASA *Task Load Index* (TLX) is one of the most used tests for this purpose.
- Preferences between different interfaces and/or features ([Katz et al. 1997] [Tijerina et al. 2000]).

9 Older Drivers

There is an increasing interest towards the growing older drivers' community. For example, a substantial part of current studies (especially those conducted by UMTRI) about human performance with in-vehicle devices, involves both younger (18-30 years) and older (65-75 years) drivers.

According to [Mourant et al., 2000], in-vehicle devices are a two-edged sword for older drivers because with advancing age drivers experience diminished perceptual and cognitive abilities that make it difficult to use in-vehicle displays. When using an in-vehicle display to obtain potentially useful information, a driver usually makes a small head movement to the right together with an eye-movement of about 30-35 degrees and adjusts his/her eyes for close vision which involves convergence eye movements and accommodation of the eye lenses. For people who are 60 years or older, these processes take longer and thus older drivers spend more time than young drivers acquiring information from an in-vehicle display.

Some of the main effects of age on driver performance are [Green, 2001]:

- Depending on the driving situation, the visual demand of older drivers is 15-50% greater than younger ones.
- Older drivers require 40% longer to respond to warnings on HUDs (*Head-Up Displays*).
- Older drivers require 33-100% longer to read maps in a simulator, with an increasing difference as the task complexity grows; moreover, older drivers made more errors.
- Older drivers require 40-70% longer to read maps on the road, with an increasing difference as the task complexity grows.
- Older drivers require 80% longer to enter destinations in static vehicle conditions.

The differences reported above might also be underestimated because no drivers older than 75 were included in the tests carried out by UMTRI.

Driving in "normal" conditions already imposes a larger cognitive load on older drivers than on younger ones. This workload is further increased by the introduction of in-vehicle devices. This additional workload imposed on older drivers is particularly worrying, especially considering that the completion times of some tasks [Tijerina et al., 2000] are in the order of minutes and so lengthy distraction times could expose older drivers to unacceptable levels of risk.

10 Conclusions

In this paper, we surveyed the different topics and issues in the study and prevention of risks of in-car usage of mobile devices (such as cellular phones) and complex interfaces (such as *Advanced Traveller Information Systems* or ATIS).

Using mobile devices and services while driving inevitably introduces a certain level of distraction for the driver. The driving distractions can be categorized in three types: visual (or *eyes-off-the-road*), cognitive (or *eyes-off-the-road*) and mechanical (or *biomechanical interference*). Among these types of distractions, the cognitive one seems to be the most difficult to eliminate, because a certain level of mental workload would be implied, for example, even if the interface presented only auditory information (eliminating visual distraction) and accepted vocal input (eliminating mechanical interference).

Receiving a phone call, manipulating the navigation system (e.g., entering the destination) and operating Internet information services are among the most distracting tasks related to mobile devices, performed by the driver while the vehicle is in motion. Several studies highlight the risk of using mobile devices while driving, although there is no extensive and detailed crash statistical data to determine the magnitude of the distraction induced by these tasks. There is the need to conduct basic research about how people normally drive (in absence of in-vehicle devices) and about what actually happens prior to real crashes in order to be able to formulate models of driving and possibly develop workload manager systems.

During the design of the interfaces for devices that will be used in cars, a particular attention must be devoted to reducing their interference with the primary driving task. Researchers and system designers need to study in depth this interference, to find out the most distracting tasks and the most effective metrics and techniques to measure the usability, efficiency and safety level of a particular interface, in a consistent and replicable manner.

Other important initiatives to improve device safety are the development of guidelines and user-centered methodologies to be used during the design and production processes and their promotion as international standards to be adopted by all the manufacturers.

Finally, special attention should be devoted to the growing older drivers' community, because driving in "normal" conditions already imposes a larger cognitive load on older drivers than on younger ones and this workload is further increased by the introduction of in-vehicle devices.

References

Alliance of Automobile Manufacturers (2001). Statement of Principles on Human Machine Interfaces (HMI) for In-Vehicle Information and Communication Systems (*Draft*, October 19), Washington, D.C.: Alliance of Automobile Manufacturers.

Barickman, F. S., and Goodman, M. J. (1999). Micro DAS: In-vehicle portable data acquisition system. *Transportation Research Record* 1689, 1-8.

Brooks A. and Green P. (1998). Map Design: A Simulator Evaluation of the Time to Read Electronic Navigation Displays (*Technical Report UMTRI-98-7*). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Brooks A., Lenneman J., George-Maletta K., Hunter D. and Green P. (1999). Preliminary Examinations of the Time to Read Electronic Maps: The Effects of Text and Graphic Characteristics (*Technical Report UMTRI-98-36*). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Brooks A., Nowakowski C., Green P. (1998). Turn-by-Turn Displays Versus Electronic Maps: An On-the-Road Comparison of Driver Glance Behavior (*Technical Report UMTRI-98-37*). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Brown I. D. (1994). Driver fatigue. Human Factors, 36 (2), 298-314.

Burns P. C. and Lansdown T. C. (2000). E-Distraction: The Challenges for Safe and Usable Internet Services in Vehicles. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm.

Campbell J. L., Carney C. and Kantowitz B. H. (1998). Development of Human Factors Guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) (*Technical Report FHWA-RD-98-057*). Battelle Human Factors Transportation Center Seattle, WA.

Chiang D., Brooks A. and Weir D. (2001). An Experimental Study of Destination Entry with an Example Automobile Navigation System. *Proceedings of the Workshop on Exploring the Occlusion Technique: Progress in Recent Research and Applications*, Torino, Italy.

Dingus T. A., Gellatly A. W. And Reinach S. J. Human Computer Interaction Applications for Intelligent Transportation Systems. *Handbook of Human-Computer Interaction, Second Completely Revised Edition* (*1997*). Helander M., Landauer T. K., Prabhu P. (eds.), 53, 1259-1282.

European Commission, Task Force HMI (1998). European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems. *Telecommunications, Information Market and Exploitation of Research. Telematics applications (networks and services). Telematics applications for transport and the environment.* Directorate-General XIII (*Final Report*).

Goodman M., Bents F.D., Tijerina L., Wierwille W., Lerner N., and Benel D. (1997). An Investigation of the Safety Implications of Wireless Communication in Vehicles (Technical Report DOT HS 808 635), Washington, D.C.: U.S. Department of Transportation.

Green P. (1996). Customer Needs, New Technology, Human Factors, and Driver Science Research for Future Automobiles. *Journal of the Society of Mechanical Engineers*, 99(926), 15-18.

Green P. (1997). Potential Safety Impacts of Automotive Navigation Systems. *Proceedings of Automotive Land Navigation Conference*, June 18, 1997, Detroit, MI.

Green P. (1998). Visual and Task Demands of Driver Information Systems (*Technical Report UMTRI-98-16*). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Green, P. (1999). SAE J2364 – Navigation and route guidance function accessibility while driving (*Draft*). Warrendale, PA: Society of automotive engineers.

Green P. (2000). Crashes Induced by Driver Information Systems and What Can Be Done to Reduce Them (*SAE paper 2000-01-C008*). Convergence 2000 Conference Proceedings (SAE publication P-360). Warrendale, PA: Society of Automotive Engineers, 26-36.

Green P. (2001). Safeguards for On-Board Wireless Communications. *Proceedings of Second Annual Plastics in Automotive Safety Conference*, Troy, Michigan.

Green P., Levison W., Paelke G. and Serafin C. (1993). Preliminary Human Factors Guidelines for Driver Information Systems. (*Technical Report UMTRI-93-21*). Ann Arbor, MI: The University of Michigan Transportation Research Institute. (also published as FHWA-RD-94-087, McLean, VA: U.S. Department of Transportation, Federal Highway Administration, December, 1995).

Harbluk J. L., Noy Y. I., Eizenman M. (2002). The Impact of Cognitive Distraction on Driver Visual Behaviour and Visual Control. Minister of Transport Canada. http://www.tc.gc.ca/roadsafety/tp/tp13889/pdf/tp13889es.pdf.

JAMA: Japan Automobile Manufacturers Association (2000). Guideline for In-vehicle Display Systems - Version 2.1 (document ISO/TC 22/SC 13/WG 8/N304), Geneva, Switzerland: International Standards Organization.

Katz S., Fleming J., Green P., Hunter D.R. and Damouth D. (1997). On-the-Road Human Factors Evaluation of the Ali-Scout Navigation System (*Technical Report UMTRI-96-32*). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Lee J. D., Caven B., Haake S., Brown T. L. (2000). Speech-based Interaction with In-vehicle Computers: The Effect of Speech-based E-mail on Drivers' Attention to the Roadway. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm

Llaneras, R.E. (2000). NHTSA Driver Distraction Internet Forum: Summary and Proceedings. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/pdf/nrd-13/FinalInternetForumReport.pdf

Manes D. and Green P. (1997). Evaluation of a Driver Interface: Effects of Control Type (Knob Versus Buttons) and Menu Structure (Depth Versus Breadth) (*Technical Report UMTRI-97-42*). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Martens M. H., van Winsum W. (2000). Measuring distraction: the Peripheral Detection Task. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm

Mourant R. R., Tsai F., Al-Shihabi T. and Jaeger B. K. (2000). Divided Attention Ability of Young and Older Drivers. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm.

Nowakowski C. and Green P. (1998). Map Design: An On-the-Road Evaluation of the Time to Read Electronic Navigation Displays (*Technical Report UMTRI-98-4*). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Olsson S., Burns P. C. (2000). Measuring Driver Visual Distraction with a Peripheral Detection Task. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm

Parkes A., Hooijmeijer V. (2000). The Influence of the Use of Mobile Phones on Driver Situation Awareness. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm.

Ranney T. A., Mazzae E., Garrott R., Goodman M. J. (2000). NHTSA Driver Distraction Research: Past, Present, and Future. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Welcome.htm

Road Safety and Motor Vehicle Regulations Directorate (2003). Strategies for Reducing Driver Distraction from In-Vehicle Telematics Devices. *A Discussion Document* by Standards Research and Development Branch. http://www.tc.gc.ca/roadsafety/tp/tp14133/pdf/tp14133e.pdf.

Ross T., Midtland K., Fuchs M., Engert A., Duncan B., Vaughan G., Vernet M., Peters H., Burnett G., May A. (1996). HARDIE (Harmonisation of ATT Roadside and Driver Information in Europe) Design Guidelines Handbook: Human Factors Guidelines for Information Presentation by ATT Systems. Commission of the European Communities R&D Programme: Telematics Systems in the Area of Transport (DRIVE II).

Society of Automotive Engineers (2000). SAE Recommended Practice Navigation and Route Guidance Function Accessibility While Driving (*SAE J2364*, January 20). Warrendale, PA: Society of Automotive Engineers.

Society of Automotive Engineers (2001). SAE Recommended Practice Calculation of the Time to Complete In-Vehicle Navigation and Route Guidance Tasks (*SAE J2365*, March 13 revision). Warrendale, PA: Society of Automotive Engineers.

Stutts J. (2003). Distractions in Everyday Driving - Researcher's Remarks. *AAA Foundation for Traffic Safety Press Conference* Washington, D.C. August 6, 2003. The University of North Carolina Highway Safety Research Center. http://www.hsrc.unc.edu/pressrelease/distraction_remarks_phase2.htm.

Stutts J., Feaganes J., Rodgman E., Hamlett C., Meadows T., Reinfurt D., Gish K., Mercadante M., Staplin L. (2003). Distractions In Everyday Driving. *AAA Foundation for Traffic Safety* in Washington. The University of North Carolina Highway Safety Research Center (*Final Report*).

Tijerina, L. (1996). Executive summary: Heavy vehicle driver workload assessment (*Report* No. DOT HS 808 466). Washington, DC: National Highway Traffic Safety Administration.

Tijerina L. (2000). Issues in the Evaluation of Driver Distraction Associated with In-Vehicle Information and Telecommunications Systems. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm.

Tijerina, L., Kiger, S. Rockwell, T., and Wierwille, W. (1996). Heavy vehicle driver workload assessment Task 5: Workload assessment protocol (*Report* No. DOT HS 808 467). Washington, DC: National Highway Traffic Safety Administration.

Tijerina L., Johnston S., Parmer E. and Winterbottom M. D. (2000). Driver Distraction with Route Guidance (*Technical Report DOT HS 809-069*). East Liberty, OH: National Highway Traffic Safety Administration Vehicle Research and Test Center.

Tsimhoni O., Green P., and Lai J. (2001). Natural and Synthesized Speech while Driving: Effects on User Performance. *International Journal of Speech Technology*, 4(2), 155-169.

Tsimhoni O., Yoo H., and Green P. (1999). Effects of Workload and Task Complexity on Driving and Task Performance for In-Vehicle Displays As Assessed by Visual Occlusion (*Technical Report UMTRI-99-37*). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Vollrath M., Totzke I. (2000). In-Vehicle Communication and Driving: An Attempt to Overcome their Interference. *Driver Distraction Internet Forum*. http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/Topics013040229.htm.