NHTSA Driver Distraction Research: Past, Present, and Future

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Background

Driver distraction is a high priority topic for NHTSA. NHTSA has concerns that drivers are making potentially dangerous decisions about when to interact with in-vehicle technologies while driving and that this trend may accelerate as new technologies become increasingly available and easier to use. NHTSA has conducted research in the area of driver distraction and workload since 1991. The objective of this research is to understand the factors that contribute to driver distraction and to develop methods to assess the extent to which in-vehicle technologies may be distracting to drivers. This paper will summarize past NHTSA research in the area of driver distraction and workload, provide an overview of current ongoing research, and describe upcoming research that will be conducted using the National Advanced Driving Simulator (NADS).

What is driver distraction?

Driver distraction may be characterized as any activity that takes a driver's attention away from the task of driving. An examination of the crash data reveals that any distraction has the potential to cause or contribute to a crash. Thus, rolling down a window, adjusting a mirror, tuning a radio or dialing a cell phone have all been identified as causal or contributing factors in crashes. While the sources of distraction may take many forms, it is helpful to examine distraction in terms of four distinct categories; visual distraction (e.g., looking away from the roadway), auditory distraction (e.g., responding to a ringing cell phone), biomechanical distraction (e.g., manually adjusting the radio volume), and cognitive distraction (e.g., being lost in thought). Many distracting activities that drivers engage in can involve more than one of these components (e.g., visually searching for a control to manipulate). Recent concerns about the potential safety implications of technology based distractions center on the magnitude and nature of demands some of these devices can place on drivers.

Factors Influencing Distraction, Demand and a Driver's "Willingness to Engage."

The potential for distraction associated with any secondary task is determined by the workload or attentional demand associated with the task, as well as the driver's "willingness to engage" in that task. This latter factor refers to the conscious or unconscious decision processes involved in electing to carrying out secondary tasks while driving. Secondary tasks may involve driving-related tasks (e.g., adjusting a mirror), tasks indirectly related to driving (e.g., navigation) or tasks unrelated to driving (e.g., talking, eating). In addition, secondary tasks themselves may involve "associated" tasks that place further demands on the driver such as reading a phone number from a piece of paper while dialing a cell phone. Secondary tasks initiated by the driver can be scheduled to coincide with driving situations of relatively low task demand and thus have less potential for distracting the driver at an inopportune moment than those initiated elsewhere (e.g. incoming phone call). It is also clear that a driver's *willingness to engage* 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. It is the coincidence of driver inattention and the occurrence of unanticipated events (e.g., curve 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, if not impossible, to associate specific devices with a specific degree of risk.

Why is NHTSA concerned with driver distraction?

Driver inattention is one of the most common causes of traffic crashes (Wang, Knipling, and Goodman, 1996). Based on an analysis of NHTSA crash data, the major components of inattention-related police reported crashes include "distraction" (attending to tasks other than driving, e.g., tuning the radio, speaking on a phone, looking at a billboard, etc.), "looked but did not see" (e.g., situations where the driver may be lost in thought or was not fully attentive to the surrounds), 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. To provide additional detail about sources of distraction, Wierwille and Tijerina (1996) searched police report narratives for a set of crashes from North Carolina. They identified 2,819 crashes in which the driver's attention was diverted and found that the majority of these (55.5%) involved distraction due to a source inside the vehicle, including objects, interacting with another person or animal, or interacting with instrumentation, including the radio or a wireless phone.

The accelerating rate of in-vehicle technological developments has expanded NHTSA's interest to include a broader range of these technologies in its planning of research, and public information/outreach. The technological evolution that has taken place has created new alliances and competition among the wireless, computer, and automotive industries. The result has been a new generation of innovative technologies, characterized by portability, convenience and a multiplicity of functionality that can allow a user the broadest access to communications and informational resources in a mobile setting. It is this mobility that has raised the concern of NHTSA within the context of driving, where advanced technology is being made available to the driving public as well as the commercial driver, either as OEM or aftermarket systems and devices. Concern over this issue, among media, states, and the public, has been growing in light of recent announcements of new initiatives to bring computer functionality to the vehicle, including access to the world wide web, availability of Internet e-mail services, and the ability to "conduct business" and "e-commerce" while driving. Industry predictions of widespread use of these services suggests general availability at affordable prices in the near future. The potential for adverse safety consequences of using these systems and services by drivers highlights the importance of understanding the relationship between device design, the associated demands of these systems and how they interact with the factors that influence drivers' willingness to engage in secondary tasks while driving. It is the uncertainty of these relationships and the need to develop effective countermeasures to address the issue of driver inattention that serves as a basis for NHTSA's continued efforts in this area.

Past NHTSA Research

Truck Driver Workload Study

NHTSA's first major effort in this area was the Truck Driver Workload Study, conducted between 1992 and 1995 (Tijerina, 1996; Tijerina et al., 1996). At that time, a variety of products were beginning to be offered for use in heavy trucks, mostly for tracking of vehicles and to facilitate communication with dispatchers. Examples include satellite tracking, land navigation and route guidance systems, and wireless phones. Because of the potential for diverting the driver's attention away from the driving task, NHTSA recognized the need for a set of methods that could be used to assess the safety implications of in-vehicle devices. The major objectives of this research program were to establish the relationship between workload and safety and to develop workload assessment methods for determining the safety implications of the use of in-vehicle technologies while driving.

An experimental study was conducted in which sixteen professional drivers performed over-the-road driving under a variety of conditions. The drivers were asked to read various text messages displayed on a screen (CRT), to perform manual dialing tasks, and to respond to questions imposing cognitive demand to simulate wireless phone dialogue (Tijerina, et al., 1995, Task 7A).

Comparative Crash Risk

One major conclusion of this work was that the development of a quantitative model to predict crash incidence as a function of driver workload measures was not feasible. Among the difficulties are the complexity and multiplicity of factors involved in determining driver workload and crash causation and the limitations of existing crash data bases with respect to identifying crashes that were caused by driver distraction associated with in-vehicle technologies. Because of these difficulties, it was concluded 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 visual allocation measures, including glance duration, number of glances, and total glance time away from the road scene can be used to assess the driver’s workload associated with in-cab devices. In addition, lane-keeping measures, such as lane exceedance frequency were also introduced as safety-relevant performance measures. This study found that 2- and 4-line messages such as those used in this testing could have a substantial effect on visual scanning behavior (e.g., increased time looking away from the road scene, shortened glaces to the road while reading text) and on lanekeeping performance (greater incidence of unplanned lane exceedences). Drivers involved in cell phone dialing tasks were observed to have lane exceedences on 27% of the trials. Finally, results indicated that visual scanning, as measured by mirror sampling, was cut by almost 50 % on average when the driver was engaged in dialogue as compared to open road driving without dialogue. The tools developed in this project are widely used by many researchers as the most appropriate way to assess workload and the consequent potential for distraction associated with the use of in-vehicle technologies.

Investigation of Safety Implications of Wireless Communications in the Vehicle

In November of 1997, NHTSA published “An Investigation of the Safety Implications of Wireless Communications in Vehicles,” (Goodman, et al., 1997). The report assessed the current state of knowledge with respect to the impact of wireless phone use while driving and explored the broader safety implications of phone use while driving. With respect to the question of whether wireless phone use while driving increases crash risk, the report concluded that the use of wireless phones did increase the risk of a crash, “at least in isolated cases.” From the sample of cell phone related crashes that were examined it was also concluded that being engaged in conversation on a wireless phone while driving, rather than dialing, was most often associated with increased crash risk; most drivers were in conversation at the time of the crash. However, because of the overall lack of national data on the relationship between phone use and crashes, the authors concluded that it was not possible to estimate the magnitude of any safety-related problem associated with their use while driving. The existing data also suggested that as the use of in-vehicle wireless communication technology increases, there will likely be an associated increase in related crashes. The authors recommend options for enhancing the safe use of wireless telephones for drivers, including education, research, enforcement, and legislative initiatives. In summary, the outcome of this project was to encourage changes in data collection methods to improve our ability to estimate the magnitude of the safety problem and to assist the public, the states, and industry in making informed decisions about how and when to combine wireless phone use with driving.

Route Navigation Systems Studies

Most recently NHTSA has conducted three experimental studies addressing questions relating to the distraction potential associated with route navigation systems. These included a destination entry study, an individual differences study and a preliminary evaluation of the proposed SAE 15-second rule, which at the time was being considered as a "recommended practice" for evaluating the acceptability of navigation systems. The objectives and results of these studies are described briefly.

Destination Entry Study

A test track study was conducted to examine four commercially available route guidance systems, which used different methods of entering destinations (e.g., keypad, voice), and displaying information (e.g., speech, visual display). Sixteen subjects, representing two age groups [(35 or younger) and (55 and older)] performed destination entry and wireless phone dialing tasks, as well as radio tuning, each while driving in a low demand test track setting. Performance measures included driving performance, destination entry task performance, visual allocation and subjective assessments. On average, the older drivers required considerably more time to complete the destination entry tasks than did the younger drivers. Relative to radio tuning and wireless phone dialing, drivers required more time to complete the destination entry task. It was found that glance frequency and duration were smallest for the voice-activated system and that the percentage of time the eyes were off the road was smallest for the voice-activated system. The results suggested that using voice commands to enter information or select device functions is less distracting than visual/manual destination entry while driving. Subjective assessments also favored voice over visual/manual methods. Older drivers were no more distracted than younger drivers by the voice input, while the visual/manual interface was more distracting for older than for younger drivers. It was concluded that manual destination entry while driving is ill-advised and that a speed sensitive lockout might be helpful to ensure that such transactions cannot be attempted when the vehicle is in motion.

Individual Driver Differences Study

The objective of this study was to determine whether individual differences in driver abilities would influence the speed with which they interact with in-vehicle technologies.

Subjects performed destination entry and wireless phone dialing tasks on a test track and were later given an automated battery of time dependent, visual perception tasks and cognitive tasks. Correlations between the driving and lab tests were examined. The results indicated small but consistent patterns of correlations between lab tests and test track performance measures of distraction. The results were interpreted as support for the conclusion that drivers who differ in temporal (i.e., time dependent performances) and spatial (i.e., ability to visualize and manipulate objects in space) abilities will respond differently to in-vehicle technologies along safety-relevant dimensions.

"15-Second Rule" Study

The Society of Automotive Engineers (SAE) has been developing a recommended practice to determine whether or not a particular route-guidance system function should be accessible to the driver while driving. The essence of the draft recommended practice (SAE J2364) (Green, 1999) is that if an in-vehicle task can be completed within 15 seconds or less by a sample of drivers in a static (e.g., vehicle parked) setting, then the function is permitted to be available to drivers while the vehicle is moving. The objective of this study was to conduct a preliminary assessment of the diagnostic properties of this proposed rule, that is, how well would the static test results correspond to those collected from a moving vehicle. Ten subjects, aged 55-69 completed 15 tasks, including destination entry in route-guidance systems, manual wireless phone dialing, radio tuning, and adjusting the HVAC controls in a test vehicle. 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. The authors further identify a number of specific shortcomings of the rule, including failure to address speed maintenance or object/event detection performance, failure to address task "chunking" (i.e., how the driver's attention to a task may be divided between the roadway and the task in terms of frequency and duration of glances and manipulations), and the need to develop appropriate thresholds against which to determine if indeed there is reason to be concerned. 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 ITS information systems.

Current Research

NHTSA currently has two ongoing studies that specifically focus on questions related to driver distraction. These include an AutoPC test track study and the Wireless Telephone Interface Study.

AutoPC Test Track Study

The automotive industry is actively working to adopt voice recognition technology into in-vehicle devices to allow true hands free operation, including the ability to control the various functions of these systems. At the same time text-to-speech processing is also becoming available for automotive use. The imminent emergence of AutoPC and Internet access will allow the integration of a variety of PC-based technologies into moving vehicles. The safe operation of these technologies is predicated on the assumption that voice-activated and speech-based interfaces will be sufficient for preventing significant distraction for drivers performing increasingly complex transactions while driving. However, this assumption is not well tested. Moreover, to the extent that interactions with in-vehicle technologies are novel experiences, they can, a priori, be expected to be attention-grabbing, and thus distracting. The objectives of this research are to compare voice versus visual/manual interfaces and assess the distraction potential of selected AutoPC transactions, such as retrieving messages or contact information (e.g. phone number or e-mail address) from a data base. The experiment will be conducted on a test track, under low-demand driving conditions. Headway maintenance, lane position variability, speed variability, lane exceedences, and eyes-off-road-time will be measured while drivers perform specified in-vehicle tasks using AutoPC or related technologies and representative comparison conditions that employ visual-manual interfaces. In-vehicle tasks will include manual and voice input versions of radio tuning, wireless-phone call initiation, and e-mail retrieval. An additional objective of this work will be to evaluate the potential of using eye-tracking technology to monitor drivers' visual scanning patterns and the associated direction and degree of attention, and thus the relative distraction potential associated with selected AutoPC functions.

Wireless Phone and AutoPC Related Technology: Driver Distraction and Use Effects on the Road (Wireless Telephone Interface Study)

In recognition of the problems inherent in the study of driving behavior in artificial settings, NHTSA has developed a family of vehicle instrumentation systems that allow the assessment of driver performance and behavior under a wide range of conditions. The most recent development is MicroDAS (Barickman & Goodman, 1999), which is a portable data acquisition system that can be installed in any vehicle, including a test participant's own vehicle, 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. MicroDAS allows the unique capability of conducting naturalistic studies of driving behavior. With this capability, NHTSA has the ability to conduct long-term naturalistic studies, in which subjects are given instrumented vehicles to use for extended periods.

Currently, NHTSA is conducting a naturalistic experiment to evaluate driver workload and distraction as a function of the wireless phone interface. Subjects will participate for three consecutive two-week periods. During each period, a different type of wireless phone will be used, including a hand-held flip phone, a conventional hands-free (manual dialing, hands-free talking) phone, and an enhanced hands-free (with voice-activated dialing and hands-free talking) phone. The wireless telephone interface conditions will be varied along with the driver interface for the AutoPC radio installed in the vehicle in an effort to mask the focus of the study (i.e., assessment of wireless telephone interface designs). The MicroDAS-equipped test vehicles are programmed to record data each time the wireless phone is activated, including 30 seconds before and 30 seconds after each call. Data will also be collected any time the vehicle is in operation during the first two days a subject drives with a particular wireless phone interface. During each call, the instrumentation will record vehicle speed, braking, steering, and lane position as well as other driver/vehicle control parameters. Video data, including video of the driver's face and forward road scene, will also be recorded to permit examination of drivers' glance behavior and other factors. The data will be used to determine whether totally hands-free wireless phone conversation interferes less with driving than hand-held conversation and whether hands-free dialing interferes less with driving than manual dialing. With their permission, the driver's side of phone calls will be recorded so that the nature and intensity of the conversation can be established. This will allow determination of whether the content of the phone conversation affects driving performance. The data will also be analyzed to determine the conditions under which drivers are willing to make wireless phone calls while driving. One question of interest is whether hands-free operation encourages increased use of the wireless phones while driving.

Future Research

NADS Research

When it becomes fully operational later this year, the National Advanced Driving Simulator (NADS), will be the most technically sophisticated driving research simulator in the world. It will provide a unique research tool to safely conduct fundamental and highly focused research into wide ranging driver-vehicle-environment issues including those associated with driver distraction. Previous research has made significant progress in understanding some of the fundamental issues associated with driver distraction. However, the inability to carry out research under realistic and highly demanding conditions, has limited progress in this area. The NADS facility will offer a unique capability to study this issue 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 further provides the opportunity to assess the distraction potential associated with various in-vehicle technologies (e.g. user interfaces) under identical driving conditions, which would not be possible using on-road studies.

One of the first research programs to be undertaken on NADS will focus on the safety implications of using in-vehicle technologies. This research will cover both wireless voice communications issues as well as those associated with multifunction devices such as AutoPC, which can provide a variety of services such as access to the Internet, e-mail, and navigation, to name a few. The research carried out under this program will extend the on-road research, discussed earlier, to the NADS where drivers can safely be placed in more demanding situations using more workload intensive technologies. With regard to wireless voice communication, research will be conducted to address three questions, including: (1) Does hands-free communication interfere less with driving than communication with hand-held devices? (2) How does the content of the communication influence the potential for distraction? (3) What factors influence drivers' willingness to use in-vehicle communication and information technologies? Other, more demanding technologies will be evaluated in regard to type and characteristics of the interface, the content of the information, and the conditions under which a driver is "willing to engage." Results from the on-road and test-track studies will also be used to validate the capabilities of the NADS. Additional research on NADS will focus specifically on cognitive distraction and its assessment as well as on the development of standard test methods, procedures and driving scenarios for evaluating the safety impact of driver distraction when using different technologies.

Night Vision Systems

Because of the reduced distance at which drivers can detect and recognize critical objects and roadway features at night, infra-red night vision systems have been proposed to extend driver vision. In the night vision system currently being sold to the public, an infra-red camera picks up the heat emissions from images down the road and displays the enhanced image on a head-up display superimposed on the lower part of the windshield. This technology, however, involves a tradeoff between increased object recognition and driver distraction. If drivers look down at the display, they may see the enhanced objects more clearly than with direct vision. However, looking at the display may distract drivers attention to some degree from other objects and roadway features not visible on the display. NHTSA is currently sponsoring a research study to help better understand and quantify this tradeoff. The findings should be available by December, 2000.

Conclusions

NHTSA has long recognized the potential safety problems associated with driver distraction from use of in-vehicle technologies while driving. As a result, NHTSA has conducted a variety of research activities to examine and understand the implications of various forms of driver distraction and identify appropriate methodologies to assess the safety implications of distraction resulting from the use of in-vehicle technologies. Initial NHTSA research highlighted the complexity of the problem and the difficulties in establishing a direct link between distraction and crashes. Ongoing and future research will focus on applying our research tools and methods to better understand the relationship between in-vehicle technologies, distraction and the increased risk of a crash. Our efforts are also directed at developing technological solutions for mitigating the potential for distraction-related crashes through systems that sense threats and alert drivers of potential crash situations. These "crash avoidance systems" and associated sensors may ultimately be integrated with various in-vehicle information systems to both warn drivers and limit the availability of information under demanding driving situations.

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