

UMTRI-2003-12

DRIVER DISTRACTION AND CRASHES:
AN ASSESSMENT OF CRASH DATABASES
AND REVIEW OF THE LITERATURE

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May, 2003

1. Report No. UMTRI-2003-12		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Driver distraction and crashes: An assessment of crash databases and review of the literature				5. Report Date May, 2003	
				6. Performing Organization Code	
7. Author(s) David W. Eby, Lidia P. Kostyniuk				8. Performing Organization Report No. UMTRI-2003-12	
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, MI 48109				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Delphi Delco Electronics Systems One Corporate Center, M/C E110, P.O. Box 9005 Kokomo, IN 46904-9005				13. Type of Report and Period Covered Interim	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract <p>A distracted driver has delayed recognition of information necessary for safe driving because an event in the vehicle or outside of the vehicle has attracted the driver's attention. A distracted driver may be less able to respond appropriately to changing road and traffic conditions leading to an increased likelihood of crash. Development of technology to reduce distraction-related crashes is proceeding, including the development of a workload/distraction management system in the SAFETY VEHICLE(s) using adaptive Interface Technology (SAVE-IT) program. In order to determine the potential benefits of systems such as SAVE-IT, it is necessary to understand the crash scenarios in which driver distraction is a likely contributor. This report has two purposes. The first is to review and assess available crash databases to determine which variables are available, feasible, and appropriate for determining distraction-related crash scenarios. The second purpose is to investigate a variety of other distraction-related scenarios in crash databases and those that may not appear in crash records directly, but, nonetheless, are likely to be related to distraction-related crashes. The crash databases reviewed are: the National Automotive Sampling System General Estimates System; The National Automotive Sampling System Crashworthiness Data System; the Fatality Analysis Reporting System; the Highway Safety Information System; and regional geographic information system databases. The report examines five crash scenarios to determine the relative frequency of distraction-related crashes by crash scenario: single vehicle run off the road; rear-end; intersection/crossing path; lane-change/merge; and head-on. This review also covers a number of distracted-driving scenarios both outside and inside the vehicle including: exterior incidents; looking at scenery; passenger interactions; adjusting entertainment systems; listening to music; cellular phone use; use of route-guidance systems; eating/drinking; adjusting vehicle controls; objects moving in the vehicle; and smoking. Also presented is a framework for rank-ordering the relative contribution of these scenarios to distraction-related crash risk.</p>					
17. Key Words Distraction, Crash, Database, Inattention, Cellular Phone			18. Distribution Statement Unlimited		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 44	22. Price

Reproduction of completed page authorized

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of Delphi Delco Electronics Corporation, the Volpe Center, or the National Highway Traffic Safety Administration.

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ACKNOWLEDGMENTS

This work was sponsored by the Volpe Center and the National Highway Traffic Safety Administration under contract number DTRS 57-02-C-10049 as a sub-award agreement with Delco Electronics Corporation Division of Delphi Automotive Systems LLC. We thank Helen Spradlin and Mary Chico for gathering research articles for this review. Charles Compton of UMTRI's Transportation Data Center assisted in the review of crash databases. Lisa Molnar and Fredrick Streff helped in the development of the framework for rank-ordering scenarios by their contribution to distraction-related crash risk. Lisa Molnar, Linda Miller, and Helen Spradlin critically reviewed earlier versions of this manuscript.

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May, 2003

INTRODUCTION

Safe operation of a motor vehicle requires that a driver focus a substantial portion of his or her attentional resources on driving-related tasks, including monitoring the roadway, anticipating the actions of other drivers, and controlling the vehicle. A driver may also, however, be engaged in other non-driving activities that compete for his or her attentional resources. As these non-driving activities increase, the driver allocates greater attention to them, or the driver's attentional capacity is reduced (e.g., fatigue), and there is a reduction in the attentional resources necessary for safe driving. Driver inattention has been found to be a major factor in traffic crashes, with 20-50 percent of crashes involving some form of inattention (Goodman, Bents, Tijerina, Wierwille, Lerner, & Benel, 1997; Ranney, Garrott, & Goodman, 2001; Stutts, Reinfurt, & Rodgman, 2001; Sussman, Bishop, Madnick, & Walter, 1985; Wang, Knipling & Goodman, 1996).

One form of inattention is driver distraction which results from a triggering event (Stutts, Reinfurt, & Rodgman, 2001). A distracted driver has delayed recognition of information necessary for safe driving because an event inside or outside of the vehicle has attracted the driver's attention (Stutts, Reinfurt, & Rodgman, 2001). A distracted driver may be less able to respond appropriately to changing road and traffic conditions, leading to an increased likelihood of crash. Driver distraction has been estimated to be a contributing factor in 8 to 13 percent of tow-away crashes (Stutts, Reinfurt, & Rodgman, 2001; Wang, Knipling & Goodman, 1996).

Determining the effect of driver distraction on crash risk has proven challenging. Crash reports from which detailed crash databases are derived often lack good information about distraction-related events leading up to the crash and surrogate measures of distraction-related crashes, such as "rear-end crashes," can be overly subjective and inaccurate. In addition, even when crash data contain good distraction-related information, interpretation of these data is difficult because information about the frequency of exposure to the distraction scenario is not available. However, a recent study on self-reported frequency of distracting behaviors (Royal, 2003) and a study utilizing in-vehicle cameras

(J. Stutts, personal communication, 2003) may provide a means for determining distracted-driving-scenario exposure.

Development of technology to reduce distraction-related crashes is proceeding, including the development of a workload/distraction management system in the SAFETY VEHICLE(s) using adaptive Interface Technology (SAVE-IT) program. In order to determine the potential benefits of systems such as SAVE-IT, it is necessary to understand the crash scenarios in which driver distraction is a likely contributor. This article has two purposes. The first is to review and assess available crash databases to determine which variables are available, feasible, and appropriate for determining distraction-related crash scenarios. The second purpose is to investigate a variety of other distraction-related driving-scenarios that may not appear in crash records directly, but, nonetheless, are likely to be related to distraction-related crashes, such as eating in the vehicle or using a cellular phone.

CRASH DATABASES

There are a number of crash databases that could be used to identify circumstances in which driver distraction results in vehicle crashes. As a basis for comparing these databases and making judgments about their usefulness in determining distraction-related crash scenarios, we identified three desired areas of information related to crashes. These are: 1) distraction information (including sources of distraction inside and outside the vehicle that may have drawn the driver's attention away from the driving task at the time of the crash); 2) inattention information (including the driver's physical or mental condition at the at the time of the crash for determining the driver's level of attention to the driving task); and 3) driver demand information (including roadway, traffic, and environmental conditions at the time of the crash).

Distraction information is clearly essential because driving distraction and its impact on crashes is the main focus of the study. Inattention information is important because it provides the driver context within which driver distraction takes place. Demand information is important because safe driving demands a certain level of attention that varies not only as a function of driver characteristics, but also roadway complexity, traffic density, and the environment. Improvements and standardization of highway design (American Association of State Highway and Transportation Officials, 2001) and traffic control (Federal Highway Administration, FHWA, 2000) have done much to reduce roadway complexity and to lower the demands of driving. Some roadway segments, however, require a greater level of attention from drivers than other segments. Furthermore, the attentional demand of a particular roadway segment may change with variations in traffic volumes, density, and mix of vehicle types. Driving the same roadway segment in rain, in the dark, or under other inclement conditions may also require increased attention. As the demand on driving increases, fewer attentional resources are available for non-driving tasks leading to a greater likelihood of crashing when the driver is inattentive or becomes distracted.

A combination of the three types of information – distraction, inattention, and demand – is desirable because it will enhance our ability to determine distraction-related

crash scenarios, using a method similar to one commonly used for identifying drunk-driving crash scenarios. The methods will involve analysis of distraction-related crashes (and probably inattention-related crashes) to determine the relationship between these crashes and various measures, or combination of measures, of driving demand (roadway, traffic, or environment). By examining the records of crashes in which driver distraction was a contributing factor, it may be possible to identify commonalities in the roadway, traffic, and environment (or some combination of these variables) associated with these crashes. The likely outcome of these analyses would be a relative listing of the frequency of distraction-related crash scenarios.

The ideal crash database for this analysis would include variables related to the three general areas of crash-related information: driver distraction, inattention, and demand. Unfortunately, the ideal crash database does not exist. Researchers, therefore, must carefully select databases for analysis, recognizing their limitations. Here we examine a series of crash databases for the presence of information that is appropriate and important for analyses to determine the frequency of various distracted-driving crash scenarios. We also assess the representativeness of the databases and their usefulness for this project.

National Automotive Sampling System General Estimates System

The National Automotive Sampling System General Estimates System (NASS GES, henceforth referred to as GES) contains crash data representative of all crashes in the United States (US). The crashes recorded in GES are from a nationally representative probability sample selected from the estimated 6.8 million police-reported crashes which occur annually and include all types of crashes involving all types of vehicles. GES is the best crash database for determining national estimates of police-reported crashes. The data records in GES are coded from the original police accident reports by trained personnel (National Highway Traffic Safety Administration, NHTSA, 2002b, 2002c).

Data elements on driver distractions and inattention

In 1990, a driver distraction variable was introduced in GES. At that time, there were seven codes for this variable:

- Not distracted
- Passengers, occupants
- Vehicle instrument display (radio, CB, heating)
- Phone
- Other internal distractions
- Other crash (rubbernecking)
- Other external distractions

In 1999, this variable was expanded to include 19 categories:

- Not distracted
- Looked but did not see
- By other occupants
- By moving objects in vehicle
- While talking or listening to phone
- While dialing phone
- While adjusting climate control
- While adjusting radio, cassette or CD
- While using other devices integral to vehicle
- While using or reaching for other devices
- Sleepy or fell asleep
- Distracted by outside person or object
- Eating or drinking
- Smoking related
- No driver present
- Not reported
- Inattentive or lost in thought
- Other distraction or inattention
- Unknown

Our examination of this variable in the 2000 GES data revealed that of the 102,566 vehicle/driver records contained in the dataset, information on distraction was not recorded in 83 percent of cases (35 percent were coded “not distracted”, 45 percent “not reported,” and 3 percent “unknown”). When codes were reported for distraction, they were largely concentrated in the categories of “inattentive or lost in thought” (11.5 percent), “looked but did not see” (2.5 percent) and “sleepy or asleep” (1.1 percent). Each of the other codes combined accounted for less than 1 percent. The small number of cases for each type of distraction indicates that care should be exercised when determining national estimates of driver distraction based on the GES. Estimates based on a sample are subject to random errors that are relatively large when the estimated numbers are small. Thus, estimating

crashes for each of the many different types of distraction would not be useful, but an estimate of crashes based on larger categories of crashes might be reasonable.

One reason for the lack of reporting on distraction is that information in the GES comes from state police accident reports and most states do not have detailed driver-distraction codes on their crash report forms. As recently as the late 1990s, if inattention information was included on a state crash form it usually did not contain distraction information, including only whether the driver was asleep, fatigued, or ill. However, as concerns were raised about the distraction potential of cellular phone use and other in-vehicle technology, states began to change their crash report forms to include information on driver distraction. To illustrate this point, Michigan had no codes for driver distraction or inattention (other than alcohol and drugs) prior to 2000. In 2000, Michigan added several driver-inattention variables to indicate cellular phone use and whether the driver was distracted, asleep, fatigued, and/or sick. This trend is expected to continue and as more detailed information on driver distraction in crashes is collected by the states, information on driver inattention and distraction in GES should also increase. Thus, it is likely that the value of GES in understanding distraction-related driving will increase in the future.

Data elements on driving demand

GES contains descriptive information about the location of the crash and about the environmental conditions at the time of the crash. Information about the location of the crash includes the number of lanes, the type of roadway surface, whether the roadway was divided, whether the roadway was one- or two-way, and the speed limit. Another variable notes if the crash occurred at an intersection or was intersection related. If the crash occurred at an interchange, the location within the interchange (e.g., on ramp) is recorded. The horizontal alignment is given as either straight or curved and a profile variable reports the vertical alignment as either level, grade, hillcrest, or sag. Presence and types of traffic controls are also recorded.

GES does not include variables on the traffic volumes, density, or traffic mix at the site of the crash. A rough surrogate variable, however, could be developed from the

functional-road-class variable, which classifies roads into urban or rural, principal arterials, major arterials, major collectors, minor collectors, or local roads or streets. Because traffic volumes are usually higher in urban locations than in rural ones, and because traffic volumes are highest on principal arterials and lowest on local roads and streets, this functional road classification offers a reasonable hierarchy for ordering traffic volumes.

Environmental conditions that can be obtained from the GES include atmospheric conditions such as rain, sleet, snow, fog, smoke, smog, and blowing sand and/or dust. The light conditions are included as daylight, dark, dark but lighted, dawn, and dusk. There is also a road surface variable which denotes the condition of the road surface as dry, wet, snow, or slush.

The National Automotive Sampling System Crashworthiness Data System

The National Automotive Sampling System Crashworthiness Data System (NASS CDS, henceforth referred to as CDS) is a database designed to assist in studies of vehicle crashworthiness. CDS contains detailed information on a representative, random nationwide sample of police-reported crashes involving passenger vehicles (passenger cars, light trucks, vans, and sport-utility vehicles) in which at least one vehicle was damaged seriously enough to require towing from the crash scene. All crashes included in the sample (about 5,000 per year) are studied in detail by field research teams. The data records in CDS come from information and measurements at the crash site and from the crash-involved vehicles, other physical evidence, interviews with crash victims, and review of medical records (NHTSA, 2001a, 2003b).

Data elements for driver distraction and inattention

In 1995, a detailed coding of “Driver Distraction/Inattention to Driving” was added to CDS. All distractions that apply are coded. These data elements are:

- By other occupant(s)
- By moving object in vehicle
- While talking/listening cell phone
- While dialing cell phone
- While adjusting climate controls
- While adjusting radio, cassette, CD
- While using other device/controls integral to vehicle

- While using/reaching device/object brought into vehicle
- Inattentive lost in thought
- Sleepy or fell asleep
- Distracted by outside person, object, or event
- Eating or drinking
- Smoking related
- Other, distraction/inattention

Examination of the coding of this variable in the 2000 CDS file showed that out of 7,579 vehicle/driver records, 87 percent did not have distraction/inattention reported (35 percent were coded “attentive and not distracted” and 52 percent were “unknown”). The remaining 13 percent were coded with one of the other distraction codes. The greatest percentage of these (2 percent each) were “other distractions” and “sleepy or fell asleep.” All other codes accounted for less than 1 percent each.

Data elements on driving demand

Data on the roadway in CDS is similar to that found in the GES. Information on the road cross-section includes the number of lanes, the type of road surface, whether the roadway was divided, whether traffic was one-way or two-way, and the speed limit. Horizontal alignment is denoted as either straight or curved and the profile is denoted as level, grade, hillcrest, or sag. Crash location at an intersection or within an interchange is noted. Presence and types of traffic controls are also included.

CDS does not have traffic volume information nor does it have a variable that could serve as a surrogate. The environmental conditions that could be obtained from the CDS data are the same as in GES and include atmospheric conditions (rain, sleet, snow, fog, smoke, smog, and blowing sand and dust), light conditions (daylight, dark, dark but lighted, dawn, and dusk), and roadway-surface conditions (dry, wet, snow, or slush).

Fatality Analysis Reporting System

The Fatality Analysis Reporting System (FARS) contains information on all vehicle crashes in all 50 states, the District of Columbia, and Puerto Rico that resulted in at least one fatality. Trained analysts code FARS records from police accident reports, other information including witness statements, and autopsy reports (NHTSA, 2002a, 2003a).

This database is the best source of information available for those interested in traffic fatalities.

Data elements on driver distraction and inattention

Driver distraction and inattention is coded in FARS in the “related factors-driver level”. At present, this variable has 99 possible codes grouped according to general categories for convenience. Up to four of these related factors can be coded for every driver involved in a crash.

The category “physical and mental condition” of the related factors-driver level variable includes codes related to driver inattention:

- drowsy, sleepy, asleep, fatigued
- emotional (e.g. depression, angry, disturbed)
- inattentive (talking, eating, etc.)

The “inattentive” factor is frequently recorded for drivers. In the 2000 FARS file, 3,949 (7 percent) out of the 57,403 drivers were coded as “inattentive.” The other two driver variables were less frequent in the 2000 data, with 2 percent coded as “drowsy, sleepy, asleep or fatigued” and less than 1 percent coded as “emotional.”

In 1991, a list of electronic devices was added to the “related factors- driver level” variable under the category “Possible Distractions (inside vehicle)”. These devices are recorded regardless of whether they were in use at the time of the crash. The devices included in this category are:

- Cellular phone
- Fax Machine (1991-2001)
- Cellular Telephone in use in Vehicle (since 2002)
- Computer (1991-2001)
- Computer Fax machines/printers (since 2002)
- On-board navigation system
- Two-way radio
- Heads-up display

Data for these distraction codes are not found frequently in FARS data. Of the 57,403 drivers in the 2000 FARS file, only 108 (.2 percent) had one of the possible distraction codes noted in their record. NHTSA (2002a) noted that in 1998, only 64 drivers

out of 56,865 had one of the “possible driver distractions” coded in their FARS record. NHTSA also pointed out that 31 states did not report any driver distractions on their police accident reports and therefore distraction could not be identified and included by FARS.

Data elements on driving demand

The variables in FARS that describe the roadway and environment at the time and location of the crash are the same as in GES. These include number of lanes, the type of road surface, whether the roadway was divided and whether traffic was one-way or two-way, speed limit, and traffic controls. Horizontal alignment (straight, curved) and profile (level, grade, hillcrest, or sag) are noted. Intersection and interchange crashes are also noted. FARS does not have information on traffic volumes or traffic mix. However, as in GES, a functional-road-class variable is available thus making it possible to use it as a rough surrogate for traffic volume.

The same environmental conditions that can be obtained from GES can be obtained from FARS. These include atmospheric conditions (rain, sleet, snow, fog, smoke, smog, and blowing sand and dust), light conditions (daylight, dark, dark but lighted, dawn, and dusk), and roadway-surface conditions (dry, wet, snow, or slush).

Highway Safety Information System

The Highway Safety Information System (HSIS) is maintained by the Federal Highway Administration and is used in studies of the relationship between road features and crashes. HSIS contains information on crashes, roadway inventory, and traffic volumes as well as other road geometric features for nine states: California, Illinois, Maine, Michigan, Minnesota, North Carolina, Utah, and Washington. Ohio joined HSIS in 2002. Participation of states in HSIS is based on the availability and quality of their data and the ability to merge data from various files (Highway Safety Information System, 2000a, 2000b, 2000c, 2000d, 2001).

Data for each state comes in a set of relational databases that are different for each state. These data include a roadway inventory, information on traffic volumes for the roads included in the inventory, and crashes that occurred on the roads in the inventory. All

roads in a state, however, are not necessarily in the inventory. In Michigan, for example, only the state trunkline roads are included in the inventory and therefore in HSIS.

Data elements on driver distraction and inattention

The driver distraction data available in HSIS for each state are the same as those available from each state's crash data files. Examination of the HSIS codebooks indicates that all the states have some information on driver inattention and distraction, but it is not as detailed as that found in CDS, GES, or FARS. The driver inattention and distraction data are found in the following variables: contributing or apparent contributing factors; physical or apparent physical condition; and driver condition. Most HSIS states have a variable that can denote driver inattention such as drowsy, asleep, fatigued, or ill. Four of the states have a variable indicating distraction. Two states have one code for some electronic devices. The following list shows each HSIS state and the relevant variables.

- California - drowsy or fatigued, fatigue;
- Minnesota - inattention/distraction, driver on car phone/CB/2-way radio;
- Washington - apparently asleep, apparently ill, apparently ill, inattention;
- Michigan - cellular phone, distracted, asleep, fatigued, and ill;
- Illinois - illness, asleep/fainted, medicated;
- North Carolina - ill, fatigued, asleep, impairment due to medicine;
- Utah - asleep, fatigued, ill;
- Maine - driver inattention, asleep, fatigued.

Data elements on driving demand

Each state's HSIS data system has a roadlog data file that contains detailed information about the road system in the state. The road system is divided into homogenous segments along routes. Although the states' roadlogs are different from each other, each describes the road cross-section, alignment, and traffic control in detail. The elements in the roadlogs include the rural/urban designation, functional classification, cross-sectional elements (such as the number of lanes), lane widths, type of roadway surface, width and type of each shoulder, median width, and access control. Parking lanes are noted as is the presence of curbs. Locations of traffic control devices are noted. Horizontal curves are described in some states by degrees of curvature (or radius) and length of curve. Vertical alignment is given in grades. Minnesota and California have

additional intersection databases. Data include the intersection type, number of legs, traffic control, and description of the intersection approaches.

The HSIS files for each state also include data on traffic, including information on the Average Annual Daily Volume (AADT), speed limit or design speed, and for some states, the proportion of trucks on the road. Environmental conditions include weather (rain, snow, sleet, etc), light, and the roadway surface.

Regional Geographic Information System Databases

Many states and regions are developing regional Geographic Information System (GIS) databases that include the road network, traffic volumes, crashes, pavement condition, population, and land use. For example, the state of Michigan has developed a GIS database for the Michigan trunkline road system that includes road characteristics and crashes. Other organizations in Michigan have adapted the GIS database for their own purposes. The Southeast Michigan Council of Governments (SEMCOG) is using the GIS database as a tool for planning regional transportation policy. Several counties in southeast Michigan are also in the process of developing GIS databases of their roadways and crashes, including the Traffic Improvement Association of Oakland County and the counties of Washtenaw and Jackson. The databases are used to identify traffic-problem areas, manage resources, and produce maps rapidly and accurately. They were not developed for research purposes, but could be used for that purpose, if needed.

Summary

Each database reviewed has certain advantages and disadvantages relative to identifying and understanding distraction-related crash scenarios. Table 1 summarizes the features of the databases reviewed along with the dimensions important for identifying distraction scenarios.

Table 1: Summary of Database Assessment					
Database	Distraction/ Inattention Variables	Road Features	Traffic Volumes	Environmental Conditions	Nationally Representative
GES	Detailed list of distractions	General data on cross-section, alignment, and traffic control	No, but can use functional class as surrogate	Yes, atmospheric, light, and road surface	Yes, national sample of all crashes
CDS	Detailed list of distractions	General data on cross-section, alignment, and traffic control	No	Yes, atmospheric, light, and road surface	Yes, national sample of crashes involving passenger vehicles with towable damage
FARS	One general distraction variable. List of electronic devices noted as possible distraction if present.	General data on cross-section, alignment, and traffic control	No, but can use functional class as surrogate	Yes, atmospheric, light, and road surface	Yes, but only of fatal crashes
HSIS	General driver conditions or inattention variables, two states have cell phone distraction variable	Detailed data on road cross section, and alignment	Yes, AADT percent trucks	Yes, atmospheric, light, and road surface	No, data from eight states. States were selected for data quality, not sampled.
Regional data bases	Tend to use distraction variables available on state police crash reports, which usually are general	May have detailed data on road cross section, and alignment	Yes, AADT, percent trucks, peak period volumes, average daily traffic volumes	Yes, atmospheric, light, and road surface	No, data are region specific

As seen in this table, no single database has all the factors desired for identifying distraction scenarios and estimating their magnitude nationally. The CDS and GES, however, appear to be the best suited for these purposes. Cases in both data systems come from national probability samples. The population of crashes for GES and CDS are different (GES samples from a population of all police-reported crashes of all severities, and CDS samples from all police-reported crashes in which a passenger vehicle sustained enough damage to be towed away), but both can be used to obtain national estimates. Both have a variable with detailed codes for various types of driver distraction. Although

the information about the roadway is relatively general, it is sufficient to convey a general level measure of roadway complexity. Both have information on the atmospheric, light, and road surface conditions. Traffic volume information is not available in either database. The GES data does have the functional road classification at the crash site, which can be used as a surrogate measure. Although CDS does not have any variables that can be used as traffic volume surrogates, it has enough positive attributes to argue for using it for analyses of distraction scenarios.

FARS has the same roadway, environmental, and traffic volume surrogates as GES, but the driver distraction information is not as detailed as in GES and CDS. Furthermore, FARS contains only fatal crashes, which limits its usefulness in identifying and estimating the magnitude of distraction scenarios under more general conditions.

HSIS contains detailed information on the roadway. While the other databases give general information of the roadway characteristics at the location of the crash, HSIS can provide information about the approach to the crash site. HSIS also has information on traffic volumes and some information regarding vehicle mix. However, there are some significant drawbacks for using HSIS to identify and quantify distracted-driving scenarios. First, the information on driver distraction is very general. Second, the states in HSIS were selected because of data availability, quality, and the ability to merge the various roadway and crash files, and they are not necessarily representative of the US as a whole.

Use of regional GIS data bases for identifying driver distraction scenarios has the same weakness as found in the HSIS. The information on roadway features and traffic can be detailed, but the information on driver distraction can be very general. Furthermore, these data are not nationally representative.

Although GES and CDS appear to be the best suited for the purpose of this study, there are some problems with using these data. The number of cases of driver distraction in these data files is not large and the standard errors associated with national estimates will be large. Thus, estimates of the magnitude of driver distraction will be of low precision. However, from among the crash data systems reviewed, these two have the most detailed information on driver distraction and appear to be the best candidates for the task.

DISTRACTED DRIVING CRASH SCENARIOS

Due in part to the relatively recent addition of distraction-related variables in crash databases and in part to the incomplete nature of these variables, there are relatively few studies of crash databases that have attempted to determine the relative frequency of distraction-related crashes by crash scenario. This section will review those few studies as a preliminary means for developing a set of crash scenarios for which distraction is an particularly important contributing factor. We organize this section based upon the following crash scenarios that have been utilized in distraction-related crash analyses: Single vehicle run off the road; rear-end; intersection/crossing path; lane change/merge; and head-on.

Single Vehicle Run Off the Road Scenario

Off roadway crashes account for about 23 percent of crashes nationally (Najm, Sen, & Smith, 2002). Campbell, Smith, and Najm (2002) analyzed GES data from 2000 and CDS data from 1997-2000 in a study of factors that contribute to crashes nationally. They found that inattention (defined primarily by distraction variables except for the inclusion of the looked-but-did-not-see variable) was a contributing factor in 12 (CDS) to 14 (GES) percent of single vehicle run off the road crashes. Thus, distraction/inattention was one of the top three contributing crash factors in this study. Other work has utilizing 1998 GES data examined light vehicle “pre-crash scenarios” based upon vehicle movements and critical events prior to the run-off-the-road crash for freeways and non-freeways separately (Najm, Koopman, Boyle, & Smith, 2002; Najm, Schimek, & Smith, 2002). This study found that driver distraction was a contributing factor in 4.1 percent of freeway and 6.1 percent of non-freeway single vehicle run off the road crashes. The most frequent pre-crash scenarios differed somewhat depending upon the road type with “initiating a maneuver and losing control” and “negotiating a curve and departing road edge” as the two most common scenarios relative to non-distraction-related crashes for freeways and “going straight and departing the road edge” and “negating a curve and departing a road edge” as the two most frequent pre-crash scenarios for nonfreeways.

Wang, Knipling, and Goodman (1996) have analyzed 1995 CDS data to compare distraction-related crashes to other crashes by crash type. They report that distraction-related crashes account for about 13 percent of crashes nationally. Their analyses by

crash type and distraction showed that distraction-related single vehicle crashes (both run-off-the-road and on-road) account for about 18.1 percent of single vehicle crashes and 41.2 percent of all distraction-related crashes. Thus, the single vehicle run off the road crash scenario is a relatively common distraction-related crash scenario.

Rear-End Scenario

Rear end crashes are the most common crash scenario, accounting for nearly 30 percent of crashes nationally (see e.g., Najm, Sen, & Smith, 2002). Analysis of 1995 CDS data found that distraction was a contributing factor in 21 percent of rear-end crashes in which the lead vehicle was moving (LVM) and in 24 percent of crashes in which the lead vehicle was stopped (LVS) (Wang, Knipling, & Goodman, 1996). This study also found that among the distraction-related crashes, rear-end/LVM crashes were found in about 10 percent of cases while rear-end/LVS crashes were found in 22 percent of distraction-related crashes. In addition, rear-end crashes into stationary vehicles were the second most common distraction-related crash scenario (single-vehicle-run-off-the-road crashes were the most frequent). Other work on 1996 GES data found that distraction-related crashes were slightly more frequent for rear-end/LVM than for rear-end/LVS crashes (Wiacek & Najm, 1999).

More recent research on distraction related rear-end crash scenarios considered data in both GES and CDS (Campbell, Smith, & Najm, 2002). This work considered three rear-end scenarios: LVS, LVM, and lead vehicle decelerating (LVD). The study showed that 36 percent of rear-end/LVS crashes, 37 percent of rear-end/LVD crashes, and 23 percent of rear-end/LVM crashes were distraction related. In all three scenarios, distraction was the most common contributing factor except for rear-end/LVM in which the percent of this type of crash with an unknown contributing factor was greater. Thus, it appears that distracted drivers account for a large proportion of all rear-end crashes, whether or not the lead vehicle is moving.

Intersection/Crossing Path Scenario

Intersection crashes (or crashes where vehicles cross paths) are the second most common type of crash in the US based upon GES data (Najm, Sen, & Smith, 2002). Analyses of intersection/crossing path crashes in 1995 CDS by contributing factor show that distraction is implicated in only about 7 percent of these crashes (Wang, Knipling, &

Goodman, 1996). Considering all distraction-related crashes, the study found that about 18 percent were intersection/crossing path scenarios. In a detailed study of specific behaviors and unsafe driving actions that lead to crashes, distraction-related intersection crashes were found in slightly more than 2 percent of crashes analyzed (Hendricks, Freedman, Zador, & Fell, 2001). These data, however, were only for serious crashes and are not nationally representative. Thus, too little data exist for making strong conclusions about the impact of driver distraction on intersection/crossing path crashes.

Lane-Change/Merge Scenario

Crashes involving a vehicle changing lanes or merging account for only about 9 percent of crashes nationally (Najm, Sen, & Smith, 2002). Wang, Knipling, and Goodman (1996) found that distraction was a contributing factor in 5.6 percent lane-change/merge crashes and among all distraction-related crash scenarios, this scenario accounted for less than 2 percent of crashes. More recent research utilizing 2000 GES data has found a much higher incidence of inattention/distraction (29 percent) in lane-change/merge crash scenarios (Campbell, Smith, and Najm, 2002). Further analysis, however, shows that a large proportion of these cases are coded as “looked but did not see” which is often not included as a distraction variable. As with the previous scenario, more research is needed to understand the relative frequency of driver distraction as a contributing factor in this crash scenario

Head-On Scenario

Head-on or opposite direction crash scenarios account for less than 3 percent of crashes based on 2000 GES data (Najm, Sen, & Smith, 2002). Analyses of 1995 CDS data showed that distraction is a contributing factor in these types of crashes in about 7 percent of cases (Wang, Knipling, & Goodman, 1996). However, among the various crash scenarios, head-on crashes were the least likely (2.2 percent) of all distraction-related crashes. Further research on the role of driver distraction and this crash scenario is needed.

Summary

This section reviewed the few studies on driver distraction as a causative factor in various crash scenarios. Several of the scenarios have received only scant research attention making it difficult to draw strong conclusions about the relative frequency of

distraction related crashes in these scenarios. Based upon the available data, however, we conclude that single-vehicle-run-off-the-road and rear-end crashes are the two most common scenarios in which driver distraction is a causative factor. The lane-change/merge crash and intersection/cross path scenarios are likely to follow distantly as the third most frequent driver distraction crash scenarios. It appears that head-on crashes are the least frequent scenario involving driver distraction. Thus, based upon these data, a SAVE-IT system should be designed at a minimum to mediate both single vehicle run off the road and rear-end crashes. These crash scenarios are not only two of the most common crash types, but the frequency of these crashes also have a strong distraction component.

DISTRACTED-DRIVING SCENARIOS

As discussed previously, distracted driving is one form of driver inattention and is distinguished from inattention by a triggering event that can occur either outside or inside of the vehicle. This section describes the literature related to the various events that can trigger driver distraction. This section will omit review of factors related to the forms of driver inattention such as drowsiness/fatigue, medical/emotional impairment, age, individual difference, gender, or daydreaming. We recognize, however, that these factors, in particular age and individual differences, can influence the level of driver distraction and its effects on crash outcomes.

Outside the Vehicle

Exterior incident

An exterior incident refers to an event outside the vehicle that draws the driver's attention. A wide range of incidents are possible and include, but are not limited to, crashes, police activity, vehicle actions, and pedestrians. Several studies have found that exterior incidents are the most frequent contributor to distraction-related crashes (General Assembly of the Commonwealth of Pennsylvania, 2001; Glaze & Ellis, 2003; Stutts, Reinfurt, & Rodgman, 2001; Wang, Knipling, & Goodman, 1996). While the frequency with which a driver encounters an exterior incident is unknown, one would think the exposure to this type of potential distractor is quite high (perhaps multiple incidents per trip).

In an attempt to further delineate the most common type of exterior incidents involved in distraction-related crashes, Stutts, Reinfurt, and Goodman (2001) examined a sample of crash narratives from two years of CDS. They found that the most common exterior incident in distraction-related crashes involved traffic or a vehicle, such as a vehicle swerving or changing lanes, an emergency vehicle, or bright vehicle lights. The next two most common incidents were police activity and an animal in the roadway, followed by, in order of frequency: people/object in roadway; sunlight/sunset; crash scene (rubbernecking); and road construction.

Looking at scenery/landmark

Another potential distraction outside of the vehicle is scenery or landmarks. In a recent study by Virginia Commonwealth University (Glaze & Ellis, 2003), researchers

analyzed more than 2,800 surveys filled out by police officers at driver-inattention-related crash scenes regarding the main distraction that contributed to the crash. In nearly 10 percent of cases, looking at scenery/landmarks was reported. This distraction factor was second only to exterior incidents.

We could find no human-factors literature utilizing simulators, or other laboratory research, investigating the distraction potential of scenery or landmarks. However, scenery is an integral component of certain US roads, known as “scenic byways” (see FHWA, 1999)¹. Analyses of crashes along these byways compared to matched non-scenic byways might provide evidence of the distraction potential of scenery/landmarks.

Inside the Vehicle

Passengers

Travel with a passenger occurs in about one-third of automobile trips in the US. Given the incredible variety of human interactions, it is not surprising that some of these interactions can be distracting to an automobile driver, and may lead to an increased risk of crash. For young drivers in the US, at least, analyses have shown that the rate of crashes increases with the number of passengers present in the vehicle, and crash risk is increased even further when the passengers themselves are young (Chen, Baker, Braver, & Li, 2000; Doherty, Andrey, & MacGregor, 1998; Williams, 2003). On the other hand, research on non-teenage drivers has found either no change or a reduction in crash risk when passengers are present (Doherty, Andrey, & MacGregor, 1998; Vollrath, Meilinger, & Krüger, 2002; Williams, 2003). Thus, it may be that young drivers are more susceptible than older people to the distracting influence of passengers or that the interactions that young people have with their passengers are qualitatively different.

Analyses of distraction-related crash data files have found passenger-related distractions to be a relatively common triggering event for the crash (General Assembly of the Commonwealth of Pennsylvania, 2001; Glaze & Ellis, 2003; Royal, 2003; Stevens & Minton, 2001; Stutts, Reinfurt, & Rodgman, 2001). In their analysis of CDS crash narratives, Stutts, Reinfurt, and Rodgman, (2001) found that verbal interaction with the

¹Scenic byways have also been designated by the Automobile Association of America, the US Forest Service, and the National Geographic Society.

passenger was the most common passenger-related event, followed by tending a child or infant, and the passenger doing something (e.g., yelling, reaching, fighting, etc.).

Adjusting entertainment system

The vast majority of motor vehicles are equipped with entertainment systems that include radios, cassette players, and/or compact-disc (CD) players. Operation of these systems usually involves manual manipulation of buttons, knobs, and media, as well as visual input, leading to a potential for physical, cognitive, and visual distraction. Analyses by several researchers have shown that adjusting an entertainment system is one of the leading in-vehicle triggering events for distraction-related tow-away crashes (Stutts, Reinfurt, & Rodgman, 2001; Wang, Knipling, & Goodman, 1996); distraction-related police-reported crashes (Glaze & Ellis, 2003), and distraction-related fatal crashes (Stevens & Minton, 2001).

McKnight and McKnight (1993) used radio tuning as a baseline for comparing cellular phone activities on simulated driving performance. They found driving performance decrements during radio tuning to be similar in magnitude to the decrements found for intense cellular phone conversations, suggesting that the two activities produce similar levels of driver distraction.

Music

The most common circumstance in which people listen to music is while driving alone in a motor vehicle (Slobada, 1999; Slobada, O'Neill, & Ivaldi, 2001). In one study (Slobada, O'Neill, & Ivaldi, 2001), subjects recorded where they were and whether they were listening to music at seven random times during the day when cued by a pager. Of the people traveling, 91 percent were listening to music, compared to only 46 percent listening to music while at home.

Whether music listening is a contributing factor to distraction-related crashes is unknown. However, research is beginning to uncover an interesting relationship between music and driver performance. Music is a complex stimulus that includes an intensity level, tempo, and style that collectively elicit a psychological response. The response a person has toward a certain piece of music depends mostly upon that individual's personal

characteristics. As such, research to date has focused upon the effects of music intensity level and tempo on driving performance.

With a background noise level in motor vehicles of about 60 decibels (dBA) (Dahlstedt, 2001), it is not surprising that in-vehicle stereos tend to be set with an output of 80 to 130 dBA (Ramsey & Simmons, 1993). Considering the fact that an amplified rock concert has an output of about 115 dBA or greater, in-vehicle music is often quite loud. What is the effect of music intensity on driving? Listening to soft music (about 55-70 dBA) while driving may improve reaction times to unexpected breaking events, perhaps signaling a reduction in driver distraction (Turner, Fernandez, & Nelson, 1996). A similar effect was not discovered at a high intensity (80 dBA). On the other hand, more recent research has shown that under high-demand driving conditions, both soft and loud music decreased reaction times to unexpected centrally-located events, but significantly increased reaction times to peripherally-located events (Beh & Hirst, 1999). Thus, the relationship between music intensity and driver distraction needs further investigation.

The only research to date on the effect of music tempo on driver performance found an interesting relationship between the two (Brodsky, 2002). In this study, the effects of three tempos, ranging from about 60 to 130 beats-per-minute on several measures of driving performance were investigated while music intensity was held constant. Subjects "drove" along a simulated roadway on a microcomputer. The study found that both average driving speed and number of lane crossings significantly increased with tempo, while both the number of missed red-lights and collisions also increased with tempo, but not significantly so. These results led Brodsky to conclude that music tempo increases driving risks perhaps by competing for attentional space. It is, perhaps, premature to draw conclusions about driver distraction and music until further research is conducted with a broader range of subjects and conditions. Brodsky (2002) utilized only music students in his first experiment and undergraduates in the second experiment. The results, however, show that the effects of music on driver distraction is a promising line of inquiry.

Cellular phone use

Use of cellular (mobile) phones while driving is a growing traffic safety concern. Cellular phone ownership has been increasing rapidly over the last several years and is predicted to rise to more than 80 percent by 2005 (Telecompetition Inc., 2001). Self-

reported data show that about two-thirds of cellular phone use occurs while in a motor vehicle (Gallup, 2001; Bureau of Transportation Statistics, 2000; Insurance Research Council, 1997). Direct observation studies of cellular phone use have found that about 3 percent of the driving population are conversing on a hand-held cellular phone at any given moment during daylight hours (Eby & Vivoda, in press; Eby, Kostyniuk, & Vivoda, in press; NHTSA, 2001b; Reinfurt, Huang, Feaganes, & Hunter, 2001). According to NHTSA (2001b) estimates, this use rate equates to about 600,000 drivers using a cellular phone at any given time during daylight hours in the US.

Evidence obtained from simulated driving (e.g., Alm & Nilsson, 1995; Consiglio, Driscoll, Witte, & Berg, in press; de Waard, Brookhuis, & Hernández-Gress, 2001; McKnight & McKnight, 1993; Serafin, Wen, Paelke, & Green, 1993; Strayer & Johnston, 2001) and on-the-road driving (e.g., Brookhuis, deVries, and de Waard, 1991; Hancock, Lesch, & Simmons, in press; Tijerina, Kiger, Rockwell, & Tornow, 1995) has shown that use of a mobile phone can lead to decrements in tasks required for safe driving. There is general agreement in the literature that the most distracting activities involving cellular phone use are dialing and receiving phone calls (see e.g., Alm & Nilsson, 2001; Brookhuis, de Vries, & de Waard, 1991; Green, 2000; Tijerina, Johnston, Parmer, Winterbottom, & Goodman, 2000; Zwahlen, Adams, & Schwartz, 1988). In addition, use of hand-held phones tend to be associated with greater decrements in driving performance than hands-free phones, but the conversations tend to be equally distracting, especially when the information content is high (see e.g., Consiglio, Driscoll, Witte, & Berg, in press; McKnight & McKnight, 1993; Patten, Kircher, Östlund, & Nilsson, in press; Strayer & Johnston, 2001).

Evidence is also mounting, although still far from conclusive, that the use of cellular phones increases crash risk. In their analysis of the CDS data, Stutts, Reinfurt, and Rodgman (2001) found that cellular phone use or dialing was implicated in about 1.5 percent of distraction-related crashes. One would expect this percentage to increase as the predicted use of cellular phones increases. More recent work in Virginia has found that about 5 percent of distraction-related crashes involve cellular phones (Glaze & Ellis, 2003). Utilizing self-reported data on cell phone crash involvement, Royal (2003) estimates that there are 292,000 drivers in the US who report cell-phone involvement in a crash in the past five years. Results from epidemiological studies in which cellular phone use has been linked with crash records, are beginning to support the hypothesis that use of a cellular

phone while driving increases crash risk (Koushki, Ali, & Al-Saleh, 1999; Laberge-Nadeau, et al., in press; Redelmeier & Tibshirani, 1997; Sagberg, 2001; Violanti & Marshall, 1996).

Route-guidance systems

Advances in computer and communication technology over the last two decades have led to the development of a wide array of advanced in-vehicle information systems, collectively called telematics. As described by Kantowitz (2000), these systems can be classified into three categories: advanced traveler information systems (e.g., route-guidance); safety and collision avoidance (e.g., automated cruise control); and convenience and entertainment (e.g., in-vehicle Internet). The proliferation of in-vehicle technology has generated concern that these systems, singly and in combination, might cause an increase in driver distraction (see e.g., Tijerina, Johnston, Parmer, Winterbottom, & Goodman, 2000; Westat, 2000).

One of the most widely available in-vehicle advanced technologies is the route-guidance system. These systems provide the driver with information about a route to a destination supplied by the driver. Because these systems use vehicle location technology, such as GPS, route directions can be timed to correspond with the driver's information needs as he or she drives. There is little information about the incidence of route-guidance systems in vehicles or the frequency with which they are used.

Analysis of the crash databases yielded no instances in which use of a route-guidance system was indicated as a contributing factor in distraction-related crashes (Stevens & Minton, 2001; Stutts, Reinfurt, & Rodgman, 2001). In addition, natural use studies of various route guidance systems have found no adverse effect on traffic safety, nor any increase in self-reported distraction (see e.g., Eby, Kostyniuk, Streff, & Hopp, 1997; Kostyniuk, Eby, Hopp, & Christoff, 1997; Kostyniuk, Eby, Christoff, Hopp, & Streff, 1997; Perez, Van Aerde, Rakha, & Robinson, 1996).

Despite these results, there is general agreement in the literature that the function of destination-entry is quite distracting if it involves visual displays and manual controls (see Tijerina, Johnston, Parmer, Winterbottom, & Goodman, 2000 for an excellent summary of this work). While most destination-entry would probably occur in a stationary vehicle, Green (1997) has pointed out that there are several scenarios in which a driver might

engage in destination-entry while driving, and in turn be at greater risk for a distraction-related crash: driver is in a hurry and enters the destination after starting the trip; driver changes his or her mind about the destination after starting trip; driver gets other information, such as a radio traffic report, then decides to change the route; driver entered the wrong destination; and the driver does not know the exact destination prior to departure and enters the actual destination later. Thus, there are several scenarios in which use of a route-guidance system could lead to distraction-related crashes.

Eating or drinking

Many of us would agree that eating and drinking in the car is a common activity for drivers. Certainly the activity leads to physical distraction, as it requires the driver to hold the food or drink. Eating and drinking in a vehicle can also result in cognitive and visual distraction as the driver attempts to locate items or prevent them from spilling. Thus, eating and drinking in the vehicle may be a contributing factor in distraction-related crashes. Indeed, Stutts, Reinfurt, and Rodgman (2001) have found evidence for the presence of this activity in about 2 percent of distraction-related crashes in the CDS database. In-vehicle eating or drinking has also been indicated in about 5 percent of police-reported crashes in Pennsylvania (General Assembly of the Commonwealth of Pennsylvania, 2001) and a small number of fatal, distraction-related crashes in the UK (Stevens & Minton, 2001). We could find no simulator or on-the-road studies addressing the distraction-potential of in-vehicle eating or drinking.

Adjusting vehicle controls

Motor vehicles have a variety of systems that the driver controls including lights, safety belts, turn signals, windshield wipers, and heating/ventilation/air-conditioning (HVAC). Operation of these systems through steering-wheel or dashboard controls can draw attention away from driving thus leading to distraction. Generally, most systems, except for HVAC, are simple controls that require little attention to operate, at least in a familiar vehicle. However, HVAC systems, which generally have at least two controls with multiple settings, can lead to distraction even in a familiar vehicle. Studies that have investigated distraction-related crashes in various databases have found that adjustment of vehicle controls account for about the same frequency of distraction-related crashes as eating and drinking—about 2-5 percent (General Assembly of the Commonwealth of Pennsylvania, 2001; Stevens & Minton, 2001; Stutts, Reinfurt, & Rodgman, 2001).

Objects moving in vehicle

People often transport objects in their vehicles such as groceries, packages, purses, laptop computers, and briefcases. If these objects are not secured, the kinematics of normal driving can cause them to slide along the vehicle floor or fall off the seat. These events can draw attention away from the driving task during braking and/or turning which are critical safety-related maneuvers. People also transport pets, who, if not constrained, can move about the vehicle causing distractions.

An object moving in a vehicle does seem to be a factor in distraction-related crashes. Stutts, Reinfurt, and Rodgman (2001) found that a moving object in the vehicle was the triggering event in about 4 percent of distraction-related crashes in the CDS database, and in some years the percentage was as high as 7.6. In a pilot, focus-group study in Michigan, objects falling off the seat was one of the most commonly cited reasons by drivers as a cause relating to their rear-end crashes (Kostyniuk & Eby, 1998).

Little is known about the frequency of this distraction-related event. However, anecdotally, one would expect that the majority of people transport objects on nearly every trip. The frequency with which these objects move and whether this movement attracts the driver's attention is unknown.

Smoking

The Centers for Disease Control (CDC) estimate that about 23 percent of the adult population are current smokers, with little change in prevalence over the last several years (CDC, 2002). We could find no research on the prevalence of smoking in vehicles. However, given that many jurisdictions are banning smoking in public buildings, the vehicle may be one of the few places left, besides at home, where a person can smoke. Thus, smoking while driving may be a frequent activity.

Does smoking while driving lead to distraction? Cigarette smoking has been identified as a contributing factor in about 1 percent of distraction-related crashes in the CDS (Stutts, Reinfurt, & Rodgman, 2001), nearly 5 percent of distraction-related crashes in Pennsylvania (General Assembly of the Commonwealth of Pennsylvania, 2001), and in a small percentage of fatal distraction-related crashes in the UK (Stevens & Minton, 2001). These percentages were similar to those for the involvement of cellular phone use in

distraction-related crashes. Analysis of the CDS narratives showed that, in order of prevalence, smoking-related distractions were: lighting the cigarette; reaching or looking for the cigarette; the cigarette blowing back into the vehicle; and dropping the cigarette (Stutts, Reinfurt, & Rodgman, 2001).

Two studies on cigarette smoking and simulated driving were found (Ahston, Savage, Telford, Thompson, & Watson, 1972; Sherwood, 1995). Both studies report mixed results, with drivers who were smoking exhibiting faster reaction times in some conditions and slower reaction times in other conditions. Since both studies were interested in the nicotine level, differences in reaction times may have been due to the introduction of this chemical rather than the physical or cognitive distraction of smoking. In addition, neither of these studies had smokers attempt to light or search for cigarettes while driving. Thus, we conclude that smoking while driving is a potential triggering event for distraction-related crashes and is a topic in need of additional empirical research.

Other scenarios.

A number of other distracted driving scenarios have been discussed in the literature but little empirical data were available to assess them. These scenarios, however, may be ones in which technologies, or other strategies, are particularly well suited for mitigating driver distraction. We include them here for completeness.

Reading. Clearly driving and reading can lead to visual, cognitive, and physical distraction. Reading printed materials such as a book, newspaper, or mail is considered by 80 percent of people surveyed nationally to distract drivers enough to make driving more dangerous (Royal, 2003). More than one-half of respondents also considered looking at maps or written directions to be activities that make driving more dangerous.

Wireless technologies. Wireless technology is proliferating and includes personal data assistants (PDA), wireless email, pagers, and beepers. One would expect that use of these technologies while driving will become more frequent in the future. Royal (2003) found that remote Internet equipment such as PDAs was the second most frequently selected distracting activity after reading. About 40 percent of respondents thought that pagers or beepers were distracting enough to make driving more dangerous.

Night vision systems. These systems utilize infrared technology to obtain heat signatures of pedestrians or animals on or near the roadway and present this information to the driver via a display. Because the systems are designed for nighttime, they are used in higher-demand driving situations. As with all visual displays, night vision systems can lead to distraction. As described by Ranney, Garrott, and Goodman (2001), a driver looking at the display may have enhanced object recognition over direct object viewing, but the display may distract driver attention from other objects or features not visible in the display.

Personal grooming. This activity involves a range of behaviors and most likely leads to some level of visual, physical, and cognitive distraction. More than 60 percent of respondents in a nationwide telephone survey thought that personal grooming was one of the most distracting activities for drivers (Royal, 2003).

Summary

This section reviewed a number of distracted-driving scenarios that may increase the likelihood of distraction-related crashes. One important question remains: What is the relative contribution of these scenarios to distraction-related crash risk? As discussed in the section on crash databases, the best way to answer this question would be to analyze a database containing reliable and accurate information about crashes and distractions, as well as some way to measure exposure (i.e., the frequency with which various distraction-related scenarios occur during driving). Unfortunately, such a database does not exist.

One could, however, as a first pass, rate scenarios on measures that are known or believed to be related to the likelihood of a crash. There are at least four measures that we believe are related to the likelihood of a distraction-related crash. The first is the frequency with which the event occurs (*exposure*). Scenarios that occur frequently are more likely to lead to distraction-related crashes than scenarios that occur less frequently, all else being equal. The second measure is *volition*. By this, we mean the degree of control the driver has over initiation of the scenario. Some scenarios are completely voluntary, such as the adjustment of vehicle controls, in which case the driver can coordinate the initiation of the scenario with driving situations that require low attentional resources. Other scenarios are generally out of the driver's control, such as the appearance of an emergency vehicle (exterior incident), in which case the driver must deal

with the distraction on top of whatever attentional demands are already required for safe driving. The third measure is the relationship of the scenario to the attentional *demand* of the driving task. Certain scenarios can be caused by changes in driving task demand. For example, objects placed on the seat of a car will move only when the driver brakes or turns a corner, situations in which greater attention to the driving task is likely to be required to prevent a crash. Other scenarios, such as answering a cell phone, have no relationship to the attentional demands of driving. Scenarios that have a close relationship with driving task demand would be more likely to increase crash risk because the distraction occurs at a time when greater attention is needed for driving. The fourth measure is the overall level of *distraction*; that is, the potential for the scenario to result in either/or physical, visual, auditory, or cognitive distraction. The more distracting a scenario, the greater the likelihood that the scenario will result in a crash.

For each of these measures, one could construct a scale where higher numbers indicate a greater likelihood of a crash. Each scenario could then be judged on each measure independently. Preferably, these judgments would be based upon empirical studies. For example, exposure might be assessed using results from direct observation (Eby, Kostyniuk, & Vivoda, in press; Stutts, personal communication, 2003) or self reported data that is weighted to be nationally representative (Royal, 2003). In the absence of good empirical data, however, an alternative approach for assessing these scenarios would be to have a group of experts make the judgments. Scenarios could then be ranked by some combination of scores for each measure to obtain a crash-risk metric for each scenario.

Clearly there are limitations to this method of rank-ordering distraction-related scenarios. Many of the measures will be influenced by the age, sex, and other characteristics of the driver. In addition, the combination of the four measures into a single metric is not trivial. Should some measures count more toward crash risk than others? We present this method here, however, as a framework for better understanding distraction-related crash scenarios and as a first step, in the absence of adequate crash data, to rank the relative contributions of various distraction-related scenarios to crashes.

DISCUSSION

One purpose of this review was to examine available crash databases to assess their usefulness in determining distraction-related crash scenarios that a workload/distraction management system like SAVE-IT could be designed to prevent.

While all databases reviewed had limitations, we concluded that the GES and CDS are the best suited for our purpose. In fact, all recent crash analyses on driver distraction have utilized one or both of these databases (see e.g. Campbell, Smith, & Najm, 2002; Najm, Koopman, Boyle, & Smith, 2002; Najm, Schimek, & Smith, 2002; Stutts, Reinfurt, & Rodgman, 2001; Wang, Knipling, & Goodman, 1996; Wiacek & Najm, 1999). We note, however, as do others, that these databases have important limitations. The first is that the number of crash records coded with a driver distraction variable is small and large standard errors will be associated with national estimates. The second limitation is that only police reported crashes are included in GES and only crashes in which a vehicle is towed away are included in CDS. Thus, neither database is representative of all crashes nationally. Finally, the distraction variable is often self-reported to a police officer. Since drivers may be reluctant to reveal an activity that may suggest personal fault in the crash, driver distraction in crashes may be biased and/or under-represented.

The second purpose of this review was to investigate a variety of scenarios in which driver distraction may be important. We consider scenarios defined by previous crash analyses as well as distraction-related driving scenarios that may not appear in crash records directly, but are likely to be related to distraction-related crashes. We found that few studies have considered distraction in relation to crash scenarios. Those that have, generally find that single-vehicle-run-off-the-road and rear-end crash scenarios have a sizeable proportion of crashes that are distraction related. Several other scenarios were reviewed but generally are lacking enough data for which to draw strong conclusions. Thus, the SAVE-IT system should be designed to mitigate, at a minimum, these two crash types.

The review of distracted-driving scenarios, based upon events that can trigger driver distraction, covered a wide range of scenarios arising from events both inside and outside the vehicle. For each scenario we assessed the available data on the frequency and distraction potential of the scenario. For some scenarios, such as use of cellular phones, a relatively large volume of research has been conducted. For other scenarios, such as eating or drinking in the car, very little research was available. It is also important to note that empirical exposure measures for nearly all scenarios are lacking; that is, we do not know how frequently certain distraction scenarios occur in the absence of a crash. Without good measures of exposure, it is impossible to calculate the crash risk of a certain

scenario. In the absence of good data about these distraction-related scenarios and the resulting crashes, it is difficult to even rank the relative contribution of these scenarios to distraction-related crash risk. As a first pass in rank-ordering these scenarios, we present a simple framework based on an empirical or subjective rating of each scenario on exposure, volition, attentional demand, and level of distraction. Future research, perhaps with experts on driver distraction and crashes, should begin to assess the relationship of these distracted-driving scenarios to crash risk.

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