An Investigation of the Safety Implications Of Wireless Communications in Vehicle

150021

Table of Contents

Table of Contents
(continued)

Preface

The wireless communications industry is perhaps matched only by the personal computer field in the rate at which new products and features are being introduced to the marketplace. In the two years since the research for this report was initiated, the technology has changed dramatically and what was once a novelty, used primarily by businesses, has now become commonplace among the masses. Today, cellular telephones are owned by more than 50 million Americans and new technological breakthroughs have seen a migration from analog to digital architectures along with the recent introduction of "Personal Communications Services (PCS)" as a competitor to the cellular market. Driven by these developments, new capabilities beyond voice communications are being made available at an accelerated rate, compelling the user to upgrade to palm-size devices that allow activities such as checking of e-mail, "surfing the net," receiving stock quotes - from the classroom, the beach or perhaps from our vehicles.

The issues discussed in this report relate to all forms of wireless communications technology that may be used by drivers. In an effort to simplify the language in this report, as a service to the reader, we have elected to use the familiar phrase "cellular telephone" throughout the document, rather than a more general identifier such as "wireless communications device." It should be noted, however, that the issues addressed herein are independent of the underlying technology, service or carrier and apply to all wireless communications devices and associated systems.

Executive Summary

The extensive growth in the wireless communications industry over the past ten years has been accompanied by growing concern for the potential hazards of drivers using wireless communication devices from moving vehicles. Given the National Highway Traffic Safety Administration's (NHTSA) mission to save lives, prevent injuries, and reduce traffic-related health care and other economic costs (through regulation, enforcement, economic incentives, educational programs, basic and applied research, and technology demonstration programs), the Agency has taken a particular interest in this issue.

DOT currently has a number of programs that focus on how best to utilize wireless technology in the vehicle to support efficient and effective emergency response (e.g., automated collision notification [ACN], nationwide 911 access to emergency services from vehicles, in-vehicle information on traffic hazards and roadway conditions). In addition, the safety benefits of having a communications capability available within a vehicle are well documented and supported by both law enforcement and consumer safety groups, which frequently promote the use of these devices to ensure the security of the driver as well as to report congestion, crashes, and drunk drivers.

Nevertheless, there has been increasing concern over the safety of using communications devices while driving, particularly within the public sector, and this has been reflected in the growing number of legislative initiatives in the states that address the use of wireless communications in vehicles. In response, NHTSA has prepared this report to help ensure that the public, the wireless industry, and the states have sufficient knowledge upon which to make informed decisions regarding the issues and to identify needed initiatives and research to help ensure that the economic, safety, and convenience benefits of mobile wireless communications can be maintained within an acceptable margin of safety. The objective of this effort is thus to assess the current state of knowledge regarding the safety implications of using wireless communication while driving a motor vehicle and to explore the broader safety issues associated with such use. This report examines the topic by reviewing available data and information on user characteristics, examining crash statistics, performing statistical analyses, and conducting a comprehensive critical review of relevant published research studies.

The report addresses four specific questions as follows:

- ***Does use ofcellular telephone technology while driving increase the risk of a crash?***
- ***Wbat is the magnitude ofthe traffic safety problem related to cellular telephone use while driving?***
- ***Willcrashes likely increase with increasing numbers of users of cellular telephone technology in the fleet?***
- ***Wbat are theoptions for enhancing the safe use of cellular telephones by drivers?***

Based on the information collected it can be concluded that in some cases, the inattention and distraction created by the use of a cellular telephone while driving is similar to that associated with other distractions in increasing crash risk. Both the research studies and crash data reviewed in this report highlight several factors by which cellular telephone use while driving can increase the risk of a crash. Among these, conversation appears to be most associated with the crashes reviewed.

Furthermore, it is clear that at this time there are insufficient data to indicate the magnitude of any safety-related problem associated with cellular telephone use while driving. This is a consequence of inadequate reporting and thus it cannot be determined whether a problem requiring action exists. Rather it serves to underscore the need for enhancing such data collection at both the state and national levels.

The data also suggest that as the use of in-vehicle wireless communications technology increases there will be an associated increase in related crashes if little changes. However, the accuracy of this prediction in either direction (i.e., increase or decrease in crashes) is uncertain, given the pace at which cellular telephone designs and the functions they can perform are changing. Such changes, along with state legislative initiatives and changes in wireless subscriber characteristics, virtually ensure that usage patterns will change over time and thus influence associated crash trends.

In the report, NHTSA presents a variety of options for enhancing the safe use of cellular telephones by drivers and addressing the many issues raised. These include educational, research, enforcement and legislative considerations and initiatives. The intent is to better define the nature and magnitude of any potential traffic safety problem and assist the public, the states and the industry in making informed decisions on how best to address any issues related to cellular telephone use and driving.

Americans spend substantial amounts of time commuting and members of the public place high importance on keeping up with their tasks and activities. It is therefore not surprising that individuals will attempt to optimize their time in the automobile by doing other things concurrently. It may be unrealistic and perhaps ill-advised to conclude that drivers should have no advanced in-vehicle information systems at their disposal because they might be a source of distraction. A number of intelligent transportation system (ITS) initiatives intended to improve the highway safety and efficiency, are, in fact, focusing on increasing such information availability. These initiatives, however, have heightened NHTSA concern over possible synergistic effects of the various technologies that might increase driver workload beyond acceptable levels.

Until we have a better understanding of the nature and magnitude of any safety related problem, rather than restricting access, the goal should be to make in-vehicle information systems, including wireless communication, as compatible with safe driving as the state-of-the-art allows. This can be accomplished through the application of good engineering and human factors design practice. This must be done while addressing possible adverse safety implications for the population as a whole. In addition, the report offers a number of recommendations for addressing the broad range of issues identified. These recommendations include:

- ***Improving data collection and reporting.***
- ***Improving consumer education.***
- ***Initiating a broad range of research to better define and understand the problem.***
- ***Addressing issues associated with use of cellular phones from vehicles to access emergency services.***
- ***Encouraging enforcement of existing state laws to address inattentive driving behavior.***
- ***Working with states on legislative options.***
- ***Using the National Advanced Driving Simuhtor (NADS) and instrumented vehicles to study optimal driver/vehicle interfaces.***
- ***Developing a sound basis for carrying out cost benefit analyses.***

Appropriately addressing these recommendations will not only enhance the safety of wireless communication from vehicles in the short term, but ultimately will allow the Agency to bring to the table the information necessary to determine whether more aggressive action is required.

Report Summary

Introduction

Since the introduction of cellular telephones in 1983, there have been dramatic changes in the cellular industry. With a growth rate of about 40 percent per year, it is estimated that by the year 2000 there will likely be about 80 million cellular telephone users in the United States. Changes in the technology, from heavy, cumbersome and expensive cellular telephones, to inexpensive, miniature hand held units, smaller than a pack of cigarettes, have had a significant impact on when, where and how we conduct our affairs, both business and personal. Societal pressures for increased efftciency, more leisure time, and an improved sense of safety, have placed wireless communications at the forefront of potential solutions for an increasingly mobile and technologically sophisticated populace.

While voice communication has been the primary focus of the cellular industry, recent technological and societal trends-in mobile communications and computer hardware and software (e.g., size, flexibility, connectivity), and the desire to "work on-the-road" have resulted in a move towards integration of technologies. This trend is such that cellular communications can now be the focal point of a truly "mobile office," including e-mail, fax and Internet services in addition to telephone, voice mail and paging capabilities from any location.

It was inevitable that the reduced size, reduced cost and increased functionality of the cellular telephone would find its use by drivers in vehicles increasing dramatically. Indeed, time spent commuting, caught up in traffic and just plain traveling, could now be productive. In addition, the cellular telephone brought with it a sense of security for those concerned about traveling alone in unfamiliar areas or concerned about vehicle breakdown. It is not surprising then that more than 85 percent of cellular telephone owners use their phones at least occasionally while driving, and more than 27 percent use their phones during half or more of their trips.

Cellular telephone use while driving is not without controversy. Public, legislative, and media concern about the safety of using a cellular telephone while driving has been expressed for some time. In recent years, perhaps because of the growing user population, the frequency with which concern has been voiced has grown considerably. It is the frequency with which these concerns have been raised, from the public, members of Congress and the media, that has prompted the research described in this report.

Objective and Scope

The objective of this report is to assess the current state of knowledge regarding the impact of cellular telephone use on motor vehicle drivers while driving, and explore the broader safety issues associated with such use.

While the primary scope of this report focuses on the potential impact of voice communications on driving, continuing development and availability of cellular technologies with integrated office functionality (e.g., network/Internet access, e-mail, paging, etc.) has also raised questions among some observers about the potential implications of such use on traffic safety. Thus, where relevant, consideration is also given to the possible impact of these technological developments.

The approach taken in preparing this report included a review of available literature, targeted data collection, focus groups, public opinion, and the identification of potential links between driver phone use and specific traffic hazards. The information contained in this report is drawn from the broadest range of sources available. Thus, this document reflects the current state of knowledge from a variety of perspectives including the general public, law enforcement personnel, legislators, cellular industry representatives, insurance companies, academia and the government.

It is hoped that the information presented in this report will be useful to the states in addressing the issue of cellular telephone use and safety, to the industry in optimizing the design and implementation of cellular technologies for safety, and to the driving public in using these communications and associated technologies appropriately.

Organization of this Report

The report begins with a general discussion of background information, including the cellular industry's emphasis on safety and a summary of past and present legislative initiatives aimed at limiting the use of cellular telephones while a vehicle is in motion. Chapter 2 presents an overview of "Cellular Telephone Use in America." It presents results from public surveys which describe the changing demographics of the user population. This chapter also provides a closer look at phone user opinions on the safety of cellular telephone use while driving.

The next chapter (3) discusses available crash information. All relevant information from the federally sponsored Fatal Analysis Reporting System (FARS), and the National Automotive Sampling System (NASS) are presented. In addition, the data from the states of Oklahoma and Minnesota, the only two states which attempt to systematically record cellular telephone use prior to a crash, are discussed.

During June 1996, the Japanese National Police Agency conducted a crash investigation program that focused on cellular telephone use. The results of that project are also reviewed. Finally, individual case studies are described to illustrate the circumstances that can lead to a serious crash.

Chapter 4 presents a study drawn from an analysis of the narrative sections of selected (i.e., cellular telephone related) police crash reports from the State of North Carolina. The multi-year analysis was designed to identify changes in frequency of cellular telephone related crashes that may be related to increases in the number of users as well as identify the nature of relevant crashes.

Chapter 5 presents a comprehensive review of simulator, and on-the-road, instrumented vehicle research conducted on cellular telephone use while driving. Available epidemiological studies are also reviewed. A critical analysis of these studies demonstrates their applicability to real world driving situations, and addresses their limitations, given the complexities of cellular telephone use in the driving environment.

The final chapter (Chapter 6), provides a discussion of what was learned in conducting this research and assembling this report. It identifies common threads drawn from the myriad of sources. The discussion also focuses on what is still not known or well understood and makes recommendations for targeted research in a number of arenas. Finally, based on all the information gathered, a set of specific conclusions are presented.

The appendices provide acknowledgments of contributions, copies of selected existing and proposed legislation, a glossary of cellular technology terms, a list of references, a market survey of cellular communications devices currently available (1995) and in use in motor vehicles. In addition, comprehensive critical reviews of the cellular telephone research studies are presented in the Appendix, along with a discussion of human factors considerations for the design of cellular telephones that can influence the safety of their use from a moving vehicle.

Industry Focus on Safety

The cellular industry in general has placed considerable emphasis on safety, both from the standpoint of application and utilization. The Cellular Telecommunications Industry Association (CTIA), various manufacturers as well as service providers have specifically focused on safe driving as an important consideration relating to cellular telephone use. In addition, manufacturers of cellular accessories have specifically targeted safety in their products.

From an examination of cellular telephone products and literature, it is apparent that manufacturers clearly recognize the potential risks of in-vehicle cellular telephone use and make a major effort to educate their users on the "how," "what," "when" and "where," of cellular phone use from the standpoint of safety. For example, they encourage the use of hands-free equipment in motor vehicles, along with use of memory-dial capabilities and voice activation features. To further safety objectives, the industry is continually improving the ease of use features (particularly for installed car phones) for drivers.

Legislative Initiatives

While the benefits of cellular telephone use have been frequently called out by both the cellular industry and law enforcement authorities, concern regarding the safety of operating a motor vehicle while using the phone has been of sufficient magnitude that legislative action has sometimes been initiated. Such action has taken place within the international community as well as within some U.S. states. In several instances within the international community, legislative action has, in fact, been successfully adopted, typically allowing the exclusive use of hands-free, wireless telephones while driving. In the United States, however, no such attempts have been successful. In Washington state, however, the motor vehicle code was amended to allow use of an "approved" headphone in association with "hands-free" wireless communications systems.

It is interesting to note that, in their legislation, some nations recognize the broader issue of driver distraction. For example, the ***Swiss Code of Traffic Regulations*** prescribes that "The driver must concentrate on the road and the traffic while driving. He or she may not carry out activities while driving which negatively impact the operation of the vehicle."

User Demographics and Public Opinion

The recent growth of cellular telephone use is a phenomena that crosses all age and gender boundaries. More than just the latest electronic gadget, cellular telephones have become integral parts of our business and personal lives. They are used to schedule appointments, broker deals, call for assistance, report emergencies and maintain contact with loved ones.

Currently about 9 percent of the more than 50 million cellular telephones in use in the U.S. are owned by people less than 24 years old. A number of surveys have been conducted by industry and other interested groups in attempts to characterize the role that cellular telephones play in American society. An overview of user demographics and reported cellular telephone usage patterns has been assembled from industry surveys. These surveys also address driver concerns and crash rates for cellular telephone users.

It is apparent from these surveys that the use of cellular telephones has greatly expanded as the size and costs of cellular telephones continue to shrink and the potential safety and convenience benefits become more widely recognized. As a result, the user group has grown from the middle-aged businessman to the young and elderly who often make personal calls. Since 1990, the usage patterns have shifted from primarily business use to an emphasis on personal use. The majority of subscribers tout the safety benefits of cellular telephone availability.

Issues of perceived safety and risk of using a cellular telephone while driving, are also highlighted in the survey data. For example, a recent survey by ***Prevention Magazine*** indicated that 18% of respondents believed that their use of cellular telephones was distracting while they were driving, while 85% of the respondents use their cellular telephone while driving at least occasionally. The survey also indicated that 70% of the drivers found cellular telephone use to be the same or more distracting than tuning a car radio. A survey recently released by the National Highway Traffic Safety Administration found similar usage patterns.

Focus groups were conducted with law enforcement personnel who spend much of their day observing driving behaviors. These rookie and veteran police officers were queried as to their personal experience with cellular telephones, their observations of driving behavior and their opinions about cellular telephone use on the highways. Generally, the law enforcement community is supportive of the availability of cellular telephones and their use in vehicles. The immediate notification of true emergencies is a benefit widely acknowledged.

Additional public outreach efforts included detailed discussions with cellular telecommunications industry representatives, Internet queries, and public service notices in local publications. This attempt to tap into “conventional wisdom” demonstrated that drivers are not necessarily aware of their driving performance while they are engrossed in a call. Frequently, the potential hazards cited by some cellular telephone users (such as being careful while dialing) do not match the problems (such as lane meandering) cited by non-users who are sharing the road.

Emergency Response

Cellular telephone users in California made approximately 29,000 emergency calls in 1995.In 1996, it was estimated that 2.8 million emergency calls were made, an increase by a factor of 100. The industry estimates that 18 million such calls will be made nationwide, sometimes overburdening response networks with multiple notifications for non-life threatening events.

Efforts are also underway to seek changes in technology from cellular companies that would enable emergency dispatchers to automatically locate cellular telephone callers. It is unknown at this time how many of these calls are made from vehicles. Unlike calls made using land lines, cellular calls cannot be traced back easily to specific locations. This presents a challenge for emergency responders to locate callers who may be disabled or unsure of their location.

In some states, including California, Colorado, Maryland, Virginia, Delaware, Texas and Florida, the cellular emergency calls are directed to the state police. The increase in the number of calls has been so great, that these states are attempting to build infrastructures to handle the volume of calls received. The state police surveyed are generally appreciative of the quick notification capabilities afforded by cellular telephones. Problems arise, however, when numerous calls are made to report the same incident, or the emergency network is used frivolously. When a serious mishap occurs, as many as 100 or more calls may be received, which jam the lines and potentially prevent other emergencies from being reported. Of greater concern are the 50%-60% of the “911” calls that do not reflect true emergencies.

Crash Data

The National Highway Traffic Safety Administration uses a variety of data sources to identify emerging safety problems, monitor trends and evaluate the effectiveness of various countermeasures. Primary tools include the Fatal Analysis Reporting System (FARS) and the National Automotive Sampling System (NASS) funded by NHTSA, and police crash reports collected by the states.

The FARS and NASS data sets rely upon police crash reports as a source for information regarding crashes. The FARS adds additional official records to their files (such as driver records and available medical data). The NASS program employs trained investigators to document and photograph vehicle damage and scene data, as well as to gather additional information from interviews and medical records to enhance the data file.

In recent years, both NASS and FARS have attempted to identify cellular telephone use as a pre-crash factor from police crash report narratives. Although there is a serious under-reporting bias in the data, there are trends which show that cellular telephone use is a growing factor in crashes. Driver inattention is the most frequently cited pre-crash condition for drivers who use cellular telephones.

Specific aspects of cellular telephone use have been identified which demonstrate that phone conversation rather than dialing is the most frequently reported related factor. Contrary to expectations, the majority of drivers were talking on their telephones rather than dialing at the time of the crash. A few drivers also were startled when their cellular telephones rang and, as they reached for their phones, they ran off the road. Other driver factors included driving too fast for conditions or failing to yield. The overwhelming majority of cellular telephone users were in the striking vehicle, and struck cars or other large objects that were in clear view of the driver.

Only Oklahoma police crash reports contain a data element that recognizes telephone installation and telephone use related to a crash. Police officers are limited to recording cellular telephones they can see (such as installed car phones) after a crash. Portable units are not likely documented. The data contained in the crash reports cite driver inattention as a major factor in cellular telephone related crashes. The number of crashes that may be attributed to cellular telephone use is, however, much smaller than would be predicted in a statistical model based upon driver inattention factors.

The highway safety record should provide definitive data on the role that cellular telephone use plays in traffic crashes. Unfortunately, only Oklahoma and Minnesota provide police crash report (PCR) forms with data elements that specifically address cellular telephone use as a pre-crash variable. Minnesota, however, only reports the presence of a cellular telephone; not its use. Therefore, it is not clear whether the small number of cellular telephone-related crash reports in these and the NHTSA (FARS and NASS) data sources indicates under-reporting or reflects the inherently safe operation and use of cellular telephone technology. A discussion of the uses and limitations of existing data sets is presented.

The Japan National Police conducted a highway safety data collection effort focused on cellular telephone use during June 1996. The results of that project are not consistent with U.S. data in terms of driver actions and crash types, but they provide a useful basis for comparison.

Analysis of North Carolina Police Crash Report Narratives

To provide additional insight into factors associated with cellular telephone use that might be related to crashes, a detailed analysis of crash narratives was executed. Using the narrative portion of the police crash reports in the North Carolina database, an analysis related crash incidence to the number of cellular telephones (as a surrogate for use while driving) reported for each of several years.

The models built from that data indicated a statistically reliable increase in crash incidence with increased numbers of cellular phones over several years. However, this analysis involved a small amount of data from a single state and required several assumptions that must be validated. Moreover, predictions may suffer if the future differs from the past in terms of substantial changes in product design, patterns of cellular telephone use, distribution of cellular telephone users, availability and use of other services, and so on.

Several reasons are given for possible under-reporting and over-reporting of cellular telephone involvement in the crash narratives that may influence the interpretations and predictions of trends. The analysis therefore provides plausible but not conclusive evidence for a trend toward increased cellular telephone-related traffic mishaps as more and more drivers purchase such products and services.

Review of the Scientific Literature

A literature review was conducted of simulator, test track, on-road and epidemiological studies of cellular telephone use while driving. The simulator and test-track studies reviewed paint an interesting and fairly consistent picture. With respect to the dialing task, the studies suggest the following. When compared to driving alone, cellular telephone manual dialing can be disruptive of vehicle control activities like lanekeeping and speed maintenance. However, this disruption does not always appear, especially in closed-course environments. Voice dialing emulations generally support this feature as a desirable design goal.

Manual dialing is sometimes, but not always, found to be more disruptive than manually tuning a radio. Subjective assessments by test participants indicate that they are generally aware of the demanding nature of manually dialing a cellular telephone. Many studies report driver behavior that resembles attempts to compensate for such disruptive effects (e.g., by slowing down).

Voice communications, if sufficiently frequent and simple to perform, appear to enhance driving performance with fatigued drivers. Simple conversations appear to have little impact on lanekeeping and speed maintenance, but sometimes affect driver situational awareness (e.g., increased reaction times, reduced mirror sampling). The relationship between the conversational materials used in these studies and the content of normal cellular telephone communications is unknown.

Based on the results of the on-the-road studies of cellular telephone use conducted to date, the following patterns arise. First, on-the-road disruptions by manual dialing to lanekeeping or speed maintenance, as compared to manual radio tuning, appear to be small to nonexistent. On the other hand, data indicate that both manual radio tuning and manual dialing can be disruptive to driving and crash data indicate radio tuning is itself associated with crash involvement.

The magnitude of visual attention demand while dialing is sometimes less than that associated with manual radio tuning, though at other times dialing may demand greater numbers of glances and total time the eyes are off the road. Driver situational awareness (as supported by mirror sampling) appears to be reduced, though some experimental evidence exists that this reduction occurs only under conditions where drivers judge it to be acceptable, i.e., quiet motor ways. Cognitively demanding voice communications appear to also increase driver brake reaction times, again indicating a reduction in situational awareness.

There is currently no way to determine how closely behavior in the simulator or test track would match behavior exhibited on the roadway other than to compare the two sets of results obtained with identical test materials and protocols. One comparison of on-road study results with those obtained in a part-task simulator using the same dialing and voice communications tasks and materials led to somewhat different results. In general, it appears that in those studies, professional heavy vehicle drivers allowed the driving task to deteriorate more in the simulator than they did on the road. This suggests that the consequences of primary driving task failure on the road provide an incentive to the drivers to maintain consistent performance while driving on public roads. This incentive can be difficult to adequately emulate in the simulator environment.

The conclusions to be drawn from assessments of the effects of hands-free voice communications tasks are less clear. On-road studies indicate that if the voice communications activities have any effects, they are on driver situational awareness and not on vehicle control performance *per se*. The simulator studies that show vehicle control disruption may reflect an experimental artifact, i.e., that drivers do not place as high a priority on the driving task in a simulator as they do on the road.

The literature review findings may be summarized as follows. Manual dialing can be disruptive of both vehicle control performance, and situational awareness and judgment. The incidence and magnitude of vehicle control disruption while driving on public roads appears to be less than that encountered in driving simulators or on test tracks, but may nonetheless pose a safety concern. On-road studies indicate that if hands-free voice communications activities have any detrimental effects, they are on driver situational awareness and not on vehicle control performance.

Discussion

The data and information discussed in this report cover a broad range of issues related to the safety of using cellular telephones while driving. It is clear that trends in both cellular technology and patterns of use described in this report have been shown to have both positive and negative implications for safety. It is also evident that significant deficiencies exist in available information and data that prevent a clear and conclusive determination of whether cellular telephone use while driving is a significant safety problem.

Nevertheless, there are some findings and issues that are fundamental to the question of the safety of using cellular telephones while driving. For example, driver inattention, a key outcome of driver distraction, has been implicated in many traffic crashes. While cellular telephones clearly have distraction potential, from many standpoints, such effects may be minimized if drivers are aware of the hazards, are judicious in their use of the technology, and if ergonomically sound cellular telephone designs are used. This highlights the important role the industry can play in consumer education and in ensuring that cellular telephone designs and in-vehicle applications are appropriately implemented.

Furthermore, while safety benefits of cellular telephone use are well recognized, they are not without drawbacks. Solutions must be sought to minimize the burden on emergency response centers from multiple reporting and non-emergency calls, which themselves may place drivers at greater risk.

The deficiencies in cellular telephone related crash data highlight the importance of developing improved data collection strategies. The discussion of these deficiencies points out the care that must be exercised in interpreting the data that is available.

Care must also be exercised in considering the impact of proposed solutions. Thus, while both hands free dialing and hands-free conversation may reduce the risk of a crash for the individual driver, by reducing such risk more drivers may be willing to use the cellular telephone while driving or may be willing to engage in longer conversations. To the extent that conversation itself contributes to risk, the overall impact may be a net loss in safety across the population of cellular telephone users.

A review of the research literature and, in particular, a survey of wireless technologies reveal that there were extensive differences between the various wireless communications devices in terms of design features that could influence ease-of-use and hence could potentially impact safety. These "human factors" aspects of the systems encompass specific design considerations related to the display, controls, size, shape, location and other features that can influence the operability of the devices in terms of the demands on the driver. To the extent that these design considerations can influence demands on the driver, it is suggested that industry attention to them may offer significant benefits in reducing risk associated with use of cellular telephone systems.

Finally, the rapid changes in cellular technology and the associated increase in functionality points out that solutions to today's safety issues may not address those of the future. Indeed, future trends, not only with regard to wireless communications, but also within the context of Intelligent Transportation System (ITS) technologies have the potential to overload the driver. NHTSA is specifically interested in possible synergistic effects of advanced in-vehicle technologies that may impact on highway safety. Such synergistic effects may impact either negatively or positively on safety. A safety-negative impact might arise, for example, if cellular telephone use combined with use of an electronic route guidance system while driving proves too demanding for the driver to handle. On the other hand, a safety-positive synergy might arise between, say, cellular telephone use and a crash avoidance system that alerts the driver to possible crash risks that might arise while the driver is on the telephone. Little is currently known about the synergistic effects of advanced in-vehicle systems on highway safety. NHTSA thus considers it important to develop a better understanding of safety risks that might arise with use of advanced in-vehicle technologies, used both singly and in combination, while driving. NHTSA also seeks to identify opportunities to capitalize on crash avoidance systems that promote the safe use of other in-vehicle technologies that enhance travel efficiency, safety, and satisfaction. Thus, the importance of ergonomic considerations in the design and integration of all in-vehicle technologies must be considered of paramount importance.

What conclusions can be drawn, given the available data? The cogency of a conclusion depends on the adequacy of evidence, the degree to which the conclusion logically follows from the evidence, and the degree to which no relevant information has been omitted from consideration. These three points will be considered for each of the following key questions:

- ***Does use of cellular telephone technology while driving increase the risk of a crash?***

- ***What is the magnitude of the traffic safety problem related to cellular telephone use while driving?***

- ***Will crashes likely increase with increasing numbers of users of cellular telephone technology in the fleet?***

- ***What are the options for enhancing the safe use of cellular telephones by drivers?***

Does cellular telephone use while driving increase the risk of a crash?

The available evidence is adequate to support the conclusion that the answer to this question is "Yes," at least in isolated cases. The conclusion appears reasonably plausible, particularly in light of the trends in the data, the growing complexity of the technology, and the inherent distraction potential of using such devices from a moving vehicle. What remains unknown is the relative contribution of cellular phone use, per se, and charactertistics of the involved drivers (e.g., less capacity to time-share attention between cellular telephone use and driving tasks, greater propensity for risk taking, fatigue).

What is the magnitude of the traffic safety problem related to cellular telephone use while driving?

The data reviewed here are inconclusive as to the magnitude of the problem. Cellular telephone use while driving is currently inadequately reported in crash records. As a result, the data that could serve as a basis for determining the magnitude of the crash problem do not exist. The lack of data cannot be interpreted to mean that there is no problem of sufficient magnitude to warrant action. The trends in the available data reviewed in this report, the growing complexity of the technology and the sensitivity of political and societal considerations, only serve to reinforce the need to collect more comprehensive and accurate data. In the recommendations that follow various approaches are proposed for enhancing the availability and quality of the data to support a more accurate determination of the magnitude of the problem.

Will crashes likely increase with increasing numbers of cellular telephones in the fleet?

Again, the answer is "Yes", if the North Carolina data and modeling results are any indication. The adequacy of that data and modeling results are modest at best. The logical strength of the statistical predictions depends on the representativeness of the data sample to the country as a whole and the adequacy of assumptions behind the model (e.g., national cellular telephone counts as a surrogate for frequency of cellular telephone use while driving). Extrapolation from statistical models assumes that the future will be like the past. It is evident that cellular telephone designs are evolving and cellular telephone usage patterns will change over time.

The ultimate impact of these changes on crashes cannot be predicted with great confidence. Thus, the answer to the question is less cogent than the answer given to the first question, and has been duly qualified in this report. Nonetheless, it logically follows from the above that if more cellular telephones are in use, then there will be more opportunity for distraction and, hence, there will likely be an increase in related crashes - unless, of course, changes take place in the technology or its use that mitigates such a trend.

What are the options for enhancing the safe use of cellular telephones by drivers?

People in general are finding it harder and harder to keep up with all of the tasks and activities for which they are responsible. American motorists in particular spend substantial amounts of their day in automobiles, vans, trucks, and buses. It is not surprising that people will attempt to optimize their time in the vehicle by doing other things. It is unrealistic and ill-advised to suppose that drivers should have no advanced in-vehicle information systems at their disposal. A number of intelligent transportation system (ITS) initiatives intended to improve the highway safety and efficiency, are, in fact, focusing on increasing such information availability. These initiatives, however, have heightened NHTSA concern over possible synergistic effects of the various technologies that might increase driver workload beyond acceptable levels.

Goals, then, should include making in-vehicle information systems, including cellular telephone technology, as compatible with safe driving as the state-of-the-art allows through the application of good engineering and human factors design practice, and educating drivers about the potential risks associated with using this technology while driving. This must be done while addressing possible adverse safety implications for the population as a whole.

Recommendations

The National Highway Traffic Safety Administration's mission is to save lives, prevent injuries, and reduce traffic-related health care and other economic costs. The Agency develops, promotes, and implements effective educational, engineering (including human factors engineering), and enforcement programs to prevent or mitigate motor vehicle crashes and reduce economic costs associated with vehicle use and highway travel. It is therefore appropriate that this report concludes with a set of recommendations on promoting the evolution and use of cellular telephone technology that is safe for use while driving.

Improved Data Collection and Reporting

- States are encouraged to record the use of a cellular telephone during a crash as part of the normal crash investigation process. This reporting may be accomplished through an expanded set of minimum standard crash data elements being developed by NHTSA and FHWA as enhancements to the Critical Automated Data Reporting Elements (CADRE). This enhanced reporting would greatly improve the ability to characterize the magnitude and nature of any traffic safety problems associated with cellular telephone use while driving.

- Information regarding cellular telephone use and crash involvement should be incorporated into telephone surveys. This data gathering could be achieved through the Motor Vehicle Occupant Safety Survey conducted periodically for NHTSA. This survey work could augment crash reporting by the States to provide additional data on public perceptions of and non-crash-related experiences with cellular telephone technology in automobiles over time.

- Law enforcement officers are encouraged to note cellular telephone use on warnings or citations for moving violations, such as speeding or reckless operation of a vehicle. Such information is distinct from police crash reports (PCRs) because no crash occurred. This type of information might be used to characterize driver-vehicle behavior and performance that serve as "distraction indicators." These indicators and their frequency of occurrence might eventually be used to develop a model that uses safety-relevant indicators to predict cellular telephone-related crash rates.

Improved Consumer Education

- Educational materials should be developed and disseminated to educate the driving public on the hazards of driving while distracted during cellular telephone use. These materials would inform drivers of the subtle influences of cellular telephone use while driving (e.g., loss of situational awareness even though lanekeeping is good). They could illustrate driving conditions where cellular telephone use is particularly ill-advised. Cellular telephone etiquette could be taught that provides guidance on how to politely refuse, postpone, or abruptly halt a conversation when driving conditions demand it. Drivers could be taught to recognize signs of "attentional impairment" in other drivers as part of defensive driving. Consumers might be given information on cellular telephone design features that may make them easier or harder to use. Consumers could be sensitized to issues of cellular telephone technology installation or placement, and crashworthiness (e.g., as it may interfere with a deploying airbag). These types of educational and outreach materials would sensitize the driving public to issues of distraction while driving and provide them with useful strategies to cope with such hazards.

Improved Cellular Telephone Research and Development

- It is recommended that research be conducted using the National Advanced Driving Simulator (NADS) and instrumented vehicles to better understand naturalistic driver behavior while using a cellular telephone. Insights into the circumstances of call initiation, call frequency, call length, and call content would be of great benefit to formulate more realistic test protocols for cellular telephone research and product evaluation.

- Human factors research should be directed to determine workload-reducing design features of cellular telephones. Some types of cellular telephones appear easier or harder to use than others based upon size, shape, configuration, visual display attributes, and data entry mechanisms and logic (see Appendix F). Human factors research results could be provided to manufacturers in the form of ergonomic design guidelines. The results could also be provided to consumers to better inform them during product selection. Preliminary guidelines exist for cellular telephones (e.g., Green, Levison, Paelke, and Serafin, 1995), but more research is required to better understand and define the impact different design choices have on a driver while the vehicle is in motion.

- It is recommended that development of "intelligent answerphone" technology be pursued for use in the automotive context. Parkes (1993) introduced the concept of an "intelligent answerphone" as a system that would divert, record, and interrupt messages appropriately based on sensed driving conditions. The development of such a system goes far beyond anything the authors are aware of that the cellular telephone industry has marketed or reported on to date. Such advanced concepts would likely require some of the same sensed information as that being developed in the Intelligent Transportation System (ITS) initiative. Thus, this recommendation would fit well within a broader effort to integrate ITS systems (route guidance systems, crash avoidance systems, collision notification systems) with cellular phone technology.

Emergency Services

- Multiple calls for the same incident can overwhelm an emergency service line and actually slow an emergency services response. It is recommended that appropriate federal and state agencies, representatives of the Cellular Telecommunications Industry Association (CTIA) and other wireless communications associations, and national organizations representing Emergency Services examine and evaluate potential solutions to this problem. Planning of cooperative efforts are already under way.
- It is recommended that a nationwide standard emergency number be created so that travelers would always know a unique cellular telephone emergency number regardless of their location. Several states have already developed specific

emergency phone numbers to be used exclusively by cellular subscribers (e.g., "#77" or "*FHP"). A nationwide standard would require cooperation among cellular telephone manufacturers, the states, and the Federal Communications Commission (FCC). Cooperative action has already begun which includes FCC rules enabling cellular telephone access to all land line response centers. NHTSA is currently working with government and industry groups to develop a unique nationwide cellular emergency response number.

Enforcement, Legislative Options, and Cost-Benefit Analysis

- As discussed in detail in this report, it is unlawful to driver recklessly in all states in the U.S. and a number of states have laws on their books that prohibit careless and inattentive driving. States are encouraged to actively enforce their reckless and inattentive driving laws, regardless of the causes of such behavior. When law enforcement officers observe reckless or inattentive driving associated with cellular telephone use, this should be noted on the citation or warning (see previous recommendations on this point). States without inattentive driving laws should consider enacting such provisions.

- The complexity of the issues, along with the inconclusive nature of empirical evidence pointing to a cellular telephone related traffic safety problem, suggests caution in formulating and implementing legislation restricting the use of cellular telephones at this time. Legislative proposals have been introduced in some States that prohibit the use of cellular telephones that require the driver to manually operate or hold the phone. These legislative initiatives seem to be based on the assumption that hands-free cellular telephones are acceptable while driving, but hand-held cellular telephones are not. Hands-free designs should reduce the demands on the driver associated with dialing, holding, reaching for or picking a handset. This in itself might be seen as a clear and unequivocal safety gain. However, hands-free designs will do nothing to mitigate the distraction potential of cellular telephone conversation. Proposed legislation may inadvertently promote greater use of cellular telephones among drivers who currently limit or altogether avoid cellular telephone use while driving by implying that hands-free designs must be safe, thus increasing exposure to other potential risks that may still exist.

An effort should be initiated to examine the cost-benefit trade-offs of legislative actions related to cellular telephone use while driving. Potential costs of unrestricted cellular telephone use may include those associated with distraction-induced crashes and degraded driving performance. On the other hand, benefits of unrestricted cellular telephone use include more efficient use of commuting time, emergency service notification capability, and the conveniences attendant to closer communications with family, business, and community,

- Costs of legislative restrictions may result in a need to invest in more expensive and sophisticated cellular equipment, restricted access while driving to otherwise desirable features, unforeseen secondary consequences (e.g., increased exposure to other safety hazards), and enforcement costs. Potential benefits of empirically grounded legislation would include savings in personal injury, property damage, and crash-caused congestion (delay) costs. An effort to codify and represent the costs and benefits of alternative legislative actions, would support more informed decision making.

Chapter 1
Background

67 Years Ago —

"A grave problem that developed in New Hampshire, spread to Massachusetts, and crept over to Albany, now has all the motor-vehicle commissioners of the eastern states in a wax. It's whether radios should be allowed on cars. Some states don't want to permit them at all- say they distract the driver and disturb the peace. The manufacturers claim that the sound of Rudy Vallee's voice is less disturbing than backseat conversation. Massachusetts leans toward the middle of the road. The commissioner there thinks the things should be shut off while you are driving, but that you should be allowed to take culture with you into the wilderness. The whole problem is getting very complex, but the upshot is that you'll probably be allowed to take your radio anywhere, with possibly some restriction on the times when you can play it."

Written by Nicholas Trott in 1930
(Courtesy of Lawrence Ashmead, New York City)
as published in The *Farmers'Almanac 1995*

1 .1 Introduction

Cellular telephones were introduced to the American marketplace in 1983. The early models of these transportable communications devices included large battery packs and carrying cases, and cost thousands of dollars. Only a decade later, cellular telephones are even smaller than a package of cigarettes, and some models are capable of multitasking activities such as transmitting computer files, paging, maintaining continuous communications through e-mail and voice-mail connections, and even "surfing" the Internet.

The Cellular Telecommunications Industry Association (CTIA), the leading national organization which represents both wireless carriers and manufacturers, reports that there are currently over 50 million cellular customers in the United States, with an industry growth rate of about 40% per year. Although this rate is expected to decline in future years, it is estimated that there will be as many as 80 million users by the year 2000.

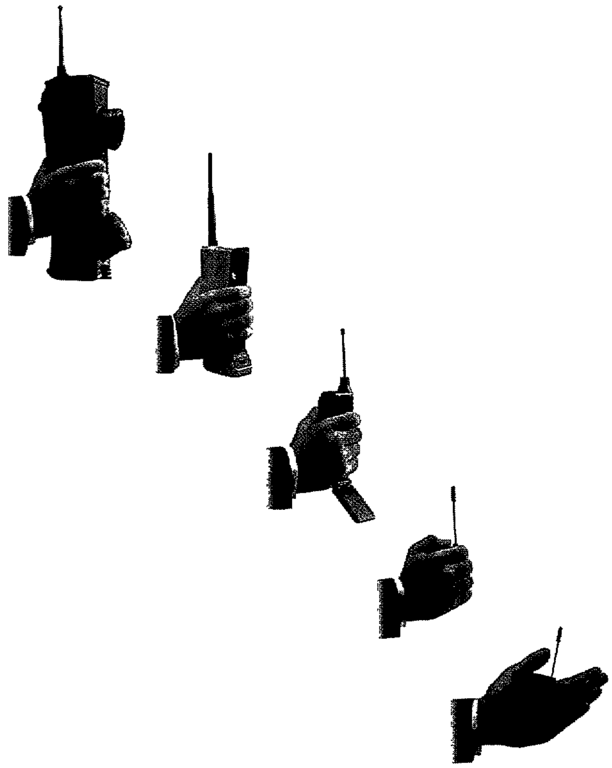
This rapid growth has brought with it a change in the demographics of cellular telephone users: from middle-aged businessmen to users encompassing all age groups, and social and economic classes, including those with less ability to task-share such as the elderly, and novice and occasional drivers. Facilitating the growth of the user base has been a reduction in the costs for cellular service, which has markedly declined, with an average monthly bill of only $51.00 for local subscribers, many of whom received their telephones for free. The cellular telephone industry is now worth an estimated $19 billion per year and growing. The number of "cell" sites (areas of service) across the nation is rapidly approaching

23,000. Given the moderate costs, availability of service areas, and ease of use, it is not surprising that cellular telephones are being rapidly adopted as fixtures in the American way of life.

Over 1 in 10 Americans now use cellular telephones, and the usage patterns are continuously changing.

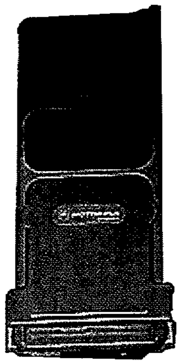
In 1995, according to CTIA, approximately 73% of all cellular telephones sold were tiny pocket models (hand-held or "flip-phone"), followed by installed cellular telephones (also called mobile or car phones), and the larger transportable devices (portable cellular telephones). Over 1 in 10 Americans now use cellular telephones, and the usage patterns are continuously changing. In 1990, industry surveys reported that 60% of cellular telephones were used primarily for business purposes, and 40% primarily for personal use. By 1394, this trend began to change, and business use accounted for 44% compared to 56% for personal conversations.

Cellular telephone usage has become so commonplace, that even social norms are being examined. Etiquette columns in newspapers have addressed the proper methods for receiving and placing calls during various social functions. In Chile, where cellular telephones compensate for poor land line service, some restaurants ask their customers to check their phones at the door, and the Long Island Railroad has established a "cellular free" parlor car for those seeking fewer distractions during their commute.

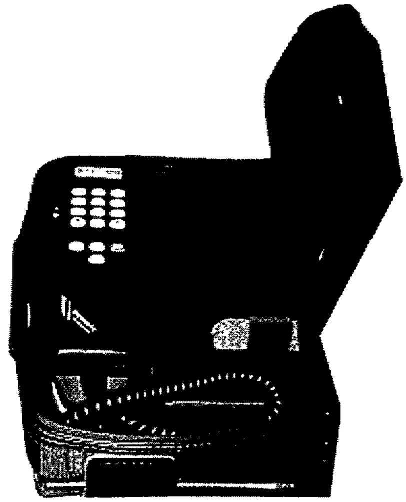


1996, Motorola, Inc. - StarTAC

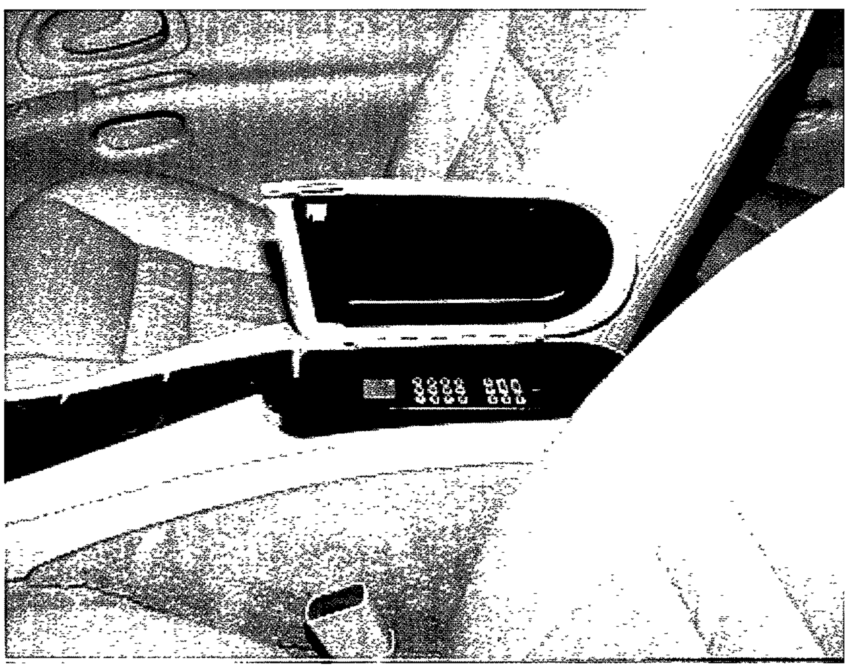
The majority of owners state that they purchased their phones for safety reasons, and many jurisdictions have developed special toll free numbers such as *FHP in Florida, and #77 in Maryland, for the reporting of drunk drivers, motor vehicle collisions and other highway emergencies. Nationally, the CTIA reports that about 18 million cellular calls are made each year to 911 or other emergency numbers. Both the law enforcement and safety communities have been very supportive of such use. In 1995, the J. Stannard Baker Award to a private citizen was bestowed upon Suzanne Peterson who initiated a program in Utah which trained 1,500 cellular subscribers in the best methods to report impaired drivers to law enforcement agencies. And a 1995 survey of consumer support for future automotive technologies conducted by J.D. Power & Associates found that automatic 911 dialing in case of a crash was a very popular feature among prospective car buyers.



Flip Telephone



Portable Telephone



Factory Installed Car Telephone

1.2 Wireless Communication Technologies

The evolution of wireless technology has seen a number of changes in recent years. While "cellular" communications, based on analog architectures, has dominated the market to date, new technological developments have resulted in the introduction of digital architectures and associated formats as well as competing technologies. Of greatest significance is the ongoing migration from analog to digital formats for cellular carriers. The competing technology, PCS (personal communications services) is based entirely on digital formats and is currently greatly expanding its geographic base to become a formidable competitor to the cellular industry. The improved clarity, security and services potentially available (e.g., high speed data transmission, paging, e-mail, etc.) through the application of digital formats, for both cellular and PCS carriers, will likely see a significant expansion in the customer base in future years. While three digital formats are currently being promoted (Global System for Mobile communications [GSM], Time Division Multiple Access [TDMA] , and Code Division Multiple Access [CDMA]), there appears to be little that functionally distinguishes them.

Insofar as available wireless services and capabilities will likely serve as bases for future competition between the two technologies (although some argue there is little difference between the two), there is particular relevance for safety in the use of these technologies while driving, since increasing availability of these services has the potential to increase both use of wireless communications in vehicles, and attentional demands on drivers using these capabilities. Nevertheless, industry projections suggest that it will be 2004 before each wireless architecture (i.e., cellular analog, cellular digital and PCS digital) will have approximately equal numbers of subscribers (Handler, 1997).

1.3 Industry Focus on Safety

Both the cellular equipment manufacturers and the CTIA frequently remind users that driving is their primary responsibility. The cellular industry in general has placed considerable emphasis on safety. In addition, manufacturers of cellular accessories have specifically targeted safety in their products.

The cellular industry in general has placed considerable emphasis on safety.

For example, in a recent advertisement, Cellular Works stated "Eliminate potential driving; hazards with a hands-free Kit from Cellular Works that converts your portable cellular to a car phone. Enjoy crystal clear conversation with both hands safely on the wheel...." Another advertisement follows a similar theme: "Now there's an easier, safer way to use your cellular phone. The CellBase™ Universal Hands-Free Car Kit lets you keep your hands free... so you can leave them on the wheel. And not only will your driving be safer in terms of other folks on the road, life will be a lot easier inside your car, too. No more flying car phone!"

From the above examples it is apparent that manufacturers clearly recognize the potential risks of in-vehicle cellular telephone use. As a remedy, they encourage the use of hands-free equipment in motor vehicles, along with use of memory-dial capabilities and voice activation features. In addition, the industry emphasizes the safety benefits and the sense of security that can accompany cellular telephone ownership. At the same time, the industry has continued to improve the ease of use features (at least for installed car phones) for drivers.

In 1995 *Prevention Magazine* published a 1994 reader survey which found that 41% of adults believe that driving is less risky now than it was in previous years. When asked what habits they had that might cause crashes, 18% reported talking on the phone. In response to industry efforts to further enhance safety, about 80% of car phones being sold for fixed or "permanent" installation in vehicles have the hands-free feature. As stated earlier, however, such installations represent a small share of the market.

Many Americans are using their hand held portable units while driving, and mounting brackets and stands for these phones are widely marketed. One question that arises is whether eliminating the need to hold the phone while using it is enough to ensure safe driving during use. Researchers have only begun to examine the safety implications of phone use while driving. A comprehensive literature review (see Chapter 5 and Appendix C) and analysis of available crash data (see Chapter 3) are presented later in this report.

One question that arises is whether eliminating the need to hold the phone while using it is enough to ensure safe driving during use.

While the evolution of car (mobile) phones has been toward more "human factored" hands-free systems, the more popular universal portables have become smaller with folding keypad/ touchpad architectures ("flip-phones"). Though very popular, the hand held units are typically difficult to operate with one hand, can be easily dropped, and may require more "positioning" by the driver, since they are more likely to experience transmission difficulties due to lower power and an integrated antenna (within the vehicle). The resulting manual and cognitive "distractions," it has been suggested, may have an even greater adverse influence on driving behavior and performance than "mobile phone" systems (i.e., permanently installed units), under certain conditions. It appears that this is the basis for the focus on hand held cellular telephones by some legislative efforts. A market survey of currently available cellular telephone models and related equipment is included in Appendix B.

1.4 Legislative Initiatives

While the benefits of cellular telephone use frequently have been called out, concern regarding the safety of operating a motor vehicle while using a cellular telephone has been of sufficient magnitude that legislative action has sometimes been initiated. Such action has taken place within the international community and within some U.S. states. In several instances within the international community legislation has, in fact, been adopted, typically allowing the exclusive use of hands-free wireless telephones while driving. In the United States, however, no such attempts have been successful.

While the benefits of cellular telephone use have been frequently called out, concern regarding the safety of operating a motor vehicle while using the phone has been of sufficient magnitude that legislative action has sometimes been initiated.

As reported in Petica and Bluet (1989), where foreign legislation has been passed, it appears that it has been based on research studies or on empirical observations, although it is not clear what specific findings, observations, or incidents may have prompted the various laws.

International Laws

Petica and Bluet (1989), of the French highway safety research institution (INRETS), conducted a survey among approximately 100 research and policy making institutes in 22 countries. They report that 66% of the responses from industrialized countries (31 responses received) view cellular telephone use by drivers as potentially dangerous, especially when hand held units are used. Only 17% of the respondents believe that there is insufficient data on the subject at this time to support legislation. Another 17% of those surveyed had no opinion.

The survey respondents had a variety of opinions as to which measures would be used to minimize the safety decrements potentially presented by cellular telephone use. The "adoption and application" of regulations was anticipated by 22%, the dissemination of information and educational materials was cited by 39% and standardization of features, and improved ergonomic design was cited by an additional 39%.

The State of Victoria in Australia was apparently the first jurisdiction to address the issue of cellular telephone use in motor vehicles in legislation (in 1988) by banning the use of hand held telephones while driving.[1] The State of New South Wales in Australia[2] and a number of other nations, have enacted similar bans since that time. These include Spain[3], Israel[4], Portugal,[5] Italy[6], Brazil[7], and Chile[8]. The penalties and fines in Spain (from 10,000 [about $80] to a possible 100,000 pesetas [about $8001) are considered to be the most stringent in Europe to date (Petica and Bluet, 1989).

The legislation of some nations prohibits the use of cellular telephones while driving specifically because it could cause driver distraction. The Swiss Code of Traffic Regulations, for example, prescribes that, "The driver must concentrate on the road and the traffic while driving. He or she may not carry out activities while driving which negatively impact the operation of the vehicle." The Code states specifically that drivers must make sure they are not distracted by radio or other audio devices.[9] Switzerland imposes a fine of 100 swiss francs (about $80) for the use of a car phone in a moving vehicle without using a hand-free device.[10]

Similarly, in Great Britain, Highway Code, Rule 43 (1992) provides, "you must exercise proper control of your vehicle at all times. Do not use a hand held telephone or microphone while you are driving . . . Do not speak into a hands-free microphone if it will take your mind off the road. You must not stop on the hard shoulder of a motor way to answer or make a call, except in an emergency." This language is apparently unique in recognizing the potential distraction caused by cellular telephone conversations. The cautions against pulling to the side of the road to make a call conflict with recommendations made by manufacturers in the U.S. to place calls from the road shoulder.

1 Road Safety (Traffic) Regulations, 1988, Reg.1502 (1)

2 Motor Traffic Regulations 1935, as amended, 90(d)

3 Law on the circulation of Motor Vehicles and Road Safety (art. 11.3) and the General Policy on Circulation (art. 18.2)

4 Transportation Regulations, 5721-1961/1970, Regulation 28, Sections l-28A and 1-28B, amended 1994

5 Decree-Law 114-94 (The Road Code), Article 85, Forbiding the Use of Certain Equipment.

6 Code of the Road - Rules of Behavior, Article 173

7 Private Communication (National Transportation Code, No. 5108, Article 89, XXI, b).

8 Montgomery Journal, Vol. 25, No. 85, p. 1 (not verified by a copy of the law).

9 Verkehrsvegelnverordnung, November 13, 1952, systematische sammlung des Bundesrechts (sr) 74 1.11 art.3, par. 1, as last amended by Verordnung, January 25, 1989, Amtliche Sammlungdes Bundesrechts (AS) 1989

10 Ordnungsbussenverordnung, March 4, 1996, No.3 11. AS 1996, p.1075 (1090)

By contrast, France and Sweden have, thus far, chosen to operate under general provisions in their existing driving codes (Petica and Bluet, 1989). French law provides, "the driver of a vehicle must constantly be in position to execute freely and without delay all driving maneuvers."[11] The law in Sweden states, "Motor vehicle drivers must take the necessary caution, care and prudence while on the road to avoid traffic accidents."[12]

In Germany, the police and Federal Highway Research Institute have collected data which they plan to analyze in 1997. The analysis will be used to determine whether legislation is needed. Meanwhile, Germany's Federal Ministry of Transport advises drivers to use "Freisprechanlage," or hands-free models, while driving.[13]

Austria and the Netherlands are reportedly considering laws that would restrict cellular telephone use to hands-free units, when the car is parked or when traveling at low speeds (Petica and Bluet, 1989). Japan and Finland have, at least initially, concluded that laws limiting cellular telephone use while driving may not be effective because it is difficult to control behavior (Petica and Bluet, 1989). Copies of many of these laws have been included in this report in Appendix A.

State Laws in the United States

It is unlawful to drive recklessly in every State in the United States. In addition, a number of states have laws on their books that prohibit careless or inattentive driving.

In Delaware, for example, drivers are specifically required by statute "to give full time and attention to the operation of the vehicle." The statute provides that persons who fail to maintain a proper lookout while operating a vehicle "shall be guilty of inattentive driving." New Mexico's law provides that drivers must give their "full time and entire attention to the operation of the vehicle." The law further provides that "any person who operates a vehicle in a careless, inattentive or imprudent manner . . . is guilty of a misdemeanor." Careless or inattentive driving is also an offense in Idaho and Wisconsin. Penalties for a first or subsequent violation of inattentive driving in these States include fines ranging from $20 to $400 and, in some cases, imprisonment. In Idaho, a offender could face imprisonment of up to six months in jail.

In one Ohio case[14] a conviction was upheld by the Court of Appeals where a driver was cited for operating a motor vehicle without giving full time and attention to its operation. The driver was using a cellular telephone and, while hanging it up, mistakenly began to exit the roadway. When he realized his error, he weaved to re-enter the interstate. While no interference or contact was made with another vehicle, an observing officer cited him for "weaving across curb and center lines of traffic."

To date, however, no State has enacted legislation to specifically limit the use of cellular telephones on the highway. Such legislation has been introduced or considered in a number of States, but none has yet been enacted.

11 Code de la Route, Titre Ier, Article R. 3-1

12 Svensk Forfattningssamling 1972:603, as amended

13 Correspondence with Presse-und Informationsamt der Bundesregierung, Bonn, Germany

14 City of Cleveland v. Issacs, 91 Ohio App. 3d 360, 632 N.E. 2d 928 (1993).

In 1989, for example, a bill was introduced to the Minnesota State Legislature to ban the use of hand-held phones on the highway. Similar bills have been introduced in Arizona, Massachusetts, Virginia and New Jersey (Frisbie, 1991). In 1995 and 1996, proposed bills attempting to address this issue in several States were introduced. None of these bills were enacted. Some of these bills are described below.

Hawaii's bill, H.R. 284, introduced in 1995, was based on a finding that "the increasing use by motorists of cellular radio telephones, or 'car phones,' together with laptop computers, portable facsimile machines, and similar devices, are a potential danger to safe driving in this State, and may constitute a contributing factor in an increasing number of the State's traffic accidents."

The bill noted that "the improper use of such hand-held equipment may be a distraction." If it had been enacted, the bill would have made it unlawful "to operate a cellular radio telephone, computer, facsimile, or other portable or laptop device, which requires holding the unit, or a portion of the unit, with one or both hands in order to operate the unit, while operating a motor vehicle." The legislation would have permitted use of "hands-free" cellular telephones, and would have otherwise permitted cellular telephone use for use in emergency situations, or if the driver had safely pulled over out of the stream of traffic to the shoulder of the road, or to another safe area off the road, and come to a complete stop. A violation of this law would have resulted in a fine of $100, but would not have resulted in the assessment of points. (Similar provisions were proposed also in Hawaii H.R. 341.)

In Virginia, House Bill 1666 would have prohibited the use of a "mobile telephone while operating a motor vehicle . . . on the highways of [Virginia] unless at least one of [the driver's] hands remained on the steering wheel . . . at all times."

Three acts were introduced in the New York State Legislature for consideration which related to cellular telephone use in motor vehicles. Each act addressed a different aspect of the issue.

- Act 9769 would have made it unlawful for a person to operate a motor vehicle while "using a cellular or car phone." A person convicted of violating this provision would have been subject to a fine of $50.

- Act 9768 would have required that manufacturers of cellular or car telephones affix warning labels to the packages of these products. The act provided that the labels read as follows, "The use of a cellular telephone or car phone while operating a motor vehicle has been known to be the cause of traffic accidents and caution is advised in such use."

- Act 9770 would have required the New York Department of Motor Vehicles to record information relating to the use of cellular or car phones as a contributing factor in crashes, and to report this information annually, starting in 1997. This is the first piece of legislation, of which NHTSA is aware, that attempted to provide specifically for the focused collection of data on cellular telephone involvement in crashes.

It should be noted that Senate Bill 6237 was introduced in 1996 in the Washington State Legislature specifically to permit the use of hands-free telephones. At the time the bill was introduced, Washington State Law prohibited an individual from "wearing a headset or earphones connected to any electronic device capable of receiving radio broadcast or playing a sound recording" while driving. The bill contained an amendment to state specifically that the law was not intended to prohibit motorists from using "hands-free wireless communications systems." The amendment was enacted into law.

A similar provision was considered in Pennsylvania. Pennsylvania Law disallows the use of headphones, earphones or other similar devices while operating a vehicle. In 1995, House Bill 1424 was introduced to permit use of "a headset in conjunction with a cellular telephone that only provides sound through one ear and allows surrounding sounds to be heard with the other ear." This bill did not pass.

The agency is aware of bills under consideration in the Legislatures of six States during 1997, addressing cellular telephone use while driving.

House Bill 0562 was introduced in the State of Illinois in February 1997. If enacted, it would prohibit a driver from using "a telephone while operating the motor vehicle unless the telephone is equipped with and the driver uses an apparatus that allows the driver to talk and listen without holding the telephone or its handset or receiver." The legislation would not permit a driver to hold or touch a telephone, its handset or a receiver while operating a motor vehicle, except "to enable the apparatus, enter a telephone number, . . . hang up or turn off the telephone."

Senate Bill 1131, introduced in February 1997 in the State of California, if enacted, would prohibit a person from driving a vehicle "while operating a cellular telephone if the operation of the telephone by the driver requires the driver to hold the telephone in his or her hand."

Oregon's Senate Bill 514, which was introduced in February 1997, would make it an offense, punishable by a fine of up to $75, for a person to drive "while using a mobile telephone if the person uses a mobile telephone while driving or moving a vehicle on a highway." Under this bill, a "mobile telephone" would mean a "hand-held device."

Legislative Bill 338, which was introduced in January 1997 in Nebraska, appears to reach even further. If enacted, this biII would prohibit any person from operating a motor vehicle "while using a cellular telephone," except in limited situations, such as for a medical emergency or if persons reasonably believe they or others are in physical danger. It appears that the bill would prohibit use of both hand-held and hands-free telephones. Persons who cause a collision because they were operating a motor vehicle while using a cellular telephone would be considered to have committed the offense of reckless driving and would be punished accordingly.

In the 220th Legislative Session of the New York State Legislature, four bills were introduced. Two of the bills, if enacted, would prohibit use of a hand held cellular telephone while operating a motor vehicle. Assembly Bill 4444 would make it unlawful for a person to operate a motor vehicle equipped with a "hand held cellular telephone which is in use while operating the vehicle." A person convicted of violating this provision would be subject to a fine of $50. Assembly Bill 5857 would prohibit a driver from operating a motor vehicle "while using a hand held cellular or cellular car telephone." It would provide a grace period of sixty seconds for the receipt and transmission of calls to pull the vehicle off the road and park in a safe location that will not interfere with the flow of traffic, and it would provide an exception for emergency situations. A violation of this provision would constitute an infraction under New York State law and would be punishable by a fine of up to $50. Second and subsequent offenses would be punishable by fines of at least $100 and $200, respectively.

The other two New York bills address the need for additional consideration of and information regarding the issue of cellular telephone use by motorists. Like the proposed legislation that was introduced in the New York State Legislature in 1996, New York's Assembly Bill 4588 (introduced in February 1997) requires the New York Department of Motor Vehicles to record information relating to the use of cellular or car telephones as a contributing factor in crashes, and to report this information annually. In accordance with this bill, reporting would begin in 1998. New York's Senate Bill 3481 would go a step further, by creating a "New York State Task Force on Communications Technology and Driver and Highway Safety." Under the bill, the task force would be charged with studying and recommending a course of action to address the use of cellular telephones while operating a motor vehicle. The recommendations would "be aimed at decreasing the risk of driving accidents due to cellular telephone use while driving" and the study would include:

> … issues of highway and traffic safety as they relate to the use of cellular telephones and other communication devices while operating a motor vehicle . . . [,] the impact of such recommendations upon businesses and individuals dependent on cellular telephones to conduct business and/or for other important purposes … [,] innovative technologies being used and/ or proposed to be used in motor vehicles cellular telephone usage that may help alleviate risks to highway and traffic safety . . . [,] recommendations for public and private strategies to address these issues, as well as public information campaigns to educate and inform our resident and non-resident motorists of dangers associated with cellular telephone use while operating a motor vehicle and methods of lessening such potential dangers.

A bill has been introduced also in the New Jersey Legislature, to study the use of cellular telephones in motor vehicles. Under the bill, Senate Bill 1070, the New Jersey Commissioner of Insurance, the Highway Traffic Safety Policy Advisory Council and the Division of Highway Safety of the Department of Law and Public Safety would be required to collect and evaluate statistics showing whether the use of "manually held and manually dialed cellular telephones or certain other cellular telephones" by motor vehicle operators "has increased the incidence of accidents or accidents per mile of similar motor vehicles." These State officials would also be required to "evaluate and advise whether the use, non-use, or extent of use of cellular telephones by motorists should be proposed as a factor in determining: (a) lower premium rates of motor vehicle insurance policies where appropriate; (b) tort liability in motor vehicle accident law suits; (c) safety instructions given to customers by sellers, installers and lessors of cellular telephones; and (d) any other safety proposal on the use of cellular telephones.

Copies of the proposed bills cited above have been included in this report in Appendix A.

1.5 Objective and Scope

Given the rising number of users of cellular telephones and the increasing number of services available through their use, it has been suggested that there may be a corresponding increase in cellular telephone related crashes. In addition, there have been a growing number of inquiries directed to NHTSA from the public, the media and members of Congress relating to the safety of using cellular telephones while driving. In response to this national level of concern, NHTSA initiated a program of research to develop a comprehensive body of knowledge on the subject. This report reflects one product of that research program.

The objective of this report is to assess the current state of knowledge regarding the impact of cellular telephone use on motor vehicle drivers while driving, and explore the broader safety issues associated with such use.

The primary scope of this report focuses on the potential impact of voice communications on driving. However, continuing development and availability of cellular technologies with integrated office functionality (e.g., network/Internet access, e-mail, paging, etc.) have also raised questions among some observers about the potential implications of such use on traffic safety. Thus, where relevant, consideration is also given to the possible impact of these technological developments.

1.6 Approach

The approach taken in preparing this report included a review of available literature, targeted data collection, focus groups, public opinion and identification of potential links between driver phone use and specific traffic hazards. The information contained in this report is drawn from the broadest range of sources available.

This document reflects the current state of knowledge from a variety of perspectives including the general public, law enforcement personnel, legislators, cellular industry representatives, insurance companies, academia and the government.

This document reflects the current state of knowledge from a variety of perspectives including the general public, law enforcement personnel, legislators, cellular industry representatives, insurance companies, academia and the government. This comprehensive approach has developed a useful body of information while also defining areas in which additional targeted research would be beneficial. It is hoped that this information will be useful to the states in addressing the issue of cellular telephone use and safety, to the industry in optimizing the design and implementation of cellular technologies for safety, and to the driving public in using these communications and associated technologies appropriately.

1.7 Organization of this Report

This "Investigation of the Safety Implications of Wireless Communications in Vehicles" is designed to present all available information, from human factors and crash investigation researchers, legislatures, law enforcement, public surveys, industry representatives, and the commercial marketplace, in a format that will allow the reader to examine and evaluate many aspects of the issues associated with cellular telephone use and driving.

The report begins with an overview of "Cellular Telephone Use in America." It presents results from public surveys which describe the changing demographics of the user population. The common business and personal usage patterns of subscribers, and the impact of such use on emergency identification and response is presented. This section also provides a closer look at phone user opinions on the safety of cellular telephone use while driving.

Chapter 3 discusses available crash information. There is a dearth of statistics with regard to cellular telephone related pre-crash factors. All available information from the federally sponsored Fatal Analysis Reporting System (FARS), and the National Automotive Sampling System (NASS) are shown.

Oklahoma and Minnesota are the only two states that attempt to systematically record cellular telephone use prior to a crash. Their data and the limitations of the data collection methodologies are reviewed. The Japanese National Police Agency conducted a focused crash investigation program during June, 1996. The results of that project do not necessarily apply to American driving situations, but do allow for interesting comparisons and contrasts with U.S. data. Individual case studies are also included which demonstrate the circumstances that can lead to a serious crash.

The "Analysis of Police Crash Report Narratives" involving cellular telephone usage in Chapter 4 represents a study drawn from an analysis of the narrative sections of selected (i.e., cellular telephone related) Police Crash Reports from North Carolina. The multi-year analysis shows that the number of cellular telephone related crashes is increasing in concert with the growing number of users. The study also identifies individuals using computers and other devices as crash antecedents.

Chapter 5 is a comprehensive review of simulator, and on-the-road, instrumented vehicle research conducted on cellular telephone use while driving. Available epidemiological studies are also reviewed. A critical analysis of these studies demonstrates their applicability to real world driving situations, and addresses their limitations, given the complexities of cellular telephone use in the driving environment.

The final chapter (Chapter 6), provides a discussion of what was learned in conducting this research and assembling this report. It identifies common threads drawn from the myriad of sources. The implications of the rapid introduction of cellular communications devices into the driving environment have not been adequately addressed by existing data collection systems. Thus, the discussion also focuses on what is still not known or well understood. The initiation of targeted research in a number of arenas is recommended.

The appendices provide copies of selected legislation, acknowledgments of contributions, a glossary of cellular technology terms, a list of references, a survey of cellular communications devices currently available and in use in motor vehicles, comprehensive critical reviews of the cellular telephone research studies presented in Chapter 5 and a discussion of human factors considerations for the design of cellular telephones that can influence the safety of their use from a moving vehicle.

1.8 Definition of Terms

In discussing the potential for cellular telephone use to adversely influence driving behavior and performance, the terms "cognitive," "cognitive capture" and "emotional content" are used. Within the context of this report, these terms describe the nature and degree of attention distributed between the tasks of driving and conversing on the phone. The task of conversing is seen as potentially having a major cognitive (thought) component where attention is focused on conversation rather than driving. The extent to which this occurs can significantly influence situational awareness (e.g., of the actions of other vehicles, the presence of a stop sign, etc.).

Cognitive capture refers to the situation where the driver may be totally "lost in thought," a condition which, in particular, could impair situational awareness. Where emotional content (i.e., personal involvement) in a conversation is high, such as arguing with someone over the phone, the likelihood of cognitive capture is increased. Those instances that require some level of cognitive involvement leading to a loss of situational awareness are viewed as increasing the risk of a crash.

Throughout this report, the phrase "cellular telephone" is used to designate the wireless communications hardware of interest. However, as pointed out earlier, a new, competing technology has emerged that also incorporates a similar architecture (i.e., handset) and hence similar concerns for safe use while driving. These Personal Communications Services **(PCS)** devices share many, if not all the display, control, implementation and user issues that have been associated with cellular telephone use in vehicles.

Since all of the research and data reviewed in this report has focused on "cellular telephones," this phraseology has been adopted throughout this report to simplify the presentation of materials. However, the discussion of issues and recommendations provided in this report apply to all wireless communications systems and associated hardware that might be used by drivers of vehicles.

Chapter 2
Cellular Telephone Use in America and Perceptions of Safety

2.1 Introduction

The recent growth of cellular telephone use is a phenomena that crosses all age and gender boundaries. More than just the latest electronic gadget, cellular telephones have become integral parts of our business and personal lives. They are used to schedule appointments, broker deals, call for assistance, report emergencies and maintain contact with loved ones. Currently about 9 percent of the more than 50 million phones in use in the U.S. are owned by people less than 24 years old. Families are purchasing pocket size units as safety devices. Cellular telephones are rapidly becoming standard accessories for teenage dates, walks in the park and senior citizen motor trips. A number of surveys have been conducted by industry and other interested groups in attempts to characterize the role that cellular telephones play in American society.

2.2 Demographics: Who is Using Cellular Telephones?

The Motorola Cellular Impact Survey[1] was conducted by the Gallup Organization in the spring of 1993, and was sponsored by the Motorola Cellular Subscription Group. Telephone interviews were held with a nationally representative sample of 660 cellular telephone users. The survey was similar to one conducted in 1991, and comparisons were made between the responses. Within the samples about two-thirds of the respondents were male. The age distributions shifted a bit from the 1991 survey relative to the 1993 survey as shown in Table 2-l. Note that for 1996, the industry reports a continuation in the trend toward more users among the younger (under 25) and the older (55 and older) age groups.

Table 2-1: Motorola Cellular Impact Surveys Age of Respondents

Age	1991	1993
18-24	6%	6%
25-34	26%	30%
35-44	34%	30%
45-54	20%	23%
55-59	6%	3%
60 or older	4%	8%
No response	3%	0%

1 The Motorola Cellular Impact Survey, "Evaluating 10 Years of Cellular Ownership in America." The Gallup Organization, Inc. Princeton, New Jersey, 1993.

The lower costs for phone purchase and monthly service have attracted users in lower income brackets as well as retired persons as shown in Tables 2-2 and 2-3. Future surveys may well include full time student as an occupation in addition to the homemakers and retired users reflected in Table 2-3.

Table 2-2: Motorola Cellular Impact SurveysIncome Distribution of Respondents

Income	1991	1993
Less than $25,000	N/A	15%
$25,000-$44,999	30%	27%
$45,000-$59,999	20%	16%
$60,000-$74,999	14%	7%
$75,000 or over	36%	28%

Table 2-3: Motorola Cellular Impact SurveysEmployment Status of Respondents

Employment	1991	1993
Full-time	83%	78%
Part-time	6%	5%
Homemaker	11%	4%
Self-Employed	N/A	*4%*
Retired	N/A	*5%*

Table 2-4: Motorola Cellular Impact Surveys and CTIA Press Releases
Primary Phone Use Patterns

	1990	1991	1993	1994
Motorola				
Business	--	*67%*	*54%*	--
Personal	--	*33%*	*46%*	--
CTIA				
Business	*60%*	--	--	*44%*
Personal	*40%*	--	--	*56%*

2.3 Use Patterns: How are Cellular Telephones Being Used?

The Motorola and CTIA data shown in Table 2-4 were basically geared toward marketing considerations such as cellular telephone use patterns, attributes and beliefs. In terms of business versus personal use, the actual percentages vary somewhat between the two sets of data, but the trend away from strictly business to personal use is similar.

Length of time that a phone is owned appears to influence usage patterns. New owners use their units for business calls 48% of the time. Those who have owned a cellular telephone for 5 years or more use theirs for business 78% of the time. These statistics serve as a reminder that only a few years ago, cellular telephones were purchased primarily for business use, and long-time users may be likely to continue their usage patterns.

The popularity of cellular telephones among business users is reported in several ways in the Motorola survey. Nearly all respondents (97%) agreed that cellular telephone use increases their flexibility. Eight of ten respondents (80%) make business calls while commuting to or from work, and 57% of the respondents feel as if they can leave the office on time and make calls while traveling home.

Those subscribers who use the cellular telephone primarily for personal calls also report improved time management. Increased flexibility is cited by 94% of this group, while 52% have called for directions, 34% have ordered carry-out food and 6% have shopped with their cellular telephone.

The potential safety benefits of cellular telephone ownership are generally recognized and widely advertised. The Motorola survey highlights these benefits in Table 2-5. These findings point out the broad range of safety benefits identified by users and the general trend emphasizing such use as

Safety Related Uses of Cellular Telephones

Safety Benefits	1991	1993
Called for help for another's disabled vehicle	38%	40%
Called for help for own disabled vehicle	25%	39%
Called for assistance for own medical emergency	7%	13%
Called for assistance for another's medical emergency	23%	28%
Called police to warn of hazardous road conditions	24%	28%
Considered buying another cell phone for other family member as safety precaution	N/A	52%
Have purchased an additional phone for other family member as safety precaution	N/A	28%
Encourage my teenagers to use phone while out at night	N/A	26%

Table 2-5: Motorola Cellular Impact Surveys

a basis for having a cellular telephone available in a vehicle. Of note are the implications of the findings for the growth of the user population, particularly for non-business users, young drivers and women. The sense of security that the availability of a cellular telephone provides and its use in reporting emergencies are clearly major factors in the accelerated growth of the industry and in the support generated among law enforcement authorities for industry efforts at promoting the safety benefits.

2.4 Use of Cellular Telephones for Emergency Response

The principal safety relevant use of cellular telephones is to call in an emergency. Literally millions of cellular calls are being made to emergency dispatchers each year. In a 1996 member survey conducted by the American Automobile Association (AAA) Potomac region (near Washington, D.C.), 86.6% of the respondents favor the creation of a uniform nationwide emergency number similar to "911". The Federal Communications Commission (FCC) has adopted rules that would guarantee access to "911" service from cellular phones. It also seeks technology changes from cellular companies that would enable emergency dispatchers to automatically locate cellular telephone callers. Unlike calls made using land lines, wherein over 90% of the callers can be identified as to their location, cellular calls cannot be traced back easily to specific locations. This presents a challenge for emergency responders to locate callers who may be disabled or unsure of their location. In a Notice of Proposed Rulemaking published on June 12, 1996, the FCC proposed that by April 1998, all cellular carriers must be able to relay a caller's Automatic Number Identification (ANI) and the location of the base station or cell site to the designated Public Safety Answering Point (PSAP) for a 911 call. Under Phase II of this plan, all carriers would be required to have the ability to identify the location of a 911 caller to within 125 meters, 67% of the time by October 2001. These requirements are dependent upon the PSAP's ability to handle the additional calls, and the creation of a mechanism that will allow the carrier to recover its costs for such services.

**Table 2-6: California Highway Patrol Report
Cellular 911 Traffic Growth
*(California Highway Patrol)***

Year	Total Cellular 9 11 Calls
1985	29,000
1986	94,200
1987	171,333
1988	333,600
1989	575,000
1990	747,500
1991	971,655
1992	1,400,000
1993	1,644,760
1994	1,829,077
1995	2,176,400
1996*	2,800,000

* estimate

The automotive industry is also addressing the issue of caller location identification, using a different technologic approach, as part of the Automated Collision Notification (ACN) program under the Intelligent Transportation System (ITS) initiatives. Using global positioning system (GPS) technology, operational tests are now being conducted to assess the applications and utility of such technologies to improve emergency response.

The Cadillac Corporation has, in fact, already introduced their Onstar System in the 1997 model year. It links a hand-held, voice-activated phone with a GPS satellite device. Onstar allows dispatchers in customer service centers to locate Cadillac owners who are in distress, or who locked their keys in their cars. Emergency response can be dispatched from the Cadillac operated service centers.

In some states, including California, Colorado, Maryland, Virginia, Delaware, Texas and Florida, the cellular emergency calls are directed to the state police. The increase in the number of calls has been so great, that these states are attempting to build infrastructures to handle the volume of calls received.

Among these states, only California has attempted to aggregate information on the increase in emergency use calls from cellular telephones. Table 2-6 shows a growth factor of nearly 100 during the previous 11 years. These calls are directed to 24 regional communications centers and represent 30% of the total statewide telephone traffic handled by these centers.

The state police surveyed are generally appreciative of the quick notification capabilities afforded by cellular telephones. Problems arise, however, when numerous calls are made to report the same incident, or the emergency network is used frivolously, Even though only 20% of drivers currently use cellular telephones, many emergency response networks are being overwhelmed. Dispatchers report that the multiple incident notifications clog phone lines, and require personnel to continually tell concerned motorists that the problem has previously been reported.

Of greater concern are the 50%-60% of the 911 calls that do not reflect emergencies. Recent examples in California include reporting the theft of a plastic lawn chair, calling for directions or dialing 911 to test their phones. In September 1996, Maryland was the first state to introduce a “311” exchange for non-critical calls to emergency responders. This is an attempt to screen out non-emergency use of the “911” exchange.

Statistics on the number of “911” calls have not been maintained by other states surveyed. In Florida, the highway patrol has asked motorists to restrict their emergency calls to matters relating to drunk drivers, highway crashes and other threats to safety. The Florida police report that the emergency lines are too often used by motorists who want directions or help with their flat tires. Even when a serious mishap occurs, as many as 100 or more calls may be received simultaneously, which jam the lines, and prevent other emergency calls from being reported.

In Maryland, Virginia, Delaware and Colorado, the state police report that they are considering establishing tracking systems for cellular telephone emergency calls. These states have received many requests for information related to such use. At the present time, cellular telephone calls are directed to the emergency communications centers which may have as few as 3 lines.

The misuse and overburdening of emergency exchanges is a problem that could be addressed through education and technology. In the spring of 1996, the majority of counties in Maryland have adopted statutes that authorize a $.50 monthly fee to all cellular telephone subscribers. These funds will be used to support emergency communications centers.

2.5 Users Opinions: How Safe Is Cellular Telephone Use While Driving?

Prevention Magazine addressed the issue of cellular telephone use while driving in its surveys conducted in 1994 and 1995 and published as Auto Safety in America in 1995[2] and 1996[3]. Each survey includes approximately 1260 adult respondents. The magazine reports that the demographics of its sample are representative of the U.S. population. The studies were conducted via telephone interviews by Princeton Survey Research Associates, Inc.

[2] ***Prevention Magazine,*** "Auto Safety in America." Princeton Survey Research Associates, May, 1995
[3] [Ibid - May, 1996]

The results show that safety is an important concern for many respondents. In 1994, 64% reported that safety is at least as important as performance when selecting a new car. The majority of respondents (89%) believe that in recent years auto companies have increased their commitment to building safer cars. At the same time, the 1995 report also shows that most Americans do not believe that highway travel is safer today than it was in 1990. Although 73% of respondents reported wearing their seat belts, 55% exceed the speed limit and 17% admit to drinking and driving. When queried as to which activities they performed while driving which could divert their attention, the 1994 respondents provided the answers shown in Table 2-7.

**Table 2-7: Prevention Magazine, 1994 Survey
Distracting Activities Performed While Driving**

Listen to music or news	95%
Drink Beverages	71%
Eat	66%
Change tape or CD	64%
Read a map	33%
Talk on cellular phone	18%
Comb hair	16%
Put on make up	14%
Read a newspaper or magazine	6%
Shave	4%

The percentages for each category were generally higher for drivers under 30 years of age.

Eighteen percent (18%) of the respondents reported that they talk on their cellular telephones while driving and they believe this activity is distracting. In the 1995 survey, 20% of the respondents reported that they had a car phone (Note: no distinction was made between installed and hand-held telephones). When asked about the frequency of phone use, the responses followed a broad pattern with only 15% of the drivers never using their phone while driving.

Table 2-8: Prevention Magazine, 1995 Survey Frequency of Car Phone Use While Driving

Response	% of Responses
Most trips	17%
About Half	10%
Less than half	12%
Very few	46%
Never	15%

Table 2-9: Prevention Magazine, 1995 Survey Cell Phone versus Radio Distraction

Response	% of Responses
More	25%
Less	14%
Same	45%
Never talk while driving	15%
Don't know/refused	1%

This suggests that cellular telephone use while driving is commonplace among some cellular telephone subscribers. Table 2-8 also indicates, however, that 61% of drivers use their cellular telephone infrequently, or not at all, while driving.

The survey measured the opinions of cellular telephone users as to whether talking on the phone was more or less distracting than tuning the car radio. Table 2-9 indicates that 70% reported that cellular telephone use was the same or more distracting, while only 14% believed it was less so. Drivers apparently attribute high distraction potential to cellular telephone use.

The Prevention survey for 1995 also attempted to determine the crash experience for cellular telephone owners versus non-owners. As shown in Table 2-10, 5% of the car phone owners admit to having had a "near miss" while talking on the phone. Table 2-11 shows that 9% of the respondents had a "near miss", and 2% were involved in a crash when someone else was driving while talking on a car phone. These results indicate a small percentage of cellular telephone users reported having experienced a tangible crash hazard associated with cellular telephone use while driving.

Table 2-10: Prevention Magazine, 1995 Survey Nearly had a car accident while using a car phone.

Response	% of Responses
Yes	5%
No	80%
Never talk while driving	15%

Table 2-11: Prevention Magazine, 1995 Survey Crash or near miss when someone else was using cellular telephone.

Response	% of Responses
Crash	2%
Near miss	9%
No	89%

During the period of November 1996 through January 1997, NHTSA sponsored a Motor Vehicle Occupant Safety Survey. A total of 4,022 respondents participated in this telephone survey. They were at least 16 years old, and were randomly selected from all 50 states and the District of Columbia. The respondents were divided about equally by gender. As a part of the survey, a series of 5 questions relating to cellular telephone ownership and usage were posed to each respondent. The results were weighted to produce national estimates.

Among all participants, 30% reported having a car phone or carrying one in the motor vehicle they usually drive. No distinction was made as to types of phones. As shown in Table 2-12, of the 45-54 age group, 39% responded positively. The 65+ group is least represented among cellular telephone owners with only 16% of that age group currently subscribed.

Educational levels also seem to influence cellular telephone ownership, with 15% of the less than high school group owning phones followed by 26% of the high school graduates. Thirty percent of those with some college education purchase cellular telephones, while 40% of college graduates are cellular telephone owners.

The survey next examined the types of phones being used in automobiles. Among owners, about 1 in 7 have installed car phones, while the remaining 86% carry " portable phones." The distribution shown in Table 2-13 is slightly different for males and females. Seventeen percent of the males have installed phones, compared to only 11 % of the females. The 16-20 and 35 and above age groups were more likely to have installed cellular telephones, while the 21 to 35 year olds more often use portables.

Table 2-12: NHTSA Survey, 1997
Own or Use a Car Phone?
% of Responses

Respondant Age	Yes	No
16-20	26	74
21-24	28	72
25-34	32	68
35-44	36	64
45-54	39	61
55-64	23	77
65%	16	84
Total	30	70

Table 2-13: NHTSA Survey, 1997
Installed or Portable Phones?
% of Responses

Respondant	Installed	Portable
Gender		
Male	17	82
Female	11	89
Age		
16-20	17	83
21-24	7	93
25-34	8	92
35-44	16	84
45-54	18	82
55-64	21	79
65+	11	89
Total	14	86

Table 2-14 reviews the usage patters for respondents. Nine out of ten cellular telephone owners use them while driving. More of the males (16%), than females (5%) use their phones on most trips. Fifty six percent of the males, and 73% of the females, (65% of all respondents) replied that they talked on their phones on very few trips or never. See Table 2-14. These responses are very similar to those found in the 1995 Prevention Magazine Survey (Table 2-8).

The NHTSA survey also examined the use of cellular telephones for emergency calls. Over one third (36%) of all respondents reported an emergency from their phones. The types of emergency included automobile crash (68%), weaving vehicle (9%), car fire (4%) and hit and run (2%) as well as less urgent issues such as a disabled vehicle (9%).

2.6 Public Comment

An effort was made to solicit thoughts and observations from professional drivers and the general public with regard to the benefits and potential hazards of cellular telephone use by drivers. As described herein, focus groups were organized from various urban and rural police organizations, professional drivers were interviewed, and queries were placed in local publications and in relevant forums on the Internet. It must be remembered, when seeking informal and voluntary public comment, that responders tend to have strong feelings about the subject matter.

Many examples were provided of hazards created by driver inattention related to cellular telephone use. At the same time, the law enforcement community and the driving public recognized the benefits of allowing motorists to report drunk drivers, crashes and other hazards on a timely basis, and allowing drivers to seek directions or assistance from the presumed safety of their vehicles.

Although some of the information presented in this chapter is not scientifically based, it is useful in reflecting public attitudes and beliefs. It is interesting to note that many of the recorded comments offer observations not unlike those found in the research results presented later in this report. Driver inattention is a major concern for many individuals. The anecdotal case reports and the focus group comments also highlight the difficulty that law enforcement personnel face in obtaining accurate information on pre-crash circumstances that may involve cellular telephone use.

Table 2-14: NHTSA Survey, 1997
Do You Talk on the Phone While Driving?
% of Responses

	Male	Female	Total
Most Trips	16	5	11
About Half	10	9	9
Less Than Half	17	12	15
Very Few	49	59	54
Never	7	14	11

Police Focus Groups

The use of cellular telephones while driving is unregulated by state and federal governments, and there is very little recorded information on how such use affects real world traffic patterns. Police officers assigned to traffic operations are trained observers who have ample opportunity to monitor driving behaviors.

Focus groups were organized to provide an opportunity for these highway safety professionals to share their observations and experiences with regard to cellular phone use. Both urban and suburban police agencies were invited to participate. Officers of all ages and levels of experience were recruited in order to provide a broad spectrum of points of view. The following agencies were generous in providing staff and assistance in arranging logistics.

- Maryland State Police: Reisterstown, Ocean City, Salisbury, Forestville, Easton Barracks
- Baltimore County Police
- Baltimore City Police
- Virginia State Police
- Alexandria Police
- Fairfax Police
- Loudoun County Police
- Prince William Police
- U.S. Park Police

A total of eight focus groups were scheduled in locations convenient to the participants. Each session continued for approximately three hours. A question path (Figure 2-l) was informally followed by the two moderators. All sessions were recorded via video camera. Data reduction was completed at a later date by the moderators who independently reviewed the video tapes and quantified the results. All participants had personal experience with cellular telephone use while driving. A few police cadets did not yet have professional experience in enforcement or crash investigation

Figure 2-1: Cellular Telephone Focus Group Discussion Topics

1. From your observations, how common is driver cellular phone use?

2. Do you notice a change in driving behavior among cellular phone users?

3. Have you observed any hazardous situations relating to cellular phone use?

4. Has anyone worked a traffic accident in which you think a cellular phone played a role? Please describe.

5. Have you heard "horror stories" related to phone use?

6. Do any of you own a cellular phone that you use while driving (business, personal, both)?

7. Under what circumstances do you use your phone (anytime, light traffic, while stopped, haven't thought about it)?

8. What kinds of calls are involved (business, family emergencies only, anything needed at the time)?

9. Have you personally had any experiences in which cellular phone use affected your driving performance?

10. How has cellular phone use changed your driving habits?

11. Do you believe cellular phone use should be regulated for automobiles?

12. Please notify DSI if you become aware of a traffic accident in which a cellular telephone played a role.

and were not able to provide responses to certain questions. A summary of the group discussions follows:

1. From your observations, how common is driver cellular telephone use?

Participants reported that cellular telephone use while driving is very common in the Washington metropolitan area. Individuals report that phone use has increased dramatically during the past 3 years. In Northern Virginia, phone use is judged to be about 50% among drivers[1]. While this figure seems high, it highlights the magnitude of the problem as perceived by this group of law enforcement personnel. The cadets believe that it has increased dramatically even among the 22-25 year old age group. Officers from Maryland's Eastern Shore reported that service has only recently been made available in this rural area, but phone use is increasing rapidly there as well.

2. Do you notice a change in driving behavior among cellular telephone users?

Driver inattention was cited by many participants as the main reason for aberrant driving behavior. Lane drifting or weaving was mentioned by half of the groups. One quarter of the groups said drivers speed up while using the phone, and one quarter of the groups said that drivers slow down during phone use. The reduction in lane tracking ability, and failure to maintain adequate headway especially in heavy traffic were special concerns when drivers were observed to be dialing their telephones.

3. Have you observed any hazardous situationas relating to cellular telephone use?

One officer was following a woman who was talking on her phone. He watched the traffic light ahead change from green to yellow to red and the woman proceeded through the intersection four or five seconds after the light had turned red. As she was being given the citation, she stated that she did not realize that there was a traffic signal at the intersection. Dialing the telephone while traveling at high speeds on the highway was most frequently mentioned as a specific activity that could be hazardous. (Note that this reflects a presumed rather than observed safety problem.)

Dialing the telephone while traveling at high speeds on the highway was most frequently mentioned as a specific activity that could be hazardous.

Driving too fast or too slow for conditions was also raised by about 25% of the groups. One participant stated that some people tend to "talk with their hands" and do not maintain adequate contact with the steering wheel.

4. Has anyone worked an automobile crash in which you think a cellular telephone played a role? Please describe.

Three officers provided specific responses. The first described a three-vehicle collision which was caused by a driver using a cellular telephone. Another driver reported the cellular telephone use. A second officer recounted a driver who had dialed a pay-per-minute adult entertainment phone service. He lost control of his vehicle and hit a dump truck head-on. He was fatally injured and died with the cellular telephone still in his hand. The investigating officer determined the nature of the call through the cooperation of the carrier. A third officer witnessed a crash in which a cellular telephone user drifted out of his lane and struck a vehicle in the center lane, which in turn struck a vehicle in the third lane.

1 Absolute judgments of percentages are of uncertain accuracy. A review of cellular telephone subscriptions matched to driver registrations would be one means of obtaining verifiable data.

Nearly half the participants stated that it is very difficult to determine if cellular telephone use was, in fact, a contributing factor to crashes. They said that witnesses are currently the best source of such information. Several mentioned that they have investigated crashes in which they believe that cellular telephone use may have played a role, but it was very difficult to verify cellular telephone use at that time.

Nearly half the participants stated that it is very difficult to determine if cellular telephone use was, in fact, a contributing factor to crashes.

5. Have you heard any "horror stories" related to cellualar telephone use?

The majority of the officers did not mention any relevant incidents beyond their personal experience. Two participants did recount events about which they had been told. The first was the pay-per-minute adult entertainment incident described above. The second involved a driver who had stopped his vehicle on the roadway in order to talk on the phone and was subsequently struck by a dump truck. These accounts represent hearsay rather than personal observations.

6. Do any of you own a cellular telephone that you use while driving (business, personal, both)?

Over 75% of the participants regularly use a cellular telephone while driving. The Maryland State Police do not allow officers to use telephones in their police vehicles, but the other jurisdictions do allow such use at the operator's expense. One officer reported that he used his cellular telephone so frequently that he had to give it up because the expense was prohibitive. It is interesting to note that participating officers believe cellular telephone use while driving may be unsafe, but the majority, nonetheless, use their cellular telephones regularly.

7. Under what circumstances do you use your cellular telephone (anytime, light traffic, while stopped haven't thought about it)?

The participants did not restrict their cellular telephone use to specific traffic conditions. Half of the respondents stated that they used their phones whenever they needed to. About 10% reserved phone use for what they considered to be emergency situations, but the majority of the users were about equally divided between using their cellular telephones for business purposes, such as retrieving messages, and using their cellular telephones for personal business.

8. What kinds of calls are involved (business, family emergencies only, anything needed at the time)?

About 50% of the group members report that they make all kinds of calls while driving. Some officers use their cellular telephones for outgoing calls only (which is understandable since they are not reimbursed for their cellular telephone use). A few individuals mentioned that they could hold private conversations with their dispatchers over the telephone. This is not possible using police radios. About 10% of the participants limit their calls to strictly business, and another 10% to strictly personal calls.

9. Have you personally had any experiences in which cellular telephone use affected your driving performance?

Most of the officers reported that they did not have any actual experiences in which cellular telephone use had an adverse effect on their driving. About 40% of the respondents did express concerns about potential difficulties with driving while they were dialing their cellular telephones. Comments included the fact that they try to be a little more careful at these times, and that their performance improved with practice. One officer stated that the installation of a "remote microphone" was helpful.

10. How has cellular telephone use changed your driving habits?

One group agreed that using a cellular telephone while driving made them more aware of the need to be careful. The remaining groups did not think that there has been any change in their driving habits. Two groups offered the comment that the driving habits of the general public are different. These changes were cited as both negative and positive. The lack of maintenance of lane position and other problems previously described were reiterated. The officers also noted that many people now report drunk drivers while they are in a position to identify both the vehicle and the exact location.

II. Do you believe cellular telephone use should be regulated for automobiles?

All groups were unanimous in their opposition to any regulation of cellular telephone use. Two groups pointed out that citizen band radios, taxi radios and police radios are not currently regulated, so it would be inconsistent, in their view, to attempt to regulate only cellular telephones. One of these groups did recognize, however, that dialing the telephone is an activity that is unique among these communications devices.

Half of the participants explained the public's use of cellular telephones to report crashes, drunk drivers and other hazards has been an asset to police. They appreciate the fact that more citizens are getting involved, on a quick response basis, from the safety of their own vehicles. One respondent believes that the cellular telephone manufacturers will address the shortcomings of current equipment by designing voice activated systems.

Additional comments from the participants include conflicting views on whether or not familiarity with cellular telephones will enhance performance. Some individuals believe that drivers will become more adept at using cellular telephones while in traffic just as police become more adept at using their radios.

Some individuals believe that drivers will become more adept at using cellular telephones while in traffic just as police become more adept at using their radios.

Others offered the perspective that people do not get better at driving while using their telephones, they just become more relaxed while doing so. A number of the participants suggested that public service announcements would be useful in providing guidance to drivers on the safe use of cellular telephones.

Public Focus Groups

In an early study by Brand (1990), public attitudes towards advanced automotive display systems were examined using focus groups. Included in this study were discussions of vehicle communication systems, including citizen band radios and cellular telephones. Consistent with survey data, Brand found that many woman viewed the cellular telephone as a safety device, and little concern was expressed for receiving incoming calls or making calls, as long as the phone had speed-dialing capabilities. Non-owners of cellular telephones, however, were particularly nervous about calls being placed while the vehicle was in motion, a response that appears to have been based on observations of drivers using cellular telephones.

Brand further reports a general concern over safety, where holding a cellular telephone while driving was seen as limiting the "physical ability to control the vehicle in crises and near-crisis situations." It was agreed by nearly all respondents that use of hands-free cellular telephones was a solution to this problem.

Internet Queries

In order to provide an opportunity for members of the general public to describe their personal experiences with and observations of cellular telephone use, questions were posted on the Internet (see Figure 2-2). The Safetynet at CompuServe was selected along with the following newsgroups:

- rec.autos.driving
- rec.autos
- rec.autos.misc
- rec.autos.simulators
- rec.autos.sport.tech
- rec.autos.tech

Although two inquiries were posted at an interval of several weeks, only about 10 responses were received. One was from Italy and one was from the U.K. Some of the responses provided no useful information. The questions were designed to elicit narrative answers that would encompass any viewpoint or circumstance.

Among cellular telephone users, there were a number of positive experiences presented. One user notified authorities of three highway crashes (one in which he was involved). The same individual also frequently used his cellular telephone to ask for directions. Three cellular telephone users were especially pleased to be able to quick dial assistance or to have the phone available for emergencies. One individual uses call forwarding on his home line so that all calls are sent to his cellular telephone during business hours or when he is not at home.

The cellular telephones are often used for business and family purposes, but about 20% of the respondents reserve cellular telephone use for emergencies.

Four of the users firmly believe that the hands-free models were better suited for in-vehicle use. One individual stated that it is impossible to conduct a business conversation, read documents, control a vehicle and weave through traffic at the same time. A second individual learned to pull to the side of the road when using his cellular telephone because he could not hold the phone, shift gears and steer the vehicle simultaneously. About 1 in 5 reported no problems in using their cellular telephone while driving, but another respondent had 2 close calls in which he was so focused on his phone conversation that he pulled in front of on-coming traffic.

Figure 2-2:
Questions Posted on the Internet

1. If you use a cellular telephone while driving, what have been your experiences?

a. Positive — reported an emergency, etc.
b. Negative — near misses or traffic crashes.
c. Special concerns — only use cellular telephone while stopped in traffic.

2. If you do not use a cellular telephone while driving, what have been your observations?

a. Positive — were assisted during an emergency, etc.
b. Negative — witnessed near misses or an accident.
c. Special concerns — observed aberrant behavior of cellular telephone user.

Additional comments received from the user's group include the observation that some drivers seem to forget that they are in a car while engrossed in conversation.

...some drivers seem to forget that they are in a car while engrossed in conversation.

Another individual stated that he sometimes asks those with whom he is speaking to hold while he changes lanes. Finally, one driver makes a point of dialing his cellular telephone only when he feels it is safe to do so.

Only one positive comment was offered by an individual who did not use a cellular telephone. He was assisted during an emergency by someone who called for help.

Observers were more apt to express concerns about unspecified dangerous driving behaviors, and avoiding being sideswiped on many occasions. The acceleration lanes extending from highway entrance ramps were mentioned as being especially hazardous areas for cellular telephone use. Some drivers were seen holding a phone with one hand and gesticulating with the other which supports the additional contention that some cellular telephone users are so absorbed by their conversations that they are unaware of the driving hazards that they create.

Three respondents did not identify themselves in terms of cellular telephone usage, but did offer observations. One believed that hands-free units with microphones should be used exclusively in motor vehicles. Another individual suggested that cellular telephones be rendered inoperable while the vehicles are in motion. He understood that his suggestion was not likely to be adopted, but wanted it to reflect the strength of his conviction in this regard. The final view was that speed limits should be restricted for drivers using cellular telephones as much as they are in some places for heavy trucks or cars towing trailers.

Solicited Observations

As an additional effort to elicit comments from the public, a notice, *shown below*, was placed in the *Pennsaver* consumer guide in Anne Arundel County, Maryland, in November, 1995.

The U.S. Department of Transportation is sponsoring research on cellular telephone use by motor vehicle drivers. Anyone with experiences or observations to share may call (410) 974-0146 (from 9:00am to 5:00 pm, Monday through Friday).

Three responses were received. The first was from a woman who, along with her husband, is an enthusiastic cellular telephone user. They both regularly use their cellular telephones to keep in touch with family members and to help stranded motorists. The caller stated that drivers must be cautious when using their phones and recommended "speaker phones." The caller has occasionally seen people driving who did not appear to be paying attention to their driving tasks while talking on their cellular telephones.

The second female respondent was not a cellular telephone user. She observed a collision at a stop light during which a cellular telephone user struck a stopped vehicle in the rear. This caller endorses limitations on cellular telephone use while driving on urban highways, but believes that rural phone use is acceptable. She stated that business people in suits often seem focused on their conversations and are not attending to traffic. The caller's husband is a truck driver and he has noted erratic lane tracking among some cellular telephone users. A friend of the caller was in an automobile crash and used her cellular telephone to summon assistance.

The third respondent was a male. He had been nearly run off the road on two different occasions by drivers who were using cellular telephones. Both situations occurred in broad daylight on major highways. The drivers were using hand-held cellular telephones during their lane encroachment activities. This respondent feels strongly that phones should not be used by drivers while vehicles are in motion.

Anecdotal Crash Reports

Although anecdotal data are not verifiable, they can be useful in providing insight into specific problem areas and incidents. The National Transportation Safety Board, for example, often supplements its in-depth investigations with anecdotal data to provide additional insight into the causal factors associated with "accidents." NHTSA also uses anecdotal data, collected through its Hotline, for problem identification related to potential vehicle defects. It is the frequency of such anecdotal reporting, in fact, that ultimately provided motivation for this study.

During the course of this effort, extensive discussions with cellular telephone users and "observers" has taken place and helped guide the investigators in examining public sensitivities and concerns with regard to cellular telephone use and driving. Such data further served to guide the researchers in using more traditional sources of information. It should also be noted that public anecdotal experiences can frequently get the attention of authorities and ultimately influence policy, apart from rigorous scientific inquiry. While some of the anecdotal incidents identified in this study were unusual in nature, their description is provided here to further highlight the range of situations that can lead to behaviors resulting in cellular telephone related crashes.

The particular examples cited point out the importance of phone records and witnesses in establishing crash precursors as well as the difficulties that researchers and law enforcement personnel may experience while attempting to discern cellular telephone related pre-crash factors. A sample of several such cases follows.

- In Fairfax, Virginia a driver ran off the road and struck a pole fatally injuring himself. He died with a cellular telephone in his hand. The police determined through follow up investigation with the cellular carrier that he was using the phone at the time of the crash. This example highlights the importance of access to telephone records to verify cellular telephone use as a pre-crash factor.

- In Las Vegas, Nevada, an attorney reported an incident that apparently was widely discussed among local citizens. A driver (Vehicle 1) was observed talking on his hand-held cellular telephone when he struck a stopped vehicle (Vehicle 2) ahead of him, pushing it into a third vehicle waiting at the traffic signal (Vehide 3). With the phone still in hand, the driver of Vehicle 1 jumped out of his car and ran to the driver of Vehicle 3 to whom he related that he saw Vehicle 2 strike him (Vehicle 3) and that he struck Vehicle 2 so it could not get away. The police, however, were able to

determine that the driver of Vehicle 1 had been at fault in the crash on the basis of witness testimony!

- A businessman reported that he was in a right turn only access lane behind a stopped vehicle. He realized he was late for a meeting and placed a call using his installed car-phone in a hand-held mode. The vehicle ahead of him began to make a right hand turn, stopping again before completing the turn. Distracted by the phone, the businessman proceeded without stopping, and struck the rear of the lead vehicle. The culpable driver stated that this was an unnecessary call, and served to make him aware of how distracting cellular telephone use can be in a driving situation. The front of his vehicle was damaged moderately, but he did not report the crash to his insurance company.

- The final example occurred in 1988 in Prince George's County, Maryland. A bus, a Mercedes Benz and a truck were stopped in the left turn lane. An approaching BMW, with the driver talking on a cellular telephone, struck the rear end of the truck at approximately 40 MPH, setting off a chain collision. The driver of the BMW apparently was unaware of the impending collision (no brakes were applied). He still had the phone in his hand when he exited his vehicle.

It is interesting to note that while these four anecdotal cases are atypical, they share some important characteristics with the investigated crashes that will be presented in Chapter 3. In each of these instances, the cellular telephone user was the "at fault" driver of the striking vehicle. All phone types were hand-held and all drivers were talking on their cellular telephones at the time of their crash. Driver errors, again, fall into two categories: lane tracking and failure to stop. Additional discussion of human factors and pre-crash circumstances is included in Chapters 3 and 4.

2.7 Conclusions

This section has emphasized the changing role of cellular telephones in our society and the associated changes in user demographics and patterns of use. Trends toward non-business use, expansion of the range of users and the emphasis on safety and security represent important considerations that must be balanced against concerns for any adverse safety consequences.

While users generally recognize that talking on a cellular telephone can be distracting, only 15 percent report that they never use the phone while driving. Survey results suggest that the extent of such distraction is comparable to or somewhat greater than that of the radio, but it must be recognized that a radio is manipulated for only a short period, while the phone may be in use for relatively extended periods of time. Thus, exposure may be far greater for the cellular telephone.

The extraordinary growth in cellular telephone use for reporting emergencies is viewed as an asset by many law enforcement and emergency response officials Unfortunately, it has also created a significant burden on resources for some jurisdictions, many of which are receiving multiple calls for the same incident (increasing population exposure in potentially hazardous situations) or receiving calls that are not true emergencies (preventing other emergencies from being reported). Some localities have already reported in excess of one hundred "911" calls for a single incident.

With the accelerated growth in the number of cellular telephone subscribers, it is important to educate the public and develop strategies for addressing multiple notifications of an incident. State and federal government agencies are developing various approaches to meeting the demands of the public with regard to providing adequate facilities for emergency response.

> The extraordinary growth in cellular telephone use for reporting emergencies is viewed as an asset by many law enforcement and emergency response officials

The information gleaned from the focus groups shows that police officers clearly support the use of cellular telephones for emergency notification. Many participants cite dialing as a potentially distracting activity. They also note, however, that they have observed instances of driver inattention related to cellular telephone use that resulted in failures to stop, or to retain lane position. The majority of the focus group participants owned cellular telephones and are opposed to legislation that could limit their use by drivers.

Finally, although of little scientific value, the anecdotal cases do illustrate many aspects of cellular telephone use that are not readily apparent, the importance of access to phone records, the extreme nature of some individuals' use of cellular phones, and the difficulties in identifying cellular telephone use as a factor in crashes without witnesses.

Chapter 3

Crash Data Relating to Cellular Telephone Use While Driving

3.1 Introduction

The National Highway Traffic Safety Administration a variety of data sources variety of data sources to identify emerging safety problems, monitor trends and evaluate the effectiveness of various counter-measures. Primary tools include the Fatal Analysis Reporting System (FARS) and the National Automotive Sampling System (NASS) funded by NHTSA, as well as police crash reports collected by the states. The FARS and NASS data sets make use of police crash reports as a source for information on crashes.

The FARS collects police crash reports along with other official records (such as driver records and available medical data). The NASS program employs trained investigators to document and photograph vehicle damage and scene data, and to gather additional information from interviews and medical records to enhance the data file.

Researchers must keep in mind that police crash reports are law enforcement documents. Generally, police officers are tasked with three primary duties at a crash site: tend to the injured, restore traffic flow, and issue citations for violations of the law. The identification and evaluation of specific pre-crash circumstances may be very difficult for factors such as cellular telephone use which are not in violation of the law.

With the exception of Minnesota and Oklahoma, no state includes a specific data element relating to cellular telephones on their police accident reports.

With the exception of Minnesota and Oklahoma, no state includes a specific data element relating to cellular telephones on their police crash reports. Cellular telephone usage, then, can only be identified when such information is obvious, made known to a police officer (or researcher in the case of NASS), and the information is recorded in the narrative section of the police crash report form.

Recently, many states have indicated that when a cellular telephone is reported to be in use, and when criminal charges are pending following a crash, they will now attempt to secure the telephone records. This was generally not the case prior to 1996.

FARS and NASS files began recording cellular telephone use as a possible driver-related factor in 1994.

The lack of a systematic data collection protocol generally leads to under reporting of specific factors of interest. As is shown later in this section, the simple and loosely defined data elements found on the Oklahoma form lead to skewed results in the FARS national database. This demonstrates the critical need for a focused data collection program that can address the relative risk of cellular telephone use while driving. Data searches were conducted using the currently available FARS and NASS files which began recording cellular telephone use as a possible driver-related factor in 1994. In addition, coded information from Oklahoma and Minnesota and derived narrative information from North Carolina police crash reports were reviewed (see Chapter 4).

3.2 Fatal Analysis Reporting System

The Fatal Analysis Reporting System is a census of all motor vehicle related fatalities that occur within 30 days following a crash and which are recorded by police crash reports in the 50 United States and the District of Columbia. Approximately 40,000 deaths are recorded in this data file each year. In 1994 and 1995, a total of 36 and 40 cases, respectively, were identified that included cellular telephone use as a "possible distraction inside the vehicle".

Table 3-1, suggests that over half of these fatalities occurred in Oklahoma each year. Again, it is important to note that only Minnesota and Oklahoma include data elements relating to cellular telephone use on their police crash reports (see Figures 3-l and 3-2). Minnesota showed no cellular telephone or CB radio related fatal crashes for 1994 or 1995. It can be assumed that the absence of data from highly populated and urbanized states such as New York can also be attributed to the limitations within the data sources.

Table 3-l : 1994-l 995 FARS Possible Cellular Telephone Related Fatalities

	1994		1995	
State	Frequency	%	Frequency	%
Arizona	1	2.8	--	--
California	3	8.3	4	10
Illinois	1	2.8	3	7.5
Indiana	1	2.8	--	--
Louisiana	--	--	2	5
Maryland	1	2.8	--	--
Missouri	--	--	2	5
New Jersey	--	--	1	2.5
North Dakota	1	2.8	--	--
Oklahoma	1	58.3	26	65
Oregon	1	2.8	--	--
Pennsylvania	1	2.8	1	2.5
Texas	4	11.1	1	2.5
Washington	1	2.8	--	--

The anomaly in the data set is directly attributable to the "cellular telephone installation" and "cellular telephone use" data elements which are found on Oklahoma's crash reports and which are discussed later in this report. For purposes of FARS reporting, the "telephone installed" variable was used by the FARS encoder as the indicator for a cellular telephone related crash. An examination of the actual police crash reports for Oklahoma by project staff, however, yields different results.

For 1994, only 2 crashes of the 21 shown in FARS could be verified as cellular telephone related. Among the remainder of crashes, 3 of the drivers were not considered to be at fault; in 8 crashes, use of the cellular telephone was unknown, and for an additional 8, the report indicated the phone was not in use at the time of the crash.

The 1995 Oklahoma crashes reported in FARS followed a similar pattern. Only 1 of the 26 reported crashes could definitely be attributed to cellular telephone use. For 10 others, the driver of the cellular telephone equipped vehicle was not considered to be at fault. In 13 cases, cellular telephone usage is unknown; 1 case showed no indication of phone installation or use, and in the final instance, the driver was reported to be asleep prior to the crash.

The total number of fatal crashes in Oklahoma where cellular telephones are known to have played a role as described in the report narratives includes 2 for 1994 and 1 for 1995. Only these cases are included in the discussion that follows. With regard to the Oklahoma data, there are a number of issues that should be raised. The first is that even with a simple check-off box, it is difficult to identify crashes from existing police crash reports. There has not been a focused effort to locate and describe such crashes in the U.S. to date.

There has not been a focused effort to locate and describe such [cellular telephone related] crashes in the U.S. to date.

Although the information in FARS can be misleading with regard to the proportion of cellular telephone related crashes in Oklahoma, it is believed that the cases from other states are accurately coded since the FARS analysts relied on narrative information from the police crash reports as their source for pre-crash factor identification. The cases in which cellular telephones were present, but their use is unknown, may well have included cellular telephone use as an antecedent, but the drivers were fatally injured and such usage could not be verified. For those crashes in which the driver was not considered to be "at fault" because he or she was not operating the striking vehicle, it can be argued that the lack of evasive action on the part of such drivers could, at times, be related to driver inattention associated with cellular telephone use.

When examining the 1994 FARS data, it is interesting to note that cellular telephone users were the drivers of the striking vehicles in 16 of the 17 cases. In only 1 case was the cellular telephone user the operator of the struck vehicle. As shown in Table 3-2, about half of the drivers (7) struck other motor vehicles. Three struck pedestrians and pedalcyclists, 2 of whom were in the roadway, and 1 of whom was outside the roadway. Nearly one third of these vehicles ran off the road in single vehicle collisions.

Table 3-2:
Most harmful event for cellular telephone related FARS cases*

Event Object Struck	1994 Frequency	1995 Frequency
Other vehicle	7	5
Rail train	0	0
Pedestrian/Pedalcyclist	3	3
Animal	1	0
Ditch/culvert	1	0
Guardrail	1	0
Overturn	0	1
Fence	0	0
Tree	1	0
Post/Pole	1	2
Fixed Object	1	1
Embankment	0	0
Parked Vehicle	0	1
Other	0	0
Struck by other vehicle	1	2

adjusted for Oklahoma - see text

In the 1995 data, a similar pattern is evident. Thirteen of the 15 cellular telephone related drivers were in the striking vehicle. Two of the cellular telephone related cars were struck by other vehicles. One third (5 of the 15) drivers struck other vehicles on the roadway, 3 more struck pedestrians and pedalcyclists, and the final 5 hit objects on the roadside.

In FARS, up to 3 driver-related factors can be recorded for each driver in a fatal crash. Tables 3-3 and 3-4 provide comparisons of the driver related factors for cellular telephone related crashes versus all crashes reported to FARS for 1994 and 1995.

In FARS for 1994, there are 86 possible driver-related factors that are reported by police as possibly playing a role in the crash. Because of the small sample size, one must be cautious when comparing the factors cited for the 17 cellular telephone/fax related crashes to the factors for the 54,5 14 drivers in FARS, a comparison is provided for informational purposes only. When comparing cellular telephone related driver factors to those for all fatal crashes in 1994 (Table 3-3), it can be seen that several categories are coded more frequently. These include: inattentive, driving too fast, and failure to yield. The remaining categories are roughly equivalent, or the number of observations is very small.

A similar comparison is made for 1995 FARS in Table 3-4. There are 90 possible driver related factors included in the data system to describe the pre-crash activities of 56,155 drivers involved in fatal crashes. The cellular telephone related crashes differ from the general population by showing greater instances of inattention, erratic/ reckless driving, running off the road, followed by homicide, driving on the wrong side of the road, emotional, improper passing distance, and prohibited passing. The reader is reminded that the sample sizes are very small and the comparisons must be carried out with caution.

**Table 3-3:
Driver Related Factors for Cellular Telephone-Related Crashes*
Versus All 1994 FARS Reported Crashes**

Driver-related Factor	Cellular Telephone Related Freauencv	Driver-Related Percent (%)	Driver-Related 1994 Overall FARS Percent (%)
Too Fast	5	17.9	13.8
Inattentive	7	25.0	4.2
Failure to Yield	3	10.7	6.3
Run Off Road	5	17.9	19.1
Failure to Obey	2	7.1	3.7
Erratic Driving	1	3.6	3.9
Moving Vehicle	1	3.6	0.1
Improper Turn	1	3.6	1.7
Homicide	1	3.6	2.5
Cellular Phone Use Only	1	3.6	0.0
Fax Machine Usage	1	3.6	0.0

** Only those crashes attributable to* cellular phone use are *included for Oklahoma*

Table 3-4:
Driver Related Factors for Cellular Telephone-Related*
Crashes Versus All 1995 FARS Reported Crashes.

Driver-related Factor	Cellular Telephone Related Frea uencv	Driver-related Percent (%)	1995 Overall FARS Percent
Too Fast	3	12.0	14.3
Inattentive	5	20.0	4.1
Run Off Road	6	24.0	19.5
Erratic/Reckless Driving	2	8.0	3.5
Improper Turn	1	4.0	1.5
Homicide	2	8.0	2.5
Cell Phone Use Only	2	8.0	0.0
Wrong Side	1	4.0	1.6
Emotional	1	4.0	0.1
Passing Distance	1	4.0	0.6
Prohibited Passing	1	4.0	0.3

adjusted for Oklahoma

3.3 National Automotive Sampling System

The National Automotive Sampling System (NASS) uses trained researchers to conduct investigations on a statistically stratified random sample of all motor vehicle crashes that occur in 24 locations across the U.S. About 5,000 crashes are investigated each year from among those reported by police in these selected primary sampling units.

The NASS data forms contain the same listing of potential driver-related factors as does FARS. The NASS researchers generally conduct interviews with crash involved drivers and vehicle occupants. This provides a greater opportunity to discern cellular telephone use as a pre-crash factor. Unless the police crash report cites cellular telephone use, the NASS researcher may not identify such use during the interview. More importantly, drivers who may be found culpable are less likely to consent to being interviewed or to admit to behaviors such as cellular telephone use as a pre-crash factor.

The 1995 NASS Crashworthiness Data System (CDS) file identified 8 relevant cellular telephone cases out of 4,555; 1 in which the driver was dialing the cellular telephone, and 7 in which the driver was talking on the cellular telephone (see Table 3.5). Although these numbers are seemingly small, when weighting factors are applied, it is estimated that these cases represent 3,837 similar crashes that occurred nationally during 1995. The final case reports were reviewed at the hard copy library. A brief summary of the crash circumstances can be found in Table 3-5.

Table 3-5: NASS Case Descriptions for Cellular Telephone-Related Crashes

Case 1 - The driver of the vehicle entered an intersection on a flashing red light and struck a second vehicle in the side. Both the driver and the right front passenger were engaged in conversation using a mobile telephone, permanently mounted, with a remote speaker and microphone.

Case 2 - The driver was dialing a hand-held flip phone while traveling on a divided roadway. The vehicle departed the roadway to the right and struck a utility pole and rolled on to its left side.

Case 3 - The driver was talking on a portable, hand-held cellular telephone while traveling on a rain covered roadway. The vehicle drifted onto the center median and struck a utility pole.

Case 4 - While talking on a mounted cellular telephone, the driver struck the rear of the vehicle stopped ahead of him at a traffic signal.

Case 5 - The driver was reported to be hanging up hiscenter mounted cellular telephone when he struck the rear of the vehicle stopped ahead of him at an intersection.

Case 6 - The driver was talking on his hand-held portable phone when he struck a second vehicle in a head-on configuration. Vehicle 2 reportedly was attempting a left turn on an icy road.

Case 7 - The vehicle was travelingon a two lane, divided roadway. The driver was talking on his flip phone and had a cold drink between his legs when he struck a stopped transit bus.

Case 8 - The vehicle was traveling on a road with a gentle curve to the left. The driver was engaged in conversation using a hand held portable cellular telephone. He departed the road to the right and struck a fence.

The common factor in these cases seems to be a lack of attention. All drivers wereapparently traveling in a straight line, or on a gentle curve, and were not executing difficult turning maneuvers that would have required the use of both hands. For the 5 instances in which another vehicle was struck, braking action was needed in order to avoid an obious hazard. In cases 2, 3 and 8, the drivers were not aware that they had traveled off the roadway. This observation corresponds with the statements found in the "Public Comments" section of this report (see Chapter 2). Drivers may become so absored in their conversations that they are not aware of their behavior or of the driving environment.

The common factor in these cases seems to be a lack of attention.

The NASS data cities driver inattention as a driver-related pre-crash factor in about 26% of all sampled crashes for 1995. Momentary distractions such as pushing a button on a radio would appear to have a different effect on driving behavior and ability when compared to engaging in telephone conversations that last for several minutes (and therefore several miles) of travel.

The CTIA reports that an average cellular conversation lasts 2.15 minutes. With additional time for dialing and hanging up the phone, one can assume that a driver may be occupied for perhaps 2.5 minutes on average. At 35 miles per hour (mph), the vehicle is traveling at 51.3 feet per second. At 65 mph, 95.3 feet of roadway are covered each second. At average highway speeds, from 250 to nearly 500 feet of travel are covered during the 5 seconds it takes to place a call traveling at one mile a minute. At 65 mph, about 2.7 miles of roadway are traversed during an average call (includes dialing and hanging up the phone). Even brief periods of driver distraction translate into substantial distances that might be needed for defensive driving.

3.4 Oklahoma Crash Data

The State of Oklahoma is unique in routinely collecting specific information in their police crash reports on both cellular telephone installation and cellular telephone use in crash involved vehicles. With a population of over 3 million people, 3,350,000 registered motor vehicles and nearly 75,000 reported traffic collisions annually, the state data represents a potentially useful collection of relevant information.

The Official Oklahoma Traffic Collision Report (Figure 3-1, shown on the next two pages) includes data elements that record "telephone installed" and "telephone in use" for up to 2 vehicles in a given crash. The data is collected by the investigating officer, generally at the scene of the crash. The information is based upon both observation and interviews.

According to staff members from the Oklahoma state police training academy, officers are trained to look in crash involved vehicles to see if a cellular telephone is present. Installed car phones, and large portable units are likely to be visible, but the hand-held models that make up ¾ of current sales are less likely to be detected by casual observation. If a phone is observed, then the "telephone installed" box is checked. When a phone is observed, the driver is asked if (s)he was using the phone at the time of the crash.

If a positive response is received, then the "in use" variable is checked. It is important to note that the type of use is not defined. The driver may have been dialing, answering, or talking on the cellular telephone before or during the crash. It is also possible that the cellular telephone was used only to summon assistance post-crash. The data element was intended to identify phone use at the time of the crash, but the investigating officers do not necessarily make that distinction.

The lack of strict interpretation of data collection definition presents several problems. There is a potential for under reporting. If a cellular telephone was in use, but was not visible to the investigating officer post-crash, it will not be recorded on the police crash report as "installed". It is not likely that officers would inquire about cellular telephone use in the absence of a visible phone, so the "in-use" data element may also reflect under reporting.

In addition, culpable drivers may be less inclined to admit that they were using their cellular telephones at the time of the crash. Investigating police officers are in general agreement that witnesses

Figure 3-1 Official Oklahoma Traffic Collision Report

[CITATION NUMBER]

INCIDENT REPORT ☐ REVISED REPORT ☐ FATALITY YES ☐

INVESTIGATION COMPLETED? YES NO Sheet of Sheets

OFFICIAL OKLAHOMA TRAFFIC COLLISION REPORT

DO NOT WRITE IN THIS SPACE | ACCIDENT NUMBER | ADMINISTRATIVE

MONTH | DAY | YEAR | 24 HOUR TIME | DAY OF WEEK S M T W T F S | COUNTY | COUNTY NUMBER

STREET ROAD OR HIGHWAY | DISTANCE FROM FT MI | N S E W of | (NEAREST) INTERSECTION STREET ROAD OR HIGHWAY

IN CITY | NEAR CITY | NAME OF NEAREST CITY OR TOWN | CITY NUMBER | DISTANCE FROM NEAREST CITY OR TOWN LIMITS N S E W

HIGHWAY CLASS | STATE HIGHWAY CODES | CONTROL NUMBER | INTERSECTION ID | LOCATION | COUNTY SECTION LINE GRIDS | EAST | NORTH | RAILROAD CROSSING NUMBER

MOTOR VEHICLES INVOLVED | NUMBER KILLED | NUMBER INJURED | ADMINISTRATIVE | COMMERCIAL MOTOR VEHICLE | HAZ MAT PLACARD

UNIT | OCCUPANTS | DRIVER | PEDESTRIAN | ANIMAL | TRAIN | OTHER | ★ | ★

NAME LAST FIRST MIDDLE | STREET/RFD | CITY | STATE | ZIP

DOB MO/DAY/YR | SEX | DRIVER LICENSE NUMBER | STATE | CLASS | ENDORSEMENT(S) | RESTRICTIONS | PHONE

AT

INJURY SEVERITY | TYPE OF INJURY | INJURED TAKEN BY | SAFETY EQUIPMENT IN USE | AIR BAG DEPLOYED Y N

EJECTED? Y N | PINNED? Y N | CHEMICAL TESTS | RESULTS O %BRAC | DRIVER/ PEDESTRIAN CONDITION | TOWED VEHICLE (DESCRIBE)

VEH YEAR COLOR MAKE MODEL STYLE | SIZE | VIN | LICENSE PLATE NO | MO/YR | STATE | NUMBER

REPORTING AGENCY:

OWNER'S NAME SAME AS DRIVER ☐ | LAST FIRST MIDDLE | STREET/RFD | CITY | STATE | ZIP

SECURITY VERIFICATION | INSURANCE COMPANY NAME | POLICY NUMBER

FROM MO DAY YR | TO MO DAY YR | AGENT NAME | ADDRESS | CITY | STATE | ZIP

VEH REMOVED BY DRIVER ☐ | LEGAL SPEED MPH | BEFORE CONTACT MPH | CONTACT MPH | ESTIMATED DAMAGES $ | BURNED? Y N

STATUTE/ ORDINANCE NUMBER | CITATION NUMBER | STATUTE/ ORDINANCE NUMBER | CITATION NUMBER | STATUTE/ ORDINANCE NUMBER | COMMERCIAL MOTOR VEHICLE | HAZ MAT PLACARD

UNIT | OCCUPANTS | DRIVER | PEDESTRIAN | ANIMAL | TRAIN | OTHER | ★ | ★

NAME LAST FIRST MIDDLE | STREET/RFD | CITY | STATE | ZIP

DOB MO/DAY/YR | SEX | DRIVER LICENSE NUMBER | STATE | CLASS | ENDORSEMENT(S) | RESTRICTIONS | PHONE

INJURY SEVERITY | TYPE OF INJURY | INJURED TAKEN BY | SAFETY EQUIPMENT IN USE | AIR BAG DEPLOYED Y N

EJECTED? Y N | PINNED? Y N | CHEMICAL TESTS | RESULTS O %BRAC | DRIVER/ PEDESTRIAN CONDITION | TOWED VEHICLE (DESCRIBE)

VEH YEAR COLOR MAKE MODEL STYLE | SIZE | VIN | LICENSE PLATE NO | MO/YR | STATE | NUMBER

OWNER'S NAME SAME AS DRIVER ☐ | LAST FIRST MIDDLE | STREET/RFD | CITY | STATE | ZIP

SECURITY VERIFICATION | INSURANCE COMPANY NAME | POLICY NUMBER

FROM MO DAY YR | TO MO DAY YR | AGENT NAME | ADDRESS | CITY | STATE | ZIP

VEH REMOVED BY DRIVER ☐ | LEGAL SPEED MPH | BEFORE CONTACT MPH | CONTACT MPH | ESTIMATED DAMAGES $ | BURNED? Y N

STATUTE/ ORDINANCE NUMBER | CITATION NUMBER | STATUTE/ ORDINANCE NUMBER | CITATION NUMBER | STATUTE/ ORDINANCE NUMBER | CITATION NUMBER

INJURED | WITNESS | PASSENGER | NAME LAST FIRST MIDDLE INITIAL | SEX | ADDRESS | DOB MO/DAY/YR

UNIT | INJURY SEVERITY | TYPE OF INJURY | SAFETY EQUIPMENT IN USE | AIR BAG DEPLOYED Y N | EJECTED? Y N | PINNED? Y N | INJURED TAKEN BY | POS IN VEH

INJURED | WITNESS | PASSENGER | NAME LAST FIRST MIDDLE INITIAL | SEX | ADDRESS | DOB MO/DAY/YR

UNIT | INJURY SEVERITY | TYPE OF INJURY | SAFETY EQUIPMENT IN USE | AIR BAG DEPLOYED Y N | EJECTED? Y N | PINNED? Y N | INJURED TAKEN BY | POS IN VEH

DAMAGE TO PROPERTY OTHER THAN VEHICLES $ | OWNER | ADDRESS

SIGN HERE (OFFICER'S RANK AND NAME) (BADGE NUMBER) | TROOP OR DIVISION | REVIEWED BY (INITIALS & BADGE) | DATE OF REPORT

DRIVER/PEDESTRIAN CONDITION	INJURY SEVERITY	TYPE OF INJURY	SAFETY EQUIPMENT IN USE	SECURITY VERIFICATION	CHEMICAL TEST	VEHICLE SIZE	SUPPLEMENTAL REPORT REQUIRED	POSITION IN VEHICLE
1 APPARENTLY NORMAL 2 DRINKING - ABILITY IMPAIRED 3 ODOR OF ALCOHOLIC BEVERAGE 4 DRUG USE INDICATED 5 VERY TIRED 6 SLEEPY 7 SICK 8 CONDITION NOT KNOWN 10 BODY DEFECTS 11 OTHER	1 NO INJURY 2 POSSIBLE INJURY 3 NON-INCAPACITATING 4 INCAPACITATING 5 FATAL INJURY	1 HEAD 2 TRUNK -EXTERNAL 3 TRUNK -INTERNAL 4 ARM 5 LEG	1 NOT IN USE 2 SEAT BELT 3 SHOULDER BELT 4 COMBINATION OF 2 & 3 5 CHILD RESTRAINT 6 AIR BAG 7 SAFETY HELMET 0 UNKNOWN	1 NO 2 OWNER 3 OPERATOR 4 BREATH/BLOOD 5 OTHER	1 REFUSED 2 BREATH 3 BLOOD 4 BREATH/BLOOD 5 OTHER	S SMALL M MEDIUM L LARGE		1 2 3 4 5 6

COLLISION DIAGRAM

INDICATE NORTH BY ARROW ONE INCH = FEET

UNIT ___ N S E W

DIRECTION OF TRAVEL

UNIT ___ N S E W

VISIBILITY OBSCURED BY

TELEPHONE INSTALLED?

IN USE?

TELEPHONE INSTALLED?	UNIT 1	UNIT 2	IN USE?	UNIT 1	UNIT 2	INVESTGATION MADE AT SCENE?	Y	N	HIT & RUN?	Y	N	PHOTOGRAPHS TAKEN?	Y	N	OVERSIZE VEHICLE	P	E

WHAT VEHICLES WERE GOING TO DO

1 GO AHEAD
2 TURN LEFT
3 TURN RIGHT
4 MAKE "U" TURN
5 STOP
6 SLOW FOR CAUSE
7 START FROM PARK
8 CHANGE LANES
9 OVERTAKE
10 PASS
11 BACK
12 REMAIN STOPPED
13 REMAIN PARKED
14 OTHER ___ *EXPLAIN*

UNIT ___ UNIT ___

WHAT VEHICLE(S) DID

1 WENT AHEAD
2 TURNED LEFT
3 TURNED RIGHT
4 SWERVED LEFT
5 SWERVED RIGHT
6 ENTERED "U" TURN
7 STOPPED
8 STARTED FROM PARK
9 ENTERED OTHER LANE
10 OVERTAKING
11 PASSING
12 BACKED
13 REMAINED STOPPED
14 REMAINED PARKED
15 RAN OFF ROAD - RIGHT
16 RAN OFF ROAD - LEFT
17 OTHER ___ *EXPLAIN*

UNIT ___ UNIT ___

TRAFFIC CONTROL

1 STOP SIGN
2 TRAFFIC SIGNAL
3 FLASHING SIGNAL
4 YIELD SIGN
5 WARNING SIGN (TYPE IN REMAKRS)
6 RAILROAD ADVANCE WARNING SIGN
7 RAILROAD CROSSBUCKS
8 RAILROAD GATES
9 RAILROAD SIGNAL
10 NO PASSING ZONE
11 OFFICER
12 NO CONTROL
13ABNORMAL CONTROL
14 OTHER ___ *EXPLAIN*

UNIT ___ UNIT ___

TYPE OF ROAD

1 ONE-WAY ROAD
2 ALLEY
3 TWO LANES
4 THREE LANES
5 FOUR OR MORE (DIVIDED)
6 FOUR OR MORE (UNDIVIDED)
7 DRIVEWAY
8 TURN BAY
9 ON RAMP
10 OFF RAMP
11 CONSTRUCTION ZONE
12 OTHER ___ *EXPLAIN*

UNIT ___ UNIT ___

ROAD CHARACTER

1 STRAIGHT - LEVEL
2 STRAIGHT - UPGRADE
3 STRAIGHT - DOWNGRADE
4 STRAIGHT - HILLCREST
5 CURVE - LEVEL
6 CURVE - UPGRADE
7 CURVE - DOWNGRADE
8 CURVE - HILLCREST
9 OTHER ___ *EXPLAIN*

UNIT ___ UNIT ___

OBJECT STRUCK BY VEHICLE OR LOAD ON FIRST CONTACT

1 FENCE POLE
2 UTILITY POLE
3 GUARD RAIL
4 GUARD RAIL END
5 GUARD POST
6 CULVERT
7 TRAFFIC SIGNAL
8 BARRIER
9 CURB
10 ISLAND
11 TRAFFIC CONTROL SIGN
12 SAND BARRELS
13 ATTENUATORS
14 PAVEMENT DROP OFF
15 DITCH
16 EMBANKMENT
17 TREE
18 DIVIDING STRIP
19 RETAINING WALL
20 FENCE
21 BRIDGE ABUTMENT
22 BRIDGE PIER
23 BRIDGE RAIL
24 BRIDGE POST
25 BRIDGE CURBS
26 BRIDGE SUPERSTRUCTURE (BEAMS)
27 OTHER HIGHWAY STRUCTURE (EXPLAIN IN REMARKS)
28 OTHER ___ *EXPLAIN*

UNIT ___ UNIT ___

WEATHER

1 CLEAR
2 FOG
3 CLOUDS PRESENT
4 RAINING
5 SNOWING
6 OTHER ___ *EXPLAIN*

LIGHT

1 DAYLIGHT
2 DARKNESS
3 LIGHTED
4 DAWN
5 DUSK
6 OTHER ___ EXPLAIN

LOCALITY

1 RESIDENTIAL
2 BUSINESS
3 INDUSTRIAL
4 SCHOOL
5 NOT BUILT UP
6 OTHER ___ EXPLAIN

ROAD SURFACE

1 CONCRETE
2 ASPHALT
3 GRAVEL
4 DIRT
5 OTHER ___ EXPLAIN

UNIT ___ UNIT ___

ROAD CONDITION

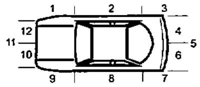
1 DRY
2 WET
3 ICE
4 SNOW
5 MUDDY
6 OTHER ___ *EXPLAIN*

UNIT ___ UNIT ___

POINT OF FIRST CONTACT ON VEHICLE

TOP ___ BOTTOM ___

UNIT ___ UNIT ___



VEHICLE CONDITION

1 APPARENTLY NORMAL
2 BRAKES
3 HEADLIGHTS
4 STEERING
5 TAIL LIGHTS
6 BRAKE LIGHTS
7 TIRES/WHEELS
8 SUSPENSION
9 OTHER ___ EXPLAIN

UNIT ___ UNIT ___
UNIT ___ UNIT ___

PEDESTRIAN ACTION

1 CROSSING AT INTERSECTION
2 CROSSING/NOT AT INTERSECTION
3 CROSSING/AT OTHER CROSSWALK
4 GETTING ON VEHICLE
5 GETTING OFF VEHICLE
6 WALKING WITH TRAFFIC
7 WALKING AGAINST TRAFFIC
8 PUSH ON VEHICLE
9 WORK ON VEHICLE
10 PLAYING
11 OTHER WORK
12 OTHER ___ *EXPLAIN*

UNIT ___ UNIT ___

UNSAFE UNLAWFUL OR OTHER ACTION *(THIS SECTION PRIMARILY FOR GENERAL STATISTICAL AND ADMINISTRATIVE PURPOSES)*

BLOCKS 1 THRU 10 MUST BE DESCRIBED WHEN CHECKED

UNIT 1	UNIT 2		UNIT 1	UNIT 2		BLK	REMARKS UNIT1	BLK	REMARKS UNIT1
		1 FAILED TO YIELD/STOP			6 UNSAFE VEHICLE				
		2 FOLLOWED TOO CLOSELY			7 LEFT OF CENTER/PASSING				
		3 UNSAFE SPEED			8 NOT KNOWN/IMPROPER ACTION				
		4 MADE IMPROPER TURN			9 PEDESTRIAN/BICYCLE ACTION				
		5 CHANGE LANES UNSAFELY			10 OTHER *(DESCRIBE)*				

are the best source of information relating to driver use of cellular telephones. Witness testimony is often not available, however, and can be unreliable.

Oklaboma began recording cellular telephone use on their police crash reports in July 1992. The 1992 figures shown in Table 3-6 reflect only 6 months of data. It is interesting to note that there were nearly as many observations of telephone in-use recorded in the second half of 1992 as there were for the entire year of 1993. This may be attributable to the focus on new data elements that often occurs when they are introduced to data collectors. It is unlikely that the number of cellular telephones in cars has dropped since 1992 given the national growth. For purposes of this review, we will compare information only for those periods in which data was collected for a full year.

An analysis of the Oklahoma data shows a 26% increase in the number of cellular telephones available in crash-involved cars from 1993 to 1994. Likewise, the number of phones reported as "in use" increased by 15% during this same period. For the second half of 1992, 9.3% of identified cellular telephones were in use at the time of the crash. In 1993, about 10.4% of those cellular telephones known to be available in crash involved motor vehicles were reported to be in use at the time of the crash. In 1994, this percentage decreased to 9.5%. Thus, approximately 1 in 10 of the telephones known to be in vehicles at the time of the crash were reported to have been "in use." The reader should remember, however, the uncertainties that are introduced by the data collection methods.

Table 3-6 Oklahoma Vehicles Involved in Collisions

	1992*	1993	1994	93-94 Increase
Phone in Car	968	1136	1437	26.5%
Phone in Use	90	118	136	15.3%
% in Use	9.3%	10.4%	9.5%	

"6 months

Cellular telephone use is more common in urban areas with Tulsa and Oklahoma counties accounting for 60% of cellular telephone in use crashes in 1993 and 51% in 1994 (as cited on the police crash report). Of the 77 counties in Oklahoma, phone use crashes were reported in 32 counties in both 1993 and 1994. (seeTable 3-8).

In their *Annual Oklahoma Traffic Accident Facts* report, the state provides an analysis of the causes of collisions similar to the driver pre-crash factors used in FARS and NASS. As can be seen in Table 3-7, contributing causes for all 217,651 police re-

Table 3-7 Contributing Causes of Oklahoma Collisions, 1992-1994

	All (%)	Cell. Usage (%)
Failed to Yield	19	15
Following Too Closely	11	13
Unsafe Speed	12	6
Improper Turn	11	10
Changed Lanes Unsafely	5	6
Stopped in Traffic Lane	--	1
Failed to Stop	7	6
Unsafe Vehicle	2	1
Left of Center	2	2
Improper Overtaking	--	1
Improper Parking	2	--
Inattention	9	17
DUI	4	7
Other	16	15

Table 3-8:
Oklahoma Vehicles Involved in Collisions 1993 and 1994

County	1993	1994	1993	1994	County	1993	1994	1993	1994
Adair	1	2	-	-	LeFlore	9	11	3	-
Alfalpa	5	5	1	-	Lincoln	7	15	1	-
Atoka	2	2	-	-	Logan	3	16	1	1
Beaver	6	17	-	-	Love	6	8	-	-
Beckham	13	15	2	-	McClain	7	11	1	3
Blaine	6	8	1	-	McCurtain	2	8	-	-
Bryan	4	10	-	-	Mcintosh	6	16	-	-
Caddo	3	9	3	-	Major	3	9	-	-
Canadian	20	26	2	3	Marshall	3	3	1	-
Carter	13	15	1	3	Mayes	10	10	-	-
Cherokee	4	5	-	-	Murray	4	5	1	-
Choctaw	5	1	-	-	Muskogee	23	26	2	-
Cimarron	7	3	-	-	Noble	3	13	3	-
Cleveland	55	63	3	3	Nowata	1	-	-	-
coal					Okfuskee	1	1	-	-
Comanche	24	21	6	-	Oklahoma	320	371	38	33
Cotton	1	3	-	-	Okmulgee	4	2	1	-
Craig	6	5	1	-	Osage	12	16	1	-
Creek	19	25	-	-	Ottawa	5	4	1	-
Custer	23	14	-	-	Pawnee	4	9	1	-
Delaware	4	6	-	-	Payne	17	34	3	18
Dewey	5	9	1	-	Pittsburgh	11	21	1	-
Ellis	2	6	-	-	Pontotoc	2	12	1	-
Garfield	29	26	2	1	Pottawatomie	12	18	-	-
Garvin	7	12	1	-	Pushmataha	1	3	-	-
Grady	22	22	2	3	Roger Mills	5	3	1	-
Grant	5	7	-	-	Rogers	28	40	1	3
Greer	1	3	-	-	Seminole	1	3	1	-
Harmon	1	-	-	-	Sequoyah	2	4	1	1
Harper	3	5	-	1	Stephens	6	13	1	-
Haskell	4	-	1	1	Texas	10	9	-	-
Hughes	3	5	1	-	Tillman	3	3	1	1
Jackson	9	10	2	-	Tulsa	222	247	33	37
Jefferson	1	3	1	-	Wagoner	7	9	3	-
Johnston	3	3	-	-	Washington	8	11	1	-
Kay	22	26	1	-	Washita	6	6	1	1
Kingfisher	16	27	1	1	Woods	9	3	1	-
Kiowa	6	-	-	-	Woodward	5	13	2	=
Latimer	-	-	-	-					
					Totals	1136	1437	118	136

ported crashes were compared with those for the 299 cellular telephone in use crashes for the period 1992-1994. The columns show the percentages for each group. "Driver inattention" is the most frequently identified factor among cellular telephone users. It represents 17% of the factors for cellular telephone users as compared to only 9% for all crash involved drivers. The next most frequently noted conditions are "failure to yield" and "following too closely".

Of particular interest is the fact that the FARS data for 1994, as previously described, shows the four most common identified cellular telephone related factors as "inattention", "driving too fast", "run off road" and "failure to yield". The similarity, given the long list of possible factors, is striking.

Attempts to regulate cellular telephone use by drivers have been introduced in a number of states during the past decade (see Chapter 1). These proposed bills have generally not included provisions for the systematic data collection needed to understand and quantify related performance factors (a bill was introduced in New York State in 1994 to address such data collection - see Appendix A). The data from Oklahoma is unique insofar as it attempts to record both the installation and the use of a cellular telephone at the time of the crash. The lack of rigorous guidelines for data collection compromise the utility of the data set. The results do, however, mirror trends found in other sources of information.

The NASS and FARS files, and anecdotal observations of driver performance, are similar to the Oklahoma data in demonstrating an apparent link between cellular telephone use and driver inattention. In addition, cellular telephone use is extending beyond central city limits to more rural counties, as indicated in the Oklahoma data and reported by CTIA. The number of telephones both available and in-use during or immediately following a crash are increasing rapidly, Industry sales figures, and emergency dispatch units report similar increases.

3.5 Minnesota Crash Data

In 1991, the State of Minnesota revised its police crash report forms (see Figure 3-2). The police officers record from 0 to 2 apparent contributing factors for drivers involved in motor vehicle collisions. Among the 32 possible factors is "driver on car phone/CB - 2 way radio." According to the Minnesota Office of Traffic Safety, there were approximately 100,000 crashes in Minnesota in 1995, with about 180,000 involved drivers. Cellular telephone/CB - 2 way radio use was not cited as a factor in any of the fatal crashes. For injury producing crashes, and for property damage only, this factor was recorded 0.1% of the time.

The Minnesota Department of Public Safety has included these statistics in their 1995 edition of *Crash Facts*. In previous years, the number of citations was so small that the phone/radio factor was grouped in with other "miscellaneous" factors. The pre-crash factors are often determined from interviews with involved parties. The Minnesota Office of Traffic Safety data analyst who provided these statistics compared the accuracy of the cellular telephone/radio pre-crash factor to that for self reported seat belt usage after a crash.

The NASS and FARS files, and anecdotal observations of driver performance, are similar to the Oklahoma data in demonstrating an apparent link between cellular telephone use and driver inattention.

Figure 3-2 State of Minnesota Police Accident Report

STATE OF MINNESOTA - DEPARTMENT OF PUBLIC SAFETY

PS-320003-08 1-91

TRAFFIC ACCIDENT REPORT

(FOR POLICE USE ONLY AS REQUIRED BY STATUTE)

PAGE OF

LOCAL CASE NO

HIT AND RUN ☐ ATTENDED ☐ UNATTENDED	PUB PROP	VEHICLES	KILLED	INJURED	$ MIN	MONTH	DATE	YEAR	DAY	TIME	AM ☐ PM ☐

ROUTE SYSTEM	ROUTE NUMBER OR STREET NAME	☐ AT INTERSECTION WITH	OR	☐ MI ☐ FT	☐ N ☐ S	☐ E ☐ W
ON						

COUNTY NO	☐ CITY ☐ TWP	INT ELEM	REFERENCE POINT	ROUTE SYS	ROUTE #, STREET, CORP LIMIT, REF POINT OR FEATURE

UNIT 2 ☐ VEHICLE ☐ PEDESTRIAN ☐ BICYCLE

	Unit 1			Unit 2		
FACTOR 1	DRIVER LICENSE NUMBER - 1	STATE	CLASS	DRIVER LICENSE NUMBER - 2	STATE	CLASS
FACTOR 2	NAME (FIRST, MIDDLE, LAST)	RSTRCTNS COMPLIED	WTHDRAW	NAME (FIRST, MIDDLE, LAST)	RSTRCTNS COMPLIED	WTHDRAW
MNUVER	ADDRESS	DATE OF BIRTH		ADDRESS	DATE OF BIRTH	
PHYSCL	CITY, STATE, ZIP			CITY, STATE, ZIP		
RCOMND	ADDRESS CORRECT / SEX / EJECT / RSTRNT / INJCOD / TO HOSP / TRANSPORT ☐ AMBULANCE ☐ OTHER			ADDRESS CORRECT / SEX / EJECT / RSTRNT / INJCOD / TO HOSP / TRANSPORT ☐ AMBULANCE ☐ OTHER		

	Unit 1			Unit 2		
VEHTYP	OWNER NAME			OWNER NAME		
FIRE	ADDRESS	OCCUP		ADDRESS	OCCUP	
TOW	CITY, STATE, ZIP	PULLING UNIT	DIRECT	CITY, STATE, ZIP	PULLING UNIT	DIRECT
DMGLOC	MAKE / MODEL / YEAR / COLOR	SEQUENCE OF EVENTS		MAKE / MODEL / YEAR / COLOR	SEQUENCE OF EVENTS	
DMGSEV	PLATE # / STATE / YEAR	INSURANCE		PLATE # / STATE / YEAR	INSURANCE	

INJURED PASSENGERS/WITNESSES		UNIT	POSTN	AGE	SEX	EJECT	RSTRNT	INJCOD	TO HOSP	TRANSPORT
										☐ AMBULANCE ☐ OTHER
										☐ AMBULANCE ☐ OTHER
										☐ AMBULANCE ☐ OTHER
										☐ AMBULANCE ☐ OTHER

ACCTYP

OWNER OF OTHER DAMAGED PROPERTY AND/OR YELLOW TAG NUMBER(S)

AMBULANCE SERVICE(S) AND/OR STATE AMBULANCE RUN NUMBER (S)

FXDOBJ

ON BRIDGE

LOCATN

RDWORK

RDESIGN

RDSURF

RDCHAR

NORTH

DESCRIPTION, CHARGES PENDING, AND/OR CITATIONS ISSUED

DEVICE

WORKING

SPEED LIMIT

INTREL

WEATHER

PHOTOS TAKEN

LIGHT

DIAGRAM

OFFICER RANK, NAME, BADGE#, AND AGENCY ☐ PATROL ☐ SHERIFF ☐ LOCAL ☐ OTHER

UNIT	MOTOR CARRIER	HAZ MAT	HAZ PLACE	NAT'L CLASS/ID	NAT'L CLASS/ID	NAT'L CLASS/ID	BDY TYP
ADDRESS		MOTOR CARRIER ID		MC SOURCE	AXELS DOWN	AXELS UP	TRAILER HITCH
CITY, STATE, ZIP		ICR#		INSPECTOR #			GVWR

Figure 3-2 State of Minnesota Police Accident Report (continued)

FACTOR 1 & FACTOR 2 - APPARENT CONTRIBUTING FACTORS (UP TO TWO PERDRIVER)
(NOTE: PLEASE INDICATE PRIMARY FACTOR IN THE BOX MARKED FACTOR 1

0 - NO CLEAR CONTRIBUTING FACTOR
1 - FAILURE TO YIELD RIGHT OF WAY
2 - ILLEGAL/UNSAFE SPEED
3 - FOLLOWED TOO CLOSELY
4 - DISREGARDED TRAFFIC CONTROL DEVICE
5 - DRIVING LEFT OF ROADWAY CENTER, NOT PASSING
6 - IMPROPER PASSING/OVERTAKING
7 - IMPROPER/UNSAFE LANE USE
9 - IMPROPER TURN
10 - UNSAFE BACKING MODE
11 - NO/IMPROPER SIGNAL
12 - IMPEDING TRAFFIC
13 - DRIVER INATTENTION
14 - DRIVER INEXPERIENC
15 - PEDESTRIAN VIOLATI
17 - FAILURE TO USE LIGHTS
18 - DRIVER ON CAR PHONE/CB/2-WAY RADIO
CONTRIBUTING FACTOR
42 - DEFECTIVE TIRE OR TIRE FAILURE
43 - DEFECTIVE LIGHTS
44 - INADEQUATE WINDSHIELD GLASS
OVERWEIGHT VEHICLE
CTOR
90 - OTHER

18 - DRIVER ON CAR PHONE/CB/2-WAY RADIO

MNUVER - PRE-ACCIDENT MANEUVER

BY VEHICLE
1 - GOING STRAIGHT AHEAD/ FOLLOWING ROADWAY
2 - WRONG WAY INTO OPPOSING TRAFFIC
4 -LEFT TURN ON RED
5 -MAKING RIGHT TURN
6 -MAKING LEFT TURN
7 -MAKING U-TURN
8 -STARTING FROM PARKED POSITION
9 -STARTING IN TRAFFIC
10 -SLOWING IN TRAFFIC
11 -STOPPED IN TRAFFIC
12 -ENTERING PARKED POSITION
13 -PARKED LEGALLY
14 -PARKED ILLEGALLY
15 -AVOIDING UNIT/OBJECT IN ROAD
17 -CHANGING LANE
18 -OVERTAKING/PASSING
19 -MERGING
20 -BACKING

BY PEDESTRIAN
41 -CROSSING WITH SIGNAL
42 -CROSSING AGAINST SIGNAL
43 -CROSSING MARKED CROSSWALK
44 -CROSSING (NO SIGNAL OR MARKED CROSSWALK
45 -WALK/RUN IN ROAD WITH TRAFFIC
46 -WALK/RUN IN ROAD AGAINST TRAFFIC
47 -STANDING IN ROAD
48 -EMERGING FROM BEHIND PARKED VEHICLE
49 -CHILD GETTING OFF SCHOOL BUS
50 -GETTING ON/OFF VEHICLE
51 -PUSHING/WORKING IN VEHICLE
52 -WORKING IN ROADWAY
53 -PLAYING IN ROADWAY

BY BICYCLIST
71 - RIDING WITH TRAFIC
72 - RIDING AGAINST TRAFFIC
73 - MAKING RIGHT TURN
74 - MAKING LEFT TURN
75 - MAKING U-TURN
76 - RIDING ACROSS ROAD
77 - SLOWING/STOPPING/

PHYSCL - APPARENT PHYSICAL CONDITION
1 -NORMAL (NO DRUGS/ALCOHOL
2 -UNDER THE INFLUENCE
3 -HAD BEEN DRINKING
4 -COMMERICAL DRIVER OVER .04 BAC
5 - HAD BEEN TAKING DRUGS
6 - ASLEEP
7 - FATIGUED
8 -ILL
9 -OTHER
99 -UNKNOWN

RCOMND - RECOMMENDATIONS
0 -NOT APPLICABLE
1 -PHYSICAL EXAM
2 -DRIVER EXAM
90 -OTHER

VEHTYP - VEHICLE CONFIGURATION
1 -AUTOMOBILE
2 -PICKUP
3 -VAN
4 -MOTORHOME/CAMPER
5 -TAXICAB
6 -POLICE VEHICLE
7 -FIRE DEPARTMENT VEHICLE
8 -SCHOOL BUS
9 -AMBULANCE
10 -MILITARY VEHICLE
11 -SNOWMOBILE
12 -ATV
14 -MOTORCYCLE
15 -MOTORSCOOTER/MOTORBIKE
16 -MOPED/MOTORIZED BICYCLE
17 -HIT AND RUN VEHICLE
18 -ROADWAY MAINTENANCE VEHICLE
19 -OTHER PUBLICLY-OWNED
20 -OTHER PRIVATELY-OWNED VEHICLE
21 -BICYCLE
22 -PEDESTRIAN
31 -2-AXLE, 6-TIRE, SINGLE UNIT TRUCK/STEPVAN
32 -3 OR MORE AXLE SINGLE UNIT
33 -SINGLE UNIT TRUCK WITH TRAILER
34 -TRUCK TRACTOR WITH NO TRAILER
35 -TRUCK TRAILER WITH SEMI- TRAILER
36 -TRUCK TRACTOR WITH
37 -TRUCK TRACTOR WITH TRIPLE TRAILERS
38 -UNKNOWN HEAVY TRUCK
39 -NON-SCHOOL BUS
90 -OTHER VEHICLE TYPE
99 -UNKNOWN

DMGLOG - PRINCIPLE DAMAGE AREA(S) OF VEHICLE
0 -NOT APPLICABLE
1 -FRONT
2 -RIGHT FRONT
3 -RIGHT CENTER
4 -RIGHT REAR
5 -REAR
6 -LEFT REAR
7 -LEFT CENTER
8 -LEFT FRONT
9 -TOP
10 -BOTTOM
11 -MULTIPLE AREAS
99 -UNKNOWN

DMGSEV - DAMAGE SEVERITY
0 -NOT APPLICABLE
1 -NONE
2 -LIGHT
3 -MODERATE
4 -SEVERE
5 -TOTAL
99 - UNKNOWN

ACCTYP - ACCIDENT TYPE BY 1ST HARMFUL EVENT
COLLISION WITH A(N)
1 -UNIT ON SAME ROADWAY
2 -UNIT ON SEPARATE ROADWAY
3 -PARKED MOTOR VEHICLE
4 -TRAIN
5 -BICYCLIST
6 -PEDESTRIAN
7 -DEER
8 -OTHER ANIMAL
9 -FIXED OBJECT

NON-COLLISION
11 -OVERTURN
12 -FIRE/EXPLOSION
13 -SUBMERSION
90 -OTHER
99 -UNKNOWN

FXDOBJ - FIXED OBJECT STRUCK
0 -NOT APPLICABLE
1 -CONSTRUCTION EQUIPMENT
2 -TRAFFIC SIGNAL
3 -RR CROSSING DEVICE
4 -LIGHT POLE
5 -UTILITY POLE
6 -SIGN STRUCTURE/POST
7 -MAILBOXES AND/OR POSTS
8 -OTHER POLES, ETC
9 -HYDRANT
12 -MEDIAN SAFETY BARRIER
13 -BRIDGE/PIER/GUARDRAIL
14 -OTHER GUARDRAIL
15 -FENCE (NON-MEDIAN BARRIER)
16 -CULVERT/HEADWALL
17 -EMBANKMENT/DITCH/CURB
18 -BUILDING/WALL
19 -ROCK OUTCROPS
20 -PARKING METER
90 -OTHER

DEVICE - TRAFFIC CONTROL
0 -NOT APPLICABLE
1 -TRAFFIC SIGNAL (SEE WOKRING)
2 -OVERHEAD FLASHERS (SEE WOKRING)
3 -STOP SIGN - ALL APPROACHES
4 -STOP SIGN -OTHER
5 -YIELD SIGN
6 -OFFICER/FLAGPERSON/ SCHOOL PATROL
9 -NO PASSING ZONE
10 -RR CROSSING GATES (SEE WORKING)
11 -RR CROSSING FLASHING LIGHTS (SEE WORKING)
12 -RR CROSSING STOP SIGN
13 -RR OVERHEAD FLASHERS (SEE WORKING)
14 -RR OVERHEAD FLASHERS/ GATE (SEE WOKRING)
15 - RR CROSSBUCK

LOCATN - LOCATION OF FIRST HARMFUL EVENT
1 -ON ROADWAY (ALLEY, DRIVEWAY, ETC.)
2 -ON SHOULDER
3 -ON MEDIAN
4 -ON ROADSIDE
6 -PRIVATE PROPERTY
7 -OUTSIDE RIGHT-OF-WAY
90 -OTHER

WORKING -WAS ELECTRONIC MECHANICAL TRAFFIC CONTROL WORKING PROPERLY?
0 -NOT APPLICABLE
1 -SIGNAL WORKING PROPERLY
2 -SIGNAL NOT WORKING PROPERLY
3 -SIGNAL WORKING IN MODIFIED FASHION (E.G. TEMPORARILY
90 -OTHER
99 -UNKNOWN

RDWORK - ROAD WORK
1 -NONE
WORK ZONE MARKED
2 -CONSTRUCTION
3 -MAINTENANCE
WORK ZONE NOT MARKED
5 -CONSTRUCTION
6 -MAINTENANCE
90 -OTHER
99 -UNKNOWN

INTREL - RELATIONSHIP TO INTERSECTION/JUNCTION
1 -INTERCHANGE AREA
2 -INTERSECTION
3 -INTERSECTION-RELATED
4 -ALLEY/DRIVEWAY ACCESS
5 -AT SCHOOL CROSSING
9 -NOT INTERSECTION/JUNCTION
99 -UNKNOWN

RDESGN - ROAD DESIGN
1 -FREEWAY (INCLUDES RAMPS)
2 -OTHER DIVIDED HIGHWAY
3 -ONE-WAY STREET
4 -4-6 LANES UNDIVIDED (2-3 LANES EACH WAY
6 -2 LANES (1 LANE EACH WAY)
7 -ALLEY/DRIVEWAY
8 - PRIVATE PROPERTY

WEATHER - WEATHER/ATMOSPHERE
1 -CLEAR
2 -CLOUDY
3 -RAIN
4 -SNOW
5 -SLEET/HAIL/FREEZING RAIN
6 -FOG/SMOG/SMOKE
7 -BLOWING SAND/DUST/SNOW
8 -SEVERE CROSSWINDS
90 -OTHER

RDSURF - ROAD SURFACE CONDITIONS
1 -DRY
2 -WET
3 -SNOW/SLUSH
4 -ICE/PACKED SNOW
6 -DEBRIS
7 -OILY
90 -OTHER

LIGHT - LIGHTING
1 -DAYLIGHT
2 -DAWN (AM)
3 -DUSK (PM)
4 -DARK (STREET LIGHTS ON)
6 -DARK (NO STREET LIGHTS)
90 -OTHER
99 -UNKNOWN

RDCHAR - ROADWAY CHARACTERISTICS
1 -STRAIGHT & LEVEL
2 -STRAIGHT & GRADE
3 -STRAIGHT AT HILLCREST
4 -STRAIGHT AT SAG
5 -CURVE & LEVEL
7 -CURVE AT HILLCREST
8 -CURVE AT SAG
90 -OTHER

DIAGRAM - VEHICULAR RELATIONSHIPS WHICH LED TO IMPACT
0 -NOT APPLICABLE
1 -REAR END
2 -SIDESWIPE - PASSING
3 -LEFT TURN INTO ONCOMING TRAFFIC
4 - RAN OFF ROAD -LEFT SIDE
5 -RIGHT ANGLE
6 -RIGHT TURN INTO CROSS
7 -RAN OFF ROAD - RIGHT SIDE
8 - HEAD-ON
9 -SIDESWIPE -OPPOSING
90 -OTHER
99 -UNKNOWN

STATE OF MINNESOTA
DEPARTMENT OF PUBLIC SAFETY

POLICE TRAFFIC ACCIDENT REPORT

PS-32003-06 (1-91)

BDYTYP - CARGO BODY TYPE

0 -NOT APPLICABLE
1 -VAN
2 -DRY BULK CARGO TANK
3 -LIQUID BULK CARGO TANK
4 -GAS BULK CARGO TANK
5 -FLATBED/PLATFORM
6 -DUMP
7 -CONCRETE MIXER
8 -AUTO TRANSPORTER
9 -GARBAGE/REFUSE
10 -BUS
11 -COMBINATION
12 -SPECIAL PREMIT LOAD
90 -OTHER
99 -UNKNOWN

SEQUENCE OF EVENTS - PLEASE INDICATE UP TO FOUR CODES THAT REPRESENT THE SEQUENCE OF ACCIDENT-RELATED EVENTS.

1 -COLLISION WITH UNIT ON SAME ROADWAY
2 -COLLISION WITH UNIT ON SEPARATE ROADWAY
3 COLLISION WITH PARKED MOTOR VEHICLE
4 - COLLISION WITH TRAIN
5 - COLLISION WITH BICYCLIST
6 - COLLISION WITH PEDESTRIAN
7 - COLLISION WITH DEER
8 -COLLISION WITH OTHER ANIMAL
9 -COLLISION WITH FIXED OBJECT
10 -COLLISION WITH FALLING OBJECT
11 OVERTURN
12 -FIRE/EXPLOSION
13 -SUBMERSION
14 -JACK KNIFE
15 -CARGO SHIFT
16 -LOSS OR SPILAGE OF NON-HAZARDOUS MATERIAL
17 -LOSS OR SPILAGE OF HAZARDOUS MATERIAL
18 RAN OFF THE ROAD
19 SEPARATION OF UNITS
20 -DOWNHILL RUNAWAY
21 -UNDERRIDE - REAR
22 - UNDERRIDE SIDE
90 - OTHER
99 - UNKNOWN

TRAILER HITCH - TRAILER HITCH CONFIGURATIONS

3 -A - TRAIN HITCH (WITH FIFTH WHEEL)
4 - B - TRAIN HITCH (WITH FIFTH WHEEL)
5 - C - TRAIN HITCH (WITH FIFTH WHEEL)
6 - PINTLE HITCH
90 -OTHER (INCLUDING COMBINATIONS)
99 -UNKNOWN

M.C. SOURCE - SOURCE OF IDENTIFICATION

1 - CAB CARD
2 - SHIPPING PAPERS
3 - SIDE OF VEHICLE
4 -DRIVER
90 -OTHER

GVWR - GROSS VEHICLE WEIGHT RATING

0 - NOT APPLICABLE
1 -LESS THAN 10,000 POUNDS
2 -10,000 TO 11,999 POUNDS
3 -12,000 TO 25,999 POUNDS
4 -26,000 TO 56,999 POUNDS
5 - 57,000 TO 80,000 POUNDS
6 - 80,001 TO 105,000 POUNDS
7 - 105,001 TO 120,000 POUNDS
8 -GREATER THEN 120,000 POUNDS
99 - UNKNOWN

DIRECT - PRE-ACCIDENT DIRECTION

1 NORTH
2 -NORTHEAST
3 -EAST
4 -SOUTHEAST
5 -SOUTH
6 -SOUTHWEST
7 - WEST
8 -NORTHWEST
99 - UNKNOWN

RSTRNT - RESTRAINT DEVICE

1 - SEAT BELT NOT INSTALLED
2 -SEAT BELT INSTALLED, NOT USED
3 -SEAT BELT INSTALLED, USED
4 -SEAT BELT INSTALLED, IMPROPERLY USED
5 -PASSIVE BELT INSTALLED USED
6 -PASSIVE BELT INSTALLED, CIRCUMVENTED
7 -AIRBAG DEPLOYED, SEAT BELT USED
8 -AIRBAG DEPLOYED, SEAT BELT NOT USED
9 -CHILD RESTRAINT NOT INSTALLED
10 -CHILD RESTRAINT INSTALLED, NOT USED
12 -CHILD RESTRAINT INSTALLED USED
13 -CHILD RESTRAINT IMPROPERLY USED
14 -HELMET NOT USED
15 - HELMET USED
90 - OTHER
99 -UNKNOWN

POSITN - OCCUPANT SEAT POSITION

1 - LEFT FRONT
2 - FRONT CENTER
3 - RIGHT FRONT
4 - SECOND SEAT LEFT
5 - SECOND SEAT CENTER
6 - SECOND SEAT RIGHT
7 - THIRD SEAT LEFT
8 - THIRDSEAT CENTER
9 - THIRD SEAT RIGHT
10 -OUTSIDE OF VEHICLE
11 -MOTORCYCLE/SNOWMOBILE/BICYCLE DRIVER
11 -MOTORCYCLE/SNOWMOBILE/BICYCLE PASSENGER ON UNIT
13 -MOTORCYCLE/SNOWMOBILE/BICYCLE TRAILER/SIDE UNIT
90 -OTHER
99 -UNKNOWN

EJECT - EJECTION

0 -NOT APPLICABLE
1 - TRAPPED, EXTRICATED
2 - PARTIALLY EJECTED
3 - EJECTED
4 - NOT EJECTED
99 - UNKNOWN

INJCOD - INJURY CODE

K - KILLED
A - INCAPACITATING INJURY
B - NON- INCAPACITATING INJURY
C - POSSIBLE INJURY
N - NO APPARENT INJURY
X - UNKNOWN

3.6 Cellular Telephone Related Crash Experience in Japan

In June 1996 the National Police Agency of Japan conducted a study in which the agency attempted to ascertain the frequency of cellular telephone use as an antecedent to a motor vehicle crash. During the month of June, 129 cellular telephone related crashes were identified. Of these, 76% involved rear end collisions, 2.3% were single vehicle crashes, 2.3% were pedestrian impacts, and 19% were categorized as "others" which would presumably include intersection and lane change related collisions. The driver related factors vary somewhat from those found in the U.S. data.

Only 16% of the drivers were conversing on the phone at the time of the crash, 32% were dialing, 5.4% were hanging up the phone, and 42% were responding to a call.

Only 16% of the drivers were conversing on the phone at the time of the crash, 32% were dialing, 5.4% were hanging up the phone, and 42% were responding to a call. The large number of crashes related to handling the telephone (32% dialing, 42% answering) may be a reflection of the fact that in Japan, 94% of telephones sold in 1995 were hand-held models compared to 73% in the U.S. It is not known if installed car telephones, and voice activated models are readily available in that market.

For the 42% of drivers who were involved in a crash as a result of responding to a call, the behaviors were described as looking aside to try to pick up the telephone, being careless in driving because of hearing the phone ring, and dropping the receiver. Of all cellular telephone related crashes, only 23 (18%) included female drivers. The majority of drivers were in the 20-29 age range. A comparison of driver factors by age group is shown in Table 3-9 (below).

The Japanese data represent the only identified attempt at comprehensive data collection of cellular telephone use by crash involved drivers by a national police department for a defined period of time. The differences in vehicle design, phone design and configuration, phone use, traffic conditions and even driving habits make it impossible to extrapolate the research results to the U.S. population. The study does show that concern for the effects of cellular telephone use while driving is of international interest and that there are a number of factors that must be considered in an analysis of the data.

Table 3.9: A Comparison of Driver Age and Causal Factor

	under 19	20-29	30-39	40-49	50-59	Over 60
Speaking	9	48	14	19	5	5
Dialing	2	40	18	28	10	2
Receiving	4	44	22	24	6	0

3.7 Case Studies

Driver behaviors and specific traffic situations that serve as antecedents to cellular telephone related motor vehicle crashes are not typically recorded on police crash reports except in Oklahoma and Minnesota as previously described. Although all states have reckless driving laws and many states prohibit careless or inattentive driving, there are no state laws that specifically limit phone use while driving. As pointed out earlier, the identification of pre-crash cellular telephone use is difficult for police officers and for researchers.

As a case in point, in a special one-time study, NASS investigators identified only 10 cellular telephone-related crashes among 60,233 police crash report narratives reviewed during April, May and June of 1996. Table 3-10 describes these crashes. Unless cellular telephones are mounted in the vehicle, there may be no physical evidence based on police crash reports alone. Even when cellular telephone presence is obvious, some drivers may not admit to pre-crash phone use for fear of being considered at-fault for the crash. The best current sources for identifying cellular telephone use are witnesses. Such observations may not, however, be recorded on a police crash report.

The best current sources for identifying cellular telephone use are witnesses.

In a separate effort to explore some of these issues, a pilot program was established in the Baltimore-Washington-Northern Virginia area in which police agencies were asked to notify the Dynamic Science, Inc. (DSI) crash investigation team when a cellular telephone related crash was identified. Several jurisdictions agreed to cooperate, and posted fliers (see Figure 3-3, next page) to remind officers of the program. Five crashes were reported over a period of 6 months. This does not necessarily reflect the incidence of such crashes since the levels of cooperation varied by jurisdiction.

- In the first case, the driver of a pick up truck in a rural area of Virginia was talking on a hand-held cellular telephone according to witnesses. His vehicle (Vehicle 1) drifted to the left, causing the vehicle next to him (Vehicle 2) to leave the roadway to the left. Vehicle 1 then struck Vehicle 2, which subsequently struck a third vehicle stopped at the crossroads. The pick-up truck driver denied using the cellular telephone, when queried by the investigating state trooper. The driver also refused to provide any additional information to the research team.

- The second case was reported by the state police in a suburban Virginia area. A pick up truck was being driven while a hand-held cellular telephone was in use. The driver looked down toward the cradle, and struck a Ford sedan that was ahead of him. The trooper stated he was not authorized to release personal information or a copy of the police crash report to DSI, so no further investigation was possible.

- The third crash occurred in the suburbs of Washington, D.C. A 1989 Plymouth van operated by a repair service went through a red light and was struck in the side. The van operator was talking on his hand-held, flip-phone, getting directions for his next assignment and writing these directions at the same time. There was a cellular telephone holder mounted in the van, but it was broken prior to the crash.

  No hands free capabilities were available to the driver. The repair service operates 5 vans with various models of hand-held cellular telephones. Each driver uses the phone 30-40

Figure 3-3 - Posted Flyer

WANTED

Cellular Telephone-related Motor Vehicle Crashes

for scientific research sponsored by the
U.S. Department of Transportation

Call (301) 858-7028
(410) 974-0299 Anytime

Please provide:

- ☐ Your name, phone number, location
- ☐ Time and date of call
- ☐ Vehicle make and model

If known:

- ☐ Crash location and date
- ☐ Crash details
- ☐ Damage and injury
- ☐ Type of phone/usage

Do not hesitate to call - even if you are missing some details

Dynamic Science, Inc.
530 College Parkway, Ste. K
Annapolis, MD 21401

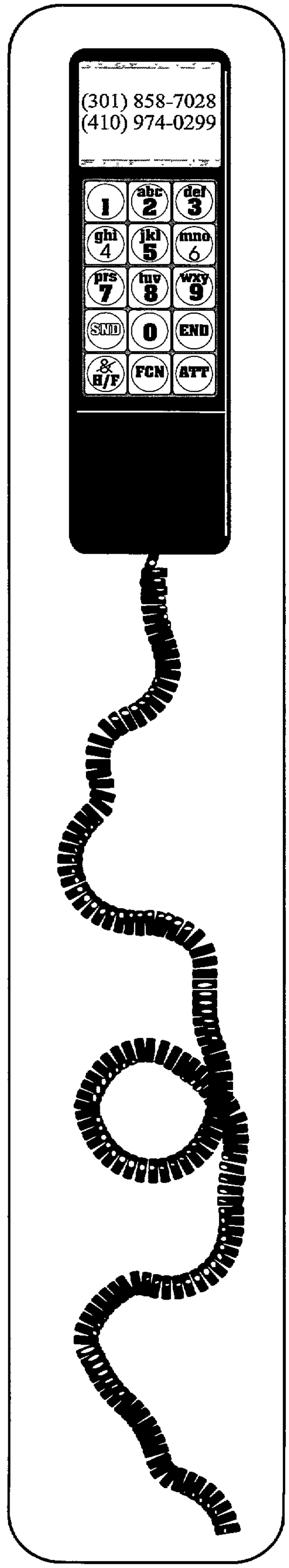


Table 3-10: NASS GES PAR Descriptions for Cellular Telephone Related Crashes

Case 1
The driver of the vehicle was talking on his cellular telephone to get directions when his vehicle hit a concrete island on the left, and veered through the right lane down an embankment into a tree.

Case **2**
The driver of the vehicle took his eyes off the road while attempting to "use" a cellular telephone and the vehicle veered to the right, striking a curb.

Case 3
The driver was talking on a cellular telephone and proceeded to turn left at an intersection as the light was turning yellow/red, and turned into the path of an on-coming vehicle.

Case 4
The driver attempted to answer the cellular telephone and ran off the road into a tree.

Case 5
The driver, reaching for a cellular telephone, ran a red light and struck another vehicle.

Case 6
The driver was answering his cellular telephone, when he looked up and saw a vehicle stopped in front of him and was not able to stop in time.

Case 7
The driver "was distracted by a cellular phone" and skidded into an intersection against a red signal and struck another vehicle.

Case 8
The driver was talking on a cellular telephone and "not paying attention" when she rear ended another vehicle stopped for a crossing pedestrian.

Case 9
The driver was talking on a cellular telephone and did not see a red light until it was too late to stop for an on-coming vehicle.

Case 10
The driver was talking on a cellular telephone and made a left turn into another turning vehicle in an adjacent turning lane.

hours per month to coordinate schedules and request directions. According to a company representative, it is not unusual for drivers to take notes while talking and operating their vehicles.

The company does not currently have rules for cellular telephone use, but the attorney present during the interview advised that guidelines will be forthcoming. While the combination of cellular telephone use and writing was likely the primary cause of this crash, it underscores the potential risks of secondary tasks associated with cellular telephone use.

- The fourth incident involved a young driver of a 1992 Toyota Camry. The vehicle was traveling on a rural road at 1:00 am when the center mounted, dealer installed car phone rang. The driver attempted to answer the telephone when he drifted off the road to the right and struck a light pole.

- In the fifth case, a woman was driving her minivan on a rural road near her home when she became startled because her cellular telephone rang. As she reached over to retrieve the phone from its bracket, she drifted off the road to the right, sideswiping a tree. Her child, in the right front passenger position, received fatal head injuries in the collision.

- The sixth case study occurred in Arizona. In 1992, DSI investigated a crash in which a driver using a hand-held cellular telephone drifted to the left on a curve and struck a police vehicle head-on, killing the police officer.

- In a seventh case, the 50 year old female driver of the 1996 minivan was travelling northbound on a 2-lane undivided roadway. Ahead of the minivan was a 15 passenger school bus that was approaching a railroad crossing. In accordance with the state motor vehicle code, the school bus driver turned on his 4-way flashers, came to a stop and opened the bus doors at the grade crossing.

  The driver of the minivan looked away from the roadway to pick up her cellular telephone and, when she looked back, the bus had stopped. She collided with the rear of the bus, deploying both airbags. A 6 year old restrained right front seat passenger received critical injuries in this crash.

3.8 Discussion

The taxonomy in Table 3-l 1 reflects each of the particular crashes that were reported to or investigated by DSI as part of this study, as well as the 3 FARS cases, 8 NASS cases and 10 NASS/GES police crash reports presented previously. In all 28 crashes, the cellular telephone user is considered "at fault." Only 1 of the telephones is known to be a hands-free mobile unit. All others were of the hand-held type or were not specifically described on the police crash report.

The crash circumstances also fall into well defined categories. Fifteen of these crashes were attributable to drivers moving out of their designated traffic lanes. An additional 8 of the 28 cases included a collision with a stopped vehicle in the same travel lane. The remaining 5 cases occurred when the driver using the cellular telephone failed to stop for a red traffic signal.

Given the tendency for individuals to deny culpability following a crash, it is probably appropriate to consider these circumstances as useful topics upon which to focus a more detailed crash investigation research program. The patterns tend to reflect the observations shown in the Public Comment in Chapter 2. Drivers often recognize that they need to be cautious while dialing, but they tend to forget they are behind the wheel once they become engrossed in conversation.

Table 3-11 Summary of Case Studies

Source	Striking /struck	Phone Type	Cell Phone Usage	Driver Error	Object Struck
NASS 01	Striking	Hands free w/ remote speaker and microphone	talking	fail to stop	vehicle
NASS 02	Striking	Hand-held, flip phone	dialing	lane tracking	pole
NASS 03	Striking	Hand-held	talking	lane tracking	pole
NASS 04	Striking	Hand-held, mounted	talking	fail to stop	vehicle
NASS 05	Striking	Hand-held, mounted	hanging up	fail to stop	vehicle
NASS 06	Striking	Hand-held	talking	lane tracking	vehicle
NASS 07	Striking	Hand-held, flip phone	talking	fail to stop	vehicle
NASS 08	Striking	Hand-held	talking	land tracking	fence
FARS 94-1	Striking	Hand-held	answering	lane tracking	vehicle
FARS 94-2	Striking	Hand-held	talking	lane tracking	vehicle
FARS 95-l	Striking	Hand-held, mobile	talking	lane tracking	vehicle
Case Study 1	Striking	Hand-held	talking	lane tracking	vehicle
Case Study 2	Striking	Hand-held	talking	fail to stop	vehicle
Case Study 3	Struck	Hand-held, flip phone	talking	fail to stop	vehicle
Case Study 4	Striking	Hand-held, center mounted, mobile phone	answering	lane tracking	tree
Case Study 5	Striking	Hand-held, vehicle mounted	answering	lane tracking	tree
Case Study 6	Striking	Hand-held, vehicle mounted, mobile phone	talking	lane tracking	vehicle
Case Study 7	Striking	Hand-held, mobile phone	reaching	fail to stop	vehicle
PCRl	Striking	unknown	talking	lane tracking	island
PCR2	Striking	unknown	use	lane tracking	curb
PCR3	Struck	unknown	talking	fail to stop	vehicle
PCR4	Striking	unknown	answer	lane tracking	tree
PCR5	Striking	unknown	reaching	fail to stop	vehicle
PCR6	Striking	unknown	answering	fail to stop	vehicle
PCR7	Striking	unknown	distracted	fail to stop	vehicle
PCR8	Striking	unknown	talking	fail to stop	vehicle
PCR9	Striking	unknown	talking	fail to stop	vehicle
PCRlO	Striking	unknown	talking	lane tracking	vehicle

Note: PCR refers to Police Crash Report (formerly PAR, Police Accident Report)

Chapter 4

Analysis of Police Crash Report Narratives

4.1 Introduction

Given the nature and extent of cellular telephone use in the automobile today, the potential implications for safety on the road are obvious. The predicted growth in cellular telephone use along with the implementation of increasingly complex functionality (e.g., e-mail, paging, access to the www) heightens the importance of understanding the potential implications for safety as well as the nature of causal factors associated with any relevant crashes. Such information could be invaluable to both system designers and users.

4.2 Purpose

This research was undertaken to supplement existing data and provide a somewhat different perspective on the relationship between cellular telephone use and safety. In addressing this type of issue, it is common practice for researchers to examine crash records, histories, or data bases as a means of determining common trends, contributing factors, and causes. When crash data bases are studied, information is usually gleaned from information filled in by investigating officers. Examples of information gathered in this manner include alcohol involvement, character of the crash, and whether or not seat belts were used. Such information is usually contained in specific check-off or fill-in "boxes" on crash reporting forms.

When dealing with potential sources or contributing factors, the fill-in and check off approach appears to work well for conventional causes of crashes. However, when the potential source is unusual or relatively new, performing searches on categorized or "boxed" information may not uncover the true influence of the potential source on number of crashes. In such cases, a different approach must be used.

Many crash reporting forms contain so-called narratives in which the reporting officer describes in a few sentences how the crash occurred and what the contributing factors were. These narratives usually allow greater freedom in describing the crash and therefore may contain more detailed information on contributing factors or causes. To take advantage of these narratives, they must be entered into a data base and then they must be retrievable by keywords.

The State of North Carolina has had an ongoing project for many years that is being carried out jointly by the State's Department of Motor Vehicles (DMV) and the Highway Safety Research Center (HSRC) at the University of North Carolina, Chapel Hill. DMV enters the narratives as they become available, and HSRC uses computer search programs that find, retrieve, and print narratives containing keywords. The printed narratives can then be screened by researchers to determine whether they do indeed involve the target influence or cause, or are spurious.

This chapter describes an attempt to use the keyword-narrative search approach to determine the extent to which cellular telephone usage in vehicles is contributing to crashes.

This chapter describes an attempt to use the keyword-narrative search approach to determine the extent to which cellular telephone usage in vehicles is contributing to crashes. Because cellular telephones are a relatively recent technology, more conventional approaches to crash database searches are not likely to provide accurate information. It appeared that the keyword-narrative search approach would be more likely to produce accurate and meaningful results.

Of course, there are other research approaches to understanding the effects of cellular telephone usage on driver behavior and driver workload, many of which have been discussed in Chapter 3 of this report. A bibliography is also provided as Appendix E, referencing the variety of methods that can be used. However, none of these methods directly assesses the effects of cellular telephone usage on the number of crashes per se. Rather, the connection is implied through such measures of cognitive load as eyes-off-road time, lane deviations, and missed detections of targets. It thus appears that this study is the first attempt to assess the occurrence and nature of cellular telephone related crashes in a crash data base.

Previous searches using the narrative approach have worked reasonably well. Perel (1976, 1988) has used the approach with reasonable success to determine driver-vehicle interaction problems, particularly those involving hand and foot controls. More recently, Wierwille and Tijerina (1995) have used the approach successfully to show that increased allocation of vision to interior sources of the vehicle is associated with increased crash incidence.

4.3 Method

To conduct the search, a set of keywords and combinations had to be constructed. This list was developed based on words that reporting officers might employ to describe cellular telephones or their use. Such terms as "car phone" and "talk . . . on" were included.

The list is shown in Table 4-l. It should be noted that the list is written using a coding scheme. A comma means that the stem word may have any ending. For example "phon," will retrieve any narrative containing any of the words phone, phoning, phoned, phones, etc. An asterisk between words indicates that the two words need not appear consecutively. For example "speak,*on" will retrieve a narrative with the words "speaking to his wife on." Thus, the list was constructed to retrieve as many relevant citations as possible. Of course, the list was expected to provide a large number of spurious citations, which had to be screened by direct reading.

The list shown in Table 4-l also contains a number of computer-related terms. At the time that the study was planned, there were anecdotal indications that in-vehicle use of computers, facsimile machines, and data terminals might be causing some crashes. Since such devices are sometimes connected through modems to cellular telephones, it seemed prudent to perform the searches simultaneously. In that way, it might be possible to uncover behaviors involving cellular telephones as part of a system in which information is being transferred with computers.

Table 4-I. Keyword list used for the data base search

answer,	comput,	laptop,	phon,
auto,*dial,	convers,*on	listen,*on	port,*comput,
beep,	dial,	mac,	port,*phon,
call,*on	facsi,	microcomp,	powerbook,
carfon,	fasci,	minicomp,	receiv,
carphon,	fax,	mob,*phon,	reciev,
carteleph,	fon,	modem	ring,
cell,	handset	modum	speak,*on
celphon,	hang,*up	notebook,	talk,*on
celul,	headset	PC,	teleph,
com,*link,	keyboard	P.C.	tel,*number

Personnel at HSRC were able to obtain large data bases for the years 1989, 1992, 1993, 1994, and for the first part of 1995. Databases of sufficient size were not available for the years 1990 and 1991. Search programs were prepared for each of the latest five available years, they were run, and the narratives containing keywords were retrieved and printed. The printed narratives were then transferred to the author for careful examination. The main reason for studying the most recent five years of data was to determine if there were trends occurring.

Following receipt of the results, all narratives were carefully read to determine whether cellular telephones or connections to cellular telephones (such as when using a fax) were primary contributors to crashes. If so, the narratives were saved. If not, they were discarded. Thereafter, a classification scheme was developed and saved narratives were categorized using the classification scheme.

4.4 Results

Tables 4-2 through 4-6 (see following pages) contain the results for each of the search years. Included for each year are: the size of the database, the number of computer retrievals or hits, the number of saved narratives, and the number of saved narratives by category. Each table contains both the actual number of saved narratives and the "adjusted number," which assumes a data base size of 200,000.

The adjusted number is obtained by multiplying the number of saved narratives by 200,000, then dividing by the actual data base size, and then rounding to the nearest tenth. The adjusted number is used to compare crash occurrences across years. (The reason for using the number 200,000 is that databases for each given year tend to fluctuate around this number. Since number of entries is not necessarily an indication of the total number of crashes, adjustment must be performed.)

It should be mentioned that, in a few of the saved narratives it could not be determined whether the driver or the front seat passenger was involved with the cellular telephone at the time of the crash. These few cases have been entered as one-half of a crash under the assumption that the driver and passenger would be equally likely to be distracted by the cellular telephone. This assumption is conservative, because it is probably more likely that the driver would be using the cellular telephone than the passenger.

Table 4-2. Cellular Telephone Related Crashes by Category for the Year 1995.

Data Base Size: 127,328
Initial Number of Retrievals: 522

Actual Number	No. Adjusted to 200,000	Category
1	1.6	Looking at cellular telephone to determine status or connecting cellular telephone to vehicle
1	1.6	Answering cellular telephone or distracted by ringing cellular telephone
0	0.0	Dialing cellular telephone
7	11.0	Using cellular telephone
1	1.6	Hanging up cellular telephone (not dropped)
4	6.3	Reaching for cellular telephone (not dropped)
4	6.3	Picking up dropped cellular telephone
1	1.6	Pulling off road to use cellular telephone or moving vehicle for better reception of cellular telephone
19	30.0	TOTAL CELLULAR TELEPHONE RELATED
0	0.0	Looking at computer screen or mobile data terminal
1	1.6	Distracted by beeper (pager)

Table 4-3. Cellular Telephone Related Crashes by Category for the Year 1994

Data Base Size: 209347
Initial Number of Retrievals: 782

Actual Number	No. Adjusted to 200,000	Category
0	0.0	Looking at cellular telephone to determine status or connecting cellular telephone to vehicle
1	1.0	Answering cellular telephone or distracted by ringing cellular telephone
3	2.9	Dialing cellular telephone
12.5	11.9	Using cellular telephone
0	0.0	Hanging up cellular telephone (not dropped)
0	0.0	Reaching for cellular telephone (not dropped)
3	2.9	Picking up dropped cellular telephone
1.5	1.4	Pulling off road to use cellular telephone or moving vehicle for better reception of cellular telephone
21	20.1	TOTAL CELLULAR TELEPHONE RELATED
2	1.9	Looking at computer screen or mobile data terminal
1	1.0	Distracted by beeper (pager)

Table 4-4. Cellular Telephone Related Crashes by Category for the Year 1993.

Data Base Size: 192140
Initial Number of Retrievals: 637

Actual Number	No. Adjusted to 200,000	Category
2	2.1	Looking at cellular telephone to determine status or connecting cellular telephone to vehicle
3	3.1	Answering cellular telephone or distracted by ringing cellular telephone
3	3.1	Dialing cellular telephone
5	5.2	Using cellular telephone
3	3.1	Hanging up cellular telephone (not dropped)
4	4.2	Reaching for cellular telephone (not dropped)
2	2.1	Picking up dropped cellular telephone
		Pulling off road to use cellular telephone or moving vehicle for better reception of cellular telephone
22	22.9	TOTAL CELLULAR TELEPHONE RELATED
0	0.0	Looking at computer screen or mobile data terminal
0	0.0	Distracted by beeper (pager)

Table 4-5. Cellular Telephone Related Crashes by Category for the Year 1992.

Data Base Size: 175178
Initial Number of Retrievals: 644

Actual Number	No. Adjusted to 200,000	Category
0	0.0	Looking at cellular telephone to determine status or connecting cellular telephone to vehicle
3	3.4	Answering cellular telephone or distracted by ringing cellular telephone
0	0.0	Dialing cellular telephone
7	8.0	Using cellular telephone
1	1.1	Hanging up cellular telephone (not dropped)
2	2.3	Reaching for cellular telephone (not dropped)
1	1.1	Picking up dropped cellular telephone
0	0.0	Pulling off road to use cellular telephone or moving vehicle for better reception of cellular telephone
14	15.9	TOTAL CELLULAR TELEPHONE RELATED
0	0.0	Looking at computer screen or mobile data terminal
0	0.0	Distracted by beeper (pager)

Table 4-6. Cellular Telephone Related Crashes by Category for the Year 1989.

Data Base Size: 189464
Initial Number of Retrievals: 1307

Actual Number	No. Adjusted to 200,000	Category
0.5	0.5	Looking at cellular telephone to determine status or connecting cellular telephone to vehicle
2	2.1	Answering cellular telephone or distracted by ringing cellular telephone
1	1.1	Dialing cellular telephone
6	6.3	Using cellular telephone
2	2.1	Hanging up cellular telephone (not dropped)
1	1.1	Reaching for cellular telephone (not dropped)
0	0.0	Picking up dropped cellular telephone
0	0.0	Pulling off road to use cellular telephone or moving vehicle for better reception of cellular telephone
12.5	13.2	TOTAL CELLULAR TELEPHONE RELATED
0	0.0	Looking at computer screen or mobile data terminal
0	0.0	Distracted by beeper (pager)

It should also be mentioned that the categories selected do, in some cases, overlap one another. For example, the "answering the cellular telephone" category overlaps the "using the cellular telephone" category. However, each saved narrative has been placed in only one category, based largely on the wording appearing in the reporting officer's narrative. Thus, the categories provided are not necessarily mutually exclusive, but are logically derived from the narratives.

Further analysis was carried out by comparing total adjusted number of cellular telephone related crashes across years. Figure 4-l shows a plot of the data by year. Also included in the figure is a parabolic curve that has been hand-fitted to the data. The curve was obtained by forcing a fit through a value of 13 for 1989, a value of 20 for 1993, and a value of 28 for 1995. These three points then define the parabola whose equation appears in the figure. (It should be emphasized that this is a "fitted" curve, not one obtained by mathematical or statistical optimization.)

Table 4-7 summarizes the actual adjusted number of cellular telephone related crashes by year and then uses the fitted parabolic curve to estimate the number of crashes for future years. A regression line fit, to be described subsequently, has also been used to estimate crashes in future years. Of course, projecting to future years in this way is highly speculative, but it does help to illustrate the likely range of adjusted crashes as cellular telephones become more prevalent.

As just indicated, regression using a linear model was performed on the available data. The results of the regression are presented in Table 4-8 and Figure 4-2. The table shows that the slope of the line, strictly speaking, is not significant (a= 0.05),

Figure 4-1 Plot of Adjusted Number of Cellular Telephone Crashes by Year with Fitted Parabolic Curve.

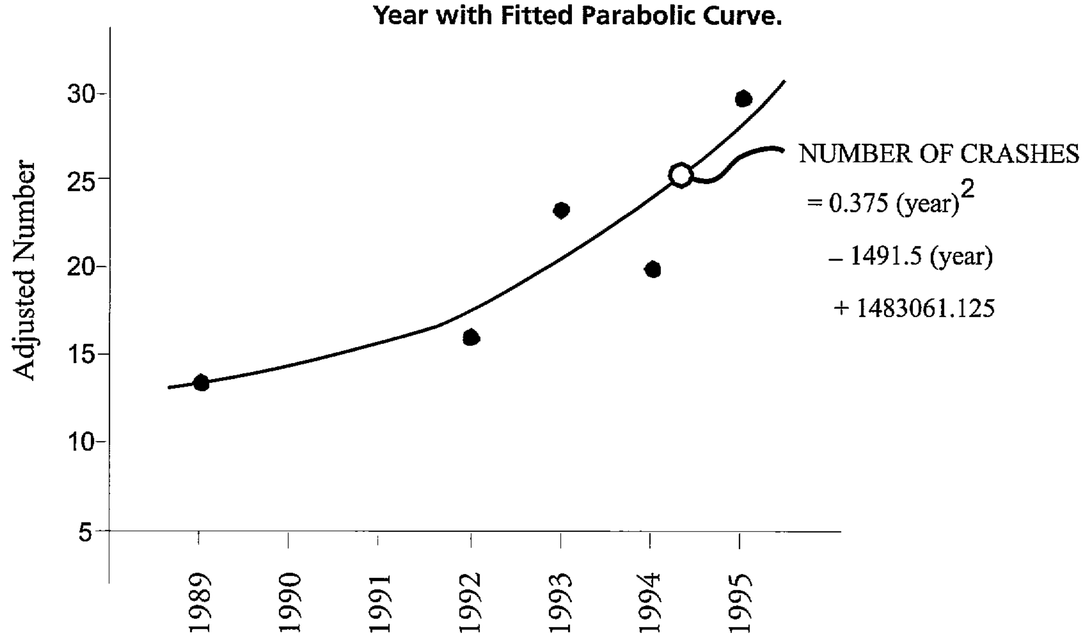


Table 4-7 Actual and Projected Numbers of Adjusted Cellular Telephone Related Crashes by Year.

		ADJUSTED NUMBER	
ACTUAL	YEAR	DATA	
	1989	13.2	
	----	----	
	1992	15.9	
	1993	22.9	
	1994	20.1	
	1995	30.0	
PROJECTED	YEAR	Parabolic Fit	Linear Regression
	1996	33.1	28.5
	1997	39.0	31.0
	1998	45.6	33.5
	1999	53.0	35.9
	2000	61.1	38.4

p= 0.056, assuming a two-tailed test. However, with the accelerated increase in availability of cellular telephones and the consequent influence their use has on visual allocation, as demonstrated in the review of research (see Chapter 5), it is reasonable to assume that an increase in such use will be associated with an increase in related crashes. Thus, if the prior hypothesis is assumed to be that cellular telephone use (over years) would be associated with increased crashes, then a one-tailed (directional) test would be appropriate. For this case $t_{critical}$ is $t_{.05,\,3df} = 2.353$, and the slope is then significantly different from zero ($p < 0.05$). Figure 4-2 shows the plotted data with the regression line superimposed. Also shown are the 95% confidence limits on the regression line. If one chooses to use the regression line to estimate the adjusted number of crashes, its equation is given at the top of the figure and its values are included in Table 4-7.

Another way to view the total adjusted number of cellular telephone related crashes is in comparison with the number of cellular telephones in use (in general) during the same period of time. Such a view gives a more direct indication of whether or not crashes can be expected to increase with cellular telephone prevalence. The Cellular Telecommunications Industry Association (CTIA) provided the following information on the number of cellular telephones in use in the U.S. by year:

1989	3,508,944
1992	11,032,753
1993	16,009,461
1994	24,134,421

Additional information from CTIA indicated that between 1994 and 1995, the number of cellular telephones increased by approximately 9.6 million, leading to an estimate of 33,734,421 for 1995.

Figure 4-2 Plot of Adjusted Number of Cellular Telephone Related Crashes by Year with Regression Line and 95% Confidence Limits on Regression Line

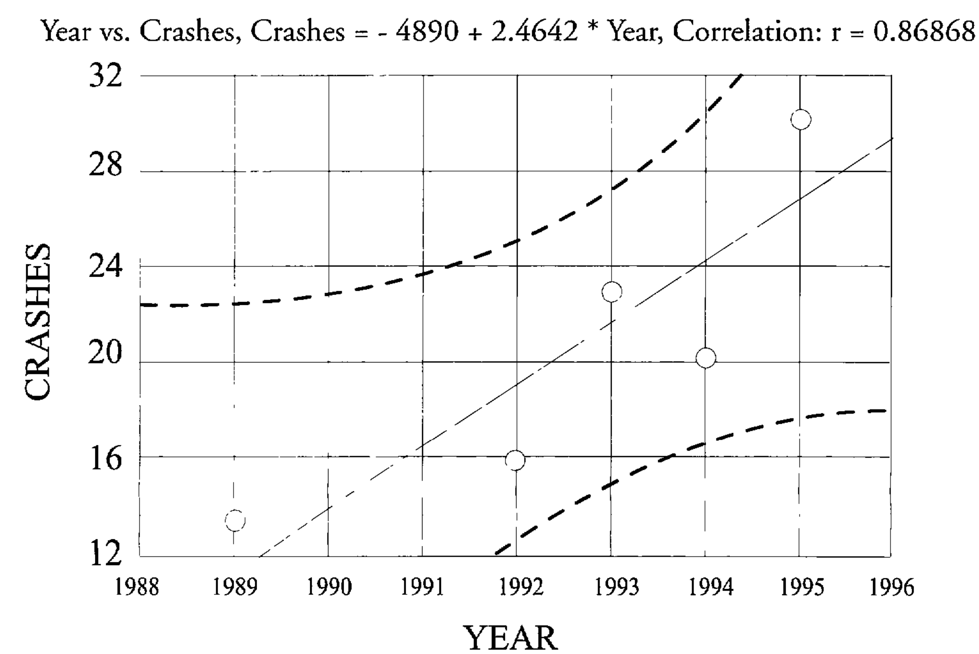


Table 4-8 Linear Regression Summary Performed on the Adjusted Number of Crashes by Year.

Regression Summary
R = 0.86868235 R^2 = 0.75460903 Adjusted R^2 = 0.67281204
F(l, 3) = 9.2254 p< 0.05599 Std. Error of estimate: 3.7354

N=5	Fitted Parameter Estimate B	St. Err. of B	t(3)	p-level
Intercpt	-4889.65	1616.573	-3.02470	0.056548
Slope	2.46	0.811	3.03733	0.055985

Again, using a linear model, a regression analysis was carried out with the adjusted number of cellular telephone related crashes in North Carolina as the dependent variable and the number of cellular telephones in use in the U.S. as the independent variable. The results are presented in Table 4-9 and are plotted with 95% confidence limits in Figure 4-3. The figure also designates each data point by its year and provides the regression equation above the plot. The table shows that the slope of the regression line is significant and the R-value is relatively high.

These results show that the number of cellular telephone related crashes is increasing reliably with their prevalence. However, in observing figure 4-3, if the number of crashes per year is divided by the number of cellular telephones in use during that year, the crashes per cellular telephone in use is seen to be decreasing. (This result is discussed later in the chapter.)

A regression analysis was also carried out with the intercept forced through zero. (It could reasonably be assumed that if there were no cellular telephones in use in the U.S., there would be no crashes resulting from them.) The value of the slope under these conditions was 0.988 North Carolina crashes per million cellular telephones in use in the U.S., and the slope was significant t(4) = 6.501, p< 0.01.

The results show that the number of cellular telephone related crashes is increasing with their prevalence.

4.5 Discussion

The results of the database search and analysis have provided useful information on cellular telephone related crashes. The results suggest that the number of cellular telephone related crashes is increasing with the growing number of cellular telephones in use. However, given the small sample size and large standard errors of estimate, the results must be considered exploratory rather than confirmatory in nature.

Figure 4-3 Adjusted Number of Crashes in North Carolina vs. Number of Cellular Telephones in Use in the U.S. (millions), by Year.

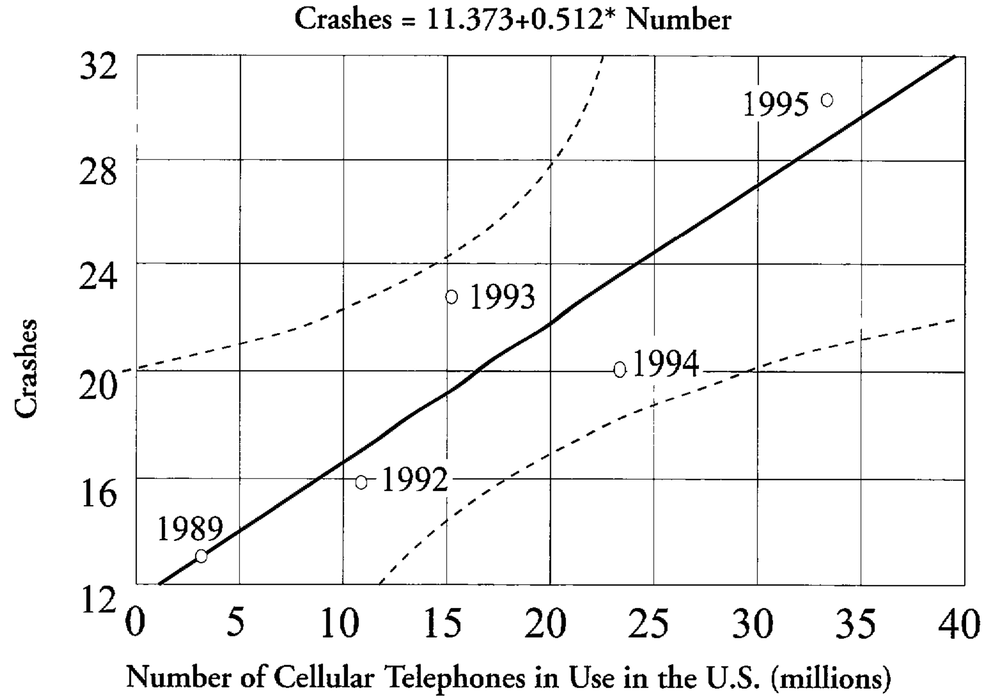


Table 4-9 Linear Regression Summary Performed on the Adjusted Number of Crashes vs. Cellular Telephones in use in the U.S.

Regression Summary
R = 0.91630320 R^2 = 0.83961156 Adjusted R^2 = 0.78614875
F(1, 3) = 15.705 p< 0.02870 Std. Error of estimate: 3.0200

N=5	Fitted Parameter Estimate B	St. Err. of B	t(3)	p-level
Intercpt	11.37265	2.652577	4.287398	0.023322
Slope	0.51161	0.129100	3.962902	0.028699

The study also provides clues as to what specific cellular telephone activities are most likely to cause trouble. For example, reaching for cellular telephones or picking up dropped cellular telephones is a major contributor among relevant crashes. Wierwille and Tijerina (1995) observed a similar trend in an earlier study on in-vehicle visual allocation (see Figure 6- 1, Chapter 6). In particular, reaching for and picking up dropped items resulted in a large number of crashes. They hypothesized that drivers felt compelled to retrieve the dropped items, because of a perceived sense of urgency to do so.

The study also provides clues as to what specific cellular telephone activities are most likely to cause trouble.

In many cases, retrieving the dropped item is not urgent, particularly when compared with the crash risk it entails. Users could be warned about this activity, and taught to wait until it is safe to reach for or to retrieve a dropped handset. The results also suggest that safety benefits would accrue from hands-free dialing and intercom system design features that reduce demands placed on the driver while driving and using the cellular telephone.

The ratio of cellular telephone-related crashes to cellular telephone subscribers is non-constant over the years. In general, it appears to be decreasing in this data set. Due to the sample size, this may simply be due to random variation: the logic of a straight-line fit assumes this. On the other hand, over the period of time covered in the data, there has been a progressive evolution toward hand-held phones, which now constitute the majority of cellular telephones in use. The handhelds are less likely to be reported than mobile phone (installed) units since they are less likely to be seen by police investigating a crash. This would explain the downward trend in the crash involvement ratio that may be derived from the data. Hence, the only legitimate way to understand the true ratio is to secure the cooperation of cellular telephone carriers and check for cellular telephone use during the pre-crash period of every crash that occurs.

Furthermore, a conclusion that cellular telephones are getting safer over time is not warranted based on the currently available data. We know that hand-held cellular telephones represent more than 70% of current cellular telephone phone sales. An examination of the crash data and the case studies shows that nearly all the crashes included in this report involved phones of the hand-held type. This over representation compared to the proportion of hand-held units sold would suggest that drivers using hand-held units may experience a greater risk of crash involvement. The risk may be associated with specific design factors such as the flip top design or the smaller keypad architecture, or it may be related to mounting and accessibility issues. The preponderance of cellular telephone related crashes reported to be associated with responding to a call in the Japanese data, where the use of handhelds is even more widespread than in the United States, lends further credence to this argument.

As an aside, the present study did not uncover a large number of computer-related crashes. There were only two instances of such crashes, both occurring in 1994. Additional instances, including a crash that involved the use of a fax machine, were noted earlier in the discussion of the FARS and NASS data (see Section 3). While the incidence of such crashes is small, it does indicate the willingness of some drivers to use such devices in vehicles while driving.

To the extent that the computer and fax functionality is now being incorporated directly into cellular telephone architectures, there is some concern that such expanded and convenient use beyond voice communication may further compromise safety when these functions are accessed from a moving vehicle. Given the expense of these systems, however, it may be some time before they are generally available at affordable prices. As the availability of laptop computers and various cellular interfaces become more prevalent, however, the likelihood that they will appear as a contributing factor in crash databases might increase. It may be a bit too early for these devices to appear frequently as a contributing factor in the databases at this time.

This study uncovered relatively low numbers of crashes resulting from cellular telephone usage. However, through other, more comprehensive crash analyses it has generally been recognized that driver inattention/distraction is associated with between 30 and 50 percent of crashes (Sussman, Bishop, et al, 1985).

In the Wierwille and Tijerina (1995) study, based on an analysis of the same database, driver inattention/distraction was associated with only about 1.5 percent of crashes. This finding suggests that the reporting of crashes as inattention/distraction related on the North Carolina crash report form greatly underestimates the true incidence of this type of crash. In fact, in addition to the Sussman study cited above, several other sources of data (e.g., Treat, et al, 1977; NASS CDS) suggest that the frequency of such crashes should be substantially greater than was actually found. It is important therefore to review possible reasons why such crashes may be under-reported (or over-reported).

Some of the possible reasons for under-reporting might include:

1. Drivers may attempt to hide their use of cellular telephones at the time that the crash occurred.

2. Drivers may not consider the use of their cellular telephones as relevant and therefore may not mention their use.

3. Investigating officers may not have asked about cellular telephone use or may not have considered cellular telephone use as relevant in crashes.

4. North Carolina does not have a major metropolitan area such as Los Angeles, Atlanta, or Chicago, and therefore the number of cellular telephones in the driving population may have been below average compared with other states. On the other hand, North Carolina does have several medium size metropolitan areas including Charlotte, Winston-Salem, Greensboro, Research Triangle Area, and Wilmington.

5. North Carolina has a large population with incomes that are below average. Those having such incomes may have been less likely to have been cellular telephone users. This might have caused the state to have fewer cellular telephones in use when compared with other states.

6. It is estimated that only about one in two crashes in North Carolina is reported to authorities. The remainder are handled privately and therefore would not appear in crash data bases.

7. Even though the market share for installed car phones has decreased, the absolute numbers of such phones being sold continue to increase each year. This is a consequence of the increased availability of such installations as new car options. Typically, these cellular telephones include hands-free features. It is possible that the incidence of crashes related to installed car phone use is not increasing due to the evolution in installed car phones toward hands free models as well as other improvements to design and installation (e.g., more convenient locations, larger, more readable displays).

8. The greatest increase in cellular telephone sales can be attributed to the introduction of the portable, hand-held (e.g., flip-phone) models. Because these phones can easily be displaced or concealed following a crash, it may be more difficult for police officers to detect the presence of cellular telephones and their possible use as an antecedent to crashes.

Of course there are also reasons why cellular telephone related crashes might be over-reported. They include:

1. Drivers might have attributed crashes to cellular telephone use when in fact there was another cause, such as speeding.
2. Investigating officers might have jumped to the conclusion that cellular telephones were the primary contributor, when some other factor was the primary contributor.
3. As investigating officers may have become more aware that cellular telephones could be causing crashes, they may have over-emphasized them as a cause in their reporting.

4.6 Conclusions

This study has been successful in demonstrating the usefulness of the keyword-narrative search approach as a means of studying crash frequency and type related to cellular telephone use. The results demonstrate that there is an increasing trend in these crashes, and the results also provide information on the types of specific activities that are causing the crashes.

The study did find that the number of reported cellular telephone related crashes is relatively small, considering what might be expected based on anecdotal reporting. In an earlier study using this same database, Wierwille and Tijerina (1995) also found a relatively low number of reported crashes as being inattention/distraction related (as derived from police crash reports).

These findings are in sharp contrast with what would be expected on the basis of detailed crash investigations (1.5 percent vs. 30-50 percent).

The number of reported cellular telephone related crashes is relatively small, considering what might be expected based on anecdotal reporting.

Whether the reported number of crashes is in fact small or is a result of under-reporting remains to be determined.

In 1995 NHTSA's National Automotive Sampling System - Crashworthiness Data System (NASS CDS) began collecting data on precrash inattention/distraction related factors. The 1995 findings indicate that inattention/distraction related crashes account for about 26 percent of tow-away crashes with 0.1 percent of all CDS tow-away crashes attributable to cellular telephones (Wang, Goodman and Knipling, 1996). Although the actual number of relevant crashes for this period is relatively small, the findings are consistent with other data and suggest that under-reporting is the likely explanation for the low numbers in the North Carolina data.

In summary, the findings indicate relatively few cellular telephone related crashes in North Carolina during the period from 1989 through 1995. It has been argued that these data may substantially underestimate the true incidence of these crashes, based on other research that suggests that attention related crashes should occur more frequently than found in the North Carolina data. This suggests the need for improved reporting techniques to better identify and categorize these crashes.

The data indicate the wide range of crash causal factors associated with cellular telephone use.

In addition, the findings suggest an increase in cellular telephone related crash frequency as more cellular telephones become available. Furthermore, as the functionality of cellular telephones is expanded to include more “demanding” tasks (e.g., access to the internet, email, faxing, etc.), there is concern that there will be an associated increase in risk where these services are accessed from a moving vehicle. Finally, the data indicate the wide range of crash causal factors associated with cellular telephone use. While this information may be useful to designers of cellular telephone systems, it also highlights the relative importance of conversation itself as an important causal factor.

Chapter 5

A Review of Human Factors Studies on Cellular Telephone Use While Driving

5.1 Introduction

A number of research investigations have examined driving behavior and performance during cellular telephone use. This chapter provides a review of those studies that have been published and are available in English or were accessible for translation. It organizes them chronologically according to the experimental method used: simulator and test track studies on the one hand, and on-the-road studies on the other hand. In addition, epidemiological and observational investigations are also presented and discussed.

The summaries of each study highlight key aspects and findings of the research. Appendix C contains additional details and critiques for each of the studies mentioned here. See Parkes (1993) and Petica (1993) for other literature reviews on the subject. Before proceeding with this review, some additional comment is in order.

Cellular telephone use while driving can be characterized by the tasks that make up such use. These tasks include the following:

- Accessing the Cellular Telephone — This may involve removing a handset from a 'pod" installed in the vehicle, reaching into a pocket or briefcase to retrieve the phone, or initiating a "hands-free" connection (e.g., answering a call, placing a call).

- Dialing — This may include accessing a directory or stored number and keying in one or more digits.

- Voice Communications Usually relates to dialogue, listening, and talking.

- Associated Tasks — Additional actions the user might carry out in association with Cellular Telephone use (e.g., taking notes, referencing a calendar or a map).

The first task has typically been considered as trivial, especially if the location of the handset is well learned or the unit is of the hands-free variety. However, in a recent Japanese study (see Chapter 3), it was found that 42% of cellular telephone related crashes occurred in response to a call, and involved being startled or distracted by the ring, dropping the phone, or turning to pick up the phone.

While the relevance of these data to crashes in the United States is unclear, the results suggest that receiving a call may have more significance than is readily apparent. The dialing and voice communications tasks have not typically been considered trivial among researchers and these have been the focus of most of the published research in this area.

Dialing and voice communications tasks have been the focus of most of the published research in this area.

Cellular telephone use may also involve associated tasks. These include such activities as accessing written information, taking notes, or examining a map. Such tasks may become more prevalent as the functionality (e.g., faxing, e-mail, paging) of cellular telephones is expanded. In addition, any added functionality to cellular telephones may itself introduce new tasks (e.g., surfing the web, preparing a fax) that go well beyond the distraction potential of dialing or simple voice communication. Given the recency of these developments, however, these tasks and the implications of the expanded functionality have not yet been addressed in the research.

5.2 Research Methodologies

Human factors studies have often made use of driving simulators, closed courses (test tracks), or on-the-road data collection. Therefore, it is appropriate to comment initially on what impact such methods may have on study results.

Driving simulators vary significantly in their attributes. Some simulators offer a compelling visual scene with accurate and effective visual cues while others present a less realistic scene with more impoverished visual cues. Given the primacy of vision in driving, caution must always be exercised since the simulator may provide reduced, less salient, or even misleading visual information compared to that afforded to the driver in the real world. Thus, results may sometimes be an artifact of the simulator's ability to provide the same type or quality of visual information as that normally available to the driver.

Driving simulators may or may not have a motion base. If absent, one may be concerned that the additional kinesthetic or haptic cues present in real world driving may account for some of the effects ascribed in the simulator study to other factors. If such cues are present, one may be concerned that the latency, magnitude, direction, and duration of forces generated by the simulator do not accurately reflect the forces that accompany real world maneuvers or are not in appropriate synchrony with the visual scene. In either case, simulator motion sickness can lead to test participant attrition, particularly among older and female drivers (Green, 1995).

Perhaps the most problematic aspect of all regarding simulator studies is the simulator's effects on driver priorities with regard to the driving task and concurrent cellular telephone tasks. Test participants may react in the simulator differently from how they would react in the real world because there are no serious consequences associated with driving errors in the simulator. As Weimer (1995) points out, "...what are the consequences [in the simulator] if you mow down an old lady in the cross walk or plow head on into a computer generated truck? The consequences in the real world are imprisonment or death, which raises the stakes considerably" (p. 43).

Test participants may react in the simulator differently from how they would react in the real world because there are no serious consequences associated with driving errors in the simulator.

Thus, the willingness to use a cellular telephone and the consequences of such use in a simulator as compared to the real world may be very different. The validity of the reviewed simulator research results may, therefore, be called into question. Recall, for instance, the Prevention Magazine survey data (see Chapter 2) which highlighted the importance of perceived risk as a factor in the willingness of a driver to use a cellular telephone while driving. However, the use of high fidelity simulators such as the National Advanced Driving Simulator (NADS), will greatly enhance our ability to address such concerns.

Closed course or test track studies represent a step closer to real world driving. How big a step depends on the nature of the course and the research protocol used. Extremely short duration runs at relatively low speeds on straightaways without other traffic or obstacles nearby will probably lead drivers to ascribe a level of priority to the driving task not much higher than would be found in a driving simulator.

High speed driving on a test track with other vehicles present, and real consequences (possibility of a crash) for failing to maintain adequate vehicle control, will perhaps lead to more realistic priority given to the driving task. However, the behavior of a driver in a test track or closed course is still likely to be somewhat removed from real-world driving because of the absence (usually) of significant other traffic, pedestrians and cyclists, and much less cluttered environments (signs, intersections, traffic lights, varying roadway geometry).

Neither these comments nor those made about driving simulators are meant to imply that they cannot be used to gather useful information. Each of these methods has a place in highway safety research, particularly as a means to minimize safety hazards in exploratory research. However, one cannot be blind to the limitations of the methods and the need for validation of simulation results by means of on-road studies.

On-the-road studies, as a rule, provide the greatest degree of realism. Typical research procedures involve an instrumented vehicle (not the test participant's own vehicle) and a ride-along experimenter or observer who operates the data capture system, provides instructions to the test participant, and otherwise serves as an extra set of eyes and ears to look out for traffic contingencies and conflicts.

The benefits of on-road studies are that they provide the driver with real driving task demands and priorities.

The benefits of on-road studies are that they provide the driver with real driving task demands and priorities. However, they are far from perfect (Smiley, 19%). There are limits as to what can be done experimentally while on the road. The test participants are usually screened to have good driving records. They are usually driving under conditions where there is no real sense of urgency to get from one place to another as quickly as possible. Perhaps most importantly, the test participants are keenly aware that they are driving an unfamiliar vehicle, with a stranger in the passenger seat, and everything that is going on is being recorded.

Would drivers likely behave differently if alone, in their own vehicles, running late, without their behavior and performance being captured? Probably yes. Would they likely behave in a riskier fashion? Probably yes. The real question is how much riskier would drivers act with regard to cellular telephone use. To capture such data may require "black box" technology installed in a volunteer's own vehicle to randomly sample behavior over a long period of time. However, none of the studies to be described here made use of such a method. Thus, on-the-road studies represent the most realistic, though still imperfect means of studying cellular telephone use while driving.

5.3 Simulator and Closed Course Studies of Cellular Telephone Use

The earliest published study on mobile telephone use and its impact on drivers was that of Brown, Tickner, and Simmonds (1969). They point out that mobile phone use may involve two sources of interference. The first source is the manual-visual demand of dialing. The second source is the attentional demand of the communications task. Brown et al. (1969) focussed on the latter only by simulating a hands-free phone application. A sample of 24 male subjects drove a car on a 1.5-mile closed course without traffic to collect measures on judgments of gap size (possible vs. impossible to clear), number of gaps actually cleared successfully, total course travel time (interpreted as speed), and control inputs (steering and foot controls and associated lateral and longitudinal accelerations).

The telephone communications task was a paced grammatical reasoning task in which the driver heard a short sentence followed by the letters "A" and "B" where each sentence claimed to describe the order of the letter pair that followed. The driver decided whether the sentence was true or false and responded accordingly. Examples are provided below:

Incoming Phone Message:	Driver (Correct) Response
"A follows B . . . BA"	"True"
"B precedes A . . . AB"	"False"

Results indicated that gap judgments were significantly degraded during the communications task and travel speed was reduced. Additionally, concurrent driving was associated with longer decision times for the grammatical reasoning task and more errors relative to performing the grammatical reasoning task alone while the car was parked.

Unfortunately, travel speed was a global measure based on circuit completion time. Thus, it is impossible to tell if drivers drove more slowly throughout the telephoning task or took the additional time driving around incorrectly judged "impossible" gaps. The "intelligence test" nature of the dialogue materials were highly demanding, probably more so than normal cellular telephone conversations.

Finally, there were no other vehicles on the closed course and no serious consequences to making a gap judgment error, factors that might have prompted the test participants to work harder at answering the logic questions than on the driving task. This study demonstrated that driver judgments about gaps could be disrupted by concurrent dialogue of a demanding nature.

Kames (1978) also made use of an instrumented vehicle on a closed course to examine the effects of three types of dials (rotary dial, push-button dial, and push button dial-in-handset) on driving performance and behavior while concurrently dialing. Eighteen (18) test participants drove a 4.4 mile course on a deserted airfield and each worked with six different versions of dials over six different sessions. At predetermined locations, an experimenter asked the test participants to dial a number. Measures taken concurrently included lane position, range of speed, reaction time to a subsidiary task, steering wheel movement rate, range and duration of head movements, and dialing completion times.

In general, results indicated that rotary dials were the slowest with which to work but that other varieties of dial designs and locations (dash-mount, visor area-mount) had relatively minor impacts on driver lane position variability and apparently no significant effects on other measures of driving performance. Drivers nonetheless reported being uncomfortable about dialing while driving.

This study provides evidence that a) drivers can maintain reasonable control over a path control function like lanekeeping while dialing and b) drivers sometimes nevertheless express concern about concurrent dialing and driving. Lanekeeping is a skill-based activity that is more resistant to distraction effects than a perceptual or judgment activity like gap acceptance (McKnight and McKnight, 1991). This would bring this set of results and those of Brown, Tickner, and Simmonds (1969) into harmony. However, the Kames (1978) also suffers from many of the same threats to validity as the Brown et al. (1969) study.

This study demonstrated that driver judgments about gaps could be disrupted by concurrent dialogue of a demanding nature.

Drory (1985) reported a driving simulator study that examined the effects of voice communications on 60 truck driver subjects in the context of a fatigue study. Subjects drove a Redifon light motor vehicle simulator for 7 hours. The voice communication task involved four requests randomly placed during each 15-minute interval via a speaker (again a hands-free simulated device) to ask the driver to report current position by reading aloud the last two digits of the odometer. Measures taken included steering wheel reversals, tracking error, number of brake responses to the appearance of tailgate lights during the simulator run, and average brake reaction time, among others.

Interestingly, this simple voice communications task enhanced performance on all driving measures when compared to driving with no such tasks even though voice communications increased subjective assessments of fatigue.

This study empirically supports the professional driver's intuition that a concurrent task, like voice communications, can break the monotony of driving and help keep the driver awake.

This study empirically supports the professional driver's intuition that a concurrent task, like voice communications, can break the monotony of driving and help keep the driver awake. This study is also somewhat unique in that the test participants were professional heavy truck drivers. This is a population that, compared to the driving public at large, is perhaps more uniform in terms of selection and training, has more extensive driving experience, and perhaps has more experience driving and concurrently engaging in voice communications tasks (e.g., talking on a Citizen's Band or CB radio).

Finally, while the simple communications task had a beneficial effect on these fatigued drivers, such benefits may well not apply to more complex or emotional communications (that may be more distracting) or to non-fatigued drivers.

Stein, Parseghian, and Allen (1987) used a Systems Technology, Inc. (STI) driving simulator to conduct a study, with 72 test participants of both genders and varying ages, of the effects of cellular mobile phone use on driver performance. (See also Department of the California Highway Patrol, 1987).

The STI fixed-base interactive simulator projected a simplified computer-generated image of a two-lane roadway with road signs and a horizon. The car accelerated (as evidenced by forward looming in the visual scene) when the driver pressed the accelerator. The car stopped (as evidenced by an appropriate cessation of flow in the visual scene generator) when the driver pressed the brake pedal. The simulator was configured in a cut-down 1981 Honda Accord car cab with corresponding equations of motion to vary the visual scene based on driver inputs. The steering system provided appropriate visual feedback for the Honda as well as a typical "road feel".

The study examined dialing and voice communications tasks (both listening and talking) effects on driving performance. In addition, the study included a manual radio tuning task, included for comparison purposes because it represented an in-cab task determined to have a socially acceptable level of driver performance decrement.

Subjects dialed by manually keying in a lo-digit phone number plus an enter key, by recalling a number from memory (i.e., pressing "RCL l"), or by a voice command (i.e., lift handset and say "TRAVEL AGENT"). Placing a call, the subject driver heard and was required to memorize specific flight information given by a "travel agent"; this information included airline, flight number, originating airport, and destination.

On an incoming phone call, the driver had to convey the memorized information. Phone location was an independent variable (dash-mounted, console-mounted) and handset vs. hands-free call receiving method was another independent variable.

Dependent or measured variables included primary traffic safety variables (number of crashes and speeding tickets that could be handed to the test participant during the sessions) and safety surrogate measures that indicate an increased probability of crash involvement (lane position, lane position variability, speed control variability, and responses to road signs).

The specific performance measures used by researchers vary considerably. Given that the relevance of such measures may not be clear to all readers, Stein, et al.'s (1987) explanations are given before reviewing study results. Excessive speed can lead to loss of vehicle control so this is a valuable indicator of cellular telephone intrusion into the driving task. Furthermore, speed variability (traveling much faster or slower than prevailing traffic) has safety implications in terms of increased rear-end crash hazard exposure.

Lanekeeping is a predictor of safety involvement because an unintended lane exceedence (i.e., leaving one's lane) increases the possibility of several types of crashes. These include lane change, roadway departure, and opposite direction crashes. Sign recognition and adherence also plays a role in traffic safety, especially if the sign contains safety-relevant regulatory information such as speed limits or warnings.

Results of the study generally indicated that measures of overall safety (crashes and speeding tickets) were infrequent and not attributable to cellular telephone use of any kind.

Results of the study generally indicated that measures of overall safety (crashes and speeding tickets) were infrequently observed and not attributable to cellular telephone use of any kind. Lanekeeping performance was substantially degraded (i.e., lane standard deviation grew) with manual dialing; this effect was greater for a console mounted phone, and the greatest degradation was for older subjects (i.e., 55 years or older).

This pattern of effects held on both straight and curved road segments of the simulator scenario. In addition, obstacle detection was degraded with manual dialing in some instances with middle-age or older drivers. Manual radio tuning was more disruptive of lane keeping than memory-dial and voice-dial, but substantially less so than manual dialing of a lo-digit number.

The authors conclude that with the exception of manual dialing, their study results indicate no significant traffic safety problems. They recommended positioning the cellular telephone as close as possible to the driver's line of sight. They also recommend that both voice recognition and memory dialing should be encouraged, but drivers should be instructed not to refer to a list of memory codes while driving. Limiting the number of button pushes while dialing should be considered for further development.

This study was the first using simulator methodology that investigated both manual dialing and voice communications (both listening and talking) within the same study. The degradation of lane keeping is in contrast to the results of Kames (1978), who found no such effect. This may be due to differences in experimental route difficulty, the nature of the in-vehicle (dialing) tasks, or perhaps a reduced emphasis on the driving task by test participants in the driving simulator.

Unfortunately, the results do not clearly distinguish effects associated with the dialing task and those associated with the ensuing voice communications task. It was reported that middle-age and older drivers had up to between 3 and 5 times the likelihood of hitting an obstacle when receiving a call with a hands-free phone (relative to driving alone), even though actual crashes themselves did not occur.

This might mean that, though the margin of safety was lower than when driving without concurrent voice communications, it was adequate to avoid crashes. Nonetheless, the study does indicate that manual dialing can sometimes be problematic in terms of maintaining safe driving performance.

The study does indicate that manual dialing can sometimes be problematic in terms of maintaining safe driving performance.

Zwahlen, Adams, and Schwartz (1988) conducted two experiments in automobiles on a closed course (an unused airport runway) to investigate the impact of phone dialing on driving. Drivers used a standard (i.e., not a cellular) push-button phone (to simulate a cellular telephone) and manually entered an 11-digit number. The experiment varied phone location (high vs. low on the dash), and whether the driver could look at the road while dialing (allowed vs. not allowed). Also drivers did not correct dialing errors.

An assessment of lane keeping for straight road driving indicated that manual dialing increased lane standard deviations to potentially dangerous levels. Not being able to look at the roadway ahead while dialing was most disruptive; low-mounted phone position was also disruptive to lane keeping, though much less so than the look/no-look manipulation. When averaged across two different vehicles (a compact passenger car and a station wagon), the standard deviation for lane position was 15.4 inches for a 675 foot run. Zwahlen et al. predict that for a 12 foot wide lane this would lead to lane exceedences under ideal conditions (e.g., daylight, dry, straightaway) 11.9 percent of the time at 40 mph.

The manipulation of looking behavior was an attempt to emulate "worst case" driving behavior. This, plus the absence of other traffic or serious consequences for poor lanekeeping may account for the magnitude of effects. Somewhat reassuringly, when the telephone was mounted in the low position, drivers who were permitted to look at the road while dialing did so on 47 out of 50 runs. This compares to looking on only 37 out of 50 runs when the telephone was mounted in the high position, presumably because this position afforded some monitoring of the path via peripheral vision. This suggests that drivers can be sensitive to at least some of the performance-degrading features of telephones in vehicles and attempt to compensate for the degradation.

This suggests that drivers can be sensitive to at least some of the performance-degrading features of telephones in vehicles and attempt to compensate for the degradation.

Boase, Hannigan, and Porter (1988) investigated the effects of talking while using a hands-free phone (again a simulated device) while the driver was engaged in a laboratory computer game of "squash" that the authors claimed (without rigorous justification) to involve some of the same task demand characteristics as driving. Without a rigorous means to tie the computer game to driving demands, the results are judged not directly applicable to driving and so will not be discussed here.

The main telephoning variable was type of dialogue. Informational dialogue (ID) was mostly simple question-and-answer dialogues like making appointments, checking dates, and so on; it was mimicked by asking subjects simple questions like their favorite foods or educational experiences. The negotiation dialogue (ND), uncovered in focus groups with businessmen, involved negotiation and deal-making; this was simulated by having subjects engage in a dialogue such as to return faulty merchandise to a store or to modify an airline itinerary altered by the air carrier. This represents an interesting attempt to use dialogues that might arise naturally in mobile or cellular telephone use.

Alm and Nilsson (1990) conducted a motion-base driving simulator study of the effects of hands-free mobile phone conversation on driver performance as measured by reaction time, lane position, speed level, and Task Load Index (TLX) subjective workload assessments for easy (80 km two-lane rather straight road) and hard (80 km two-lane very curvy road) driving tasks.

The "conversation" was actually the Baddeiey Working Memory Span Test. A number of 3-to-5-word sentences were presented over the phone of the form "X does Y" and the subject had to answer "YES" if it was reasonable or "NO" if not. For example, one sentence might be, "The train bought a newspaper", to which the correct response is "NO"; another sentence might be, "The boy brushed his teeth" to which the correct response is "YES". After 5 sentences, the subject was to recall the last word in each sentence. This telephone task was paced.

Results for 40 test participants were complex but generally indicated that this telephone conversation increased driver brake reaction time and resulted in a reduction in travel speed when the driving task was easy (i.e., mostly straight road segments). It degraded lane position and this was most pronounced when the driving task was hard (i.e., mostly curvy road segments). Finally, subjective workload was always rated higher with telephone conversation. The nature of the conversational materials is such that they are likely to be more cognitively demanding than normal cellular telephone conversations.

The increase in brake reaction time to a visual stimulus presented in the simulator scene during easy routes but no increase during hard (curvy) routes implies that test participants were somewhat sensitive to the primary driving task demands and attempted to manage their attention to the communications task accordingly.

The speed reduction found may represent an attempt by the test participants to reduce the primary driving task demand by slowing things down. However, going substantially slower than the prevailing travel speed is also associated with traffic mishaps, as noted earlier. Thus, this speed reduction, rather than being a safety positive outcome, may actually represent an increase in crash hazard exposure.

The speed reduction found may represent an attempt by the test participants to reduce the primary driving task demand by slowing things down.

Nilsson and Alm (1991) extended the previous study to an older test participant sample by carrying out the same experiment for "easy" road segments, only this time with 20 test participants (equal numbers of males and females) between the ages of 60 and 71 years. The analysis used the previous study data set in combination with the newly acquired data to assess the impact of the voice communications task on elderly test participants.

Results indicated that, compared to younger drivers, the elderly drivers had longer average brake reaction times, showed greater lanekeeping variability during the conversation task, and drove faster than younger drivers while using the telephone. This last finding, the authors note, may be an artifact of the limited perceptual information about speed provided by the driving simulator.

Nilsson (1993) (see also Alm and Nilsson, 1995) then extended the driving simulator investigations to a car following situation. Forty (40) test participants, 20 participants below 60 years of age and 20 participants aged 60 years or older, performed the voice communications task described earlier while simultaneously driving the simulator so as to catch up to and then follow another car. When the lead vehicle brake lights came on, the test participant was to apply the brakes as quickly as possible. When the lead vehicle's right turn signal was turned on, the test participant was to turn on the simulator left turn signal. The speed level was constrained in the simulator so that it was not possible to overtake the lead vehicle.

When compared to driving without the voice communications task, drivers had longer brake reaction times, and headway distance decreased. Older drivers had longer brake reaction times than younger drivers, all else being equal, and older drivers on average allowed greater following distances than did younger drivers.

When compared to driving without the voice communications task, drivers had longer brake reaction times, and headway distance decreased.

Younger drivers on average approached the lead vehicle at an 11.5 km/hr higher closing rate while engaged in the voice communications task than did older drivers. No effects on lanekeeping performance were found. All test participants reported greater subjective workload during the voice communications task than without the voice communications task.

Alm and Nilsson (1995) point out that the failure to increase headway to accommodate increased brake reaction times might be interpreted to mean that test participants were unaware of the impact cellular telephone tasks were having on their ability to react quickly. On the other hand it might also be interpreted to mean that the test participants already believed they had sufficient headway during the telephone task to compensate for any decreased reaction time. Again, because of the extreme nature of "intelligence test" voice communications materials, the relevance of this study to normal cellular telephone communications is unclear.

The driving simulator environment, with its lack of real-world consequences, might also have had subtle effects on test participants so, relative to real world driving, they paid more attention to the intelligence test questions than to the driving task. Finally, because of the limited duration of the testing, it remains to be seen if drivers could learn to modify their driving over time to adapt to cellular telephone use or if a non-paced voice communications task might lead to altogether different outcomes.

M&night and M&night (1993) (see also McKnight and M&night, 1991) conducted a study of cellular telephone use on driver attention using an open-loop simulator that consisted of videotaped road scenes. Because of the simulator's nature, driver inputs had no effect on what was presented on the simulator screen.

The simulator testing included 47 situations to which a driver might ordinarily respond. These situations included vehicles stopping, turning, and entering a motor way; road changes such as lane drops, narrow bridge, and so forth; pedestrians or animals entering the travel lane; route changes; traffic control signals like stop signs and light changes; etc.

As the subject "drove" along the video scene, accelerator pedal use, brake onset, and steering and turn signal use were recorded. The dialing component of the telephone task was to place a call to the subject's home number manually, The conversation component of the telephoning task involved both simple conversations (e.g., gathering demographic information, chit-chat on what the subject did the previous weekend), and complex conversations (i.e., math problems of the form

$$2+3+4+1/2+3+4+6=?$$

or short term memory problems that required the subject to listen to a list of 5 or 6 digits and then answer whether certain digits were in that list).

Complex phone conversations led to the greatest increases in missed events and time to respond, followed by a radio tuning task, with simple phone conversation having the least effect.

Results indicated that complex phone conversations led to the greatest increases in missed events and time to respond, followed by a radio tuning task, with simple phone conversation having the least effect. Placing a call (e.g., dialing home) did not degrade performance any more than simple conversation but delayed responses about the same as complex conversations. The relative increase in chances of a highway traffic situation going unnoticed ranged from about 20 percent for placing a call to 29 percent for complex conversations.

Older drivers were most adversely affected by telephoning in their ability to detect driving situations.

Older drivers (i.e., 50 - 80 yrs) were most adversely affected by telephoning in their ability to detect driving situations. However, time to respond was only affected by age when placing calls.

This study is laudable for being the largest conducted up to that time (150 test participants of both genders and spanning the ages 17 to 80 years). The dialing task of dialing one's own number (probably highly over learned) is likely to be easier than dialing a less familiar key sequence. On the other hand, the paced "intelligence test" nature of the intense conversational materials may be so difficult as to be unrepresentative and generally irrelevant to the interference potential of most calls placed or received while driving.

Furthermore, the high percentages of missed detections would, if encountered in the real world, lead to a veritable epidemic of crashes, yet no such epidemic has yet been reported through either formal or informal means. This suggests caution in interpreting the results as absolutely applying to real world driving.

Serafin, Wen, Paelke, and Green (1993) have reported on a car simulator study of mobile phone usability in terms of features such as manual vs. voice dialing, instrument panel vs. head-up displays (HUD), length of phone number (7 vs. 11 digits) and number familiarity (unfamiliar vs. previously memorized). The communications tasks included loose ends (how many unconnected ends are there in a capital letter), listing (name as many items in a category as possible in a fixed time period, e.g., "a type of furniture") , talking (answer the question, "What did you do last weekend?"), and listening (i.e., listen to a hypothetical situation and answer multiple choice questions about it). Each task lasted about 30 seconds and all test participants were given the same materials.

The driving simulator run simulated a night drive on a single lane, slightly curvy road. The dependent driving measure was standard deviation of lane position. In terms of the driving performance of 12 test participants, lane standard deviation was greater with manual dialing, voice input resulted in less lane position deviation for all drivers, and dialing times were faster for older drivers dialing unfamiliar numbers. The effects of the communications tasks on lane variation were not reported, presumably because none were found. In addition to the manual dialing-induced lane keeping disruption, this study also found that age influenced both driving performance and dialing times.

Pachiaudi and Chapon (1994) reported results of research into cellular telephone use on a car simulator conducted in France. The nature of the car phone communications task was not described but the simulator scenario was a simple route for which drivers were to try to maintain constant speed (either 90 or 130 kph). Of the 17 subjects in the study, only two showed no change in travel speed while telephoning. For nine subjects, telephoning caused them to modify their travel speed (slow down) while for the other subjects, speed control was momentarily lost and this led to increased speed variability or increase in speed without attempts to correct for this. Clearly, such disruption with vehicle control would be of concern on the highway. Less clear is the extent to which drivers would allow such disruptions to occur on the highway.

5.4 On-Road Studies of Cellular Telephone Use While Driving

A number of on-road studies have been conducted that bear upon questions of the effects of cellular telephone use while driving. Hayes, Kurokawa, and Wierwille (1989) studied driving performance while engaged in various instrument panel tasks (including entering a 7-digit number into a telephone keypad) by means of an instrumented vehicle driven on public roads. Twenty-four test participants (I2 males and 12 females grouped into three groups by ages: 18-25, 26-48, and 49-72) each drove four 15-minute runs along a preselected route. During each run, the test participant completed various in-vehicle tasks.

Of particular interest was the manual dialing task. Results indicated that the dialing task took less time to complete than a radio tuning task and demanded fewer glances, regardless of age. This suggests that 7-digit input, using a keypad and mounting location like that reported, is no more time consuming or visually demanding than radio tuning. No vehicle performance measures were reported.

This suggests that 7-digit input, using a keypad and mounting location like that reported, is no more time consuming or visually demanding than radio tuning.

Brookhuis, De Vries, and De Waard (1991) examined the impact of telephone use on driver performance in an instrumented passenger car on the road measured every work day for 3 weeks. Twelve (12) subjects drove while and while not operating a mobile telephone under three driving conditions: light traffic, heavy traffic on an outer belt following a confederate lead vehicle, and driving in city traffic. The dialing component was either manual or hands-free, and the telephone conversation consisted of a 3-minute test, presented over the phone, of a paced serial addition task that was a fairly hard combination of a memory test and an addition test.

Results indicated a variety of interesting patterns. There was a decrease in lane standard deviation while in telephone conversation, particularly while driving on a quiet motor way. Steering wheel amplitudes were substantially higher with manual dialing. There was a decrease in the number of rearview mirror checks during conversation, but only on the quiet motor way.

There was also a statistically significant increase in brake reaction time while telephoning of about 600 milliseconds (ms) to adapt to a slowing lead vehicle and a non-significant increase of about 130 ms to brake for a stopping lead vehicle (i.e., lead vehicle brake lights suddenly come on). However, drivers did not decrease their average travel speed (termed speed coherence in the paper), and this compounded with the greater reaction times could lead to an increase in rear-end collision hazards.

An alternative interpretation, however, is that drivers believed they nonetheless had sufficient headway distances to lead vehicles so as to make slowing down unnecessary. In general, the results of this study show that cognitively intensive cellular telephone communications tasks undertaken while driving may increase driver reaction time to objects and events, and may decrease situational awareness such as that updated by means of mirror sampling.

Drivers appeared in this study to modulate their performance in instances where they thought it safe to do so (e.g., decreased mirror sampling while driving, but only on quiet motor ways, where presumably such a decrease would be more acceptable).

Fairclough, Ashby, Ross, and Parkes (1991) compared cellular telephone use with speaking to a passenger while the driver drove on an open roadway. Driving behavior was measured in terms of route completion time, eye movement behavior, heart rate, and subjective workload assessments.

Both speaking conditions resulted in higher subjective workload assessments and longer route completion times as a consequence of reducing travel speed about 10 percent in the mixed urban and rural route. No differences in driver visual allocations were noted. Heart rate was significantly higher while using a cellular telephone than while speaking to a passenger directly or driving with no speaking. The nature of the communications task was one in which drivers negotiated a predetermined topic, e.g., booking a summer holiday or negotiating a partial exchange deal of a car until they reached a conclusion that was satisfying to them.

This study is interesting in that it suggests that cellular telephone conversations and conversations with a passenger need not be substantially different in terms of their effects on the driver. The speed reduction was relatively small and may have no substantial safety implications. It is not clear that similar results would necessarily arise given emotionally laden conversations, e.g., negotiations with a belligerent caller and potential losses at stake.

This study suggests that cellular telephone conversations and conversations with a passenger need not be substantially different in terms of their effects on the driver.

Parkes (1991) used a set of intelligence tests for conversations conducted over a cellular telephone or with a passenger concurrent with driving. The route involved a mixture of suburban and rural English roads. Results showed that test participants scored significantly lower on the intelligence test items when using the cellular telephone than in the other experimental conditions.

Part of this apparent discrepancy between this study outcome and that reported by Fairclough et al. (1991) is that videotape analysis revealed the experimenter-as-passenger naturally made allowances for traffic movements when administering the test. Such allowances could not be made in the cellular telephone call to a remote office. One suggestion made by Parkes is that an "intelligent answer phone" be developed that can divert, record, and interrupt messages appropriately based on driving circumstances.

Parkes (1993) summarized an on-the-road study in "low complexity driving" using a three-lane motor way with moderate traffic flow. Subjects drove two 2O- minute journeys, one in silence, and one involving four conversations. These communications involved mental arithmetic and memory tasks. Driving behavior was measured in terms of accelerator depression, steering wheel reversals, and travel speed. Subjective workload assessments were collected by means of the Modified Cooper-Harper Scale and the TLX. Finally, global observations by a ride-along experimenter included recordings of the number of lane changes, overtaking behavior, and proportion of time spent in each of the three lanes.

Results indicated no evidence of change in driving behavior during phone conversations. Speed choices, lane occupancy, and accelerator depressions were consistent across all experimental conditions. Subjective workload assessments did reveal an increase in perceived workload.

Results indicated no evidence of change in driving behavior during phone conversations.

The duration of conversations was limited to 2 minutes only, however, and Parkes notes that longer calls might involve a greater demand on driver resources. Furthermore, the driver input and speed measures may simply have not been sensitive to any disruptive effects of the conversations, though perhaps lane keeping measures would have been (had they been taken).

Green, Hoekstra, and Williams (1993) (see also Serafin, Wen, Paelke, and Green, 1993) conducted a small scale on-road study of cellular telephone use and route guidance system use while driving. Eight (8) test participants drove a 1991 Honda Accord station wagon over a 19-turn 35-minute route that included sections of residential neighborhoods, city streets, and expressways.

During the trip, the driver was asked to dial a familiar telephone number and to participate in a simulated cellular telephone conversation. The simulated conversations included: a) a 30-second description (e.g., three options for dining out) to which they had to respond with one choice, b) talking (e.g., describe what they did last weekend), and c) a listing task (e.g., list all the fruits you can in the time allotted).

Differences were found in the standard deviation of steering wheel angle (dialing was more difficult than conversations, which were not significantly different from each other but greater than with driving alone). Differences were also found in standard deviation of throttle position, with throttle position varying most during the talking task and least in dialing. The safety implications of such effects are unclear. No other significant effects were found. This may be an artifact of the small sample size used in the study. Alternatively, it may signify that drivers appropriately prioritized the driving task and generally maintained adequate control over the vehicle.

Tijerina, Kiger, Rockwell, and Tornow (1995a) (see also Tijerina, Kiger, Rockwell, and Tornow, 1995b) carried out an on-road study of heavy vehicle driver workload while engaged in both dialing and voice communications tasks. Sixteen (16) male professional truck drivers between 32 and 60 years of age, accompanied by a ride-along experimenter, drove a conventional tractor with a 53-foot single trailer loaded to a gross weight of approximately 76,000 pounds on non-revenue runs. The routes taken included undivided and divided rural and urban highways, conditions of light (non-rush hour) and heavy (rush hour) traffic density, and both daytime and night/dusk driving conditions.

Driver visual allocation (number of glances, duration of glance and time between glances to various locations), lanekeeping, speed maintenance, and driver steering and pedal inputs were measured. Dialing included 7-digit, lo-digit, and auto-dial (RCL 1) dialing; radio tuning was included as a baseline manual task.

Two types of voice communications materials were also included. "Easy" communications included paced, question-and-answer dialogue where questions related to driver demographics (e.g., "What is your date of birth?"). "Moderate" dialogues consisted of paced question-and-answer dialogue consisting of questions that required some mental arithmetic (e.g., "How much longer can you drive today before you reach your hours of service limit?"). Dialogues were paced to last approximately 1 minute.

Results indicated that 7-digit and lo-digit manual dialing took even more glances on average than radio tuning, and took significantly greater total glance time away from the road than did radio tuning. Steering holds and accelerator holds showed patterns indicative of greater driver inattention during 7-digit and 1O-digit manual dialing and radio tuning than that associated with the auto-dial task.

... 7-digit and IO-digit manual dialing took even more glances on average than radio tuning,

Speed variability was not practically significant and lane variability did not differ substantially among the dialing and radio tuning tasks. However, lane exceedences were found in 27 percent of all manual task trials, compared to only 14 percent of trials where the driver only read a l-line message from a CRT display. This suggests that cellular telephone dialing and manual radio tuning, though not significantly different, can be disruptive of lanekeeping performance, even among professional truck drivers. Note that the greater girth of the semi-tractor-trailer also makes lane exceedences more likely than in a passenger car.

Results obtained during the voice communications tasks indicated that there was no concurrent degradation in lanekeeping or speed maintenance measures during the conversations. However, there was a reduction in mirror sampling during dialogues (approximately 6 percent of time spent mirror sampling, regardless of dialogue type) when compared to driving without dialogues (approximately 12 percent of time spent mirror sampling). This suggests that even a non-visual task like dialogue can affect driver situational awareness such as that maintained by mirror sampling.

This suggests that even a non-visual task like dialogue can affect driver situational awareness such as that maintained by mirror sampling.

Kantowitz, Hanowski, and Tijerina (1996) (see also Hanowski, Kantowitz, and Tijerina, 1995) presented the results of a part-task simulator study that used the same tasks and conversational materials as the Tijerina et al. (1995a) study. Fourteen (14) male commercial truck drivers each drove eight simulator sessions on an STI fixed-base driving simulator mounted in a heavy truck test buck and with equations of motion for the visual scene appropriate to the heavy vehicle. Concurrent with driving, drivers completed the same types of dialing and voice communications tasks as were just described.

There were many differences between the on-road and simulator study results. With regard to manual tasks, for example, mean lane position was closest to lane center for the autodial task and farthest for the radio tuning task in the simulator. Yet on-road data indicated no reliable differences in effects of manual task on mean lane position, lane variability or lane exceedences.

In the simulator study, lane deviations during the manual tasks were smaller in high traffic density than in low, yet no such effects arose on the road. Similarly, during the voice communications tasks, no degradation of lanekeeping or speed maintenance were found on the road. In the simulator, however, this was not wholly the case.

For example, the simulator study found lane exceedences were greater during dialogues of either type than when driving only, yet no significant differences were found between dialogues and baseline driving on the road.

Despite the similarity of tasks, materials, and procedures, numerous differences existed between the simulator study and the on-road study. These differences range from differences in the heavy vehicle cab layout versus that of the test buck, to very different road scene characteristics. This pattern of differences suggests that heavy vehicle drivers in the simulator adopted a more lax attitude toward the driving task, (lanekeeping) perhaps because there is no safety risk associated with degraded lanekeeping.

On the road, the drivers maintained more or less consistent lanekeeping and speed control throughout all phases of the testing, thus providing evidence that they accorded appropriate priorities to the driving task and the cellular telephone tasks.

Briem and Hedman (1995) studied hands-free mobile telephone use by 20 test participants (half of them male and half female) while they engaged in a pursuit tracking task in a laboratory setting. Test participants "drove" for 20 minutes while engaged in three secondary tasks. A "radio" manipulation task required turning on, tuning and listening, and turning off a car radio. "Easy" telephone conversations were 2 minute dialogues about current events. "Difficult" telephone conversations were 2-minute working memory tests similar to those used by Alm and Nilsson (1990). Velocity and acceleration dynamics were applied to the tracking task to simulate firm road and slippery road conditions which test participants tracked half of the time. Obstacle avoidance was also included in the tracking task.

Measured responses were road position (measured as pixels off of the curved line), small and large position deviations, speed, steering wheel movements, and collisions. The pattern of results is complicated but the authors summarize the key findings as follows. On the slippery road condition, radio manipulation led to the greatest deterioration of tracking performance. Male drivers exhibited better control while driving under difficult conditions. The authors concluded that simple conversation with a hands-free phone does not impair performance but that difficult conversations may, particularly under conditions that put heavy demands on the driver's attention and skill. While the results may be intuitively appealing, the limited fidelity of the simulated driving task and the artificial nature of the difficult conversation suggest a need for validation of the findings under more realistic conditions.

5.5 Epidemiological Studies

The advantage of an epidemiological approach to research is that there are fewer experimental artifacts to contaminate the data. Drivers, for example, are assumed to be driving under normal circumstances and are not aware they will be part of a study until after the study period is over.

The authors reported that talking more than 50 minutes per month on the cellular telephone while driving was associated with a 5.59-fold increase in crash risk.

The main disadvantage of epidemiological studies is that such studies cannot establish causal relationships, because many factors that may influence the results are not controlled or even measured. They nevertheless can uncover interesting associations that merit further experimental investigation. Two recent epidemiological studies of cellular phone use and traffic safety are reviewed below.

Violanti & Marshall (1996) used a case-control design and logistic regression techniques to examine the association of cellular telephone use in motor vehicles and traffic crash risk. The amount of time per month spent talking on the cellular telephone along with eighteen other driver inattention factors were examined. Data was obtained from 100 randomly selected drivers involved in crashes within the last two years and compared to that of a control group of 100 randomly selected drivers not involved in crashes within the last ten years.

Groups were matched on the basis of geographic residence. To assess risk, data concerning the frequency of attention diverting driver behaviors and other factors that might influence the association between cellular telephone use and crashes were collected using a mail survey.

The authors reported that talking more than 50 minutes per month on the cellular telephone while driving was associated with a 5.59-fold increase in crash risk. Those users involved in crashes tended to be younger, with less driving experience and more previous crashes than non-crash involved subjects. Crash involved subjects also talked longer and appeared to be engaged in more intense business calls than non-crash involved drivers. The authors conclude that talking on the cellular telephone was associated with an increased risk of a crash.

Violanti and Marshall (1996) discuss a number of limitations to their research. In their subject sample, there were only 7 cellular phone users among the 60 study participants who had a reportable crash and 7 cellular phone users among the control group of 77 study participants who had not had a crash in at least 10 years.

While the researchers report that the power of their statistical testing to reject a false null hypothesis of "no difference" between the case and control group was over 90 percent, they acknowledge that a larger sample of cellular telephone users are needed for validation of their findings. Response bias is mentioned but discounted by virtue of the moderate response rates in both groups (from initial samples of 100 persons in each group) and the finding that non-responders were demographically similar to the responders.

More problematic was the lack of direct evidence that the persons were using a cellular telephone at the time of the crash. The researchers did not ask about this directly for fear of an inappropriate or misleading response. Finally, while they did include 18 reported driver inattention behaviors (e.g., talking with others, lighting cigarette/cigars, drinking beverages while driving), Violanti and Marshall indicate that many other factors that influence driver attention have gone unmeasured. The researchers emphasize that their findings suggest a statistical association and not a causal relationship between cellular telephone use and crashes.

In a later study (to be published - see Appendix E, Violanti, 1997), Violanti analyzes the Oklahoma crash data for the period between 1992 and 1995. For a discussion of the Oklahoma data set see Chapter 3, Section 3.4.

The most recent epidemiological study on the relationship between cellular telephone use and traffic safety is that of Redelmeier and Tibshirani (1997). Because of its unique approach and the unusually high degree of media attention paid to this study, it will be examined in some detail. The editorial prepared by Maclure and Mittleman (1997) on this study will also be referenced.

Redelmeier and Tibshirani studied 699 Toronto drivers who had cellular telephones and who were involved in motor vehicle collisions resulting in substantial property damage but no personal injury. Each person's cellular telephone calls on the day of the collision and during the previous week were analyzed through detailed billing records. The time of each collision was estimated from each subject's statement, police records, and telephone listings made to emergency services.

These collision times were classified as "exact" if information from all three sources was available and consistent or when one source was missing but the remaining two sources were available and consistent. Otherwise, a given collision time was classified as "inexact" and the earliest time given by the different information sources was used.

. ..the risk of a collision was estimated to be between 3.0 and 6.5 times as high within 10 minutes after a cellular telephone call began as when the telephone was not used.

Of the 699 cases analyzed, 231 (33% of the sample) were judged exact and 468 (67% of the sample) were judged inexact. The authors reported that the risk of a collision was estimated to be between 3.0 and 6.5 times as high within 10 minutes after a cellular telephone call began as when the telephone was not used.

Maclure and Mittleman (1997) carried out additional analyses on the same data and confirmed that the risk more than doubled within five minutes after the start of a call.

Three additional findings in the Redelmeier and Tibshirani study were:

a) cellular telephone units that allowed hands-free operation offered no safety advantage,
b) thirty-nine percent of the drivers called emergency services after the collisions, suggesting that a cellular telephone may have advantages in collision notification, and
c) the relative risk of having a crash while using a cellular telephone was estimated to be similar to the hazard associated with driving with a blood alcohol level "at the legal limit."

Now consider some of the details. Redelmeier and Tibshirani themselves point out several limitations to their study. They note that causality cannot be inferred from such a study. By way of example, they mention that emotional stress might lead to both increased cellular telephone use and decreased driving ability, so that individual calls may have nothing to do with increased crash risk. They also list four weaknesses in their study.

- First, only volunteer drivers participated, perhaps leading to underestimates of risk caused by riskier drivers opting out.

- Second, they point out that people vary in their driving behavior from day to day, though Redelmeier and Tibshirani consider the findings hard to explain in terms of such variations because of consistent findings between the whole sample and a subset of 72 subjects who remembered (up to a year later) having driven during both the hazard period and the control period.

- Third, case-crossover analysis does not eliminate all forms of confounding, particularly in regard to temporary conditions, though again, the article's authors believe such factors are unlikely to account for the magnitude of association observed.

- Finally, they point out that collision involvement did not mean the cellular telephone owner was judged "'at fault". This was left unspecified in the article and the authors indicate that perhaps cellular telephone use merely decreases a driver's ability to avoid a collision caused by someone else.

Maclure and Mittleman (1997) point out additional limitations to the study and qualifications to its results. While they applaud the use of the case-crossover design (Maclure was the originator of this approach), they indicate that the use of pilot study subject data to adjust for the "intermittency of driving" (i.e., to account for the fact that some drivers didn't even drive during the control period) was not convincing because of possible unmeasured differences between the pilot subjects and the study subjects.

The study contrasted a time period on the day of the collision with a comparison period on a day preceding the collision.

They have more faith in the analysis of the 72 people who recollected driving during both periods, though they acknowledge that a relative risk result from this group may be an overestimate

Table 5-l Calculation of Relative Risk Metric

	YES	NO	
Phone in Use within l0-minutes on a Crash Day prior to Crash?	13	24	
Phone in Use within 10 minutes on Previous Day?	157	505	
	170	529	= 699

Relative Risk =

No. Cases of Phone in Use on Crash Day but not on Preceding Dav / No. Cases of Phone in Use on Preceding Day but not on Crash Day = 57/24 = 6.5

due to incomplete participation and faulty memory. Maclure and Mittleman indicate that the lack of a safety advantage for hands-free phones may simply be the result of too little statistical power to test for this effect. The risks associated with placing a call, the risk extinction curve over time after a call ends, and the kinds of collisions that are most likely to increase are all in need of future research, they point out.

To these caveats and critiques, the present authors add the following. While Redelmeier and Tibshirani distinguish between exact and inexact collision time estimates, no separate analysis of the 231 exact cases is reported. The distinction between exact and inexact, once made in the report, is analyzed in only one instance, reported in a single phrase without comment on p. 455.

Determining the exact time of a collision is difficult. Contamination across sources (e.g., driver statement is also used in a police record to indicate crash time) may have occurred. The analysis of the 72 people who remembered up to a year or so later that they were driving in both periods is susceptible to memory errors. By any reckoning, the time of collision is subject to numerous sources of error.

Average call length (based on calls placed the week before the collision by this group of subjects) was 2.3 minutes, with 76% lasting 2.0 minutes or less. This suggests a positively skewed distribution with a long right tail, a distribution of mostly short (i.e., less than 2 minute) calls with some calls lasting substantially longer. The importance of this data relates to the fact that the investigators focussed their analysis on 5-minute and lo-minute-long hazard intervals prior to the collision. It is not known if the subject was actually on the cellular telephone at the time of the collision.

The study contrasted a time period on the day of the collision with a comparison period on a day preceding the collision. The authors assert that this approach would identify an increase in risk if there were more telephone calls immediately before a collision than would be expected solely by chance. The key measure that was analyzed is termed “relative risk.”

In other words, relative risk was defined as “the probability of having a collision when using a cellular telephone at any time during a 10-minute interval as compared with the probability of having a collision when not using a cellular telephone at any time during a lo-minute interval.” (p. 456). Quantitatively, relative risk is calculated as follows. The example in Table 5-l is an explanation of the “crude” relative risk assessment given on p.455 of the article, as explained by Redelmeier in a phone interview with one of the present report’s authors.

Presumably, the interpretation is that the baseline risk (not observed or estimated) was the same on the crash day and the preceding day. Therefore, by this line of reasoning, the baseline risk was raised by some multiplier equal to the ratio of the observed cellular telephone uses on the crash days and cellular telephone uses on the preceding days.

Because of the many variables that can affect crash hazard probabilities but that cannot be equated with the case-crossover study design, the authors point out that a causal relationship between cellular telephone use and crashes cannot be drawn. The implication of causality based on relative risk metrics would require very strong assumptions about the equality of baseline risk for each matched-pair in the study on all accounts except cellular telephone use. Such assumptions may not be plausible unless it can be assured that the situation characteristics (traffic situations, driver states, nature of cellular telephone use, etc.) were the same across the two days. The implausibility of this is reflected in the fact that an adjustment factor of 35% was subsequently applied in their analysis because a subject may not have even been driving during the control period.

The comparison of relative risk of a crash associated with cellular telephones and that associated with drivers with blood alcohol levels at the legal limit deserves special mention. While such a comparison may emphasize the potential adverse consequences of using a cellular telephone while driving, it overlooks some important distinctions between the two categories of crashes.

First, no causal link has been established between cellular telephone use and crashes in their study. In contrast, the link between driving while intoxicated and crashes is far more clearly established, both in terms of the nature of the influence on driving and the magnitude of the problem.

Second, it must be recognized that cellular telephone use is a transient behavior, lasting on the average (in this study) 2.3 minutes, with the majority of calls lasting 2 minutes or less. Intoxicated drivers, however, are impaired throughout a trip and thus exposure is likely to be considerably greater. The comparison given in the article would suggest that cellular telephone use, per unit time, is actually much more hazardous than driving in an intoxicated state. This finding does not accord with what one might reasonably expect. Thus, the comparison in crash hazard exposure between cellular telephone use and driving while intoxicated is specious unless more data than provided in the article are brought forth.

With regard to the lack of an apparent safety advantage of hands-free cellular telephones, it should be noted that having such a feature does not mean it was in use at the time of a call. This issue is compounded by the fact that the specific “hands-free” features for a cellular telephone can vary considerably, requiring varying levels of interaction on the part of the driver for both dialing and conversation. Thus, the distinction between the hand-held and hands-free groups in this study are not clear-cut.

Finally, apart from the issue of self selection, a threat to the validity of any conclusions suggested by the Redelmeier and Tibshirani study resides in the nature of the study participants themselves. All 699 subjects were cellular telephone owners who had a crash. But three other groups of drivers might be logically identified for comparison: cellular telephone owners who did not have a crash,

When compared to driving alone, cellular telephone manual dialing can be disruptive of vehicle control activities like lanekeeping and speed maintenance.

non-cellular telephone owners who did have a crash, and non-cellular telephone owners who did not have a crash.

None of these three other groups were considered in the analysis. It is possible that the study participants represent members who are in some sense atypical of the driving population or of cellular telephone owners in general. They may be extreme in the nature of their phone use (e.g., greater frequency of calls, longer calls, more intense dialogue), in their driving style (e.g., more aggressive driving with less margin for error), or even in their human abilities (e.g., less capacity to time-share the driving task and telephoning task). Thus, caution is urged in using the Redelmeier and Tibshirani study results alone to infer that cellular telephone use, in general, is hazardous.

In summary, Redelmeier and Tibshirani's study represents a unique and suggestive investigation of the relationship between cellular telephone use and highway safety. Increasing the current level of understanding of the nature of this relationship awaits future research that helps untangle the many threads of potentially influential factors present in this study.

5.6 Summary and Conclusions

Experimental Studies

Dialing Task - The simulator and test-track studies described in this review deal with many facets of driver behavior and performance while using cellular telephones. With respect to the dialing task, the studies reviewed suggest the following. When compared to driving alone, cellular telephone manual dialing can be disruptive of vehicle control activities like lanekeeping and speed maintenance (Stein *et al.,* 1987; Zwahlen, *et al.,* 1988; Serafin, *et al.,* 1993). However, this disruption does not always appear, especially in closed-course environments (Kames, 1978). Research does suggest that voice dialing reduces risk and therefore may be viewed as a desirable design goal.

Manual dialing is sometimes, but not always, found to be more disruptive than manually tuning a radio (McKnight and McKnight 1991, 1993; Stein, et al., 1987). Subjective assessments by test participants indicate that they are generally aware of the demanding nature of manually dialing a cellular telephone. Many studies report driver behavior that resembles attempts to compensate for such disruptive effects (e.g., by slowing down the vehicle).

Based on the results of the on-road studies of cellular telephone use conducted to date, the following patterns arise. First, on the road, disruptions by manual dialing to lanekeeping or speed maintenance, as compared to manual radio tuning, appear to be small to nonexistent (Hayes, et al., 1989; Green, *et* al., 1993; Tijerina, *et al.,* 1995).

Emotionally laden communication may have a deleterious impact on highway safety that is even greater than that found with cognitively demanding tasks.

On the other hand, data indicate that both manual radio tuning and manual dialing can be disruptive to driving (Tijerina *et al.,* 1995a, 1995b) and crash data indicate radio tuning is associated with crash involvement (Wierwille and Tijerina, 1994). The magnitude of visual attention demand while dialing is sometimes less than that associated with manual radio tuning (Hayes, et al., 1989), though at other times dialing may demand greater numbers of glances and total time that the eyes are off the road (Tijerina, *et al.,* 1995a, 1995b).

Driver situational awareness (as supported by mirror sampling) appears to be reduced (Brookhuis et al., 1991; Tijerina et al., 1995) though some experimental evidence exists that this reduction occurs only under conditions where drivers judge it to be acceptable, i.e., quiet motor ways (Brookhuis et al., 1991).

Cognitively demanding voice communications appear to also increase driver brake reaction times, again indicating a reduction in situation awareness.

Voice Communications - For the voice communications task and its effects on driving, the following can be concluded. On the positive side, voice communications, if sufficiently frequent and simple to perform, appear to enhance driving performance with fatigued drivers (Drory, 1985). Equally important, simple conversations appear to have little impact on lanekeeping and speed maintenance but sometimes affect driver situational awareness (e.g., increased reaction times, reduced mirror sampling).

As a rule, however, the simulator and test track studies that make use of cognitively demanding "intelligence test" conversational materials generally show degradations in lanekeeping, speed maintenance, or headway maintenance (Stein, et al., 1987; Alm and Nilsson, 1990; Nilsson and Alm; 1991; Nilsson, 1993; Serafin, *et al.*, 1993). The impact of such voice communications on perceptual and judgment performance and object and event detection is also negative (e.g., Brown, et al., 1969; McKnight and McKnight, 1991, 1993).

The relationship between the conversational materials used in these studies and the content of normal cellular telephone communications is unknown. Thus, such results may represent worst-case or a typical voice communications. On the other hand, all simulator and test track studies to date have used conversational materials devoid of emotional content.

Emotionally laden communication (e..g, a broker's call to learn that a great deal of money has been lost or a domestic argument) may have a deleterious impact on highway safety that is even greater than that found with cognitively demanding tasks. A better understanding of the nature of actual cellular telephone communications in business and private calls is sorely needed. This characterization would include such factors as call frequency (to both place and receive calls), call duration, call content, and call etiquette. A metric of conversational "difficulty" would also be beneficial, though a fully defensible metric may be as elusive as metrics of reading difficulty have proven to be. Cognitively demanding voice communications appear to also increase driver brake reaction times, again indicating a reduction in situation awareness.

In terms of further conversational effects, it appears that cellular telephone conversation need not be any more demanding than conversation with a passenger (Fairclough, *et al.*, 1991) at least in terms of driver visual allocation of attention. On the other hand, cellular telephone conversations can sometimes be more demanding than passenger conversations because the passenger can accommodate the pace of conversation based on the current driving situation (Parkes, 1991).

Methodological Considerations - If there is a single common threat to the validity of simulator studies and closed course test track studies, it is the demand characteristics of those environments when compared to real world driving. There is currently no way to determine how closely behavior in the simulator or test track would match behavior exhibited on the roadway other than to compare the two sets of results obtained with identical test materials and protocols.

One comparison of on-road study results with those obtained in a part-task simulator using the same dialing and voice communications tasks and materials led to somewhat different results (Hanowski, et al., 1995; Kantowitz, et al., 1996). In general, it appears that in those studies, professional heavy vehicle drivers allowed the driving task to deteriorate more in the simulator than they did on the road. This suggests that the consequences of primary driving task failure on the road provide an incentive to the drivers to maintain consistent performance while driving on public roads. This incentive can be difficult to adequately emulate in the simulator environment.

Conclusions - It appears that manual dialing can be disruptive of both vehicle control performance and situational awareness and judgment performance. The incidence and magnitude of disruption while driving on public roads appear to be less than that encountered in driving simulators or on test tracks, but may nonetheless pose a safety concern. Therefore, designs to streamline the visual-manual demand associated with cellular telephone dialing activities appear warranted.

On road studies indicate that if the voice communications activities have any effects at all, they are on driver situational awareness and not on vehicle control performance *per se.*

It is important to point out that the majority of cellular telephones now in use are hand-held (73% of cellular telephones sold in the U. S. in 1995 were hand-held while for Japan the figure was 94%). This fact has potentially important implications for how cellular telephone use might influence driving behavior and performance since the visual allocation and manual tasks are very different for fixed mount vs. hand-held systems. Since the focus of the published research has been on fured mount systems, care must be exercised in generalizing these results to hand-held.

The manual and visual allocation tasks are very different for the fixed mount vs. hand-held architectures, so there may be significant differences in how they influence driving. For example, fixed mount systems may require considerably more glance time for dialing since the driver may have to look further away from the roadway while accessing the phone keypad.

In contrast, the hand-held allows the drivers to maintain the phone in a position where the roadway can be more easily monitored, although the hand-held may require two hands to dial, in which case steering control may be compromised. In fact, discussions with hand-held users who dial while driving indicated a variety of strategies to cope with this problem. These include holding the phone and dialing with one hand, or removing both hands from the wheel entirely during dialing while securing the wheel with the knees or wrist/forearm. In addition, hand-held telephones may be stored in glove compartments, briefcases, pockets, etc., and may thus require the driver to reach and/or search for the phone.

Finally, hand-held telephones may require that an antenna be extended, and in the case of the "flip-phone," may require additional manipulation. It was noted earlier that 94% of cellular telephones purchased in Japan in 1995 were hand-held and the largest contributor to cellular telephone related crashes in Japan (42%) was associated with responding to a call.

Solutions to some of these concerns may be found in the application of hands-free dialing technology. The conclusions to be drawn from assessments of the effects of hands-free voice communications tasks are less clear. On-road studies indicate that if the voice communications activities have any effects at all, they are on driver situational awareness and not on vehicle control performance *per se.*

The simulator studies that show vehicle control disruption may reflect an experimental artifact, i.e., that drivers do not place as high a priority on the driving task in a simulator as they do on the road. The voice communications dialogue materials that have been used in this line of research often involve "intelligence test" type materials that may represent both extreme and atypical cognitive loads when compared to normal cellular telephone communications. On the other hand, all of these studies used voice communications that were free of emotional content as well. Dialogues that involve substantial degrees of conflict, for example, may be even more disruptive than the cognitively challenging materials typically included in human factors testing.

There is a great need to better understand the characteristics of cellular telephone communications (frequency, duration, content) that normally arise in the real world in order to better understand how best to represent them in future studies. There also appears to be a need to develop better means to maintain or enhance driver situational awareness while driving. This may be accomplished through intelligent transportation

system (ITS) technologies such as the "intelligent answerphone" (Parkes, 1991), driver status monitoring (drowsy driver) or other crash avoidance systems (CAS) that warn the inattentive driver of crash hazards.

Epidemiological Studies

Violante and Marshall (1996) and Redelmeier and Tibshirani (1997) represent epidemiological research that has been carried out on cellular telephone use and traffic safety. While useful as an additional research technique that may complement experimental or observational research, it is necessary to recognize certain limitations to the epidemiological method. For this method to be valid, the case and the control have to be similar in every other way that could impact on crash probability. A statistical association does not necessarily imply a causal relationship.

For example, other factors may correlate with cellular telephone use, such as driver personality or demographic characteristics, driving style, vehicle characteristics, trip characteristics (purpose, location, time of day, type of roadway), and so forth. It may be that such associated characteristics, and not phone use itself, cause the observed statistical relationship. Furthermore, the epidemiological method addresses the general outcome (crashes), but tells us little about why that outcome occurred. If phone use was affecting driver performance, what aspect of performance, and under what conditions?

As Violanti and Marshall were careful to point out, their methods do not even establish whether a cellular telephone was in use at the time of the collision. All that is known is how much the driver tends to use the cellular telephone. If phone use did affect driving, it is not known what aspect of phone use (dialing, talking, etc.) caused the problem, and what aspect of driving performance (lane control, hazard detection, etc.) was degraded and resulted in the collision. There are also other important methodological concerns that must be considered, such as sampling biases.

The most recent epidemiological study on the relationship between cellular telephone use and traffic safety is that of Redelmeier and Tibshirani (1997). They studied 699 Toronto drivers who had cellular telephones and who were involved in motor vehicle collisions resulting in substantial property damage but no personal injury. Each person's cellular telephone calls on the day of the collision and during the previous week were analyzed through detailed billing records.

The time of each collision was estimated from each subject's statement, police records, and telephone listings made to emergency services. The authors reported that the risk of a collision was estimated to be between 3.0 and 6.5 times as high within 10 minutes after a cellular-phone call began as when the telephone was not used. Maclure and Mittleman (1997) carried out additional analyses on the same data and confirmed that the risk more than doubled within five minutes after the start of a call.

Three additional findings in the Redelmeier and Tibshirani study were a) cellular telephone units that allowed hands-free operation offered no safety advantage, b) thirty-nine percent of the drivers called emergency services after the collisions, suggesting that a cellular telephone may have advantages in collision notification, and c) the relative risk of having a crash while using a cellular telephone was estimated to be similar to the hazard associated with driving with a blood alcohol level at the legal limit.

This study is suggestive of a relationship between cellular telephone use and crashes that merits further experimental inquiry, but it has several limitations as well. Self-selection of study participants, variability in driving conditions and driving behavior, and no indication that the cellular telephone users were 'at fault', all limit the definitiveness of the study conclusions. Further, the "relative risk" metric used makes very strong assumptions about the comparability in crash risk between periods where cellular telephone use preceded crash involvement and periods where it did not.

The relationship between cellular telephone use and crashes is made more uncertain in light of the fact that the driver with a cellular telephone may not have been using it at the time of the crash, where the time of the crash is itself estimated and subject to various sources of error, and when a substantial number of study participants may not have even been driving during the "control period."

While Redelmeier and Tibshirani's study involves a number of shortcomings, it nonetheless represents a unique and suggestive investigation of the relationship between cellular telephone use and highway safety. Increasing the current level of understanding of the nature of this relationship awaits future research that helps untangle the many threads of potentially influential factors present in this study.

Chapter 6
Conclusions and Recommendations

6.1 Introduction

This report examines the safety of cellular telephone use while driving by reviewing available data and information, examining crash statistics, performing statistical analysis, and conducting a comprehensive review of relevant published research studies. In this concluding chapter, key findings are summarized and discussed. Recommendations are made in the areas of consumer education, cellular telephone design, future research, and legislation. It is hoped that these initiatives would help ensure that the economic, safety, and convenience benefits of cellular telephones can be maintained within a safety envelope acceptable to both the public and the stakeholders.

6.2 Synopsis of the Findings

Cellular telephone use is rapidly expanding worldwide and are increasingly being used by all age groups for personal communications, while business use continues unabated. Furthermore, the cellular telephone user population is expanding to include a broader representation of socioeconomic groups.

These trends have both positive and negative safety implications. Some new cellular telephone users will place calls while driving, which may lead to greater exposure to cellular telephone-related distractions in the driving population, all else being equal. Driver inattention to the driving task, the key safety-relevant outcome of driver distraction, has been implicated in many traffic crashes (Sussman, Bishop, Hadnick, and Walter, 1985). The distraction potential may be reduced if drivers are aware of the hazards and use their cellular telephones carefully while on the road. Distraction potential can also be reduced by ergonomically sound cellular telephone designs and new Intelligent Transportation System (ITS) technologies that may be capable of compensating for driver distraction by alerting drivers when traffic conflicts or hazards are present.

Distraction potential can be minimized by ergonomically sound cellular phone designs.

The safety benefits of cellular telephones are well recognized as users frequently make calls to report disabled vehicles, accidents, hazardous road conditions, medical emergencies, and crimes in progress. However, the safety benefits are not without drawbacks. For example, some emergency response networks have reported in excess of one hundred "911" calls for the same incident, making the networks unavailable for reporting other emergencies. Furthermore, traffic safety itself may be degraded somewhat if more drivers are distracted while making such calls in hazardous driving situations, e.g., slowed or stop-and-go traffic, and rubbernecking.

Older drivers in general find it more difficult to perform concurrent tasks and process information quickly (Llaneras, Swezey, and Brock, 19%). A cellular telephone, if used while driving, may aggravate age-related problems by introducing a distracting, concurrent task. In addition, older drivers will often find it more challenging to operate cellular telephones that tend toward small displays and controls designed to specifications drawn from a younger population. As reported in

Smith, Meshkati, and Robertson (1993), the older driver is generally known to take steps to minimize driving workload in general (e.g., by driving less, driving more familiar routes, driving more slowly, and anticipating traffic signal changes,). At this time, the cellular telephone use patterns of older drivers are not well documented or understood.

At this time, the cellular phone use patterns of older drivers are not well documented or understood.

Survey results indicate that most people perceive cellular telephone use while driving as distracting, and a sizeable minority report they never use the cellular telephone while driving because it is too risky. This is encouraging because awareness of risk is necessary, though not necessarily sufficient, for prudent risk management. Thus, driver motivations as well as perceptions of the likelihood of a mishap may still promote cellular telephone use while driving. The result may be an increased likelihood of a crash when perceptions are inaccurate and motivations are misguided. In this regard, most of the industry material made available to cellular subscribers urges caution during phone use while driving.

It is reasonable to expect that highway safety crash records should provide definitive data on the role or non-role that cellular telephone use plays in traffic crashes. Unfortunately, only Oklahoma and Minnesota provide police crash report (PCR) forms with data elements that attempt to address cellular telephone use as a pre-crash variable. It is not clear whether the small number of cellular telephone-related crash reports in these and the NHTSA (FARS and NASS) data sources indicate under-reporting or reflect the inherently safe operation and use of the cellular telephone technology.

In an attempt to clarify this situation, a comprehensive analysis of crashes was executed using narrative data derived from police crash reports available in a North Carolina database. The analysis related crash incidence to the number of cellular telephones (as a surrogate for use while driving)[1] reported for each of several years. The models built from that data indicate a statistically reliable increase in crash incidence with increased numbers of cellular telephones over several years.

However, this analysis involved a small amount of data from a single state and required several assumptions that must be validated. Moreover, predictions may suffer if the future differs from the past in terms of substantial changes in product design, patterns of cellular telephone use, distribution of cellular telephone users, availability and use of other services, and so on.

Finally, several reasons are given for the potential of both under-reporting and over-reporting of cellular telephone involvement in the accident narratives that may influence the interpretation and prediction of trends. The analysis provides plausible but inconclusive evidence for a trend toward increased cellular telephone-related traffic mishaps as more and more drivers purchase such products and services.

The literature review of simulator, test track, and on-road studies of cellular telephone use while driving yielded the following findings: manual dialing can be disruptive of both vehicle control performance on the one hand and situational awareness and judgment on the other hand. The incidence and magnitude of vehicle control disruption while driving on public roads appears to be less than that encountered in driving simulators or on test tracks, but may nonetheless pose a safety concern. On-road studies indicate that if

1 The use of number of cellular telephones as a "surrogate" or substitute for use ***while driving,*** assumes that trends in cellular telephone availability are highly correlated with trends in use while driving over time.

hands-free voice communications activities have any detrimental effects, they are on driver situational awareness and not on vehicle control performance.

> **Dialogues that involve substantial degrees of personal involvement may be even more disruptive than the cognitively challenging materials typically included in the human factors research.**

The voice communications dialogue materials that have been used in this line of research often involve "intelligence test" type materials (e.g., mathematical computations) that may represent both extreme and atypical cognitive loads when compared to normal cellular telephone communications. In addition, all of these studies used voice communications that were free of emotional content (e.g., an argument with a spouse). Dialogues that involve substantial degrees of personal involvement may be even more disruptive than the cognitively challenging materials typically included in the human factors research (see Chapter 5).

6.3 Discussion

The impetus for this review was the relatively large number of public, media and congressional inquiries to NHTSA regarding the safety of using cellular telephones while driving. These inquiries were generally motivated by "close calls" experienced or observed by the public or by crashes involving cellular telephone users that were reported by the media.

While there are many sources of driver distraction that have been associated with increased risk of crashes, there has been a noticeable increase in attention to the safety of cellular telephone use while driving. This is not surprising, given the growing population of users and the ease with which such use can be readily identified by other drivers. Thus, it may not be obvious to other drivers if one spills a soda or scolds a child while driving, but the novelty and position of handheld cellular telephones can quickly attract attention, and the relatively long duration of the activity further increases the likelihood that it will be noticed by other drivers.

The consequent magnitude of public attention to cellular telephone use by drivers may therefore not truly reflect a problem of sufficient magnitude to require some form of intervention, but rather the obvious nature of the behavior and associated consequences for driving. While the information and data provided in this report have presented evidence to suggest that use of cellular telephones while driving can increase the risk of crashes from several standpoints, there is little data that would allow one to determine and characterize with precision the magnitude of the problem. The discussion below highlights some of the many issues that have been raised in this report.

Quality of Crash Data

This report highlights, on a number of occasions, the deficiencies in crash data relative to the involvement of cellular telephone use as a contributing or causal factor. The identified deficiencies have underscored not only the lack of focused and rigorous efforts in collecting relevant data, but also the care that must be exercised in interpreting the data, where it is available. Consider, for example, the North Carolina data (see Wierwille, Chapter 4).

For December of 1989, the Cellular Telecommunications Industry Association (CTIA) data indicate there were 3,508,944 cellular customers nationwide. For the same year, 12.5[2] cellular tele-

[2] Note: in a few cases, whether the driver or passenger was using the phone was not clear. For those cases 1/2 crash was entered (see Wierwille, Chapter 4).

phone related crashes were identified in the North Carolina data (13.2 adjusted, Chapter 4). In December 1994 there were 24,134,421 cellular customers, almost a seven fold increase. Extrapolating to 1994 on the basis of industry growth alone, one might expect levels of cellular related crashes to be about 87.5 crashes, all else being equal. However, North Carolina crash data indicate only 21 cellular telephone related crashes in 1994 (20.1 adjusted, Chapter 4), a much smaller, though still practically significant, increase.

This discrepancy highlights the complexity of the issues. There are many possible explanations for these findings. It may be that these crashes are being reported less frequently or are harder to identify than before, that more recent cellular telephones are safer to use, that drivers are learning to use cellular telephones more safely, or that drivers are finding use of cellular telephones so unsafe to use (a characteristic often associated with hand-held phones) that they are simply not using them as often while driving.

In addition, trends in usage, from business to personal, from fixed installations to hand-held, and an emphasis on applications to safety (e.g., reporting congestion, drunk drivers) influence the relative risks associated with using cellular telephones while driving. The trends also highlight the difficulty in defining the magnitude of the problem and in predicting the impact of future trends on the basis of incomplete or limited crash data.

This is illustrated again in Oklahoma (Chapter 3), which is the only state that includes cellular telephone presence and use on its crash reporting forms. Based on the data alone, it would appear that if a vehicle is involved in a crash and has a cellular telephone, there is about a one in ten chance the phone was in use at the time of the crash. However, based on uncertainties in reporting techniques, the data may not be reliable. For example, a vehicle may be reported to have a cellular telephone only if the investigating officer sees it, in which case he would ask the driver or witnesses if it was in use at the time of the crash. If a hand-held cellular telephone was in the vehicle, it would not be reported unless it was visible.

Based on discussions with instructors at the Oklahoma State Police Training Academy, there are no strict guidelines for collecting this information, and it cannot be determined from the data whether a cellular telephone was being used at the time of the crash or was being used to report the crash. Hence, what appears to be an indication of a potential safety problem is likely a consequence of reporting deficiencies.

Cellular Telephone Industry Emphasis on Safety

While limitations in the available data and the fast pace of change in the industry make it difficult to establish whether a problem exists at a level requiring some form of intervention, it is clear that the nature of the tasks imposed by cellular telephone use as well as trends in technology and usage raise many legitimate safety concerns.

As discussed in Chapter 1, some states along with the cellular telephone industry itself have long recognized safety as an issue and have frequently focused their attention on enhancing the safety of cellular telephones through design enhancement and public information.

The cellular telephone industry has frequently focused its attention on enhancing the safety of cellular phones through design enhancement and public information.

The following examples clearly illustrate these points. Durham Radio, Inc., states in one of its ads promoting safety enhancing accessories:

> ***"Using your portable cell phone while driving can be downright dangerous."***

Likewise, the industry as a whole, through CTIA, has frequently demonstrated concern for public safety in the use of its technologies (See Table 6-l).

Similar concerns have also been raised at the state level. The State of California, for example, after an extensive review of the issue in 1987, recommended:

> ***"If possible, dial while the car is not in motion, such as at a traffic light or stop sign."***

Cellular Telephone Safety Benefits

It is often argued that cellular telephones provide so many safety and highway travel benefits (e.g., emergency calls, reporting congestion) that to limit or restrict their use would be counterproductive. There is undoubtedly some truth to this argument. Nonetheless, it is somewhat tempered by the fact that such use is often carried out from a stopped or slowed vehicle (e.g., to report congestion from within a line of slowed traffic) and any restriction on use from a moving vehicle would have a minimal impact on safety or highway travel benefits.

A related issue, pointed out earlier in this report, is that the increasing availability of cellular telephones on the roadway has led to a dramatic increase in duplicate emergency "911" calls. In some localities this situation has resulted in a significant burden on response networks, given available resources. This situation not only may prevent other emergencies from being reported promptly, but such extensive use in these situations may also lead to a substantial increase in

Table 6-l: Cellular Phone Safe Driving Tips (Source: CTIA)

Safe driving is your first priority.
Always buckle up, keep your hands on the wheel and your eyes on the road.

Make sure that your phone is positioned where it is easy to see and easy to reach.
Be familiar with the operation of your phone, so that you're comfortable using it on the road.

Use a hands-free microphone while driving.
Make sure your phone is dealer-installed to get the best possible sound quality.

Use the speed dialing feature to program in frequently called numbers.
Then you can make a call by touching only two or three buttons. Most phones will store up to 99 numbers.

When dialing manually without the speed dialing feature, dial only when stopped.
If you can't stop, or pull over, dial a few digits, then survey traffic before completing the call. (Better yet, have a passenger dial.)

Never take notes while driving.
Pull off the road to jot something down; if it's a phone number, many mobile phones have an electronic scratchpad that allows you to key in a new number while having a conversation.

Let your wireless network's voice mail pick up your calls when it's inconvenient or unsafe to answer the car phone.
You can even use your voice mail to leave yourself reminders.

Be a cellular Samaritan.
Dialing 9-1-1 is a free call for cellular subscribers; use it to report crimes in progress or other potential life-threatening emergencies, accidents or drunk driving.

caller exposure under the inherently more hazardous conditions of stop-and-go traffic, abrupt changes in speed, and reduced lane availability.

In view of the continued growth of the cellular industry, these problems are likely to increase significantly. Government agencies at the federal and state levels are currently exploring the means with which to deal with the multiple reporting issue.

Use of Hands-Free Dialing to Address Safety Concerns

With the evolution of small, hand-held cellular telephones, there has been increasing concern for the ability of a driver to operate a vehicle safely with one hand while holding/manipulating the phone with the other. The tasks of searching for the phone, extending the antenna, accessing the display, dialing or simply holding the phone, along with the potential for dropping the phone have all been associated with increased risk of a crash. In this regard, the introduction of technology that permits hands-free dialing and conversing has been touted as a potential solution to mitigating the safety problems associated with cellular telephone use while driving.

Development of means to address or mitigate the distraction potential of cellular phone conversation appears worthwhile.

Many third party suppliers are now providing conversion kits that allow older, fixed installations and hand-held cellular systems to be modified to hands-free use. The exact nature of a hands-free capability varies considerably, from one button dialing to voice activated control of both dialing and conversation, although the driver typically must take some manual action to initiate a call. Future systems in development even include availability of phone book information using a head-up display projected on the windshield.

It should be noted that foreign laws restricting the use of cellular telephones in vehicles often restrict only the use of hand-held phones and specifically permit hands free operation (see Chapter 1). Similar provisions have been characteristic of domestic attempts at legislation (see Chapter 1 and Appendix A).

While the hands-free approach may at first seem like an obvious solution to cellular telephone related safety problems, it presumes that crashes caused by cellular telephone use result primarily from dialing, from having only one hand on the wheel, or from reaching for, holding or dropping a phone. Although these factors certainly contribute to the crash picture, the data from North Carolina as well as the NASS case studies suggest that conversation itself is the most prevalent single behavior associated with cellular telephone related crashes in the United States.

This is not surprising for several reasons. First, because conversing may take place over minutes while dialing typically takes place over seconds, the greatest exposure occurs while conversing. To put this into perspective, using the CTIA 1995 average call duration of 2.15 minutes, at 65 mph, this would translate to about 2.3 miles of roadway traversed for the average duration of a conversation. While having only one hand on the wheel may influence the ability of the driver to turn or respond appropriately to adverse situations created by use of the cellular telephone, this is not the only factor that would influence the outcome of an evasive maneuver.

Second, cellular conversation may hold drivers attention (cognitive capture) over a more prolonged period, transforming what is typically characterized as a closed loop activity (i.e., driving) to an open loop activity (i.e., lost in thought) where the driver is less likely to respond appropriately to outside events. This phenomenon, though not unique to cellular telephone use, is suggested in some of the case studies reviewed where drivers have drifted off the road or into an adjacent lane.

Third, the emotional (i.e., personal involvement) or critical nature of conversation can be particularly distracting (e.g., a domestic argument, closing a deal, etc.) and is also highlighted in case studies as a causal factor.

Finally, as pointed out earlier, the driver is not fully in control of the conversation since the party at the other end has no way of knowing the traffic situation and can't adapt the conversation accordingly (see discussion below). The Japanese (1996) findings that 42 percent of cellular telephone related crashes occurred in responding to calls, indicates that even a ringing phone can elicit inappropriate responses from some drivers (e.g., startle, or reaching/searching for a phone at an inopportune time), a finding that is consistent with some of the case studies presented in Chapter 3.

Understanding the relative contribution of behaviors associated with cellular telephone use to crashes is important in evaluating the potential for successful intervention, but this is not the whole story. In the discussion of the *Prevention Magazine* survey data (Chapter 2) it was pointed out that the majority of cellular telephone users do not regularly use the phone while driving and many who do, find cellular telephone use as distracting or more distracting than tuning a radio.

Drivers might readily adjust their behavior when the perceived risk changes.

Drivers, however, might readily adjust their behavior when the perceived risk changes, a phenomenon sometimes referred to as risk adaptation or behavioral adaptation (OECD, 1990). Thus, drivers who believe that a system is safer to use or has added safety benefits might adjust their behavior to accomodate the improvement in perceived safety. Where such changes in behavior are not consistent with actual improvements or where the margin of risk is adjusted to accommodate the new (perceived) capabilities, the net outcome may not be as expected.

In some circumstances, then, changes in systems and associated changes in behavior result in outcomes that are inconsistent with the intended goals. Such considerations may also apply to legislative actions. For example, as was pointed out in Chapter 1, Washington State has amended a Senate Bill to permit the use of an "approved" headphone for use with "hands-free wireless communications systems." While such use may facilitate communications, it may also introduce another manual task for the driver - for example, having to reach for and put on a headphone in response to an incoming call. Such an action may itself place the driver at risk.

Within the context of cellular telephones, a transition to hands-free operation will undoubtedly improve the safety for the individual user insofar as it will address the concerns associated with dialing, holding, reaching for, and dropping the phone, as well as steering with one hand. However, if we assume that the population of drivers willing to use the phone while driving now increases substantially because of the touted safety benefits of hands-free operation, individual cellular telephone use and perhaps duration of calls may increase.

To the extent that conversation itself is associated with a higher risk of crashes (relative to manual dialing), the intended safety benefits of hands-free operation may paradoxically increase exposure to distraction-induced crash hazards. Where hands-free architectures are legislatively mandated, such an outcome would likely take place over time. As the population of users transition to hands-free operation, a reduction in cellular telephone crashes would likely take place initially, since the majority of use from vehicles is not currently hands-free. Thus, in the long term, the outcome may be a net increase in total crashes across the population of users. While improving safety for the individual driver, the overall magnitude of the problem may, therefore be increased. This also serves to underscore the need to enhance the safe use of cellular telephones by drivers in a comprehensive way, i.e., by addressing all aspects of cellular telephone use. These points are again raised in the discussion of human factors considerations that follows later in this chapter.

There is a need to enhance the safe use of cellular telephones by drivers in a comprehensive way, i.e., by addressing all aspects of cellular phone use.

Cellular Telephone vs. In-Vehicle Conversation

Comparisons between talking on the cellular telephone and conversing with a passenger in the car have been made frequently. It has been suggested or inferred that cellular telephone conversation is less than or no more disruptive of driving than in-vehicle conversation. However, data does indicate that a passenger in a vehicle can accommodate the conversation to the driving situation (e.g., stop conversing under high demand situations) (Parkes, 1991).

Unlike a caller (or answering machine) on the other end of a cellular telephone line, the passenger can see when the driver needs to focus on driving and can further serve to alert the driver to hazards. This suggests that future ITS technologies may have a potential role in not only alerting the driver to potentially hazardous situations, but also in alerting the individual at the other end of the conversation. Nevertheless, the data presented in Figure 6.1 must be acknowledged. This figure illustrates the distribution of causal factors related to driver inattention found in the North Carolina data for 1989 (Tijerina, et al. 1995). The element "interaction with another person or animal in vehicle" when broken down further indicates that the specific acts of talking, listening, and arguing account for about 38 percent of the 210 incidents reported in the data.

A component of this may involve the act of turning towards and looking at the passenger, a behavior not characteristic of cellular telephone conversation. Hand-held cellular telephones nevertheless sometimes require the driver to change position in order to achieve better reception of the signal and ensure the connection is not lost. Thus, it would appear that the analogy between the two activities is not that straightforward.

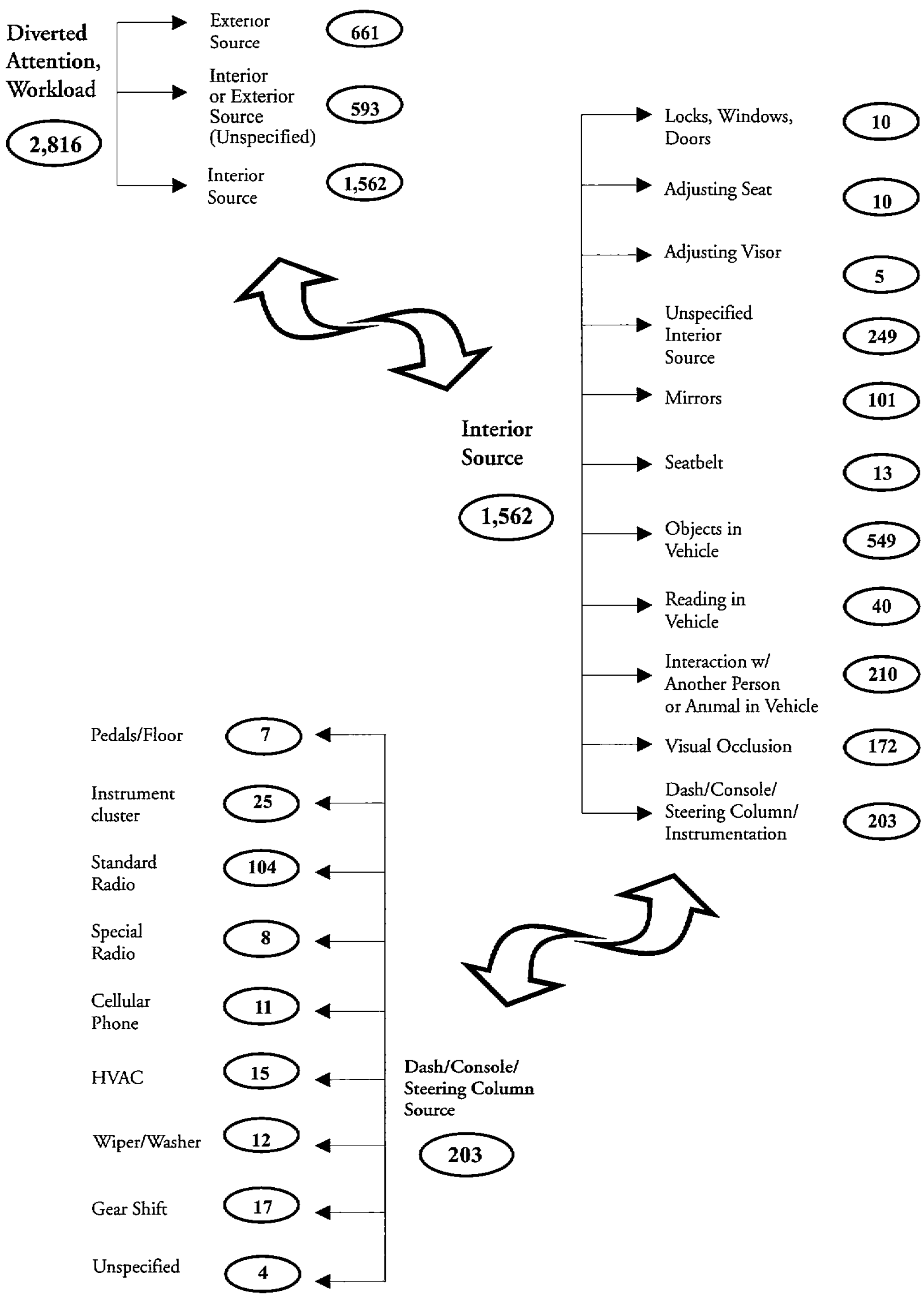
This analysis also serves to highlight the potential risks associated with in-vehicle conversation of any kind, if pursued at inopportune times. Thus, development of means to address or mitigate the distraction potential of cellular telephone conversation, at least, appears worthwhile.

Implications of Future Trends and their Potential Impact on Safety

Over the past several years, there has been a progressive trend towards the integration and merging of function among what has typically been highly disparate technologies. Thus, the functions of voice communications, data communications, paging, automated collision notification (ACN), faxing, e-mail, navigation, vehicle position (Global Positioning System [GPS]), security, and safety have typically been identified by separate and distinct hardware and software components. Increasingly, the technological barriers have been narrowing and this has resulted in multifunctional systems that will provide a wide range of services using a single wireless device. Such an evolution has taken place within the cellular in-

Figure 6-1 - Number of Crashes Distributed by Sources of Attentional Distraction

Broken Down into Interior and into Dash/Console/Steering Column Instrumentation Groups



(Source: Wierwille and Tijerina, 1994)

dustry insofar as remote communications represent a critical element that can support a wide range of function.

Existing capabilities already reflect these trends. By linking cellular communications with fax machines and laptop computers, it is now possible to receive and transmit faxes, receive and send e-mail, and, in fact, "surf the net" from within a vehicle. While we do not have any indication of the extent of such usage, anecdotal information suggests that it is more common than might be expected, given the potential safety implications.

We are beginning to see crashes, such as in the North Carolina data, where drivers were using laptop computers while driving, and third party suppliers are now providing hardware for mounting laptop computers adjacent to the driver or, in some cases, right on the steering wheel (over the airbag) (see Appendix B). In the 1996 (No. 2) issue of Inc. Technology, an article entitled "DWT (Driving While Typing)" describes how "work-on-the-road drivers" are mounting desks within their vehicles to enable them to phone, fax, e-mail, compute, and "put themselves at risk." Although manufacturers of such products warn drivers not to use the systems while the vehicle is in motion, based on observations of other "extreme" driver behavior (e.g., reading, shaving, and brushing teeth) the expectation is that some drivers will use them, regardless of the risk. [Note that some of the steering wheel mounted support brackets will not remain in place during driving when the steering wheel is rotated and thus cannot be used while the vehicle is in motion.]

The evolution of cellular technology is perhaps best dramatized by recent announcements of products now available or on the immediate horizon. The following excerpts illustrate the latest trends.

. ..next year will roll out Internet services for users of GSM [Global System for Mobile communications] based smart phones, offering customized travel and financial information, entertainment and electronic commerce capabilities, magazine titles, and other content . . .

From *PCWEEK,* July 22,1996*

In addition to digital voice capabilities, the unit enables mobile users to send and receive faxes, e-mail, and short messages, as well as access the Internet and corporate and public databases . . . users can maintain a conversation while viewing documents on the screen or launching applications.

From *PCWEEK,* March 25, 1996*

Three Swedish companies are developing wireless data transmission technology that enables mobile users to conduct video conferences and gain high speed access to the Internet while on the road.

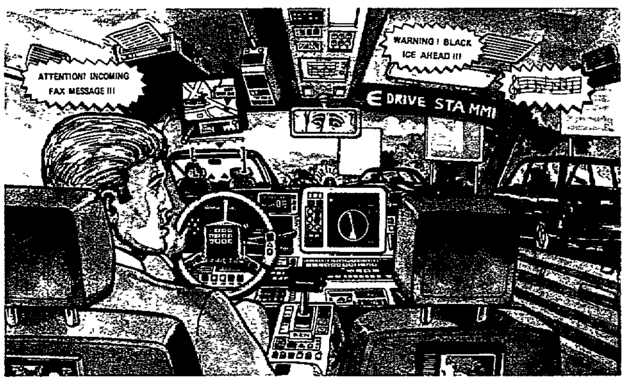
From *PCWEEK*, June 3, 1996*

Other related technologies are also evident.

GOANYWHERE [a modem] combines a packet radio modem and a conventional data/fax modem in a Type 2 PC Card.

From *PCWEEK,* July 22, 1996*

While it is unlikely that current drivers will use the capabilities offered by these integrated technologies to any great degree, given their relatively high projected cost, it may be only a matter of time before such capabilities are generally available at affordable pricing. Furthermore, current trends in the automotive industry, along with efforts supporting Intelligent Transportation System (ITS) initiatives, have highlighted the potential importance of cellular technology to various programs. These include incorporation of portable cellular telephone interfaces in vehicles (to achieve universal hands free operation), automated collision notification (ACN), in-vehicle information systems (IVIS) as well as a host of systems supporting heavy vehicle operations.



Adapted from T. Ross and G. Burnett, "The Right Road to Take," ITS International, June, 1996, prepared under Project V1037 STAMMI (CEC DGXTII DRIVE Programme)

Thus, cellular capabilities may increasingly become integral to both the automobile and commercial truck fleets to support various functions other than voice communication. Such integration with in-vehicle systems and, in particular, crash avoidance technologies, may eventually lead to "intelligent" or "cooperative" systems that are responsive to lapses in driver attention and would provide appropriate warnings or control. Comprehensive efforts at improving highway safety may thus address some of the concerns associated with the use of cellular telephones. Nevertheless, with the addition of new technologies and available services, there will likely be an associated increase in driver workload. Such an increase may itself create new safety concerns and make voice communications even more challenging. NHTSA is particularly concerned about possible synergistec effects of using multiple technologies that may increase workload beyond acceptable levels.

Human Factors (Ergonomic) Design Considerations

In surveying wireless technologies, it became apparent that there were extensive differences between the various wireless communications devices in terms of design features that could influence ease-of-use and safety. These "human factors" aspects of the systems in use go far beyond the issue of hands-free operation and how it is implemented. Rather they encompass specific design considerations related to the display, controls, size, shape, location and other aspects of the systems.

It is suggested here that industry attention to them may offer significant benefits in reducing risk associated with use of cellular telephone systems from a moving vehicle. The trends towards miniaturization (with some future systems projected to weigh as little as 3 ounces), small keypads, miniature displays and increased services, clearly have the potential to place greater demands on the driver using such systems; improvements to design may be capable of reducing such demands.

While the above considerations are very important, they must be viewed within the context of overall safety. As pointed out earlier, enhanced cellular telephone ease-of-use may promote greater frequency of use as a by-product. Current cellular telephone users and limited-use drivers may feel more secure using a hands-free phone over a handheld unit, for instance, and consequently increase their use while driving.

Others who may not be inclined to use a cellular telephone at all from a moving vehicle may now be willing to do so if they believe it is safer. The consequent increase in use among the driving public can therefore increase overall crash hazard exposure. Thus, while hands-free operation reduces or eliminates the demands of manipulation, more drivers may now be engaged in conversation, which has been shown to be distracting in itself. Facilitating use through other improvements to human factors design and implementation of wireless systems may influence exposure similarly. This type of effect has precedents in traffic safety and driver behavior which may be understood in terms of human behavior feedback or behavioral adaptation.

Evans (1991) has written a thoughtful review of driver responses to interventions that might influence traffic safety. Evans addressed such varied systems as crashworthiness enhancements, studded tires, changes in speed limits, anti-lock brakes, and so forth. The review indicated that safety may increase, remain unchanged, or decrease in sometimes perverse ways. Evans concludes that human behavior feedback or reaction to safety systems or safety-related enhancements may greatly alter safety outcomes from what is expected. A general pattern that appears is that safety change effects that noticeably improve vehicle performance will probably increase mobility by way of increased speeds, closer car following, faster cornering, and the like. Safety may also increase, Evans points out, but by less than if there had been no behavioral response.

Ergonomic enhancements to cellular telephone design and implementation may likewise induce a sense of security or safety that is not justified relative to compensatory changes in driving behavior. Thus, there is a legitimate concern that safety benefits from human factors design considerations may be less than expected. This does not mean that such human factors intervention is counterproductive, but rather that such involvement should be comprehensive and include aftermarket evaluations and longitudinal studies to gauge the effects increased ease-of-use has wrought.

The implications of these design issues and the need to understand their potential influence on safety are, in fact, called out in the recommendations that follow. Appendix F presents a taxonomy of human factors considerations that have been identified by the authors as having a potential influence on the ease with which these wireless communication devices can be used.

Secondary Safety Issues that May "Impact" the Driver

In preparing this report it became apparent that there were safety issues that extended beyond the primary concern of the influence of cellular telephone use on the ability of individuals to drive safely. These issues concern crashworthiness related to the position of installed equipment and the use of hand-held cellular telephones within the context of airbag deployment. This is an issue of considerable interest to NHTSA insofar as objects in the path of a deploying airbag can become injurious, potentially lethal projectiles or objects of impact.

In the most extreme cases, laptop computers (often used in conjunction with wireless technology) have been mounted on the steering column directly over the airbag, and have been configured to remain folded open while the vehicle is in motion. While the potential danger of such an installation is obvious, there may be other, less evident installations that pose a similar danger. The public and industry should be sensitized to this issue to ensure that equipment is not positioned to interfere with airbag deployment. These concerns are equally relevant to the holding of a cellular telephone while driving, where the proximity of the phone to the face and head, or placement in front of the steering wheel during use (e.g., for dialing), is also of concern. In this regard, the use of hands-free cellular telephones mounted on the console should be encouraged.

Thus far, there is no data available to suggest that cellular telephones may play a role in airbag related injuries, but this may be a consequence of the relatively small number of cellular telephone related crashes that have been evaluated in depth. The collection of such data is addressed in the recommendations that follow.

Society, New Technology and Perception of Risk

At the beginning of this report a 67-year-old quote (Nicholas Trott, 1930) was provided to illustrate a societal dilemma that has been with us since the Industrial Revolution, that is, the consequent risks to personal safety associated with the use of new technologies. The concerns about the use of the radio while driving, balanced against claimed benefits and comparisons to other in-vehicle distractions, are strikingly similar to what we are faced with today with wireless communications in vehicles.

Interestingly, as indicated in data from North Carolina (Wierwille and Tijerina, 1995, radio use or tuning is a common factor associated with crashes related to in-vehicle distraction, although the true extent of this causal factor at a national level also remains elusive. Nevertheless, while the early concerns have been borne out, at least in principle, there does not appear to be an epidemic of crashes related to operation of the radio. Indeed, drivers appear to be aware of the risks associated with distraction in general, and the survey data (see Chapter 2) clearly suggests drivers will frequently adjust or temper their use of the cellular telephone because of these concerns.

This is not to say that use of the cellular telephone is directly analogous to the radio since, as has been pointed out earlier, there are significant differences. Rather, it highlights an acceptance of some degree of risk associated with the use of technology and the willingness of most drivers to adjust their behavior accordingly. It is when perceptions are inaccurate, motivations are misguided, or the timing of coincident events are inopportune, that drivers appear to run into trouble.

It is when perceptions are inaccurate, motivations are misguided, or the timing of coincident events are inopportune, that drivers appear to run into trouble.

6.4 Conclusions

What conclusions can be drawn, given the data reviewed in this report? The cogency of a conclusion depends on the adequacy of evidence, the degree to which the conclusions drawn logically follow from the evidence, and the degree to which no relevant information has been omitted from consideration. These three points will be considered for each of the following key questions:

- *Does use of cellular telephone technology while driving increase the risk of a crash?*
- *What is the magnitude of the traffic safety problem related to cellular telephone use while driving?*
- *Will crashes likely increase with increasing numbers of users of cellular telephone technology in the fleet?*
- *Wbat are the options for enhancing the safe use of cellular telephones by drivers?*

Does cellular telephone use while driving increase the risk of a crash?

The available evidence is adequate to support the conclusion that the answer to this question is "Yes," at least in isolated cases. The conclusion appears reasonably plausible, particularly in light of the trends in the data, the growing complexity of the technology, and the inherent distraction potential of using such devices from a moving vehicle. What remains unknown is the relative contribution of cellular phone use, per se, and charactertistics of the involved drivers (e.g., less capacity to time-share attention between cellular telephone use and driving tasks, greater propensity for risk taking, fatigue).

What is the magnitude of the traffic safety problem related to cellular telephone use while driving?

The data reviewed here are inconclusive as to the magnitude of the problem. Cellular telephone use while driving is currently inadequately reported in crash records. As a result, the data that could serve as a basis for determining the magnitude of the crash problem do not exist. The lack of data cannot be interpreted to mean that there is no problem of sufficient magnitude to warrant action. The trends in the available data reviewed in this report, the growing complexity of the technology and the sensitivity of political and societal considerations, only serve to reinforce the need to collect more comprehensive and accurate data. In the recommendations that follow various approaches are proposed for enhancing the availability and quality of the data to support a more accurate determination of the magnitude of the problem.

Will crashes likely increase with increasing numbers of cellular telephones in the fleet?

Again, the answer is "Yes", if the North Carolina data and modeling results are any indication. But, the adequacy of that data and modeling results are modest at best. The logical strength of the statistical predictions depends on the representativeness of the data sample to the country as a whole and the adequacy of assumptions behind the model (e.g., national cellular telephone counts are a valid surrogate for frequency of cellular telephone use while driving). Extrapolation from statistical models assumes that the future will be like the past. It is evident that cellular telephone designs are evolving and cellular telephone usage patterns will change over time.

The ultimate impact of these changes on crashes cannot be predicted with great confidence. Thus, the answer to the question is less cogent than the answer given to the first question, and has been duly qualified in this report. Nonetheless, it logically follows that if more cellular telephones are in use, then there will be more opportunity for distraction and, hence, there will likely be an increase in related crashes - unless, of course, changes take place in the technology or its use that mitigates such a trend.

What are the options for enhancing the safe use of cellular telephones by drivers?

People in general are finding it harder and harder to keep up with all of the tasks and activities for which they are responsible. American motorists in particular spend substantial amounts of their day in automobiles, vans, trucks, and buses. It is not surprising that people will attempt to optimize their time in the vehicle by doing other things. It is unrealistic and ill-advised co suppose that drivers should have no advanced in-vehicle information systems at their disposal. Goals, then, should include making in-vehicle information systems, including cellular telephone technology, as compatible with safe driving as the state-of-the-art allows through the application of good engineering and human factors design practice, and educating drivers about potential risks associated with using this technology while driving. This must be done while addressing possible adverse safety implications for the population as a whole.

This report has highlighted a number of potential problem areas and issues. In the sections that follow, these problems and issues are identified and options are presented for responding to them.

6.5 Recommendations

The National Highway Traffic Safety Administration's mission is to save lives, prevent injuries, and reduce traffic-related health care and other economic costs. The Agency develops, promotes, and implements effective educational, engineering (including human factors engineering), and enforcement programs to prevent or mitigate motor vehicle crashes, injuries and fatalities, and reduce associated economic costs. This mission is accomplished through regulation, enforcement, economic incentives, educational programs, basic and applied research, and technology demonstration programs. It is therefore appropriate that this report conclude with a set of recommendations promoting safety when cellular telephone technology is used by drivers. Responsibility for implementing the various options should be shared jointly by various agencies of the federal government, state governments, industry and the private sector, both in the U.S. and worldwide.

It is also important to recognize the ongoing interest and research efforts of government and private institutions both in the U.S. and throughout the world. It is highly recommended that the results of these and future efforts be subject to peer review and shared within professional research forums. This will promote the development of a valid knowledge base.

Improved Data Collection and Reporting

There is clearly inadequate reporting of crashes that may be related to cellular telephone use while driving. To address this inadequacy, two proposals for improved tracking of cellular-phone-related crashes and near-misses are described below. The first would provide for better tracking of crashes. The second would provide one means of characterizing near-miss behavior and its frequency of occurrence.

Crash Data Collection and "Police Crash Reporting" - Only two States currently attempt to record the use of a cellular telephone during a crash on a Statewide and systematic basis. Oklahoma attempts to record both the presence and use of a cellular telephone in relation to a crash. Minnesota records only cellular telephone use as a crash contributor. A more aggressive approach (as described below) should be taken throughout the country to identify and systematically record cellular telephone use as a causal factor in crashes.

As a first step, States and local jurisdictions should be encouraged, as a part of their normal crash investigation process, to implement procedures that would help better identify and describe inattention or distraction-related crashes in general, and cellular telephone-related crashes in particular. It is also recommended that a model approach be developed to achieve uniformity in data collection and a nationally representative data sample.

In this regard, NHTSA and the FHWA are now in the process of developing a minimum standard crash data set. The data elements are expected to exceed those currently contained in Critical Automated Data Reporting Elements (CADRE) and could include one or more elements relating to cellular telephone use. The elements are being developed through a task force of experts from the traffic records community, who have been selected by NHTSA and the FHWA. Once the minimum standard crash data elements are developed, States and local jurisdictions would be free to adopt all or some of the elements, although they will not be required to do so.

It is further recommended that a study be carried out to supplement normal crash reporting with focused data collection in selected jurisdictions. This effort would be designed to provide in-depth information on the possible role of cellular telephone technologies in precipitating crashes. Police officers and crash investigators would be trained to conduct careful inspections of vehicles after crashes, and to probe for phone use during interviews with drivers and witnesses. When it is believed that a cellular telephone may have been in use at the time of the crash, cooperation with the cellular and PCS carriers would be sought for verification.

As a part of its own crash data collection activity, NHTSA has plans to continue to collect "pre-crash factor" information as part of its ongoing Fatal Analysis Reporting System (FARS) and National Automotive Sampling System (NASS) data collection efforts. Because the problem of crash under-reporting is not likely to diminish in the near term, every attempt should be made to supplement crash reporting using other approaches. For example, NHTSA and the FHWA could expand other ongoing research efforts, such as field studies that involve fleets, or NHTSA and the FHWA could include in the telephone surveys that they conduct, questions that address the use of cellular telephones and crash involvement. Respondents might be more candid about their use of a cellular telephone at the time of a crash in an anonymous telephone survey than to law enforcement officials at the crash scene. In this regard, efforts will also continue to address relevant cellular telephone issues in the Motor Vehicle Occupant Safety Survey carried out periodically for NHTSA (see Chapter 3).

Finally, it is recommended that the insurance industry cooperate with NHTSA in information sharing. The insurance industry is in an excellent position to monitor cellular telephone related crashes and preliminary discussions with members of the insurance industry indicate that the industry is already doing so.

Law Enforcement Observations - Members of the law enforcement community have stated that they routinely observe driver actions before issuing citations for speeding and other moving violations. There are instances cited in Chapter 2 when law enforcement officers reported they have pulled cellular telephone users over and issued them a warning because they were observed being inattentive to their driving. Within this context, law enforcement officers should be encouraged to record on the warnings or citations that they issue whether the driver was observed using a cellular telephone. For example, officers could include a notation that there was a "cellular telephone in use" on police warnings and citations for inattention or reckless operation of a vehicle. Specific details regarding such data collection would have to be developed within the constraints of the various jurisdictions involved. This data could be useful to states in assessing the magnitude and nature of the problem.

Information regarding "near misses" or "other distraction indicators" would also be useful to provide a broader perspective on specific behaviors exhibited by drivers using cellular telephones. This work would help determine how drivers compensate when using a cellular telephone (e.g., by slowing down, or increasing headways), and could promote a better understanding of the safety implications of such behaviors.

Improved Consumer Education

Educational materials should be developed and promoted that focus on the various ways that distraction in general, and cellular telephones in particular, can increase the risk of crashes. The intention would be to make these materials available in driver education, licensing and cellular telephone sales facilities, or through companies that provide services or products to cellular telephone users. Such programs could inform drivers of the subtle influences of cellular telephone use while driving (e.g., loss of situational awareness even though lanekeeping is good). The programs could illustrate situations in which cellular telephone use should be avoided or minimized (e.g., high-traffic density, or negotiating intersections or turns).

Appropriate education could even address cellular telephone etiquette that provides coaching on how to politely refuse, postpone, or abruptly halt a conversation when driving conditions demand it. There may be a place in such educational materials to advocate the view that cellular telephone use while driving should be reserved for short calls that are urgent. Lengthier calls should be made while the vehicle is stationary and safely off the roadway. Such materials may also educate the public on product design and implementation considerations when purchasing wireless technologies so as to sensitize the user to features of these devices that will minimize their distraction potential.

Technology Evaluation and Monitoring

Concern has been expressed within the highway safety community regarding the potential safety implications of drivers attempting to use computers, faxes, and multifunction cellular telephones while driving. Such uses have the potential to increase driver workload far beyond acceptable levels and greatly increase the risk of crashes. The exploding market for add-on equipment, such as cellular compatible fax machines and portable personal computers with modem capabilities, along with new multifunction cellular systems, demand periodic, careful, human factors evaluation to better understand their potential for having an adverse influence on driving. Such research should seek to identify design solutions that minimize driver distraction as well.

Improved Cellular Telephone Research and Development

There are several areas of research and development that could be pursued to improve the safety of cellular telephone use. Human factors studies, for example, could be conducted to provide a better understanding of the risks associated with use of cellular telephones while driving. In addition, research and development efforts could result in cellular telephone technology or designs that are more ergonomically sound and safety-conscious.

Behavioral Research - "Naturalistic" Cellular Telephone Conversations - It was mentioned in earlier chapters that human factors studies published to date suffer from a lack of information with which to structure realistic conversational materials. What is needed is research into the duration, content, and placement of personal and business calls while driving. Such information would provide an empirical basis with which to replace "intelligence test" type voice communications test materials of arbitrary length with materials drawn from the real world. Given the indications that voice communications may pose a greater safety hazard in real driving than manual dialing or other manual tasks, it is highly recommended that this research effort be pursued at the earliest opportunity.

Behavioral Research - "Naturalistic" Cellular Telephone Behavior and Performance - One of the major criticisms of existing cellular telephone research is the artificiality of the experimental situations created by research methodologies and hardware constraints. The use of simulators, directed tasks, and presence of experimenters, to name a few, may greatly influence the outcomes of the research.

One way to improve the validity of the data is to instrument cellular telephone users' own vehicles and monitor their behavior over an extended period of time. The data collected would not only help identify the specific behavioral and performance effects of accessing the phone, dialing, conversing, and responding to calls, but would also allow identification of "incidents" or "near misses" involving the use of the cellular telephone as well as allow an evaluation of different designs and configurations in a realistic, in-situ setting. Because of the importance of such research to all parties, it is highly recommended that it be pursued in the immediate future.

Design Research - Intelligent Answerphone - Parkes (1993) introduced the concept of an "intelligent answerphone" into the literature of cellular telephone ergonomics. Such a system would divert, record, and interrupt messages appropriately based on sensed driving conditions. The development of such a system goes far beyond anything the cellular telephone industry has marketed or reported on to date. It nonetheless is a laudable design goal and is compatible with evolving technologies and concepts that are part of the Intelligent Transportation System (ITS) initiative.

Design Research - Workload Reducing Features for Cellular Telephone Design - Some types of cellular telephones appear easier or harder to use while driving than others based upon size, shape, configuration, visual display quality, location in the vehicle, and optional features such as speed dialing. Continuing movement towards miniaturization has the potential to place an input-output burden on drivers through the use of small keypads, multi-line displays (i.e., small text) and various presentation formats (e.g., text scrolling). (see Appendix F)

Cellular telephones have attributes very similar to many emerging Intelligent Transportation System (ITS) technologies. As all these technologies are implemented, it will be necessary to ensure that designs and implementation strategies are optimized to minimize driver workload and distraction. It is thus recommended that design features and operational characteristics be identified that promote safe use of cellular telephones when used alone or along with ITS and other in-vehicle technologies.

It is recommended that these studies employ instrumented vehicles (e.g., DASCAR, Micro-DAS - NHTSA's suite of in-vehicle instrumentation for crash avoidance research) and high fidelity simulators (e.g., NADs) to collect measures such as those described in NHTSA's workload evaluation protocol document (Tijerina, *et al.*, 1995) to identify safer design features, methods of implementation, and strategies for use. This information would be very useful for designers of cellular telephone systems and purchasers of such systems and could be used to support development of educational programs and literature.

Design Research - Cellular Telephone Technology and Intelligent Transportation Systems: Integrated Systems Research - In addition to the Intelligent Answerphone concept, it is recommended that cellular telephone technology be more fully and explicitly integrated with other aspects of Intelligent Transportation Systems (ITS). For example, cellular telephone technology, when used in conjunction with crash avoidance system (CAS) technology may promote greater levels of driver comfort, satisfaction, and safety, On the other hand, CAS technology, route guidance systems, and cellular telephone technology all together may create unacceptably high levels of driver stress or distraction unless integrated to minimize such effects. The vehicles of the 21st century will likely be substantially more sophisticated than those of the 20th century. A focus on driver-centered and safety-conscious design should promote the best possible technological evolution.

Crashworthiness Considerations in Cellular Telephone Placement

Although installed "mobile" or "car phones" generally are placed in the center console, next to the driver, the majority of cellular telephones are hand-held units that are sometimes placed in mounting brackets. These brackets may be located on the instrument panel, floorboard, or windshield. In addition, manufacturers have developed floor-, steering wheel-, and console-mounted desk-type devices that are used for mounting or supporting computers, fax machines, and other in-vehicle equipment that can be interfaced with a cellular telephone.

The size and placement of these support devices can sometimes interfere with vehicle safety equipment such as airbags. The devices may also contribute to driver injury by becoming projectiles during a crash. Therefore, it is recommended that educational campaigns be initiated for users, installers, and manufacturers to point out the possible hazards of inappropriate placement. Furthermore, educational programs should underscore the fact that placement of such equipment in a manner that interferes with the operation of federally required safety equipment is not only ill-advised, but may be illegal.

Emergency Medical Services

Emergency service facilities can be overwhelmed when multiple calls are received for the same incident (sometimes exceeding 100 calls). This can delay timely notification regarding other emergencies. It is thus recommended that appropriate state and federal agencies, representatives of the Cellular Telecommunications Industry Association (CTIA) and other wireless associations, as well as other national organizations representing EMS, examine and evaluate potential solutions to this problem. It is highly likely that this problem will be exacerbated by the predicted increase in cellular telephone subscriptions into the next century. Discussions with the cellular industry regarding this issue already have been initiated and cooperative efforts currently are under way.

A number of states have developed specific emergency phone numbers to be used exclusively by cellular subscribers. Examples include "#77" and "*FTP", which are intended to be used to report highway emergencies. It is recommended that a nationwide standard emergency number be created so that travelers would always have access to a unique cellular telephone emergency number regardless of their location. The Federal Communications Commission (FCC) has taken a first step toward this goal by the adoption of rulemaking to link cellular emergency calls to the existing 911 landline responders. With the cooperation of the states, and the cellular telecommunications industry, it should be possible to have new cellular telephones preprogrammed so that the driver would only have to press a designated button to summon help anywhere in the U.S.

Enforcement and Legislative Options

Laws limiting the use of cellular telephones while driving have been enacted in a number of countries throughout the world. It is unlawful to drive recklessly in every State in the United States and, in a number of states, laws specifically prohibit careless or inattentive driving. While attempts have been made to enact laws limiting the use of cellular telephones while driving in some States in the U.S., none thus far has been successful. (In Washington state, however, the motor vehicle code (Title 46, Chapter 46.37) was amended to specifically permit use of "approved" headphones by motorists "using hands-free, wireless communications systems," which may be viewed as promoting the use of hands-free cellular telephones and prohibiting the use of hand held or other unapproved systems.)

States are encouraged to actively enforce their reckless and inattentive driving laws and states without inattentive driving laws should consider enacting such provisions. When law enforcement officers observe reckless or inattentive driving that is associated with the use of cellular telephones, this should be noted in the officer's report or on the citation. Similarly, where a crash occurs, it should be noted on the police crash report whether a cellular telephone was in use during or prior to the crash. This information could be useful in allowing states to assess the magnitude and nature of the problem of cellular telephone use by drivers.

Legislative proposals that have been introduced in the States have focused primarily on prohibiting the use of cellular telephones that require drivers to use their hands to operate or hold the phone. These proposals generally permit the use of hands-free models. The outcome of any restrictions or limitations, however, may not be as clear-cut as initially believed. For example, these legislative initiatives seem to be based on the assumption that hands-free cellular telephones phones are acceptable while driving, but hand-held phones are not. Properly implemented, hands-free designs should reduce the distractions associated with dialing, holding, reaching for, or picking up a dropped handset and allow the driver to keep both hands on the wheel. However, hands-free phones do nothing to mitigate the distraction potential of cellular telephone conversation.

Proposed legislation that prohibits only the use of hand held cellular telephones may, in fact, promote cellular telephone use (e.g., drivers may use their phone more frequently and for a longer duration) among limited users and non-users by suggesting that hands free use is safe. This could potentially increase "exposure" to any safety hazards that may exist. Thus, paradoxically, the outcome of legislation specifying hands free only usage, may be an increase in cellular telephone related crashes to the extent that conversation itself is a causal factor in crashes, a finding supported by this study[1].

Considering the inconclusive nature of empirical evidence reviewed in this report on the magnitude of the cellular telephone-related highway safety problem, existing legislative initiatives may thus be inappropriate on technical grounds alone. For this reason, it is important to supplement any legislation with adequate data collection to monitor the impact of the legislation on relevant crashes.

Given the widespread implementation of foreign laws restricting the use of cellular telephones in moving motor vehicles, every effort should be made to examine the effectiveness of these laws, not only in terms of crashes, but also in terms of the influence such laws have had on the behavior of drivers in their choice and use of wireless technology. While the extent to which these laws have been or are being evaluated is unknown, it would be beneficial to identify any such efforts.

An effort should be initiated to examine the cost-benefit tradeoffs of legislative actions related to cellular telephone use while driving. Potential costs of unrestricted cellular telephone use may include those associated with distraction-induced crashes and degraded driving performance. Benefits of unrestricted cellular telephone use include more efficient use of commuting time, emergency service notification capability, and the conveniences attendant to closer communications with family, business, and community.

Costs of legislative restrictions may include more expensive sophisticated cellular equipment, restricted access while driving to otherwise desirable

[1] The time to transition from hand-held to hands-free equipment, should proposed legislation be enacted (allowing use of hands-free cellular while driving), must be considered in any evaluation of effectiveness. This transition time may be quite short if, for example, the wireless industry provides hands-free units (or modification kits) at little or no cost to the subscriber in an effort to maximize revenues. On the other hand, if the industry does not respond to such legislation in this manner, the transition period may be somewhat lengthier. During this time, the incidence of cellular telephone use while driving would likely decrease substantially assuming drivers follow the law. Any study that attempted to assess the benefits of such laws on highway safety would have to carefully adjust for this effect. That is, such a study would have to take into account the transition time effect (in which substantial numbers of drivers would stop using their hand-held cellular telephone altogether while driving) as distinct from the effect if implementing hands-free wireless technology (in which drivers are using hands-free cellular telephones as much or perhaps more than hand-held devices).

features, unforeseen secondary consequences (e.g., increased exposure to other safety hazards), and enforcement costs. Potential benefits of empirically grounded legislation would include savings in personal injury, property damage, and crash-caused congestion (delay) costs. An effort to codify and represent the costs and benefits of alternative legislative actions would support more informed decision making.

In view of the complexity of the issues discussed above, it is recommended that in considering legislation, states be encouraged to base their deliberations on all available research studies, empirical observations and data that are available to them, particularly with regard to the dynamic nature of the technology and the manner in which it is used. Only when such considerations are carefully evaluated can we be assured that the outcomes will be as intended.

1 MAKING-A BIG IMPACT ON THE DRIVING PUBLIC

Yes, it's the PowerDesk, the incredibly safe invention designed to let computer owners use their laptops while seated at the wheel of their car.

Sure, you're only supposed to use it when you're safely parked, warns manufacturer Ingenious Technologies.

Speaking as a person who witnessed his college professor reading a newspaper while roaring along Interstate 95, it occurs to me some Type A executive will soon be using the PowerDesk as he barrels down the Major Deegan.

Pray he isn't in the car behind yours.

On his behalf, you should also pray that he doesn't have a driver's side air bag, whether he's on the road or in the McDonald's parking lot.

One ill-timed tap on the front bumper and that laptop will . . . Let's just say they'll need two ambulances to rake him to the hospital.

(c) New York Daily News, L.P., March 30, 1997, reprinted with permission

Acknowledgments

This report was prepared under contract DTNH22-92-D-07002 sponsored by the National Highway Traffic Safety Administration, U.S. Department of Transportation.

Authors

Michael Goodman, Ph.D., The NHTSA Contracting Officer's Technical Representative and Project Technical Director

Frances D. Bents, Vice President and General Manager for Research, Science and Technology, Dynamic Science, Inc. (DSI), Principal Investigator

Louis Tijerina, Ph.D., Transportation Research Center

Walter Wierwille, Ph.D., Virginia Tech

Neil Lerner, Ph.D., COMSIS Corporation[1]

Denise Benel, COMSIS Corporation[1]

. . .

Many individuals and organizations contributed time and talent in the preparation of this document. Louise Woodruff of DSI provided administrative support including typing, layout and design, and graphic production. Mr. Robert Schaar and Mr. Daniel Katz conducted the focus groups and analyzed the responses. Mr. Schaar also performed the market survey.

COMSIS Corporation served as subcontractor for this project. Mr. Geoffrey Steinberg and Ms. Debra Dekker of COMSIS Corporation contributed to the critical analysis of the human factors literature. The Project Technical Director and Principal Investigator would like to especially thank Dr. Louis Tijerina, for his thoughtful review and comments including his significant contributions to the critical analysis of the human factors literature as well as to the conclusions and recommendations. Dr.Walter Wierwille, using information provided by the Highway Safety Research Center in North Carolina, is acknowledged for his innovative analysis of the trends in cellular telephone usage and crash involvement. Dr. Donald Reinfurt and Eric Rodgman, of the North Carolina Highway Safety Research Center are acknowledged for assembling relevant data to support Dr. Wierwille's analysis.

The NHTSA Office of Chief Counsel and in particular, Ms. Heidi Coleman are acknowledged for their insightful comments and assistance in the legislative area. Mr.Yukio Shiosaka was helpful in translating and interpreting the results of the Japanese National Police study. Ms. Ellie Sylvan of Mobile Mark Communications Antennas provided information on European laws.

The Cellular Telecommunications Industry Association (CTIA) was generous in supplying industry sales information and educational literature. Mr. Bill Hollars, Director, Accident Records Division, State of Oklahoma, Department of Public Safety was very accommodating in responding to our numerous requests for additional information. Mr. Rogers of the State of Minnesota Department of Public Safety likewise responded quickly to our requests for information. Several members of the California Highway Patrol shared both data and insight relating to cellular telephone use and emergency response.

[1] COMSIS Corporation has subsequently been purchased by WESTAT.

The Motorola Cellular Subscriber Group contributed the results of their customer surveys as well as additional information which helped the authors to better interpret the data. The staff at the Library of Congress Research Service devoted many hours to searches for international laws and regulations.

Accolades also belong to the media. Mr. John Davis and the entire staff of Motorweek at Maryland Public Television were very generous in sharing their time. Prevention Magazine included questions relating to cellular telephone usage by drivers in their 1996 survey at the request of the NHTSA. The Pennysaver, weekly publication in Anne Arundel County, Maryland also published our survey questions as a public service. The Farmers' Almanac is acknowledged for graciously allowing the use of Mr. Nicholas Trott's quote at the beginning of this report. Ziff Davis Publishing, publishers of PCWEEK, is acknowledged for contributing their copywrited materials included in Chapter 6, and the New York Daily News for the closing article in Chapter 6.

The crash statistics and focus group information are based upon the excellent support provided by the law enforcement community in the Maryland, Virginia and District of Columbia region. Many thanks are extended to all those who worked so hard in coordinating our requests, and participating in the crash investigations and the focus group meetings. Of particular note is the consistent support and good will extended by Sgt. Mike Fisher of the Maryland State Police.

The supporting law enforcement agencies include:

- Alexandria Police Department
- Baltimore City Police Department
- Baltimore County Police Department
- Fairfax City Police Department
- Fairfax County Police Department
- Howard County Police Department
- Loudoun County Police Department
- Maryland State Police: Headquarters staff and Annapolis, Easton, Forestville, Reisterstown and Salisbury Barracks.
- Montgomery County Police Department
- Northern Virginia Law Enforcement Academy
- Ocean City, Maryland Police Department
- Prince George's County Police Department
- Prince William County Police Department
- U.S. Park Police Service
- Virginia State Police, Richmond and Fairfax

The translation of international studies and regulations was performed by The Language Institute.

To those we have failed to mention, and to the many citizens who have shared their comments and concerns, we extend our gratitude.

Appendix A
Legislation

International

Translations:

Public Penalty Regulations
Executive Federal Council of Switzerland
Article 3, 10, 12, Section 311

Spanish General Regulations for Traffic
Law 18/1989,
Royal Legislative Decree 339/1990
Articles 11 and 18

Excerpts of other Foreign Laws provided by the Library of Congress

National

The State of California
Senate Bill 1131

The State of Delaware
Delaware Code Annotated
21 Del. C. §4176 (1996)

The State of Hawaii
House Bill 284
House Bill 341

The State of Idaho
Idaho Code § 49-1401 (1996)
Idaho Code §49-236 (1996)

The State of Illinois
House Bill 562

The State of Nebraska
1997 NE Legislative Bill 338

The State of New Jersey
Senate Bill 1070

The State of New Mexico
New Mexico Statutes Annotated
§ 66-8-l 14 (1996)

The State Of New York
Acts 9768,9769 and 9770
Senate Bill 3481
Assembly Bill 4444
Assembly Bill 4587
Assembly Bill 4588
Assembly Bill 5857

The State of Oregon
Senate Bill 514

The State of Pennsylavania
House Bill 1424

The State of Virginia
General Assembly
House Bill 1666

The State of Washington
Senate Bill 6237
Annotated Code § 46.37.480 (1996)

The State of Wisconsin
Wisconsin Statute § 346.89
Wisconsin Statute § 346.95

Public Penalty Regulations
Executive Federal Council of Switzerland
Article 3, 10, 12, Section 311

Translation:

Note: | Comments in these brackets were added by the translator. "HTR" stands for hard to read and the translator is guessing or indicating the omitted word with . . . |

Public Penalty Regulations

(Ordnungsbussenverordnung or OBV)

(effective September 1, 1996*) |*added to document in handwriting|

Dated: March 4, 1996

The Executive Federal Council of Switzerland decrees on the basis of Articles 3, 10 |htr| and 12 of the Public Fine Law (Ordnungsbussengesetz or OBG) dated June 24, 1970[31]:

Article 1. Penalty Listing

The violations of road traffic regulations punishable by fines are listed in Appendix 1, along with their respective fines.

Article 2. Combination of Several Violations

If the violator commits several violations punishable by fine, such resulting fines shall be combined unless:

a. the parking of a vehicle in a no-stopping-zone is necessitated by traffic conditions (Appendix 1, Chapter 2).

b. one person is responsible for the violation both as driver and owner of the vehicle.

c. two or more general traffic regulations, signals or markings are ignored which serve the same protective purpose.

Article 3. Forms

The forms required for the penalty proceedings must, at a minimum, contain the information listed in Appendix 2.

Article 4. Directives

The courts and police departments of Switzerland can issue directives concerning the execution of the Public Penalty Proceedings.

Article 5 Previous Law Superseded

The regulations promulgated on March 22, 1972[21] shall be superseded by those contained herein.

SR...|htr| 31

[31] SR 741.03, AS 1996 1075 |htr|

[21] AS 1972 738, 1979 1546, 1981 507, 1985 ...|htr|, 1841, 1989 410, 1991 2534, 1994 167 214 116 1103,1995 4425

1078 1996-129

SR 741.031* |*added to document in handwriting|

Public Penalty Regulations

311. Use of a telephone that is not a hands-free set while driving (Article 3, par. 1| of the Traffic Regulations {Verkehrsregelnverordung or VRV}).

Traffic Regulations
(Verkehrsregelnverordung-VRV) . . . |cut off at margin| November 13, 1962

The Swiss Executive Federal Council decrees based on Article 57 and 105, par. 1 of the Road Traffic Law[23] (hereinafter referred to as SVG) and Article 2, par. 1, item c . . . ||htr| 2 of the Swiss Federal Law dated October 7, . . . |cut off at margin| about the protection of the environment (hereinafter referred to as USG).[45]:

Introduction

Article 1
(AS |htr| SVG)

741.11 Road Traffic

Part 1: Regulations for Traffic

1. Section: General Driving Regulations

Use of the vehicle, Article 3
(Article 31, par. 1 of the SVG)

1. The driver must concentrate on the road and the traffic while driving. He or she may not carry out activities while driving which negatively impact the operation of the vehicle. Additionally, the driver must take care not to reduce his or her attention to driving by listening to the radio or other sound equipment[21].

2. The driver of tour vehicles may not inform the travelers of sights or provide other information when the traffic is heavy or the roads are difficult to drive on. The drivers may not use a hand-held microphone.

3. The drivers of motor vehicles, motorcycles and bicycles may not release the steering device and, additionally, bicyclists may not take their feet off the pedals[31].

1) Amended according to item 1 of the V dated 1 l/14/79, effective l/1/80 (AS 1979 158G)
2) Third sentence added with item 1 of the V dated 1/25/89, effective 5/1/89 (AS 1989 41G)
3) Amended according to item 1 of the V dated 1/25/89, effective 5/1/89 (AS 1989 410).

TRANSLATION OF SPANISH GENERAL REGULATIONS FOR TRAFFIC

Note: Only relevant portions of applicable laws have been translated.

LAW 18/1989 OF JULY 25, 0N FUNDAMENTALS OF TRAFFIC, CIRCULATION OF AUTOMOTIVE VEHICLES, AND ROAD SAFETY

("Federal Register" No. 178, of July 27. Correction of errors in "Federal Register" No. 75, of March 28, 1990)

ROYAL LEGISLATIVE DECREE 339/1990, OF MARCH 2, IN WHICH IT IS APPROVED THE ARTICULATED TEXT OF THE LAW PERTAINING TO TRAFFIC, CIRCULATION OF AUTOMOTIVE VEHICLES, AND ROAD SAFETY

("Federal Register" No. 63, of March 14, 1990. Correction of errors in "Federal Register" No. 185, of August 3, 1990)

ARTICLE 11
General Rules for Drivers

1. Drivers must be, at all times, in condition of controlling their vehicles or animals. When approaching to other users of the road, they shall adopt the necessary safety precautions, specially in the cases involving children, old, blind, or disable persons.

2. The driver of a vehicle is obligated to maintain his/her freedom of movements, necessary field of view, and permanent driving attention, to warrant his/her own safety, as well as the safety of all passengers and road users. To this end, he/she shall be particularly careful that his/her position, and that of the passengers, animals, and objects transported, are properly maintained to avoid any inappropriate interferences.

3. It is forbidden to drive using any headpiece or telephone ear-piece connected to equipment for receiving or reproducing sound.

4. It is forbidden to drive with children younger than twelve years in the front seat, unless they utilize the required safety seat-adaptors.

ARTICLE 18
Other obligations of the drivers

1. (It repeats item 2 under article 11 above)

2. (I t repeats item 3 under article 11 above)

Australia

In Victoria and New South Wales, using hand-held mobile phones while driving is a specific traffic offense. Australia is considering national road rules to resolve conflicts and to establish a national policy in this area.

Victoria

Road Safety (Traffic) Regulations, 1988, Reg. 1505(l)

The driver of a motor vehicle must not, while driving, hold or use a telephone, microphone or similar apparatus.

New South Wales

Motor Traffic Regulations 1935, as amended, §90(d)

The driver of a motor vehicle must not, while driving, answer or use, or attempt to answer or use, a hand-held telephone.

The draft copy of the Australia Road Rules, 1996 (Commonwealth) states:

Mobile Phones

15.12(1) You must not use a hand-held telephone if you're driving or riding a vehicle.

Israel

Transportation Regulations 5721- 196l/1970

Regulation 28, Section l-28A

Anyone who drives a motor vehicle must hold two hands on the wheel or handlebars as long as that vehicle is in motion. Her may remove one hand if he needs to do anything to guarantee the proper operation of the vehicle corresponding to the rules of transportation.

Regulation 28. Section l-28B

Section 28A will also apply to a person who drives a vehicle in which there is a telephone, either permanent or portable, and the driver of the vehicle is allowed to use the phone only through a microphone for the operation of which there is no need to remove a hand from the wheel or handlebar.

Italy

The Code of the Road - Rules of Behavior

Article 173 - The driver is prohibited to use while driving any apparatus (radio, CB or earphones) with the exception of the armed forces or police as well as the drivers transporting others (chauffeurs?) . ..It is permitted to use any device that is voice-free (hands-free) that does not require the use of the hands.

England

The Highway Code, No. 3 (1992) (Eng.)

You must exercise proper control of your vehicle at all times. Do not use a hand-held telephone or microphone while you are driving. Find a safe place to stop first. Do not speak into a hands-free microphone if it will take your mind off the road. You must not stop on the hard shoulder of a motorway to answer or make a call, except in an emergency.

France

Driving Code, Title I ("Code del la Route", Titre Ier)

Article R. 3-l - The driver of a vehicle must constantly be in position to execute freely and without delay all driving maneuvers.

Sweden

Decree on Road Traffic ("Svensk Fijrfattningssamling" 1972: 603, as amended)

Motor vehicle drivers must take the necessary caution, care and prudence while on the road to avoid traffic accidents.

Republic of Singapore

Singapore Statutes and Subsidiary Legislation
Subsidiary Legislation (Chapter 276, Sections 111 and 140) Road Traffic Act
Road Traffic (Public Service Vehicles) Rules, Part II General
No Radio, Television or Acoustical Equipment to be Installed.

15.- (1) Except with the written permission of the Registrar, no person shall install or use any television, radio or acoustical equipment or cause any television, radio or acoustical equipment to be installed in or on a public service vehicle or any part thereof.

(2) Notwithstanding paragraph (l), the following equipment may be installed in a taxi:

(a) a radio telephone for calling the driver at any time to convey passengers for the purpose of gain;
(b) a radio with or without cassette player mounted and secured on the dashboard of the taxi; and
(c) a mobile telephone mounted and secured in a position as approved by the Registrar.

THE STATE OF CALIFORNIA

CALIFORNIA 1997-98 REGULAR SESSION
SENATE BILL 1131
February 28, 1997

The People of the State of California do enact as follows:

SECTION 1. Section 21700.3 is added to the Vehicle Code, to read:

21700.3. No person shall drive a vehicle upon any highway while operating a cellular telephone if the operation of that telephone by the driver requires the driver to hold the telephone in his or her hand.

SEC. 2. No reimbursement is required by this act pursuant to Section 6 of Article XIIIB of the California Constitution because the only costs that may be incurred by a local agency or school district will be incurred because this act creates a new crime or infraction, eliminates a crime or infraction, or changes the penalty for a crime or infraction, within the meaning of Section 17556 of the Government Code, or changes the definition of a crime within the meaning of Section 6 of Article XIIIB of the California Constitution.

Notwithstanding Section 17580 of the Government Code, unless otherwise specified, the provisions of this act shall become operative on the same date that the act takes effect pursuant to the California Constitution.

DELAWARE CODE ANNOTATED

(1996 Regular Session of the 138th General Assembly)
Title 21. Motor Vehicles
Part III. Operation and Equipment
Chapter 41. Rules of the Road
Subchapter IX. Reckless Driving; Driving While Intoxicated
21 DEL. C. § 4176 (1996)

§ 4176. Careless or Inattentive Driving

(a) Whoever operates a vehicle in a careless or imprudent manner, or without due regard for road, weather and traffic conditions then existing, shall be guilty of careless driving.

(b) Whoever operates a vehicle and who fails to give full time and attention to the operation of the vehicle, or whoever fails to maintain a proper lookout while operating the vehicle, shall be guilty of inattentive driving.

(c) Whoever violates this section shall for the first offense be fined not less than $25 nor more than $115. For each subsequent like offense occurring within 3 years of a former offense, the person shall be fined not less than $50 nor more than $230, or imprisoned not less than 10 nor more than 30 days, or both.

THE STATE OF HAWAII

HAWAII 18TH STATE LEGISLATURE (1995)
HOUSE BILL 284
1995 HI H.B. 284
January 23, 1995

Text: Be it enacted by the Legislature of the State of Hawaii:

Chapter 291, Hawaii Revised Statutes, is amended by adding a new section to be appropriately designated and to read as follows:

SECTION 291- Operation of Hand-held Equipment in Motor Vehicles.

(A) As used in this section, unless the context otherwise requires:

"Cellular radio telephone" means a wireless telephone authorized by the federal communications commission to operate in the frequency bandwidth reserved for cellular radio telephones.

"Computer" means an electronic device which performs logical, arithmetic, and memory functions by the manipulation of electronic or magnetic impulses.

"Emergency vehicle" has the same meaning as defined in Section 291-11.6(b).

"Facsimile" means a unit that scans and encodes a document into electric signals and sends them over telephone lines to the receiver where the signals are reconstructed to produce an exact duplicate of the document.

"Mass transit vehicle" has the same meaning as defined in section 291-11.6 (b).

(B) except as provided in Subsection (C), it shall be unlawful to operate a cellular radio telephone, computer, facsimile, or other portable or laptop device, which requires holding the unit, or a portion of the unit, with one or both hands in order to operate the unit, while operating a motor vehicle.

(c) notwithstanding subsection (b):

(1) the operator of a motor vehicle may use a cellular radio telephone, computer, facsimile, or other portable or laptop device where the device is equipped with a "hands-free" feature, including but not limited to a speaker system, number storage, or voice recognition; provided that the operator of the motor vehicle exercises a high degree of caution in the operation of the motor vehicle.

(2) the operator of a motor vehicle may use a cellular radio telephone, computer, facsimile, or other portable or laptop device that is not equipped with a hands-free feature only if:

(a) the person is operating an emergency or mass transit vehicle and the operation of that device is required during the course of the operation of that vehicle;

(b) the operator of the motor vehicle, other than those specified in subparagraph (a), has safely removed the vehicle out of the stream of traffic to the shoulder of a road or highway, or other safe area off of the road or highway, and come to a complete stop; or

(c) the operator of the motor vehicle is involved in any emergency, observes an emergency situation, or observes the operator of another motor vehicle who is driving in a reckless, negligent, or dangerous manner or who appears to be driving under the influence of alcohol or drugs, and the use of that device is necessary to report that emergency or observation to appropriate authorities.

(d) a person who fails to comply with the requirements of this section shall be subject to a fine of $100 for each violation, but shall not be guilty of a violation for which points shall be assessed pursuant to Section 286-128; provided that nothing in this section shall prevent the imposition of an additional fine, the assessment of points and imprisonment in connection with the violation of any other law, including but not limited to inattention to driving as provided in Section 291-12, or negligent injury in the first or second degree as provided in Sections 707-705 or 707-706.

HAWAII 18TH STATE LEGISLATURE (1995)
HOUSE BILL 341
1995 HI H.B. 341
January 23, 1995

Text: Be it enacted by the Legislature of the State of Hawaii:

SECTION 1. Chapter 291, Hawaii Revised Statutes, is amended by adding a new section to be appropriately designated and to read as follows:

SECTION 291- Operation of hand-held car phones in motor vehicles.

(A) as used in this section, unless the context otherwise requires:

"Cellular Radio Telephone" means a wireless telephone authorized by the Federal Communications Commission to operate in the frequency bandwidth reserved for cellular radio telephones.

"Emergency vehicle" has the same meaning as defined in Section 29l-l 1.6 (B).

"Mass transit vehicle" has the same meaning as defined in Section 291-l 1.6(B).

(B) except as provided in Subsection (C), it shall be unlawful to operate a cellular radio telephone which requires holding the unit, or a portion of the unit, with one or both hands in order to operate the unit, while operating a motor vehicle.

(C) notwithstanding Subsection (B), the operator of a motor vehicle may use a cellular radio telephone:

(1) where the device is equipped with a "hands-free" feature, including but not limited to a speaker system, number storage, or voice recognition: provided the operator of the motor vehicle exercises a high degree of caution in the operation of the motor vehicle; and

(2) that is equipped with a hands-free feature only if:

(A) the person is operating an emergency or mass transit vehicle and the operation of that device is required during the course of the operation of that vehicle;

(B) the operator of the motor vehicle, other than those specified in Subparagraph (A), has safely removed the vehicle out of the stream of traffic to the shoulder of the road or highway, or other safe area off of the road or highway, and come to a complete stop; or

(C) the operator of the motor vehicle is involved in any emergency, observes an emergency situation, or observes the operator of another motor vehicle who is driving in a reckless, negligent, or dangerous manner or who appears to be driving under the influence of alcohol or drugs, and the use of that device is necessary to report that emergency or observation to appropriate authorities.

(D) a person who fails to comply with the requirements of this section shall be subject to a fine of $100 for each violation, but shall not be guilty of a violation for which points shall be assessed pursuant to Section 286-128; provided that nothing in this section shall prevent the imposition of an additional fine, the assessment of points and imprisonment in connection with the violation of any other law, including but not limited to inattention to driving as provided in Section 291-12, or negligent injury in the first or second degree as provided in Sections 707-705 or 707-706.

SECTION 2. This Act does not affect rights and duties that matured, penalties that were incurred, and proceedings that were begun, before its effective date.

SECTION 3. New statutory material is underscored.

SECTION 4. This Act shall take effect upon its approval.

IDAHO CODE

2ND REGULAR SESSION OF THE 53RD LEGISLATURE
GENERAL LAWS
TITLE 49. MOTOR VEHICLES
CHAPTER 14. TRAFFIC -- ENFORCEMENT AND GENERAL PROVISIONS
Idaho Code § 49-1401 (1996)

§ 49-140 1. Reckless driving

(1) Any person who drives or is in actual physical control of any vehicle upon a highway, or upon public or private property open to public use, carelessly and heedlessly or without due caution and circumspection, and at a speed or in a manner as to endanger or be likely to endanger any person or property, or who passes when there is a line in his lane indicating a sight distance restriction, shall be guilty of reckless driving and upon conviction shall be punished as provided in subsection (2) of this section.

(2) Every person convicted of reckless driving under this section shall be punished by imprisonment in the county or municipal jail for a period of not less than five (5) days nor more than ninety (90) days, or by a fine of not less than twenty-five dollars ($25.00 nor more than three hundred dollars ($3OO), or by both fine and imprisonment. On a second or subsequent conviction shall be punished by imprisonment for not less than ten (10) days nor more than six (6) months, or by a fine of not less than fifty dollars ($50.00) nor more than three hundred dollars ($300) or by both fine and imprisonment. The department shall suspend the driver's license or privileges of any such person as provided in section 49-326, Idaho Code.

(3) Inattentive driving shall be considered a lesser offense than reckless driving and shall be applicable in those circumstances where the conduct of the operator has been inattentive, careless or imprudent, in light of the circumstances then existing, rather than heedless or wanton, or in those cases where the danger to persons or property by the motor vehicle operator's conduct is slight.

CHAPTER 2. GENERAL
Idaho Code § 49-236 (1996)

§ 49-236. Penalties

(1) It is a misdemeanor for any person to violate any of the provisions of this title except the provisions of Chapters 6 through 9, unless otherwise specifically provided.

(2) It is an infraction for any person to violate any of the provisions of Chapters 6 through 9 of this title unless otherwise specifically provided.

(3) Any offense punishable by imprisonment in the state penitentiary is a felony.

(4) Punishments shall be as provided in Sections 18-l 11, 1 8- 112, 18- 113 and 18- 113A, Idaho Code, unless otherwise specifically provided.

(5) Whenever a person is arrested for any violation of the provisions of this title declared to be a felony, he shall be dealt with in like manner as upon arrest for the commission of any other felony.

(6) It is an infraction punishable by a fine of seventy-five dollars ($75.00) for any person to violate the provisions of either section 49-1229, 49-1232 or 49-1428, Idaho Code.

ILLINOIS 90TH GENERAL ASSEMBLY — 1997-98 REGULAR SESSION
HOUSE BILL 562
1997 IL H.B. 562

February 5, 1997

Be it enacted by the People of the State of Illinois, represented in the General Assembly:

Section 5. The Illinois Vehicle Code is amended by adding Section 12-612 as follows:
(625 ILCS 5/12-612 new)

SEC. 12-612. Telephone; use of hands free apparatus. The driver of a motor vehicle may not use a telephone while operating the motor vehicle unless the telephone is equipped with, and the driver uses, an apparatus that allows the driver to talk and listen without holding the telephone or its handset or receiver. The driver may not hold or touch the telephone or its handset or receiver while operating the motor vehicle except to enable the apparatus, enter a telephone number, or hang up or turn off the telephone. As used in this section, "telephone" means a cellular telephone, portable telephone, or other telephone that may be used from within a moving motor vehicle.

THE STATE OF NEBRASKA

LEGISLATURE OF NEBRASKA
NINETY-FIFTH LEGISLATURE
1997 NE L.B. 338
January 14, 1997

Be it enacted by the people of the State of Nebraska:

Section 1. Section 60-601, Revised Statutes Supplement, 1996, is amended to read: 60-601. Sections 60-601 to 60-6,374 shall be known and may be cited as the Nebraska Rules of the Road.

Sec. 2. No person shall operate a motor vehicle upon a highway or street in this state while using a cellular telephone, except for the following persons: a peace officer on duty; an ambulance driver on duty; a taxi cab driver on duty; any person for medical emergency reasons; and any person in physical danger or who reasonably believes himself or herself or another person to be in physical danger.

Sec. 3. Enforcement of Section 2 of this act by state or local law enforcement agencies shall be accomplished only as a secondary action when a driver of a motor vehicle has been cited or charged with another violation or some other offense.

Sec. 4. Any person who causes a collision because he or she was operating a motor vehicle upon a highway or street in this state while using a cellular telephone commits the offense of reckless driving and shall be punished as provided in Sections 60-6,215, 60-6,217, and 60-6,218. This section shall not apply to persons listed in Section 2 of this act.

Sec. 5. Original section 60-601, Revised Statutes Supplement, 1996, is repealed.

NEW JERSEY 207TH LEGISLATURE - FIRST ANNUAL SESSION (1996)
SENATE BILL 1070.
MAY 2, 1996

Text: Be it enacted by the Senate and General Assembly of the State of New Jersey:

1.A. The Commissioner of Insurance, the Highway Traffic Safety Policy Advisory Council and the Division of Highway Safety of the Department of Law and Public Safety shall:

(1) collect and evaluate statistics showing whether the use of manually held and manually dialed cellular telephones or certain other cellular telephones by operators of any class of private motor vehicles has increased the incidence of accidents or accidents per mile of similar motor vehicles; and

(2) evaluate and advise whether the use, non-use, or extent of use of cellular telephones by motorists should be proposed as a factor in determining:

(a) lower premium rates of motor vehicle insurance policies where appropriate;
(b) tort liability in motor vehicle accident law suits;
(c) safety instructions given to customers by sellers, installers and lessors of cellular telephones; and
(d) any other safety proposal on the use of cellular telephones.

B. In making this study the commissioner, advisory council and division shall consult with each other and representatives of the motor vehicle insurance industry and cellular telephone industry, consumer and safety groups and such other persons with expertise they deem relevant. The commissioner, advisory council and division shall report their findings, including any suggested legislative proposals, to the Governor and the Legislature on or before the 180th day following the effective date of this act.

2. This act shall take effect immediately.

NEW MEXICO STATUTES ANNOTATED

CHAPTER 66. MOTOR VEHICLES
ARTICLE B. CRIMES, PENALTIES AND PROCEDURE
PART 2. TRAFFIC OFFENSES
N.M. Stat. Ann. § 66-8-114 (1996)

§ 66-8-l 14. Careless driving

A. Any person operating a vehicle on the highway shall give his full time and entire attention to the operation of the vehicle.

B. Any person who operates a vehicle in a careless, inattentive or imprudent manner, without due regard for the width, grade, curves, corners, traffic, weather and road conditions and all other attendant circumstances is guilty of a misdemeanor.

THE STATE OF NEW YORK *Proposed Legislation*

NEW YORK ASSEMBLY
ACT 9768
March 26, 1996

Text: The People of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. The general business law is amended by adding a new section 399-x to read as follows:

§ 399-x. Sale of cellular telephones or car phones.

1.For purposes of this section "cellular telephone" or "car phone" shall mean a cellular mobile radio telephone or other radio telephone not requiring an access line of service.

2.The manufacturer of any cellular telephone or car phone as described in subdivision one of this section shall affix to the front of the outside packaging of such cellular telephone or car phone a warning label to read substantially as follows:

"The use of a cellular telephone or car phone while operating a motor vehicle has been known to be the cause of traffic accidents and caution is advised in such use."

3.Violation of this section shall be punishable by a fine of not more that one hundred fifty dollars for each subsequent offense.

§ 2. The vehicle and traffic law is amended by adding a new section 1199 to read as follows:

§ 1199. Cellular telephone or car phone. The commissioner shall, through the department's public information programs and traffic safety publications, regularly inform the public of the dangers of using a cellular telephone or car phone while operating a motor vehicle. Such warning shall be in addition to any other warning required by law.

§ 3. This act shall take effect on the one hundred eightieth day after it shall have become a law, provided that necessary rules and regulations may be promulgated prior to such date.

THE STATE OF NEW YORK

NEW YORK ASSEMBLY
ACT 9769
March 26, 1996

Text: The People of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. Section 375 of the vehicle and traffic law is amended by adding a new subdivision 24-b to read as follows:

24-b. It shall be unlawful for any person to operate upon any public highway in this state a motor vehicle while the operator is using a cellular or car phone. Any person convicted of a violation of this subdivision shall for a first and subsequent conviction thereof be punished by a fine of fifty dollars.

§ 2. This act shall take effect on the sixtieth day after it shall have become a law, provided that necessary rules and regulations may be promulgated prior to such date.

THE STATE OF NEW YORK

NEW YORK ASSEMBLY
ACT 9770
March 26, 1996

Text: The People of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. Beginning with the report to be made in 1997, the Commissioner of Motor Vehicles shall include in the Department of Motor Vehicles' Annual Summary of motor vehicle accidents, information relative to whether the use of a cellular or a car phone by the operator of a motor vehicle contributed to or was a factor in such accidents.

§ 2. The Commissioner of Motor Vehicles shall take the necessary action including promulgating all rules and regulations necessary to collect such information so that it can be included into the Annual Vehicle Accident Report.

§3. This act shall take effect immediately.

THE STATE OF NEW YORK

NEW YORK 220TH ANNUAL LEGISLATIVE SESSION
SENATE BILL 3481
March 12, 1997

Text: The People of the State of New York, represented in Senate and Assembly, do enact as follows:

The vehicle and traffic law is amended by adding a new article 34-C to read as follows: 34-C Communications Technology and Driver and Highway Safety Sections

1280. New York State Task Force on Communications Technology and Driver and Highway Safety.
1281. Selection of Task Force Members.
1282. Task Force Personnel.
1283. Report of the Task Force.

SECTION 1280. New York State Task Force on Communications Technology and Driver and Highway Safety.

A. There is hereby created a task force to be known as the ""New York State Task Force on Communications Technology and Driver Highway Safety". The Task Force shall study and recommend a course of action to address the use of cellular telephones while operating a motor vehicle.

B. The study shall include, but not be limited to, investigating issues of highway and traffic safety as they relate to the use of cellular telephones and other communication devices while operating a motor vehicle. The study shall review the impact of such recommendations upon businesses and individuals dependent on cellular telephones to conduct business and/or for other important purposes. The task force shall inquire into innovative technologies being used and/or proposed to be used in motor vehicles cellular phone usage that may help alleviate risks to highway and traffic safety. The task force shall also develop recommendations for public and private strategies to address these issues, as well as public information campaigns to educate and inform our resident and non-resident motorists of dangers associated with cellular phone use while operating a motor vehicle and methods of lessening such potential dangers.

C. The task force is recommendations should be aimed at decreasing the risk of driving accidents due to cellular telephone use while driving.

D. The task force shall consist of eleven members. Of the seven *non* ex-officio members at least two shall be representatives from the mobile phone industry; at least two shall operate motor vehicles and use cellular telephones to regularly conduct business one of whom shall operate a motor vehicle weighing in excess of twenty-six thousand pounds; at least one member shall be a representative of a not-for-profit highway safety organization; at least one member shall be a representative from the insurance industry and at least one member shall be a law enforcement officer engaged in highway patrol and/or highway safety. In addition, the task force membership shall include the following ex-officio members: the Commissioner of the Department of Motor Vehicles, along with the Commissioner of Transportation, the Chair of the Governor's Traffic Safety Committee and the Superintendent of the Department of State Police.

SECTION 1281. Selection of task force members.

Excluding ex-officio members, all members of said task force shall be appointed by the Governor. Two members shall be appointed upon the recommendation of the temporary President of the Senate. Two members shall be appointed upon the recommendation of the Speaker of the Assembly. One member shall be appointed upon the recommendation of the Minority Leader of the Senate. One member shall be appointed upon the recommendation of the Minority Leader of the Assembly. The remaining five members shall be selected by the Governor. The Governor shall appoint a Chairperson from among its membership.

SECTION 1282. Task force personnel.

The task force shall utilize existing department personnel for support, as assigned by the Commissioner of the Department of Motor Vehicles, the Commissioner of Transportation, the Chair of the Governor's Traffic and Safety Committee and the Superintendent of the Department of State Police. The task force may request and shall receive from the state departments, boards, bureaus, commissions, agencies or public authorities of the state or any political subdivision thereof data and assistance as it requests and is necessary to enable it to properly carry out its responsibilities set forth herein. The task force shall have all the powers and privileges of a legislative committee pursuant to the legislative law.

SECTION 1283. Report of the task force.

On or before February first, nineteen hundred ninety-eight the task force shall issue a report to the Governor, the temporary President of the Senate, the Speaker of the Assembly, the Chairs of the Senate and Assembly transportation committees, the Chair of the Senate Energy and Telecommunications Committee, the Shair of the Senate Committee on Commerce, Economic Development and Small Business, the Chair of the Assembly Committee on Corporations, Authorities and Commissions, and the Ahair of the Assembly Committee on Economic Development, Job Creation, Commerce and Industry.

Section 3. This act shall take effect immediately.

THE STATE OF NEW YORK

ASSEMBLY BILL 4444
1997-1998 REGULAR SESSIONS IN ASSEMBLY
FEBRUARY 18,1997

1997 NY A.B. 4444

Text: The people of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. Section 375 of the vehicle and traffic law is amended by adding new Subdivision 24-B to read as follows:

24-B. It shall be unlawful to operate upon any public highway in this state a motor vehicle which is equipped with a hand held cellular telephone which is in use while operating the vehicle. As used in this subdivision, "hand held cellular phone" means a cellular mobile radio telephone or other radio telephone not requiring an access line for service, which includes both the receiver and speaker. This act shall take effect January 1, 1998.

THE STATE OF NEW YORK

NEW YORK 220TH ANNUAL LEGISLATIVE SESSION
ASSEMBLY BILL 4587
FEBRUARY 20, 1997
1997 NY A.B. 4587

Text: the People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION 1. Beginning with the report to be made in 1998, the Commissioner of Motor Vehicles shall include in the Department of Motor Vehicles' Annual Summary of Motor Vehicle Accidents, information relative to whether the use of a cellular or a car phone by the operator of a motor vehicle contributed to or was a factor in such accidents.

SECTION 2. The Commissioner of Motor Vehicles shall take the necessary action including promulgating all rules and regulations necessary to collect such information so that it can be included into the annual vehicle accident report.

SECTION 3. This act shall take effect immediately.

THE STATE OF NEW YORK

ASSEMBLY BILL 4588
STATE OF NEW YORK
FEBRUARY 20, 1997
1997 NY A.B. 4588

Text: The People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION 1. Section 375 of the vehicle and traffic law is amended by adding a new subdivision 24-B to read as follows:

24-B. (A) It shall be unlawful for any person to operate upon any public highway in this state a motor vehicle while the operator is using a cellular or car phone. Any person convicted of a violation of this subdivision shall for a first and any subsequent conviction thereof be punished by a fine of fifty dollars.

(B) It shall be a defense to a violation of this subdivision that the operator had reason to fear for his or her life or safety, was reporting a traffic accident or making a “911” emergency call.

(C) Nothing contained herein shall interfere with the use of a citizen’s band radio or the use of speaker phones.

SECTION 2. This act shall take effect on the sixtieth day after it shall have become a law.

THE STATE OF NEW YORK

ASSEMBLY BILL 5857
1997-1998 REGULAR SESSIONS SENATE - ASSEMBLY
MARCH 4, 1997
1997 NY A.B. 5857

Text: The People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION 397-C. Use of cellular telephone while operating a motor vehicle;

Prohibited. 1.
(A) No person shall operate a motor vehicle on a public highway while using a hand held cellular or cellular car telephone.

(B) An operator of a motor vehicle shall have a two minute grace period on the receipt and transmission of cellular telephone calls to pull the vehicle off the road and park the vehicle in a safe location that will not interfere with the flow of traffic.

(C) The use of a hand held cellular or cellular car telephone by an Operator of a motor vehicle shall not be a violation of this Section where the Operator was alone and had reason to fear for his or her life or safety or believed that a criminal act may be perpetrated against him/her necessitating the use of such cellular telephone while operating the motor vehicle or that the operator was using such hand held cellular or cellular car telephone to contact an E-911 system as defined in Subdivision 3, Section 301 of the county law.

2. Nothing contained herein shall prevent any passenger or occupant of a motor vehicle other than the operator from using a hand held cellular or cellular car telephone while the motor vehicle is in motion.

3. On and after January first in the year next succeeding the date on which this section shall have become a law all hand held cellular or cellular car telephones sold leased or rented in the state shall contain a message affixed to the phone stating that such telephones shall not be used by any person operating a motor vehicle except as provided in this section.

4. A violation of the provisions of this section shall constitute a traffic infraction punishable only by a fine not to exceed fifty dollars.

5. Nothing contained herein shall interfere with the use of a Citizen's Band Radio by the police or other public safety agencies.

SECTION 3. This act shall take effect on the first day of January next succeeding the date on which it shall have become a law.

THE STATE OF OREGON

OREGON 69TH LEGISLATIVE ASSEMBLY -1997 REGULAR SESSION
SENATE BILL 514
1997 OR S.B. 514
February 21, 1997

Text: Be it enacted by the People of the State of Oregon:

SECTION 1. Section 2 of this act is added to and made a part of ORS Chapter 811.

SECTION 2.

(1) A person commits the offense of driving while using a mobile telephone if the person uses a mobile telephone while driving or moving a vehicle on a highway.

(2) As used in this section, 'Mobile Telephone' means a hand-held device designed to receive and transmit voice communication over a distance.

(3) The offense described in this section, driving while using a mobile telephone, is a Class D traffic infraction.

THE STATE OF PENNSYLVANIA

PENNSYLVANIA 179TH GENERAL ASSEMBLY -- 1995
HOUSE BILL 1424
1995 PA H.B. 1424
April 25, 1995

TEXT: The General Assembly of the Commonwealth of Pennsylvania hereby enacts as follows:

Section 1. Section 3314 of Title 75 of the Pennsylvania Consolidated Statutes is amended to read:

Section 3314. Prohibiting Use of Hearing Impairment Devices.

(a) General rule. - No driver shall operate a vehicle while wearing or using one or more headphones, earphones or any similar device which the department by regulation determines would impair the ability of the driver to hear traffic sounds.

(b) Exception. - This section does not prohibit the use of:

(1) hearing aids or other devices for improving the hearing of the driver nor does it prohibit the use of :

(2) a headset in conjunction with a cellular telephone that only provides sound through one ear and allows surrounding sounds to be heard with the other ear; or

(3) communication equipment by the driver of a fire vehicle or by motorcycle operators complying with section 3525 (relating to protective equipment for motorcycle riders).

Section 2. This act shall take effect in 60 days.

THE GENERAL ASSEMBLY OF VIRGINIA

HOUSE BILL 1666
January 17, 1995

Text: Be it enacted by the General Assembly of Virginia:

1. That the Code of Virginia is amended by adding a section numbered 46.2-1078.1 as follows:

§ 46.l- 1078.1. - Using citizens band radio or mobile telephone while driving.

It shall be unlawful for any person to use a citizens band radio or mobile telephone while operating a motor vehicle, moped, or bicycle on the highways of the Commonwealth unless at least one of his hands remains on the steering wheel or handle bars at all times.

THE STATE OF WASHINGTON *Proposed Legislation*

1996 REGULAR SESSION OF THE 54TH LEGISLATURE
SENATE BILL 6237
BY SENATE COMMITTEE ON TRANSPORTATION
February 5, 1996

Text: Be it enacted by the Legislature of the State of Washington:

Sec. 1. RCW 46.37.480 and 1991 c 95 s 1 are each amended to read as follows:

1) No person shall drive any motor vehicle equipped with any television viewer, screen, or other means of visually receiving a television broadcast which is located in the motor vehicle at any point forward of the back of the driver' s seat, or which is visible to the driver while operating the motor vehicle. This subsection does not apply to law enforcement vehicles communicating with mobile computer networks.

(2) No person shall operate any motor vehicle on a public highway while wearing any headset or ear-phones connected to any electronic device capable of receiving a radio broadcast or playing a sound re-cording for the purpose of transmitting a sound to the human auditory senses and which headset or earphones muffle or exclude other sounds. This subsection does not apply to students and instructors participating in a Washington State Motorcycle Safety Program.

(3) This section does not apply to authorized emergency vehicles or to motorcyclists wearing a helmet with built-in headsets or earphones as approved by the Washington State Patrol, or motorists using hands-free, wireless communications systems, as approved by the equipment section of the Washington State Patrol.

ANNOTATED REVISED CODE OF WASHINGTON

TITLE 46. MOTOR VEHICLES
CHAPTER 46.37. VEHICLE LIGHTING AND OTHER EQUIPMENT
Rev. Code Wash. (ARCW) § 46.37.480 (1996)

§46.37.480. Television viewers -- Earphones

(1) No person shall drive any motor vehicle equipped with any television viewer, screen, or other means of visually receiving a television broadcast which is located in the motor vehicle at any point forward of the back of the driver's seat, or which is visible to the driver while operating the motor vehicle. This subsection does not apply to law enforcement vehicles communicating with mobile computer networks.

(2) No person shall operate any motor vehicle on a public highway while wearing any headset or earphones connected to any electronic device capable of receiving a radio broadcast or playing a sound recording for the purpose of transmitting a sound to the human auditory senses and which headset or earphones muffle or exclude other sounds. This subsection does not apply to students and instructors participating in a Washington State Motorcycle Safety Program.

(3) This section does not apply to authorized emergency vehicles, motorcyclists wearing a helmet with built-in headsets or earphones as approved by the Washington State Patrol, or motorists using free, wireless communications systems, as approved by the equipment section of the Washington State Patrol.

WISCONSIN STATUTES

VEHICLES
CHAPTER 346. RULES OF THE ROAD
MISCELLANEOUS RULES
Wis. Stat. § 346.89 (1995-1996)

§346.89 Inattentive Driving.

(1) No person while driving a motor vehicle shall be so engaged or occupied as to interfere with the safe driving of such vehicle.

(2) No person shall drive any motor vehicle equipped with any device for visually receiving a television broadcast when such device is located in the motor vehicle at any point forward of the back of the operator's seat or when such device is visible to the operator while driving the motor vehicle.

MISCELLANEOUS RULES
Wis. Stat. § 346.95 (1995-1996)

§346.95 Penalty for violating Sections 346.87 to 346.94.

NOTE: Only the penalty associated with the statute listed above is represented.

(1) Any person violating S. 346.87, 346.88, 346.89 (2), 346.90 to 346.92 or 346.94 (1), (9), (10), (11), (12) or (15) may be required to forfeit not less than $20 nor more than $40 for the first offense and not less than $50 nor more than $100 for the 2nd or subsequent conviction within a year.

(2) Any person violating S. 346.89 (1), 346.93 or 346.94 (2), (4) or (7) may be required to forfeit not less than $20 nor more than $400.

Appendix B
Market Survey

Dynamic Science, Inc. conducted a market survey during 1995 in order to assemble a useful description of the cellular telephones and related electronic devices that were currently in use at that time. Staff members visited retail establishments in the Washington, D.C. area and recorded descriptive information from sales literature. Phone and key pad measurements were taken at their widest points although batteries were not always present.

The battery units also affected weight measurements. In addition, consumer information was extracted from popular magazines dating from April, 1993 to the present in order to capture data on devices not currently for sale, but still likely to be in use. The tables in this appendix include information from both sources. They represent units still in use even though the trend is toward smaller, lighter weight devices.

The sizes of available portable cellular telephones range from less than 5 to about 8 inches in length. They weighed anywhere from 6 to 16 ounces. The displays accommodate up to 3 lines of messages with touch pads of l/2” to 7/8" in size. Many of the phones have optional accessories including mobile mounting kits. These kits provide a storage place for telephones within the vehicle, while also encouraging the purchase of hand held models for in-vehicle use.

The very latest technology is a hands-free unit which does not require a mounting device. The Motorola StarTAC weighs 3.1 ounces and clips to a belt or can be worn on a cord around one’s neck. It provides over one hour of service with its slim battery. Motorola offers a hands-free car kit option with cigarette lighter adapter plug. The StarTAC also can be used with a PC Card and desktop modems. The keypad is small and key travel short, but it is possible to scroll the memory and menu on the 2-line screen. It also features the new theft alarm, account authenticator and PIN dialing technologies.

Mobile (car) phones are specifically designed to be permanently mounted and integrally installed in motor vehicles. At this time, most luxury and many mid-priced automobiles are being manufactured with appropriate power cords and antennas already in place. Dealer provided mobile phones are inserted into the vehicle’s mounting brackets in the center console. Some offer “pop-up” modes.

Car phones are often designed with the driver in mind. They may include speed dial, voice activation feature and remote microphones so that they can be used in a hands-free mode. The keypads are generally larger than those for hand-held flip phones. Motor vehicle manufacturers and others are quickly adapting cellular technology for “on the road” applications.

ORA Electronics has designed Telecar which integrates a cellular telephone into a motor vehicle’s audio system. For $100, the device promotes hands-free cellular telephone operation by automatically adjusting radio volume and directing incoming calls through the radio speaker system. This technology is standard equipment on some 1998 motor vehicles.

CellPort developed by CellPort Labs integrates electronic and cellular automotive technologies to access the World Wide Web. One anticipated application will allow emergency rescue personnel to upload an incoming patient’s vital statistics to the hospital’s emergency room web site while en route.

The 1996 and newer Lincolns are delivered from the factory to the dealerships with phones installed in the center console and which are ready to be programmed. Ford Communications is the designated service provider. When the automobile engine is started, the telephone comes on automatically. Microphones are built into the "A" pillars and mirror. When the phone rings, the radio volume automatically is reduced, and the phone can be answered by voice commands. Outgoing calls can also be made using voice commands.

Lincoln Continental owners also have the option of purchasing the RESCU system. Using their cellular phone and a global positioning satellite receiver, the driver can push a button to request emergency assistance. The cellular telephone will relay the vehicle identification number and location to a response center in Texas. The operator will call back, or dial the nearest 911 agency.

General Motors is offering its "OnStar" system as an option on all 1997 front-drive Cadillacs. For $1,000 plus a monthly charge, the customer will receive a voice-activated phone. In the event of a crash, in which an airbag deploys, the system will automatically call for emergency assistance. Through a satellite linkage, OnStar will provide exact information on vehicle location. This feature may also be of assistance in the event of car theft. The audio links will also allow the driver to request directions, and to activate the car's lights and horns upon request (for example, when the owner cannot locate his vehicle in a large parking lot).

Related Devices

The 1993 Motorola Cellular Impact Survey, referenced in Section 4 of this report, asked subscribers if they used other devices in conjunction with their cellular telephones. It is unknown how often such equipment is used in motor vehicles, since there is no information on routine locations or circumstances for such use. The technological applications noted in 1993 include:

Pager	27%
Conference calls	16%
Cellular Voice Mail	13%
Faxes	11%
Electronic Mail	6%
Transmit Data over cell phone	6%

During the past several years, the market for wireless technologies has literally exploded. It would be impossible to accurately describe the many products currently available. The concern is that the small size and convenience of such equipment increase the temptation for drivers to employ them at inappropriate times. Vehicle mounting brackets for laptop computers are being sold. Some devices fit over the steering wheel, while others are designed to be placed in the direct path of a passenger's side airbag. Clearly these products can not only lead to driving distractions, but can be expected to cause serious injury or even death in the event of a crash.

A sample of some of the newest wireless devices is described below:

Nokia 9000 Communicator for use on GSMC (Global System for Mobile Communications) networks. This product provides voice, data and personal information management into a single handset. It weighs only 14 ounces and is the size of a large portable phone. Currently available in Europe and Asia, the 9000 will be introduced in the western U.S. upon the completion of the Pacific Bell Mobile Services network. With the 9000, users can make telephone calls, send and receive faxes, and access the Internet (hence, send and receive E-mail and tap into corporate and public databases). It is possible for users to maintain a conversation while viewing or transmitting data. Ericsson, NEC and Matsushita are developing similar products.

FAXView is a palm-sized personal fax reader. It weighs less than 8 ounces and, when used with a cellular or land line, allows the user to receive, read, store and send faxes anywhere without using paper. The faxes are viewed through a virtual screen. One may view multiple pages, zoom in on specific document sections, as well as set up cover pages and an address book.

Cell-U-Memo digital voice recorders. Using microchip technology, this device fits onto cellular telephones as part of the "sandwich". The largest model is 7 mm thick. It allows the user to record "phone numbers, messages, shopping lists and more while driving or on the run". The sales literature also notes, "you don't have to stop at the roadside again."

Portable Computers

In their April, 1996 edition, "Mobile Office" estimates that there will be 13.5 million portable PC users in the United States. The number who use remote access is expected to grow to nearly 20 million by the end of this decade. With the introduction of "rugged portables" and multimedia notebooks, the numbers could grow even higher. The cost of cellular modems is now below $300.00. Traveling Software's *LapLink for Windows* or Symantec's pcAnywhere software can be used with a data-ready cellular telephone to connect with any host.

Personal Communicators and Organizers

Designed to allow for e-mail, faxing, phoning, voice-to-text, news service, devices such as the Newton MessagePad 120, Sony Magic Link, Envoy Wireless Communicator and RadioMail Wireless Messaging use cellular technology to provide instant information exchange to and from any above ground location. These personal communications products, like all electronic technologies, are becoming more advanced and less expensive and are being marketed to students and homemakers in addition to traditional business groups.

Market Survey of Cellular Telephone Features

Make	Model	Item	Size (in.)	Weight (oz.)	Size of Display (lines)	Size of Pads (in.)	Watts	Features	Cost* ($)
Ante1	STR2000	Mobile mounting kit		10.5, 11.3 w/battery				Hands free, Opt.voice activated, 65 min. talk time	695
Ante1	STRl300	Mobile mounting kit		14 , 16 w/battery				Hands free, 80 min. talk time	595
AT&T	3850	Mobile mounting kit		8, 10 w/battery	2				
AT&T	3770/3770S	Hand held with Mobile mounting kit	5.5 x 2 x .75	8, 9.6 w/battery	2, ° in.	.625	.6	Speed dial, memory, pop-up antenna, 65 min. talk time	490
AT&T	3760			8.2, 10.5 w/battery				50 min. talk time	549
AT&T	3730			12.7, 13 w/battery				60 min. talk time	699
AT&T	3620	Hand held	6.5 x 2.25 xl.75	12	2, ° in.	.875	.6	Speed dial, memory	395
AT&T	3025	Transportable						Hands free, voice activated dialing, antenna	129
Audiovox	MVX-800	Mobile mounting kit	5 x 1.75 x 1	5.4, 7.6 w/battery	3			Data interface	400
Audiovox	MVX-750	Mobile mounting kit		6.2, 7.4 w/battery				Hands free, 60 min. talk time	1,195
Audiovox	MVX-700	Mobile mounting kit		6.2, 7.4 w/battery	2			Data interface, 65 min. talk time	
Audiovox	MVX-600	Mobile mounting kit		6.6, 7.9 w/battery	2			40 min. talk time	

*Note: Price information may vary depending on vendor and cellular carrier

Market Survey of Cellular Telephone Features

Make	Model	Item	Size (in.)	Weight (oz.)	Size of Display (lines)	Size of Pads (in.)	Watts	Features	Cost* ($)
Audiovox	MVX-500	Mobile mounting kit		10.6, 12 w/battery				Hands free, 65 min. talk time	995
Audiovox	MVX-300	Mobile mounting kit		7.1, 8.7 w/battery	2			55 min. talk time	
Audiovox	PT300			17.7				60 min. talk time	795
Blaupunkt	TC-242	Mobile mounting kit		11.2, same w/ battery				Hands free, 90 min. talk time	
Blaupunkt	TC-142	Mobile mounting kit		10.5, same w/ battery				Hands free, 90 min. talk time	999
Blaupunkt	TC-132	Mobile mounting kit		14.8, same w/ battery				Hands free, 90 min. talk time	1,079
DiamondTel	22X	Mobile mounting kit		7.7, 9.1 w/battery				Hands free, 60 min. talk time	1,095
DiamondTel	99X	Mobile mounting kit		10.5, 12.3 w/battery				Hands free, 90 min. talk time	899
Ericsson	DH197			11.6				120 min. talk time (digital), 75 min. (analog)	
Ericsson	CH-337 (PCS only)	Hand held w/mobile mounting kit & pager	5 x 1.5 x 1.75	6.8, 8.8 w/battery	3	.75	.6	Data, interface, speed dial, memory	150
Ericsson AH97	Hotline Pocket	Mobile mounting kit		11.6, 12.6 w/battery				Hands free, 90 min. talk time	649
Ericsson	Hotline Pocketfone II	Mobile mounting kit		14, 15 w/battery				Hands free, 95 min. talk time	

*Note: Price information may vary depending on vendor and cellular carrier

Market Survey of Cellular Telephone Features

Make	Model	Item	Size (in.)	Weight (oz.)	Size of Display (lines)	Size of Pads (in.)	Watts	Features	Cost* ($)
Fujitsu	PCX	Flip phone w/ J Mobile mounting kit		6.6, 7.4 w/battery	2			Memory, data interface, 100 min. talk time	1,295
Fujitsu	Pocket Commander Stylus	Mobile mounting kit		11.9, same with battery				Hands free, 80 min. talk time	925
GE	Pocketfone CT-400	Mobile mounting kit		11.6, same w/battery	3, 1st .5" others. 25"			Hands free, speed dial, 325 pop-up antenna, AC/DC, 90 min. talk time	
GE	Pocketfone CT-200	Mobile mounting kit		11.6	3, 1st .5" others. 25"			AC/DC, 90 min talk time	325
GE	CT-100			14.3, 15.3 w/battery				90 min. talk time	
GoldStar	PCP 100			8.8, 10.8 w/battery				30 min. talk time	849
GoldStar	PCP 99			8.8, 10.8 w/battery				30 min. talk time	799
JRC	PTR-870	Mobile mounting kit		7.2, 7.4 w/battery	2			60 min talk time	
Kenwood	KMP-H700	Mobile mounting kit		14				Hands free, 80 min. talk time	1,399
Mitsubishi	TPK13	Transportable			1, ° in	.5	3.0	AC/DC, speed dial, memory, 60 min talk time	385
Mitsubishi	CT-500	Hand held	5.5 x 2 x 1.5	5	1, ° in	.75	.6	Memory, pop-up antenna	425
Mitsubishi	4000	Mobile mounting kit		7.9, 9.1 w/battery				Hands free, 60 min. talk time	999
Mitsubishi	3000	Mobile mounting kit		10.4, 12.4 w/battery				Hands free, 48 min. talk time	

*Note: Price information may vary depending on vendor and cellular carrier

Market Survey of Cellular Telephone Features

Make	Model	Item	Size (in.)	Weight (oz.)	Size of Display (lines)	Size of Pads (in.)	Watts	Features	Cost* ($)
Mitsubishi	AH-5000	Mobile mounting kit		7.7, 6.5 w/battery	3			138 min talk time	400
Motorola	Alpha Deluxe	Hand held		8.6	1, ° in	.625	.6	Pop-up antenna	445
Motorola	Dynasty Gold 52145	Hand held (yellow)	8 x 2.5 x 1.75	8.6	1, ° in	.75	.6	Speed dial, pop-up antenna, memory, 100 min. talk time	485
Motorola	Dynasty	flip phone	6 x 2.25 x 2	11.6	1, ° in	.625	.6	Speed dial, AC/DC	385
Motorola	Dynasty 52140	flip phone	6 x 2.25 x 2	8.6	1,.44 in	.56	.6	Speed dial, memory, 100 min talk time, AC/DC	415
Motorola	Dynasty 52137	Hand held	6 x 2.25 x 1.75	9.6 oz	1,° in	.56	.6	Speed dial, memory, pop-up antenna, 100 min talk time	405
Motorola	Dynasty 52112	Transportable	7.25 x 1.75 x2.25		1, ° in	.5	3	Memory, antenna on pouch	385
Motorola	MicroTAC Ultra Lite	Flip phone, mobile mounting kit		5.9, 8.9 w/battery	1			65 min talk time, data interface	945
Motorola	MicroTAC Elite	Flip phone, mobile mounting kit		7, 9.4 w/battery	1			Hands free, 45 min talk time, data interface	1,200
Motorola	MicroTAC Elite	Flip phone, mobile mounting kit		3.9, 5.9 w/battery	2			45 min talk time, data interface	600
Motorola	MicroTAC Alpha	Mobile mounting kit		10.1, 12 w/battery				Hands free, 30 min. talk time	999

*Note: Price information may vary depending on vendor and cellular carrier

Market Survey of Cellular Telephone Features

Make	Model	Item	Size (in.)	Weight (oz.)	Size of Display (lines)	Size of Pads (in.)	Watts	Features	Cost* ($)
Motorola	Micro Digital Elite (TDMA)	Flip phone, Mobile Mounting kit		6.6, 7.9 w/battery	2			45 min talk time, data interface	
Motorola	MicroTAC DPC950	Mobile mounting kit		10.7, 12.3 w/battery				Hands free, 100 min. talk time	2,195
Motorola	StarTAC	Wearable portable		3.1	2	.2		Full featured w/security technologies	
Motorola	Ultima	Mobile mounting kit		4.8, 6.8 w/battery	2			60 min talk time, data interface	1,000
Motorola	Ultra Classic	Mobile mounting kit		16.5, 18.6 w/battery				Hands free, 132 min talk time	1,175
Muratec	CT-50	Mobile mounting kit		15.2, 15.7 w/battery				Hands free, 60 min talk time	999
Muratec	MCT200	Mobile mounting kit		15.2, 15.7 w/battery				Hands free, 60 min talk time	899
NEC	P600	Mobile mounting kit		7.8, 8 w/battery				Hands free, 60 min talk time	1,349
NEC	P400	Mobile mounting kit		7.8, 8 w/battery				60 min talk time	1,195
NEC	P300	Mobile mounting kit		14				Hands free, 80 min talk time	1,150
NEC	P200	Mobile mounting kit		14				Hands free. 80 min talk time	999
Nokia	232	Mobile mounting kit		6.9, 8 w/battery	2			50 min talk time, data interface	

*Note: Price information may vary depending on vendor and cellular carrier

Market Survey of Cellular Telephone Features

Make	Model	Item	Size (in.)	Weight (oz.)	Size of Display (lines)	Size of Pads (in.)	Watts	Features	Cost* ($)
Nokia	121			9.7, 11.1 w/battery				45 min talk time	799
Nokia	101			9.7, 11.1 w/battery				50 min talk time	
NovAtel	PTR-850	Mobile mounting kit		10, 14 w/battery				Hands free, 76 min talk time	
NovAtel	PTR-825			17, 18.5 w/battery				Opt.Hands free, 60 min talk time	400
OKI telecom	1150	Mobile mounting kit		8.2, 10.5 w/battery				Hands free, 60 min talk time	899
OKI telecom	900	Mobile mounting kit		12.8, 13.7 w/battery				Hands free, 60 min talk time	799
OKI telecom	910	Mobile mounting kit		12.8, 13.7 w/battery				60 min talk time	699
Omni Cellular	Model B	Mobile mounting kit		12				Hands free, 70 min talk time	495
Panasonic Comm.	HH900	Mobile mounting kit		8.2, 9.5 w/battery				Hands free. 80 min talk time	699
Panasonic Comm.	HH700	Mobile mounting kit		9.4				55 min talk time	899
Panasonic Comm.	HP600	Mobile mounting kit		13.4, 12.4 w/battery				Hands free, 90 min talk time	499
Panasonic Co.	EB-H105	Hand held	5.5x2.25x.75	8.5	2, ° in	.625	.6	120 min talk time	385
Panasonic Co.	EB-H70	Mobile mounting kit		4.9, 6.4 w/battery	2			50 min talk time, data interface	

*Note: Price information may vary depending on vendor and cellular carrier

Market Survey of Cellular Telephone Features

Make	Model	Item	Size (in.)	Weight (oz.)	Size of Display (lines)	Size of Pads (in.)	Watts	Features	Cost* ($)
Panasonic Co.	EB-H60	Mobile mounting kit		9.4				55 min talk time	899
Panasonic Co.	EB-H30	Mobile mounting kit		12.4, 13.4 w/battery				Hands free, 40 min talk time	499
Pioneer	PCC-900	Mobile mounting kit		9, 10.9 w/battery				Hands free, 43 min talk time	
Pioneer	PCC-700	Mobile mounting kit		9, 10.9 w/battery				43 min talk time	
Pioneer	PCH-600	Mobile mounting kit		18.6, 19.6 w/battery				Hands free, 30 min talk time	
Radio Shack	CT-352	Mobile mounting kit		6.9, 9 w/battery	2			50 min talk time, data interface	
Sanyo	CMP330	Mobile mounting kit		14.1, 17.1 w/battery				Hands free, 60 min talk time	899
Shintom	CH8950			11.1				60 min talk time	899
Sony	CM-RX100	Mobile mounting kit		6.7, N/A	2			90 min talk time, data interface	300
Sony	CM-H1	Mobile mounting kit		11.1				Hands free, 95 min talk time	995
Tandy	CT-350			12				90 min talk time	799
Tandy	CT-302	Mobile mounting kit		15.9				60 min talk time	499

*Note: Price information may vary depending on vendor and cellular carrier

Market Survey of Cellular Telephone Features

Make	Model	Item	Size (in.)	Weight (oz.)	Size of Display (lines)	Size of Pads (in.)	Watts	Features	Cost* ($)
Technophone	PC415	Mobile mounting kit		9.7, 11.6 w/battery				Hands free, 60 min talk time	599
Technophone	PC405A			9.9, 10.9 w/battery				60 min talk time	599
Technophone	PC305A	Mobile mounting kit		9.5, 10.5 w/battery				Hands free, 60 min talk time	599
Technophone	PC205A			14, 15 w/battery				60 min talk time	599
Toshiba	TCP-2000	Mobile mounting kit		5.3, 7.5 w/battery	3			60 min talk time, data interface	
Uniden	CP7500	Mobile mounting kit		7.9, 8.2 w/battery	2			72 min talk time, data interface	
Uniden	CP5500	Mobile mounting kit		10.6, 12.4 w/battery				Hands free, 72 min talk time	899

*Note: Price information may vary depending on vendor and cellular carrier

Appendix C

Research Literature Critical Review

Human Factors Research Summary

Author	Methodology	Hand-held			Hands-free/Voice Activated			Mounting Location	Conversation Task
		Dial	Receive	Talk	Dial	Receive	Talk		
Brown et al., 1969	Test track / instrumented vehicle					X	X	n/a[1]	Cognitive[2]
Kames, 1978	Test track / instrumented vehicle	X						CON & IP[3]	none
Drory, 1985	Driving simulator					X	X	n/a	Cognitive
Stein et al., 1987	Driving simulator	X	X	X	X	X	X	CON & IP	Cognitive
Boase et al., 1988	Laboratory - computer game					X	X	n/a	Simple / intense conversation
Zwahlen et al., 1988	Test track / instrumented vehicle	X						CON & IP	none
Hayes et al., 1989	On-road / instrumented vehicle	X						CON & IP	none
Alm & Nilsson, 1990	Driving simulator					X	X	IP	Cognitive
Brookhuis et al., 1991	On-road / instrumented vehicle	X	X	X	X	X	X	?[4]	Cognitive
Fairclough et al., 1991	On-road / instrumented vehicle					X	X	?	Simple / intense conversation
Nilsson & Alm, 1991	Driving simulator					X	X	IP	Cognitive
Kantowotz, et al, 1996	Driving simulator	X		X				IP	Simple task / Cognitive

Human Factors Research Summary (continued)

Author	Methodology	Hand-held			Hands-free/Voice Activated			Mounting Location	Conversation Task
		Dial	Receive	Talk	Dial	Receive	Talk		
Parkes, 1991	Laboratory, On-road/ instrumented vehicle					X	X	?	Cognitive
Green et al., 1993	On-road / instrumented vehicle	X		X				CON	Simple task / conversation
McKnight & McKnight, 1993	Driving simulator				X		X	IP	Simple/intense conversation
Nilsson, 1993	Driving simulator					X	X	IP?[5]	Cognitive
Serafin et al., 1993	Driving simulator	X		X	X		X	IP & HUD[6]	Cognitive
Pachiaudi & Chapon, 1994	Driving simulator					X	X	?	General conversation
Alm & Nilsson, 1995	Driving simulator					X	X	IP	Cognitive
Tijerina et al., 1995	On-road / instrumented vehicle	X		X				IP	Simple task/cognitive

1 Mounting location not applicable. Intercom devices were used to communicate between study participant and experimenter.

2 Cognitive tasks were used to control mental workload. Often, the chosen task was a variation of the Baddeley Logical Reasoning task where participants were to determine if the order of a pair of target letters matched the order stated in a sentence describing that pair.

3 CON refers to center console mounting location, with dial keypad horizontally aligned between front seats or on top of the transmission hump. IP refers to instrument panel mounting location, with dial keypad vertically aligned, usually within driver's line of sight.

4 Mounting location not specified by author.

5 Mounting location was not specified by author. It is assumed to be the instrument panel, however, since this study was conducted in the same driving simulator used in the study of Alm & Nilsson, 1990.

6 Head-up display in windshield.

Alm, H., & Nilsson, L. (1990). Changes in driver behaviour as a function of handsfree mobile telephones: a simulator study (DRIVE Project Vl 017, Report No. 47). Linkoping, Sweden: Swedish Road and Traffic Research Institute.

Type of Study: Driving simulator.

Keywords: hands-free cellular telephones, route difficulty, lateral position, workload, speed level, working memory span, subjective measures

Author's Abstract:

The effects of a mobile telephone conversation on drivers reaction time, lane position, speed level, and workload in two driving conditions (easy versus hard driving task) were studied in an advanced driving simulator. 40 subjects, experienced drivers in the ages 23 to 61 years, were randomly assigned to four experimental conditions. It was found that a mobile telephone conversation had a negative effect on drivers reaction time, when the driving task was easy. It led to a reduction of speed, when the driving task was easy. It had a negative effect on drivers' lane position, most pronounced when the tracking component of the driving task was hard. Finally, it led to an increase in workload for both the easy and hard driving task. The effects were discussed in terms of what subtask, car driving or telephone conversation, the drivers gave the highest priority. Some implications for information systems in future cars were discussed.

Sample and Methods:

- Drivers (20 male, 20 female) who had been licensed at least five years and who drove at least 10,000 km per year. Ages ranged from 23 to 61 (mean age 32.4).

- Subjects were randomly assigned to one of four experimental conditions:

  - "easy" (straight road) driving
  - "easy" driving and telephone task
  - "hard" (curvy road) driving
  - "hard" driving and telephone task

- The VTI Driving Simulator was used for the study.

- All subjects were given practice in the driving simulator. Those subjects in the telephone task conditions were also given practice with telephone calls.

- The cellular telephone used was an Ericsson Hot Line device mounted at the height of the steering wheel on the instrument panel.

- During testing, subjects in the telephone conditions had to answer an incoming call by pressing a telephone button which simulated a hands-free telephone operation. The telephone was mounted at the height and to the right of the steering wheel on the instrument panel. After answering, they then had to perform the cognitive task.

- Subjects in the two control conditions were only required to drive.

- The telephone task consisted of the Baddeley Working Memory Span Test where subjects had to answer "yes" if a sentence was sensible and "no" if it was nonsense. Each call to the driver on the telephone started with task instructions, followed by the presentation of five sentences. This task was paced.

- After all five sentences were read, subjects had to repeat the last word in each sentence in order of presentation.

- Each presentation (simulated telephone call) took roughly 60 seconds.

- A red square was used as a visual stimulus, acting as a hazardous object in the driver's path. Drivers were to brake as fast as possible whenever the red square appeared.

- Vehicle speed, lateral position, and brake reaction time to the visual stimulus were used as performance measures.

- Subjective measures of workload as measured by the NASA-TIX, and communication measures of the number of correct sentence judgments and the number of correctly recalled last words were also gathered.

Major Findings:

- For the easy (straight) route, drivers' brake reaction times were longer in the telephone task condition than in the control condition, while for the hard (curvy) route, drivers' reaction times were not significantly different in the telephone and control conditions.

- During the first distance measured (0-500 meters), drivers initiated the hands-free function to answer the mobile telephone.

– In the easy driving condition, no significant differences in mean lateral position were found between experimental and control groups.
– In the hard driving condition, mean lateral position increased when calls were received, compared to the control condition. In addition, when the randomly timed calls occurred during straight sections of the curvy road, mean lateral position decreased.
– Differences in lateral position for the control groups only in the easy versus hard driving conditions were not reported.

- The second distance (0-2,500 meters) measured driver performance during the entire period of the telephone task for each call.

– In the easy driving condition, drivers' mean lateral position was greater when using the telephone than in the control condition.
– In the hard driving condition, drivers' mean lateral position was greater when using the telephone than in the control condition. In addition, during calls, curvier sections of the road led to greater variation in lateral position.
– Differences in lateral position for the control groups only in the easy versus hard driving conditions were not reported.

- Subjective workload was measured by the NASA-TIX rating scales.

- Compared to the control groups, drivers who received calls had increased scores on the factors "mental demand," "physical demand," "time pressure," "operator performance," "operator effort," and "frustration level."
- An interaction between receiving calls and route was seen, so that drivers were more frustrated during telephone use, and this effect was further influenced by route difficulty.
– The hypothesis about higher workload due to telephone use was supported, but the hypothesis that workload should increase with the complexity of the driving task was refuted.

- Speed level was measured from the onset of receiving each telephone call and 80 seconds forward.

– Speed was lower for the drivers who used the telephone than for the control groups. For the easy route, speed was lower when the driver had to use the telephone. However, on the hard route, the difference in speed between telephone and non-telephone conditions was not significant.

- An interaction was seen between brake reaction time and route. For the easy route, the telephone task increased the subjects' reaction time to the visual stimulus. For the hard route, no differences were seen between the telephone task and control groups for brake reaction time.

- No differences in telephone task performance were found between the driving task complexity conditions.

Author's Conclusions:

- When the driving task was easy, a telephone task had a negative impact on drivers' ability to react quickly, but when the driving task was hard no negative impact was found.

- The demands of the hard-driving task may have induced drivers to concentrate more on the driving task, giving the telephone task secondary status, which limited its influence on drivers' behavior. In the easy driving task, drivers may not have had to allocate as much attention to the driving task, leading drivers to give the telephone task primary status.

- This explanation is supported by better memory retrieval scores during the easy task and greater frustration scores from the NASA-TLX during the hard driving task.

- The introduction of a non-driving task can have different effects, depending upon what priority drivers give the non-driving task.

- If the driving task is perceived as easy, the non-driving task may be treated as the primary task, and this may have negative effects upon drivers' ability to react quickly in an emergency.

- While a secondary task may have an alertness-arousing effect, this increase in alertness may not necessarily have a positive effect on driving. Instead, it may sometimes be used to improve performance on the secondary task, especially in easy driving conditions.

- The finding of increased physical workload scores may suggest that activation of the hands-free button should be improved, possibly by marking the hands-free button more clearly.

Critical Assessment:

- This study presents a dynamic picture of how drivers' priority, the road, and the secondary tasks mutually influence one another.

- Reaction time measures should also include a decision component following the detection of the stimulus. In a driving situation, the driver must not just detect the stimulus, but then he/she must make an appropriate response. Rarely is a single response the only appropriate response in a driving situation. The response (reaction) time is heavily influenced by the amount of uncertainty in the environment at the time of the stimulus (e.g., Hick-Hyman law). Traffic complexity should be a factor in the determination of driver reaction time.

- This study did not consider the influence of different types of conversations upon driver performance, which has been shown to have a significant influence in other studies. Furthermore, the "conversational" materials were demandingin terms of reasoning and memory requirements. This could induce a greater attentional distraction than that associated with normal cellular phone conversations. the paced nature of the taskswould also promote attention to the conversation rather than on the driving task. Presumably, paced dialogue is rare in normal cellular phone conversations.

- Drivers only received calls during driving. The act of placing a call is probably more demanding than receiving and should be a part of the experimental protocol.

- This study utilized a between subjects experimental design, comparing a group of drivers who performed the treatment task to those who did not (a control group). However, we cannot be certain that individual differences between the two groups were not present, which could explain the study's results. It is not known whether drivers in the two groups were matched to one another, or if other experimental control procedures were used to equate the individual characteristics of the drivers more closely, such as driving ability, memory recall, or simple reaction time.

Alm, H., & Nilsson, L. (1995). The effects of a mobile telephone task on driver behaviour in a car following situation. Accident Analysis and Prevention, 27(5), 707-715.

Type of Study: Driving simulator.

Keywords: hands-free cellular telephone, simulator, reaction time, mental workload

Author's Abstract:

The effects of a mobile telephone task on young and elderly drivers' choice reaction time, headway, lateral position, and workload were studied when the subjects were driving in a car-following situation, in the VTI driving simulator. It was found that a mobile telephone task had a negative effect upon the drivers' choice reaction time, and that the effect was more pronounced for the elderly drivers. Furthermore, the subjects did not compensate for their increased reaction time by increasing headway during the phone task. The subjects' mental workload, as measured by the NASA-TLX, increased as a function of the mobile telephone task. No effect on the subjects' lateral position could be detected. Taken together, these results indicate that the accident risk can increase when a driver is using the mobile telephone in a car following situation. The reasons for increased risk, and possible ways to eliminate it, are also discussed.

Sample and Methods:

- Forty subjects, 30 men and 10 women, participated in the study.
  - The subjects were divided into two groups, younger drivers (<60 years of age), and older drivers (60 years of age).

- Apparatus:
  - The VTI driving simulator was used for the study, with a Saab 9000 with manual gearbox used for the car body.
  - The mobile telephone used was an Ericsson Hot Line device with hands-free facility, mounted on the instrument panel to the right of the steering wheel.

- Participants drove an 80 km test route where they were forced into a car following situation 16 times during the test session.
  - Subjects in the experimental condition were exposed to a telephone task during eight of the car following situations.
  - In four of the telephone tasks, something safety critical occurred on the roadway,
  - Subjects in a control condition did not receive any telephone tasks.

- The Baddeley Working Memory Span Test was chosen as the telephone task where subjects had to determine whether sentences were sensible or nonsense. After 5 sentences were read, subjects were asked to recall the last word in each sentence, in order of presentation.

- Choice reaction time to the lead vehicle braking was used as a performance measure, as was headway and lateral position. Subjects were instructed to brake as fast as possible in response to the lead vehicle's braking.

Major Findings:

- Subjects in the experimental groups had a longer reaction time compared to subjects in the control groups.

- An effect was also present for age. Older subjects had longer reaction times than did younger subjects.

- Subjects in the experimental groups had a shorter minimum headway compared to subjects in the control groups.
  - The minimum headway also differed between age groups. Elderly subjects averaged a minimum headway of 50m, while younger subjects averaged a 42m headway.

- Average headway only differed between age groups, with older drivers maintaining a larger headway than younger drivers. Subjects did not compensate for an increased reaction time by increasing their headway.

- No significant difference was found between experimental and control groups for lateral position during the eight telephone tasks.

- Using the NASA-RTLX, subjects in the experimental groups rated mental demand, time pressure, effort, and frustration as higher compared to subjects in the control groups.

Author's Conclusions:

- The fact that drivers in the experimental groups did not compensate for increased reaction time with increased headway can be interpreted in two ways.
  - First, subjects may have been unaware of the impact of the mobile telephone task on their ability to react quickly.
  - A second explanation may be that subjects already had a large enough headway during the telephone task to compensate for decreased reaction time.

- The mobile telephone task led to an increased level of mental workload.
  - It is often argued that a driver can control the demands of the driving task, within reasonable limits. However, this study shows that drivers could not control the demands of the driving task, in terms of keeping the workload constant.
  - Driving in a car-following situation, and using the mobile telephone concurrently, may increase the risk of an accident if something unexpected happens.

Critical Assessment:

- The use of a simulator may have influenced driver behavior. Because drivers were not in any real danger, they may have reacted differently than if they were in a real-life situation.

- Answering questions about whether a sentence is sensible or nonsense is not a realistic task for using a mobile telephone and consequently measuring workload.

- A key factor in this study was that the telephone tasks occurred while the driver was in a car following situation. However, this is not the only road situation which may occur. To extend the validity of this study, other scenarios should have been incorporated such as performing the telephone task during a lane change or other complex maneuver.

Boase, M., Hannigan, S., & Porter, J. M. (1988). Sorry, can't talk now... just overtaking a lorry: The definition and experimentation investigation of the problem of driving and handsfree car-phone use. In E. D. Megaw (Ed.). Contemnorarv ergonomics (pp. 527-523). London: Taylor and Francis.

Type of Study:

-Structured interview of hands-free cellular telephone users (5 executives and 4 salesmen)

-Laboratory study using a computer game as the surrogate (driving) task (with a different group of participants).

Keywords: hands-free cellular telephones, dual tasks, self-assessments, age differences

Author's Abstract:

This study investigated the interactional effects of [simulated] driving and talking using a hands-free cellular telephone. Nine hands-free users were interviewed to provide preliminary information for the design of a laboratory study. The experimental data show that the quality of a complex dialogue suffered at higher simulated driving workloads. Simulated driving performance was also adversely affected with both simple and, to a greater extent, complex dialogues. These findings contrast with the comments from many users who state that their driving does not suffer because they have the option to reduce driving speed, to not answer a call, or to stay silent during a conversation.

Sample and Methods:

- 24 drivers, 6 young males, 6 young females, 6 older males, 6 older females. Age ranges not given.
- Participants played a "squash" type computer game involving tracking, prediction, and some decision making. The game was scored by tallying the number of balls hit as a percentage of total hits possible in the 90 second periods before and after the start of the dual task situation (omitting the 30 second band in which the telephone call began).
- Workloads within the squash game were calibrated prior to the experiment according to each subject's ability, which was determined after their "driver" performance on the surrogate task had reached a certain criterion level.
- An experimenter was present beside the participant during the testing sessions.
- A hands-free telephone was used but the model was not specified by the authors.
- Two participants were involved at a time. One operated the computer game while the other called the first participant five times. Callers played the role of an office worker and engaged drivers in five simple Information Dialogues (IDs), e.g., asking about favorite foods or past education. The first call occurred before task performance, the next three occurred during task performance and were timed to coincide with high, low, and mixed (both high and low) workloads, and the last call occurred after task performance.
- The entire task was then repeated with the experimenter taking the role of the caller and making calls to engage the driver in more difficult Negotiation Dialogues (NDS). The six NDs involved situations such as returning faulty goods to a shop or having a holiday booking altered by the company.
- At some point, the second participant, i.e., the caller in the ID condition, switched roles and received calls. (It is unclear whether this happened before or after the ND condition began,

or what the second participant did while the experimenter became the caller in the ND condition).

Major Findings:

- Task performance, as measured by percent of balls missed, deteriorated significantly (approximately 11%) at the high and mixed workloads, when conversation was introduced.

- The simple information dialogues produced a greater decrement in missed balls (14.5%) than did the more difficult negotiation dialogues (6.5%).

- Age differences showed decrements in task performance (percent of balls missed) in the dual task situation, with older participants performing significantly worse in the mixed workload condition.

- Recordings indicated that conversation length and pause length increased significantly in the dual task situations.

- Comparing post-task questionnaires to game scores showed that participants accurately assessed their own decreased game playing ability while conversing.

Author's Conclusions:

- Simulated driving performance [i.e., task performance] deteriorates significantly at the high and mixed workloads when conversation is introduced.

- While structured interviews with a separate population (5 executives and 4 salesmen who used hands-free cellular telephones) showed that drivers believe that their driving does not deteriorate when using the hands-free cellular telephone, the laboratory study revealed that participants perceived and stated that their game-playing ability deteriorated.

- The immediate feedback of missing squash balls may have shown experimental participants the extent of their performance deterioration while roadway drivers have no such clear-cut indication of how their driving performance in a car may be suffering.

Critical Assessment:

- Simulated squash playing while using a hands-free cellular telephone is not a good representational task of actual driving while using a hands-free cellular telephone. Since the safety of playing squash while using a hands-free cellular telephone is not really an issue, construct validity is questionable, and the results may not tell us much about the effects of cellular telephone operations or conversations on driving.

- Why omit the 30 second band in which the call began? It would be useful to know how participants performed while initially adjusting to the new dual task situation.

- The study did not consider participants previous squash-playing skills or familiarity with computer games. It is likely that an age difference in these skills obscures any age difference found in task performance.

- In the ID situation, using participants as callers allowed too little experimental control over the conversation and may have aided the callers' ability to handle the dual task once it became their turn to "take the wheel."

- It does not appear that the ID and ND situations were counterbalanced across participants (only the presentation order of WL on the squash game was counterbalanced). Therefore, learning effects may explain the better task performance in the ND situation since skill on the computer game could probably be learned very easily.

- The authors do not address the finding that performance decreased less with NDs than with IDS, which were supposedly easier. Other research suggests that driving performance may be more impaired with more intense conversation.

- Additionally, the authors did not provide a rigorous justification regarding the equivalence of the computer game to driving. In this regard, the study's relevance to real-world driving is suspect.

Briem, V., & Hedman, L. R. (1995). Behavioural effects of mobile telephone use during simulated driving. Ergonomics, 38(12), 2536-2562.

Type of Study: Laboratory study using pursuit tracking task as surrogate driving task.

Keywords: hands-free mobile telephones; driving performance, gender differences.

Authors' Abstract:

The effects on driving performance of using a hands-free, mobile telephone were investigated in a pursuit-tracking task that simulated driving. Twenty subjects in two age groups, 19-26 years (median=21 years) and 40-51 years (median 45.5 years) participated, with five males and five females in each group. The primary task was driving safely. The subjects drove for 20 min in each of three secondary task blocks with (i) simple telephone conversation about a familiar topic, (ii) a difficult telephone conversation, incorporating a test of working memory, and (iii) car radio tuning and listening. Half of the driving was done on a simulated firm road surface and half on a slippery road surface. The subjects' behavior was subsequently observed and classified in four activity categories, two without and two with a secondary task, with driving (i) on a clear road, and (ii) with obstacles, and with driving involving the secondary task components of (iii) communication, and (iv) instrument manipulation. The results show different patterns of driving performance on the two road surfaces. For driving on the slippery road, a deterioration was especially marked during manipulation of the instruments, in particular the radio, which required more prolonged manipulation than the hands-free telephone. Driving during an easy telephone conversation was associated with the least performance decrement, and could, in some cases, be seen as facilitatory. The female subjects tended to perform less well than the male subjects while driving on a slippery road. Some of this difference could be attributed to less previous driving experience. In general, the males drivers exhibited better control while driving under difficult conditions. There was no difference in driving proficiency between the age groups. It is concluded that simply conversing over a hands-free telephone while driving does not in itself impair performance. However, a difficult conversation may affect the driving adversely, and any prolonged manipulation of the telephone is liable to produce a performance decrement, particularly under conditions that put heavy demands on the driver's attention and skill.

Sample and Methods:

- Twenty (20) test participants in two age groups, 19-26 years (median=21 years) and 40-51 years (median 45.5 years) participated, with five males and five females in each group.

- A pursuit tracking task said to simulate driving was used as the primary task. In this task, test participants watched a computer monitor that displayed a curved line (the "road") and a triangle (the "car") on the upper half of the screen and an analogue speedometer on the lower half of the screen. The task was to keep the triangle on the line by means of a steering wheel, control speed with a pedal, and avoid obstacles (red horizontal bars that appeared next to the road and sometimes intruded). Various road signs (speed signs, phone-now signs, slippery road signs, end-of-slippery-road signs, and tune-radio-now signs) appeared on the screen as well. Firm road and slippery road conditions were simulated by applying velocity and acceleration dynamics, respectively, to the steering wheel controller.

- Test participants "drove" for 20 minutes in blocks associated with each of three secondary task conditions. A "radio" task required turning the radio on, tuning into and listening to at least four channels with a quick-tune (but not preset) facility, then turning the radio off. "Easy" telephone conversations were 2 minute dialogues about current events (War in Bosnia, Child prostitution in Thailand, Clinton's economic policies in the US, and the unemployment situation in Sweden). "Difficult" telephone conversations were 2-minute working memory tests similar to those used by Alm and Nilsson (1990).

- Within the 20-minute blocks, firm and slippery road surface conditions were presented in alternate 5-minute sub-blocks. During half of each 5-minute sub-block, the test participant engaged in the assigned secondary task. During the other half of each 5-minute sub-block, the test participant either drove only or drove only with obstacles that had to be avoided (i.e., no secondary task was ongoing).

- The independent variables analyzed were: two levels of Road surface (firm vs. slippery); three levels of Secondary task (radio, easy conversation, difficult conversation); and four levels of Activity (driving only, driving only but with obstacles to avoid, driving with communications over the mobile telephone (2-way) or the radio (conceived of as one-way communication in the study), and driving with manipulation of the radio or telephone). The analysis also examined the effects of between subject-variables of gender, age group, number of kilometers per year a test participant drove, and number of previous incidents that a test participant had been involved in while driving.

- The three sets of dependent variables were identified. First, road position was measured as a) Root Mean Square (RMS) position deviation off of the curved line), b) percent of time the car triangle was on the "shoulder of the road", i.e., between 25 and 50 pixels from the road, during which a green point was presented on the screen; c) percent of time the car triangle was "off the road", i.e., greater than 50 pixels from the road, during which red pointer was presented on the screen; and d) number of corrective steering movements that the driver performed. Second, the number of collisions with obstacles that appeared twice in every 5 minute sub-block was measured. Third, speed of driving was measured as a) mean driving speed relative to the given speed limit; b) RMS (absolute) deviations from the speed limit; and c) fast and slow violations, the former defined as the number of times that the test participant's speed went more than 10 km/hr above the speed limit, the latter defined as the number of times that the test participant's speed went more than 10 km/hr below the speed limit.

Major Findings:

- Preliminary assessment of the test participant variables resulted in only Gender being retained as a between-variable in subsequent analysis.

- Road position measures showed the following results. For position deviation, slippery road surfaces were the single most difficult condition. Among secondary tasks, the radio secondary task degraded performance most, followed by difficult conversation, then easy conversation. Among Activities, manipulation and driving only but with obstacle avoidance led to the greatest position deviations and small position errors. Males on average performed the tracking task better than females. Significant interactions among the three factors were reported as well for the RMS position deviation measure. Steering wheel movements revealed no effects.

- In terms of collisions, females had substantially more collisions than males on simulated slippery surfaces but males had more collisions on simulated firm or dry surfaces.

- Speed measures revealed the following. The only significant effect on mean speed revealed, somewhat paradoxically, that the test participants "drove" slower on the firm than on the slippery surfaces. In terms of speed deviation, there was significantly less speed deviation, on average, on firm surfaces than on slippery surfaces. Furthermore, speed deviation differed in statistically significant ways as a function of levels of secondary tasks, with greater speed deviations during difficult conversation than during simple conversation, with the radio task falling in between. A complex pattern of two-way and three-way interactions is reported for speed violations.

Authors' Conclusions:

The authors state that the results show that communication in the form of conversing over a hands-free mobile phone or listening to a car radio during a simulating driving task affects driving performance in various ways. Given the current state of the art in mobile communications equipment, the authors advise that the driver park the vehicle before attempting to initiate telephone calls under difficult driving conditions, such as in-town traffic, on an unstable road surface, or with reduced visibility. They conclude cautiously by pointing out that the extent to which their findings can be generalized should be determined more closely in field studies of driving while using hands-free and hands-on mobile telephones.

Critical Assessment:

- The authors present a useful characterization of the car driving task in terms of modern theory from cognitive science.

- No data are provided to support the assertion that the pursuit tracking task simulated driving. The validation of driving simulators has proven to be a difficult undertaking and the low fidelity of the tracking task to real-world driving suggests that this may not be a faithful simulation. The demand characteristics of the laboratory situation may have been substantially different from that of real world driving.

- Because the pursuit tracking task is of unknown validity with respect to real world driving, the practical significance of the statistically significant results cannot be determined.

- The authors state that the primary task for the test participants was to drive safely. However, there were no consequences to degraded performance on the tracking task.

- No description is provided for the mobile telephone used in the experiment. This makes it impossible to appreciate the nature of the manipulation demands associated with telephone. Thus, though mention is made of a manipulation task associated with the hands-free phone (something of an oxymoron), no details are provided.

- It is also unclear how the radio task data was parsed into manipulation components and "one-way communications" components. For example, there was no driver test administered to examine the extent to which the driver appreciated the contents of a radio broadcast. If so, there may have been no communications going on at all.

Brookhuis, K. A., de Vries, G., & de Waard, D. (1991). The effects of mobile telephoning on driving performance. Accident Analvsis and Prevention, 23(4), 309-316.
Type of Study: On-road research with an instrumented vehicle.
Keywords: hands-free cellular telephones, hand-held cellular telephones, on-road measures, instrumented vehicle, human information processing

Author's Abstract:

The effects of telephoning while driving were studied in three different traffic conditions, i.e., in light traffic on a quiet roadway, in heavy traffic on a four-lane ring-road, and in city traffic. Twelve subjects, unfamiliar with cellular telephones, drove an instrumented vehicle for one hour each day during three weeks and while in each of the three traffic conditions, had to operate the cellular telephone for a short while.

To ensure a fixed "heavy traffic load" in the second condition, the subjects were instructed to follow another instrumented vehicle (at a safe distance). The results showed a significant effect of telephoning while driving as opposed to normal driving (i.e., not involving telephone conversation), on the effort subjectively measured by an effort scale and objectively measured by heart rate indices and on some of the measured parameters of driving performance.

One half of the subjects had to operate the cellular telephone manually, the other half performed the cellular telephone task with a hands-free cellular telephone set. The subjects who operated the hands-free cellular telephone showed better control over the test vehicle than the subjects who operated the hand-held cellular telephone, as measured by the steering wheel movements. Also, a clear improvement over time in the course of the 15 test days was found for some of the measurements. As a consequence of the results, some advice concerning mobile telephoning can be given to authorities, manufacturers, and users.

Sample and Methods:

- Drivers who had been licensed for at least five years, who drove at least 5,000 km annually, and who had not previously used a cellular telephone.
  - 12 Dutch participants (10 male, 2 female).
  - 4 participants were between 23-35 years old, 4 were between 35-50 years old, and 4 were between 50-65 years old.

- The apparatus used was a Volvo 245 GLD with redundant controls, modified to measure lane tracking, steering wheel movements, speed, following distance, and drivers' rear view mirror checking. An event recorder also measured drivers' cardiac inter-beat-intervals.

- A driving instructor was present during the testing sessions.

- Both hand-held and hands-free cellular telephones were used, however, the models for both types of telephones were not specified by the authors.

- For three weeks the driving performance of each subject was tested on every working day [although not specified by the author, it is assumed to be Monday through Friday], with and without operating a cellular telephone under three traffic conditions, i.e., light traffic on a quiet road, heavy traffic on a 4-lane road, and city traffic. To ensure heavy traffic, subjects were to follow an instrumented lead vehicle.

- Subjects both placed and received calls, although it was not specified whether or not they did both under all experimental conditions. The cellular telephone task consisted of a 3 minute paced serial addition task that was a fairly hard combination of a memory test and a mental arithmetic test.

- Half of the subjects had to operate the cellular telephone manually by picking up the handset. The other half of the subjects performed the task with a hands-free set.

Major Findings:

- Talking on a cellular telephone while driving significantly decreased standard deviation of lateral position, i.e., swerving, particularly on quiet roads.

- Talking on the cellular telephone significantly delayed reaction time in adapting to speed of variations of a car in front by 600 msec, only when the car in front's speed changes were not easily discriminated, e.g., when the front car slowed without lighting its brake lights.

- In city driving, steering wheel movements were affected by cellular telephone use. An interaction was found between cellular telephone type (hands-free/hand-held) and movements before versus after telephone contact:
  – For drivers who dialed, the amount and amplitude of steering wheel movements were "violent" during the 20 sec. period before contact with the second party was reached, while for drivers who simply received a call, the standard deviation of steering wheel movements was elevated during the 20 sec. period after the cellular telephone rang.

- Whether or not they were using the cellular telephone, drivers checked the rear view mirror less often on the busy ring-road (heavy traffic condition) than on the quiet road (light traffic condition). However, an interaction was found between type of road and subsidiary cellular telephone task, so that telephoning did not lower rear view attention in heavy traffic any further (it "bottomed-out"), while an ample margin of rear view mirror attention was available in light traffic.

- Heart rate increased when the subsidiary cellular telephone task was carried out, compared to driving alone. This finding was in accord with drivers' self-reports of workload. Heart rate variability was also affected by increasing workload; however, practice over the three weeks of the study had a habituating effect. A significant linear trend towards slower heart rate and decreased heart rate variability was found.

- The performance on the cellular telephone task itself, i.e., the percentage of correct answers to the paced serial addition task (PASAT), significantly improved with practice over the course of the three weeks, and a strong learning effect was apparent in the first week.

Author's Conclusions:

- On quiet roads, cellular telephone use may decrease automatic information processing, and this may have an alerting effect on the driver. The author conceptualizes this effect to take place at the operational level of driving. This lowest, operational level refers to the driver's automatic action patterns and basic control over the vehicle.

- Manual dialing of the cellular telephone has adverse traffic safety consequences, leading to steering wheel amplitudes that were ten times the amplitude of those on the quiet road. This effect is comparable to that of tuning a radio while driving found in Stein, et al, (1987).

- The tactical level of the driving task is most affected by telephoning, as opposed to the strategical and operational levels. This tactical level involves reactions to the maneuvers of other cars, including checking the rear view mirror, adapting to the speed of the car in front, and braking in reaction to speed changes of other drivers. In fact, drivers seemed to employ some minimum strategy that was not affected by the subsidiary task. Evidence for this minimum strategy was found in the fact that the increase in drivers' reaction time to braking lights while telephoning was not statistically significant.

- The highest, strategical, level of driving involves route planning and speed level. As measured by speed maintenance, this level was not affected by telephoning in the present study, since drivers did not change their speed when they had the chance on the quiet road.

- Traffic safety may be decreased by cellular telephone use under certain circumstances, especially dialing by hand while driving in city traffic.

- Hands-free cellular telephones, preferably equipped with voice-activated dialing systems, are recommended.

- During a conversation it is recommended that drivers keep ample distance from other drivers and drive at moderate speed in the slower lanes.

Critical Assessment:

- This study benefits from multiple measures, i.e., physiological, behavioral, and self-report. However, correlations between these measures were not performed.

- A small sample size may have led to a failure to reveal age differences. In fact, age may have a differential effect upon strategic, tactical, and operational levels of information processing during the driving task.

- The finding of less rear-view mirror checking in the heavy as opposed to light traffic conditions is not surprising. During the heavy traffic condition, drivers had to follow a lead instrumented vehicle. Priority would necessarily be given to devote attention to this vehicle as opposed to traffic following behind, especially since the driver had to react to the lead vehicle from time to time.

Brown, I. D., Tickner, A. H., & Simmonds, D.C. V. (1969). Interference between concurrent tasks of driving and telephoning. Journal of Applied Psychology, 53(5), 419-424.
Type of Study: Closed-course test track with an instrumented vehicle.
Keywords: hands-free cellular telephones, gap judgment, spatial judgment, speed-accuracy tradeoff

Author's Abstract:

Twenty-four men were given the task of judging whether to drive through gaps which might be larger or smaller than the car. They were also given a telephoning task of checking the accuracy of short sentences. Interference between the concurrently performed tasks was investigated. Telephoning mainly impaired judgments of 'impossible' gaps ($p < .0l$). The control skills employed in steering through 'possible' gaps were not reliably degraded, although speed of driving was reduced ($p < .01$). Driving increased errors ($p < .01$) and prolonged response times ($p < .005$) on the sentence-checking task. It is concluded that telephoning has a minimal effect on the more automatized driving skills, but that perception and decision-making may be critically impaired by switching between visual and auditory inputs.

Sample and Methods:

- 24 males within the age range 21-57 years old (median age 41).

- Car driving experience of these participants ranged from 3-37 years (median time 15.5 years) .

- 22 participants were volunteers from the U.K. Ministry of Transport, and the remaining two were drawn from the Cambridge Applied Psychology Research Unit's Research Panel.
- Participants were alone in the test vehicle during the testing sessions.

- Participants communicated with the experimenter via a radiophone, consisting of a loudspeaker and telephonist headset. No manipulation of controls was necessary to perform the telephoning task.

- For the driving task, participants drove a 5 ft. wide test car around a track that required them to judge whether or not to drive through 20 gaps (4 of each size: 3 inches < car, 0 inches < car, 3 inches > car, 6 inches > car, 9 inches > car). In cases where drivers opted not to drive through a gap, the alternate route posed a comparable delay.

- In addition to judgments, successful clearing of accepted gaps, speed of performance, and lateral and longitudinal accelerations were measured.

- The telephone communications task was a paced grammatical reasoning task in which the driver heard a short sentence followed by the letters "A" and "B," where each sentence claimed to describe the order of the letter pair that followed. The driver decided whether the sentence was true or false and responded accordingly. Speed and accuracy of responses were recorded. Examples are provided below:

Incoming Phone Message: "A follows B... BA"
Driver (Correct) Response: "True"
Incoming Phone Message: "B precedes A., . AB"
Driver (Correct) Response: "False"

- The telephone task was presented over a loudspeaker in the vehicle. The subjects responded via a telephonist's headset. A second experimenter sat in the back seat of the car and controlled the transmit/receive selector by a footswitch.

- All participants had 5 minutes practice on sentence-checking while stationary, then one practice trial of driving through the course and making gap judgments without the sentence task. Finally, participants had one practice trial of driving and telephoning concurrently. Six test trials followed in this order: 10 minutes of the sentence task, first driving-only trial, first concurrent trial, second concurrent trial, second driving only trial, and another 10 minutes of the sentence task only. Drivers met the various sizes of gaps in a different order on each trial.

Major Findings:

- In impossible gaps (width either 3 inches narrower than or width equal to the car) and in the largest possible gap (width 9 inches wider than the car), the percentage of errors of gap-judgment was significantly higher when drivers also had to telephone (19.2% increase for -3 inch gaps, 22.2% increase for 0 inch gaps, and 10.8% increase for 9 inch gaps). An impossible gap error judgment was defined as attempting to go through a gap that was narrower than or equal to the width of the car. A possible gap error judgment was defined as failing to go through a gap that was wider than the car.

- Skill in steering through possible gaps, as measured by clearing the gap, was not reliably impaired by telephoning, although there was a tendency for performance to be degraded when clearance was reduced to 3 inches wider than the car.

- A 6.6% increase in driving time per circuit was observed when participants telephoned concurrently. However, drivers' speed reduction was insufficient to prevent mutual interference between gap-judgment and sentence-checking.

- Average speed (.79 sec. longer) and average accuracy (21.2 more errors) of telephoning performance (sentence-checking) were both substantially impaired when participants also had to drive.

- There was a significant positive correlation between increase in driving time and increase in errors of gap-judgment.

- There was a significant negative correlation between increase in driving time and increase in errors on sentence-checking.

Author's Conclusions:

- Concurrent telephoning may have produced both a relaxation of gap-judgment criteria and an impairment of perception, resulting from switching between sensory modes.
  - The relaxation of gap-judgment criteria would explain the increase in errors on impossible gaps, but would not explain the fact that drivers accepted <u>fewer</u> possible gaps while telephoning.
  - When telephoning, drivers' perception was impaired as a result of switching between sensory modes (auditory and visual). However, a sensory impairment could not have been the sole source of interference, or the most difficult judgment (of 3 in. clearance) would probably have been degraded most rather than least.
  - During judgments of possible gaps, the tendency for impaired perception to produce errors of rejection would have acted in opposition to the tendency for relaxed criteria to produce errors of acceptance.
  - During judgments of impossible gaps, both impaired perception and relaxed criteria would have produced errors of acceptance. This would account for the finding that divided attention had the differential effect of causing a significantly large increase in acceptance of impossible gaps, but a smaller and mainly insignificant increase in rejections of possible gaps.

- The increase in driving time observed when drivers were telephoning could have resulted from at least two possible explanations:
  - When telephoning, drivers made more gap-judgment errors, so they drove through the additional impossible gaps more slowly. This

cautiousness would account for the finding that errors of gap-judgment were positively correlated with driving time.

– Alternatively, drivers deliberately reduced speed in order to handle the additional load of the sentence-checking task. Results suggest that drivers used the additional time to maintain performance on the telephoning task, at the expense of increased errors on gap-judgement.

- Drivers' age may determine the priority given to concurrent tasks of telephoning and driving, although the present study's sample size to detect this age difference was not sufficient.

- Calls while driving will take longer than ordinary calls, since messages such as the Baddeley (1968) that contain little redundancy are substantially affected by driving; therefore repetitions would be necessary to transmit all information, in practice.

Critical Assessment:

- This study assumes people utilize limited capacity, single channel information processing. However, one could argue that auditory and visual inputs may be processed in parallel.

– While an elegant explanation for results obtained, the author acknowledges that the claim that drivers suffer from a perceptual impairment during concurrent telephoning and driving deserves further study to determine whether this impairment is a function of the driving task, the type of conversation, or driver characteristics.

- The Baddeley (1968) task is a highly demanding cognitive task, and may be atypical of normal cellular telephone conversations. More recent research (e.g., Parkes, 1991) has found that type of conversation may differentially affect driver performance.

- After repeated hits, the gaps on the driving route may have "worn in" a little. This possibility of instrument decay may affect the ability to say with certainty that the concurrent tasks were solely responsible for producing the measurements obtained.

- Generalizability of results to real-life settings may be questionable since most gaps with a width of consequence are to a driver's side when passing, rather than straight ahead. Moreover, the closed course without traffic does not resemble normal roadway conditions.

- Results of this study should be generalized with caution to modern cellular telephones since the tasks associated with modern technology may be different than what was obtained/tested in 1969.

- With an unfamiliar test vehicle, drivers may not be as proficient at judging gaps than in a familiar vehicle.

- Task order should have been randomly counterbalanced between participants, even though results show that learning on the driving and telephoning tasks was negligible.

Department of the California Highway Patrol. (1987). A special report to the legislature on the findings of the mobile telephone safety study. California State Senate Concurrent Resolution No. 8.

Type of Study: See Stein, Parseghian, & Allen (1987) for a full review.

Keywords: manual hand-held cellular telephones, memory-dial hands-free cellular telephones, voice-activated hand-held cellular telephones, cellular telephone mounting location, lane position, radio tuning, age differences

Abstract:

The impact of cellular telephone use on driver performance was tested using an interactive driving simulator. While drivers followed a 15-mile route containing curves, obstacles and signs, they sent and received mobile calls and tuned a radio. Type of cellular telephone varied (i.e., manual dialing/ hand-held: memory dialing/hands-free; or voice-activated/hand-held), as did cellular telephone mounting location (dash or center console). Performance was compared between driver age groups, genders, and driving conditions, i.e., baseline driving, mobile phoning while driving, and radio tuning. Results suggest that manual dialing leads to driver performance that is worse than radio tuning; that performance deficits related to a secondary task increase with drivers' age; and that cellular telephones that are mounted within the driver's peripheral vision may reduce accident exposure compared to cab locations that are beyond peripheral vision.

Drory, A. (1985). Effects of rest and secondary task on simulated truck-driving task performance. Human Factors, 27(2), 201-207.
Type of Study: Driving simulator.
Keywords: fatigue, performance, heavy-haul driving, repetitive tasks, secondary tasks

Author's Abstract:

The study was designed to examine the effects of extra task simulation and extra rest on performance and fatigue of [heavy] haul truck drivers engaged in a simulated driving task. Sixty male subjects, randomly selected from the population of truck drivers in a large mining company, operated a driving simulator for a period of 7 h[ours] . A 2 x 3 experimental design was employed including two levels of rest conditions and three levels of secondary-task manipulations. The results show that performance and perceived fatigue were significantly higher when a secondary task involving voice communications was added to the basic driving task, but an added vigilance task had less effect. An extra 30-minute rest period in the middle of the experimental session significantly alleviated the reported experience of fatigue but did not affect performance. The results are discussed in terms of their relevance to actual industrial driving tasks.

Sample and Methods:

- Sixty(60) professional heavy-haul truck drivers randomly selected from a total population of 300 drivers employed by a large mining firm.
  - Participants' ages ranged from 24-55 years old, with a mean of 39 years old.
  - Participants had an average of three years of haul truck-driving experience with the company.

- A modified Redifon light motor vehicle simulator was used, showing a dimly lit road with no roadside features (corresponding to boring, rural driving conditions). A data logger switched lights, timed events, and monitored driver behavior.

- Participants drove for seven hours (21 blocks of 15 minutes duration each). Between each block was a six-minute rest.

- The vigilance task required that drivers turn off a set of four lights with corresponding switches. These lights illuminated in a random pattern, with an average frequency of one every 40 seconds.

- Participants communicated with the experimenter via a speaker and intercom device. No manipulation of controls was required to initiate the voice communication task.

- The voice communication task required that drivers respond to an incoming call over the intercom by reading the two least significant digits of the odometer (e.g., if the odometer showed 47,268.3 miles, participants were to respond "8.3". Drivers were contacted four times during each 15-minute block at random intervals.

- Participants practiced until they were capable of maintaining a steady position on the simulated road and were able to operate the vigilance or voice equipment as required for the particular experimental condition. It took 15 minutes to train the average participant.

- Five measures of driving performance were continuously recorded by the simulation apparatus: steering wheel reversals (SRT), tracking error (TET), number of brake responses to the appearance of tailgate lights (BRT), average brake reaction time (BTT), and control light response time (CRT). In addition, a subjective fatigue checklist was administered 15 minutes before the end of the experiment.

Major Findings:

- In general, the voice communication condition (driver is contacted four times during each 15-minute block at random intervals via speaker and asked to report current odometer reading) tended to yield the best performance whereas the basic driving condition (no secondary tasks) yielded the poorest performance. These results are presented in more detail, as follows:
  - Brake reaction time was significantly lower in the voice communication condition than in the basic driving condition.
  - Drivers made significantly fewer steering reversals in the voice condition than in the basic condition.
  - Drivers made significantly fewer lane-tracking errors in the voice condition than in the vigilance condition (a switch-operated light-canceling task).
  - Drivers made quicker and more accurate responses to a simulation of handling control lights (to operate the hauling mechanism?) in the voice condition than in the vigilance condition. Drivers' responses in the vigilance condition, in turn, were quicker and more accurate than the basic condition.

- No significant differences in performance were found with regard to the rest factor (30 minutes rest after the first three hours) for any of the five dependent variables.

- Self-reported fatigue was significantly lower on the extra-rest condition.
  - The level of fatigue reported by drivers in the voice communication condition was significantly higher than those in either the vigilance task or the normal driving condition.

Author's Conclusions:

- A secondary task consisting of voice communication stimulus, a simple odometer screening and verbal response was more effective in maintaining good driving performance than a secondary vigilance task that required turning off lights by choosing the correct button.

- Secondary tasks should not be so demanding as to distract the operator's attention from driving and yet still have the potential of forcing him or her to maintain a higher level of alertness.

- The voice communication task forced drivers to maintain a relatively higher level of alertness and concentration which, on one hand, improved their performance, but at the same time increased their subjective reports of fatigue.

- In industrial driving situations, both performance and fatigue should be considered as independently important. Extra rest may help to alleviate increased sensations of fatigue introduced by a performance-improving secondary task; however, extra rest alone does not seem to aid performance.

Critical Assessment:

- This study highlights the possible benefit of increased performance when a secondary task, such as making verbal reports of odometer readings, is introduced into the monotonous task of driving. Results obtained by studying haul driving may not be generalizable to the less repetitive and more variable driving patterns found in non-industrial, non-simulator settings. However, the results do provide empirical evidence to support professional truck drivers' intuitions that conversation (currently accomplished mostly via the citizens band radio) can break the monotony of driving and help keep the driver awake.

- The voice communication condition did not involve a cellular telephone--rather it was handled through a speaker. While these results may help to illustrate the effect of communication on fatigue and alertness, this study's design did not consider performance effects of manipulating the cellular telephone equipment itself or the effects of engaging in different types of communication.

- Although this article's focus on heavy-haul drivers differs from the cellular telephone literature, Drory makes a useful contribution to the number of articles that find secondary tasks sometimes have what could be described as a general alerting or arousing effect on driving performance.

Fairclough, S. H., Ashby, M. C., Ross, T., & Parkes, A. M. (1991). Effects of handsfree telephone use on driving behaviour. Proceedings of the ISATA Conference, Florence, Italy, ISBN 0947719458.

Type of Study: On-road research with an instrumented vehicle.

Keywords: hands-free cellular telephones, driver workload, heart rate, eye movements, route completion time, self-report

Author's Abstract:

Previous HUSAT research estimates that 65% of all cellular telephone conversation involves verbal negotiation. The present study required subjects to drive an experimental vehicle in a real road environment over three different experimental conditions. Two of the conditions involved a secondary task of engaging in a role-play negotiation whilst driving.

One condition involved negotiation with an experimental 'stooge' via a hands-free (i.e., no dialing or holding the handset required) cellular telephone and in the other, negotiation with an experimental 'stooge' sat in the front passenger seat. The third condition was an experimental control with no verbal negotiation task involved.

Twenty-four subjects took part in the experimental study. Driving behaviour was measured both in terms of objective data (time to complete experimental route, heart rate, eye movement behaviour) and subjective data (NASA-TLX and post-experimental questionnaire). The results of the study indicate that subjects found the secondary task conditions more difficult than the experimental control.

In the speaking and driving conditions, average speed decreased, heart rate increased and the questionnaire responses revealed an equivalent increase in perceived mental workload/stress compared with the control condition. The differences between the two speaking conditions were less pronounced yet significant at the physiological level. The implications of these results for cellular telephone users and cellular telephone design are discussed.

Sample and Methods:

- 24 drivers participated.
  - All were familiar with the area of the experimental route (however road type, e.g., curvy or urban, is not described).
  - Mean age of participants was approximately 45 years old with a mean of 25 years driving experience. (Participants' age ranges and gender were not described).
  - Extraversion and introversion measures were taken with the Eysenck personality test.

- Three miniature video cameras were installed in an experimental vehicle to record drivers' face and eye movements, a view of the road ahead, and a view out of the right side of the vehicle.

- Each driver was exposed to three experimental conditions: normal driving (CONTROL), driving while conversing on a hands-free cellular telephone (CARPHONE), and driving while conversing with a person [the experimenter] in the front passenger seat (PASSENGER). Presentation order of experimental conditions was counterbalanced across subjects.
- The driving condition difficulty was not specified.

- A hands-free cellular telephone was used but the specific model was not reported by the authors.

- In both the CARPHONE and PASSENGER conditions, drivers negotiated a predetermined topic, e.g., booking a summer holiday or negotiating a partial exchange deal for the purchase of a car, until they reached a conclusion that was satisfying to them.

- Subjective data was gathered through the NASA-Task Load Index of perceived workload, and a rating scale questionnaire was developed to collect attitudinal responses to the experimental tasks.

- Driving performance data was gathered through videotape analysis of frequency and duration of eye movements. In addition, the time taken to complete each circuit of the route was recorded in seconds, indicating the average speed over the whole route.

- Psychophysiological data was gathered through a radio device strapped to the headrest that monitored electrodes on the driver's chest. Data was logged every 4 seconds, and was converted into the standard beats per minute measure of heart rate.

Major Findings:

- TLX questionnaire results revealed the highest overall workload in both CARPHONE and PASSENGER conditions compared to the CONTROL condition.

- Analysis of factors showed that mental demand, mental effort, and frustration were all higher in CARPHONE and PASSENGER conditions compared to the CONTROL condition.

- The subjective questionnaire revealed that 58% of subjects indicated that they felt more stressed in the CARPHONE and PASSENGER conditions and found these conditions more difficult.

- Participants also reported the most awareness of the extra load imposed by the secondary task in the PASSENGER condition.

- Using (what sounds like) a semantic differential questionnaire, 75% of participants indicated that speaking via the cellular telephone felt "unnatural."

- Drivers took 5% more time to complete the experimental route in the CARPHONE and PASSENGER conditions than in the CONTROL condition.

- Female participants took significantly longer than the male participants to complete the experimental route in all conditions.

- No significant differences in eye movements were found between the three conditions.

- Heart rate was highest in the CARPHONE condition, and this rate was significantly higher than CONTROL and PASSENGER conditions.

Author's Conclusions:

- The reduction in speeding while speaking, either on a cellular telephone or to a passenger, represents a means to cope with the attention tradeoff between driving and conversation tasks.

- Increased difficulty of the two speaking conditions was also reflected in the results of the subjective data.

- Since no significant differences were found in drivers' eye movements between the three conditions, the interference effects introduced by the speaking task appear to be modality-specific.

- The finding that drivers' heart rate was significantly higher in the cellular telephone condition may be explained at least two ways. First, the novelty of the cellular telephone may have induced either stress or heightened arousal. Or, second, the cellular telephone conversation may be fundamentally more demanding than speaking to the passenger, and heart rate provides a physiological index of increased effort that went undetected by either the subjective or performance-based measures of driving behavior.

- The fact that heart rate was comparable between the passenger condition and the control condition may be explained by the fact that passengers can monitor the driver's task demands and converse appropriately.

- Additional driver stress while telephoning may be attributed to subjects' perceived lack of control over the continuation and initialization of the discourse. An interface should be developed to allow the driver to break from the conversation in case of any sudden rise in the demand of the driving task. This function would be augmented with machine-generated speech output informing the caller that the conversation has been interrupted because of the driving task, thereby taking the onus from the driver in the potentially embarrassing task of excusing themselves from the conversation.

Critical Assessment:

- In the description of participants, gender information and age ranges are not given. Without this information, it is hard to know for which kind of population the results may be pertinent. The finding that females took longer than males to complete the route might be more useful if we knew how many participants were of each gender and age.

- Heart rate may be increased by participants reactance to wearing electrodes. As a measure of workload, the heart rate measure may be artificially high.

- In order to rule out the novelty explanation for heart rate results, future studies may compare workload between experienced and novice cellular telephone users. Such a study may help to show whether cellular telephone conversation is "fundamentally more demanding," as the authors suggest.

- It would be interesting to see if the experimenters-as-passengers could be trained to not monitor the driver's task demands and converse appropriately.

- This study would have benefited from an additional measure of standard deviation of lateral position.

Green, P., Hoekstra, E., & Williams, M. (1993). Further on-the-road tests of driver interfaces: Examination of a route guidance svstem and a car phone (UMTRI Technical Report No. 93-35).

Type of Study: On-road research with an instrumented vehicle.

Keywords: hand-held cellular telephone, throttle position, lateral deviation, age differences

Author's Abstract:

In this experiment 8 drivers (4 younger, 4 older) drove a 19 turn, 35-minute route. The route included sections through residential neighborhoods, on city streets, and on expressways. They were guided by an experimental navigation system that provided turn-by-turn instructions via a display mounted on the instrument panel. During the trip each driver was asked to dial a telephone number and participate in a simulated telephone conversation. At the end of the trip drivers were asked to rate the difficulty of a variety of driver-information-system-related tasks.

The instrumented car recorded lateral position in the lane, speed, throttle position, steering wheel angle, eye fixation location, and other measures. Typical lateral standard deviations were 0.5 feet and decreased with speed. Speed standard deviations were slightly in excess of 1 mile per hour. Using the cellular telephone and navigation systems resulted in slight increases in the standard deviation of throttle position and the standard deviation of steering wheel angle.

There were 8 navigation errors in this experiment, comparable to the 25 errors from 30 drivers in a previous experiment, a fairly low number. This experiment demonstrated that repeatable and reliable measures of driver performance and behavior could be obtained using the test protocol employed in this experiment.

Sample and Methods:

- Eight licensed drivers participated (four under 30 years old and four aged 60 or older). An equal number of men and women were in each age category. The corrected visual acuity of all participants ranged from 20/17 to 20/20 on a Titmus vision test.

- The vehicle used was a 1991 Honda Accord station wagon modified to measure lane tracking, steering wheel position, speed, accelerator/throttle percent declination, road scene, driver scene, and audio.

- A Motorola cellular telephone lying on the passenger seat was used for the cellular telephone tasks.

- Drivers engaged in three types of secondary tasks over the hand-held cellular telephone. In the listening task, drivers listened to a 30-second description of a scenario and then were prompted to make a decision based on the information they heard (e.g., drivers heard a description of three options for dining out, and then had to decide where to go). In the talking task, drivers were asked to describe something (e.g., what they did last weekend) for 30 seconds. For the listing tasks, a category was named (e.g., fruits) and drivers listed as many items in that category as possible in 30 seconds.

- Drivers made a total of 12 cellular telephone calls, including 3 practice calls while stationary, 3 practice calls while driving, and 6 calls during the test session while driving. Drivers made each of the three types of cellular telephone calls (listening, talking, and listing) first while driving on a 50 mph road, and then on a 65 mph expressway. The 12 calls were made in a fixed order by all drivers at the same locations along the test route. Each call included dialing a familiar number on a hand-held cellular telephone and completing one of the three conversation tasks.

- Data was also collected for the same driving performance measures while drivers used the navigation system. These results are not reported here.

Major Findings:

- Baseline driving, defined as driving along the seven straight segments of the road without using either the cellular telephone or the navigation system, revealed the following:
  - Older drivers had larger standard deviations of steering wheel angle than younger drivers.
  - Younger drivers had a mean lateral position further to the left than older drivers.
  - For both younger and older drivers, mean lateral position was further to the left when the speed limit was over 55 mph than when it was 50 mph.
  - Standard deviation of lateral position decreased as speed limit increased.
  - For both younger and older drivers, mean speed increased as speed limit increased.

- The following effects of cellular telephone use on driving on straight roads were found:
  - Young drivers had a smaller standard deviation of steering wheel angle than older drivers, similar to the baseline and navigation data.
  - As measured by increases in steering wheel angle standard deviation, all three conversation tasks were equally difficult, and dialing was more difficult (distracting) than the conversation tasks.
  - Throttle position varied the most during the talking task, suggesting that talking was most difficult. Throttle position varied the least during dialing, suggesting that dialing was least difficult.
  - Measurements of mean lateral position showed that older drivers positioned the test vehicle closer to the center of the lane (3.0 feet to the right of the left edge verses 2.5 feet for younger drivers). This bias occurred for all road segments.
  - Differences in mean lateral standard deviation were found between road types. However, no differences were found between tasks, drivers' age, or their interaction.
  - Differences in mean speed were found as a function of road segment. In addition, on the expressway, younger drivers had a greater mean speed than older drivers, but not on the two-lane rural road.

- The following comparisons between baseline and cellular telephone task conditions were made:
  - As measured by mean speed, participants drove more slowly while using the cellular telephone than in the baseline or navigation conditions.
  - Participants drove more steadily, as measured by standard deviation of speed, in the baseline condition than in the cellular telephone condition.
  - As measured by standard deviation of lateral position, drivers had less lateral variability when using the cellular telephone (dialing or conversing) than when driving alone.
  - There was no differences between task conditions for absolute lateral position. An effect was seen between young and old participants, with older drivers positioning the vehicle closer to the center lane marking.
  - When the vehicle was driven at a fairly steady speed, mean throttle position was greater while telephoning than in the baseline condition.

Author's Conclusions:

- Except for the standard deviation of steering wheel angle and throttle position, the cellular telephone task conducted concurrently with driving did not lead to differential effects in driving performance. This lack of significant differences could be due to the short sampling period or small sample size. This makes sense in that throttle and steering wheel measures are direct driver inputs while speed and lateral position are the results of those inputs as smoothed by vehicle inertia.

- The finding that age and road segment led to occasional differences, with the pattern that older drivers had larger values and more stable performance on higher speed roads, is consistent with previous studies.

- The main road-related factor in concurrent driving and cellular telephone use is speed.

- The standard deviation of lateral position does not seem to make sense, with lower standard deviations occurring while the cellular telephone was used. This could reflect a tradeoff with speed.

Critical Assessment:

- It is unclear how findings of differences in throttle position or standard deviation of steering wheel angle translate into practical safety decrements.

- Types of calls and roadways should be counter-balanced between drivers to control for practice effects.
- The sampling interval for the dialing task (10 seconds) was one-third of that for the other tasks (30 seconds), which may explain some of the differences.

- Although results for use of the cellular telephone itself and performance on the subsidiary task are given, they were not analyzed to show tradeoffs in driver attention between driving and cellular telephone tasks.

- The finding that lower standard deviations of lateral position were found while drivers used the cellular telephone could make sense, given the possibility of overall increased activation (e.g., Brookhuis et al., 1991).

- Drivers' lack of familiarity with the test vehicle may lead to poorer, or at least less consistent, driving performance.

- The listening and talking tasks used materials that were more realistic than the complex "intelligence test" materials used by other researchers.

Hanowski, R., Kantowitz, 6. and Tijerina, L.(1995). NHTSA Heavy Vehicle Driver Workload Assessment Final Report Supplement -Workload Assessment of In-Cab Text Message Svstem and Cellular Phone Use bv Heavv Vehicle Drivers in a Part-Task Driving Simulator (NHTSA Contract DTNH22-91-C-07003).

Kantowitz, B., Hanowski, R., and Tijerina, L. (1996). Simulator Evaluation of Heavy-Vehicle Driver Workload II: Complex secondary Tasks. Proceedings of the Human Factors and Ergonomic Society 40th Annual Meeting, pp.877-881.

Type of Study: Driving Simulator.

Keywords: cellular telephones, commercial vehicle operation, simulation

Note: For a related on-the-road study see Tijerina, et al., 1995.

Author's Abstract:

This report and the associated conference paper contain the results of a simulator study conducted to serve as a supplement to a NHTSA heavy vehicle driver workload field study. Its purpose was the evaluation of effects of cellular phone and text message display use tasks on driver-vehicle performance. Fourteen truck drivers participated and were asked to engage in three cellular phone dialing tasks (auto-dialing; local 7-digit dialing, and long distance dialing), two cognitive cellular phone tasks (responding to questions of a biographic nature or involving mental arithmetic), and seven CRT message reading tasks (tachometer checking, time checking, radio tuning, 4-line reading, auto-dial, local dial, and long distance dial).

Driver-vehicle performance was also evaluated relative to traffic density. Results indicated that driver-vehicle performance varied with respect to each of the three kinds of in-cab tasks.

Performance was also differentiated with respect to traffic density, although to a lesser extent. Of note is that the CRT reading tasks had a relatively more noticeable impact on driver-vehicle performance than either the dialing or cognitive tasks. This report concludes with a comparison of simulator and on the road data collection results and prospects for future heavy vehicle driver workload assessments.

Sample Studies:

- 14 professional heavy vehicle drivers. Participant ages ranged from 26 to 68 years old, with a mean age of 47.1 years. Twelve of the drivers had previous cellular phone experience.
- The STISIM driving simulator developed by Systems Technology Inc. was the research apparatus. The closed-loop, low fidelity simulator is fully interactive and includes a 5-speed transmission, variable vehicle dynamics, simulated road noise, tire squeal, and wire frame rendering of displayed objects.
- The truck cab mock-up replicated the interior of a Kenworth truck cab, including a truck seat, steering wheel and turn-indicator assembly, and a neutral gear shift.
- The windshield of the cab was divided into two sections. The left front housed a 20 inch color monitor to present the various driving scenarios. The right section of windshield and driver side window were covered to reduce ambient lighting.
- Verbal responses were used for most of the in-cab tasks. Manual responses were required for a tachometer task and an object detection task.
- A Motorola Attache Cellular Telephone, Model #TX400 was installed to the right of the driver.

- A text message display consisting of a 7-inch diagonal VGA-compatible green-phosphor CRT was mounted on top of the instrument panel to the right of the seated driver.

- Driving scenarios consisted of six separate modules, each approximately 100,000 feet in length and required about 30 minutes to complete at 55 mph.

- Modules were defined by high and low traffic volume conditions and manual dialing events or no manual dialing events.

- At preset distances within a scenario, messages appeared on the text message display and were announced by an auditory alarm.

- When prompted by the text message display, drivers dialed a number and reached a recorded message presenting a set of paced questions, seven seconds apart, allowing time for the driver to respond. Dialog tasks lasted about 60 seconds and included biographic (easy/low difficulty) and arithmetic (moderate difficulty) questions.

- Manual dialing was completed by pushing a "send" button.

- All curves built into the scenarios were easy (i.e., shallow)and included nine to the right and nine to the left.

- In cab tasks were divided into cellular-telephone dialing and dialogue, text message reading, tachometer reading, time reading, manual radio tuning and object detection (pedestrian). All but object detection tasks were initiated by a text message.

- Manual task data (auto-dial, 7-digit, and 10-digit manual cellular telephone dialing, plus radio tuning as a control condition) and cognitive task data (the two question-and-answer dialogue tasks) served as measures of driver performance.

Major Findings:

- For manual tasks, mean lane position was closest to lane center for all dialing tasks and farthest for the radio tuning task relative to driving only without in-cab tasks.
  - Lane deviations during the manual tasks were smaller in high density traffic than in low density traffic.
  - Lane exceedences were greater during dialogues of either type than when driving only.

- Drivers reduced their speed for the local-dialing task.

- Standard deviations of vehicle speed were higher for radio tuning and local-dialing tasks.

- Latency to detect a pedestrian was <u>slower</u> when no phone call was in progress.

Author's Conclusions:

- Results indicate some disruption of simulated driving due to complex tasks.

- The standard deviation of lane position was affected by inserting secondary tasks.

- Lane exceedence was also influenced by secondary tasks.

- Time to detect a pedestrian in the roadway was improved by adding a complex secondary task.

- There were no effects of traffic density considered over the entire secondary task.

- During data entry, drivers were more careful about lane position when traffic was heavy.

- Comparison of results with the companion on-road study (Tijerina, et al., 1995) indicated a number of differences.
  - The on-the-road study found the greatest lane position standard deviation associated with message reading taks followed by the long-distance phone task. The simulator study found no differences between all reading and all dialing tasks.
  - Variability was greater in the simulator study.
  - No differences in lane exceedence were found in the on-the-road study for dual task conditions versus driving only. However, such differences were found on the simulator.

Critical Assessment:

A comparison of results with the companion on-the-road study (Tijerina, et al., 1995) yields a number of differences in findings. Despite the smilarity in tasks, materials and procedures, many differences existed between the two studies that could account for the discrepant findings and highlight the potential limitations of simulators for carrying out studies involving “risk taking” behaviors.

- Road scene characteristics were very different between the two studies.

- The cab layout for the two studies were different.

- The pattern of differences between the two studies suggested that heavy vehicle drivers in the simulator adopted a more lax attitude toward the driving task, perhaps as a result of the no-risk consequences of degraded lanekeeping in the simulator.

- Limitation in simulating driving condition variables (e.g., ambient lighting, road type) and the actions of other vehicles has the potential to limit the applicability of results where driver secondary task behavior (e.g., dialing a number, tuning the radio) might increase the risk of a crash.

Hayes, B. C., Kurokawa, K., & Wierwille, W. W. (1989). Age-related decrements in automobile instrument panel task performance. Proceedings of the Human Factors Society 33rd Annual Meeting.

Type of Study: On-road research with an instrumented vehicle.

Keywords: instrument panel, telephone dialing, radio-tuning, hand-off-wheel time, glances to display

Author's Abstract:

This research was undertaken, in part, to determine the magnitudes of performance decrements associated with automotive instrument panel tasks as a function of driver age. Driver eye scanning and dwell time measures and task completion measures were collected while 24 drivers aged 18 to 72 performed a variety of instrument panel tasks as each drove an instrumented vehicle along preselected routes. The results indicated a monotonic increasing relationship between driver age and task completion time and the number of glances to the instrument panel. Mean glance dwell times, either to the roadway or the instrument, were not significantly different among the various age groups. The nature of these differences for the various task categories used in the present study was examined.

Sample and Methods:

- 24 licensed drivers (12 males, 12 females). Drivers' ages fell into three groups of eight: 18-25,26-48, and 49-72.
  - Participants all had either correct or uncorrected near and far visual acuity of at least 20/40, as measured by a Titmus II vision tester. Participants' hearing was also screened informally.

- Apparatus:
  - 1985 Cadillac Sedan deVille with power mirrors, a fuel data center, a digital dashboard, cruise control, electronic climate control, modified steering wheel containing a Pontiac 6000 center hub push-button radio control panel.
  - Data recording instruments were also installed, including video cameras to measure eye movements and road conditions.
  - Location of an auxiliary instrument panel varied among four positions (high, low, parallel with dash, or angled). This panel included a 12-button standard telephone keypad, a 9-position discrete rotary knob, a 4-position discrete rotary knob, a 3 x 6 push-button matrix, two radio/cassette players (Kraco and Sparkomatic), a Pontiac 6000 push-button radio control panel, and an LED display custom designed to allow discrete or continuous adjustment.

- Participants performed 200 tasks involving the auxiliary instrument panel and the existing controls and displays. Each participant drove four 15-minute runs. Presentation order of tasks, road type, and panel location were counterbalanced. Task completion was measured by means of videotaped hand-off-the-wheel time and number and duration of eye glances to the display. Display and control training required approximately 1 hour. Once a participant was familiarized with the use of each control, the participant practiced with the instruments while driving until error-free performance was demonstrated.

Major Findings:

- Increased driver age significantly increased task completion time, hand-off-the wheel time, number of glances to the display, total glance time to the display, number of glances to the roadway, number of transitions between the roadway and display, total transition time, and mean transition length.

- No effect of gender on number of glances to the display or roadway, number of transitions between the roadway and the display, and total transition time.

- Task completion times increased with age for four representative tasks: tuning an analog radio (tune), dialing a 7-digit number on the telephone keypad (dial), pressing a button then reading the time on the radio (time), and adjusting the volume of a radio (volume). Of these four tasks, the radio tune task took the longest to complete for all ages, the dial task took all ages longer to complete than the time or the volume task.

- With one exception, number of glances to the display decreased according to task in this order: tune, dial, time, volume. The exception was that while young and middle-aged drivers glanced at the display more for the dial task than for the time task, older drivers glanced at the display more for the time task than the dial task. For the dial task, no differences in number of glances were found between the age groups. However, for the other three tasks, older drivers glanced at the display significantly more than young or middle-aged drivers, whose number of glances were comparable.

Author's Conclusions:

- The older drivers tested required more glances to the instrument panel in order to retrieve the necessary information for successful task completion, required more time to complete the instrumentation tasks, and required more time to move their eyes between the roadway and the display. This latter observation may be due to decreased motor functioning at later ages.

- Older drivers may require more glances to the display in order to interpret it, and further, may retain less information while time sharing between the roadway and the display.

- Presbyopia further reduces older drivers' visual acuity, contrast sensitivity, light transfer capability, glare sensitivity, and chromatic sensitivity.

- Character size of dashboard instrumentation labels should be increased.

Critical Assessment:

- While not specifically focused on the effect of cellular telephone use on driving behavior, this study illuminates the radio/dialing debate, a point to which the cellular telephone literature constantly returns. It is interesting to note that in the present study, while the dialing task was completed in less time and with fewer glances than radio tuning, the dialing task also did not differ between age groups. This finding may suggest that in comparison to other tasks where age differences mediate the amount of distraction, dialing has more constant attention demands common to drivers of diverse ages.

Kames, A. J. (1978). A study of the effects of mobile telephone use and control unit design on driving performance. IEEE Transactions on Vehicular Technology, VT-27 (4), 282-287.
Type of Study: Closed-course test track with an instrumented vehicle.
Keywords: hand-held cellular telephone, dash-mounted, lane position, head movement, driver preferences

Author's Abstract:

Concern about the effects of cellular telephone use on driving control led to the development of a methodology for evaluating driving performance. A summary of the methodology is presented along with the results of a study comparing the effects of dialing a cellular telephone to the effects of adjusting the car radio. A detailed account of a study of the effects of alternative control unit designs is provided. Three types of dials were implemented for this study.

They are a rotary dial, a push-button dial, and a push-button dial-in-handset. Three mounting locations for the push-button were studied: on the dashboard, in the dashboard, and in the visor area. The rotary dial and the dial-in-handset models were mounted on the transmission tunnel. The results of the study indicate that the *design* of a dial that is located within the reach and sight of the driver has little effect on driving control. User preferences favored a push-button dial mounted in the dashboard area.

Sample and Methods:

- Eighteen participants (12 males, 6 females), each of whom had at least three years of driving experience participated with ages ranging from 19 to 65 years.

- Participants were trained in responding to the subsidiary task, a visual identification task in which drivers verbally identified which one of four possible stimulus conditions (two colors of lights at two light locations) was in effect, and then extinguished the lights with a switch located near the brake pedal. This subsidiary task was chosen because reaction time was to be used to measure drivers' attentional load (however these results were not reported).

- When participants appeared to understand how to respond to the subsidiary task, they drove 5 miles to the driving track, a deserted airfield, and drove once through a 4.4 mile course, responding to the subsidiary task.

- Each driver dialed with each of six telephone dial designs: (1) rotary dial mounted below the dash, (2) push-button dial mounted horizontally on the dash, (3) push-button dial mounted horizontally in the visor area, (4) push-button dial mounted vertically in the dash, (5) 4 x 3 push-button dial-in-handset mounted vertically on the dash, and (6) 4 x 3 push-button dial-in-handset hand-held by the driver or (7) 6 x 2-type push-button dial-in-handset hand-held by the driver. The test of the hand-held dialing models (6 and 7) was split so that half the subjects used the 4 x 3 arrangement while the other half used the 6 x 2 arrangement.

- In each of the six telephone dial sessions, participants were given the opportunity to practice dialing one number while the car was parked.

- The instruction to begin dialing was given by the experimenter at predetermined locations along the route. It is not known whether the experimenter was present in the vehicle, or whether the signal to initiate a call was given from a remote location.

- Although never clearly specified, it is assumed that the driver did not need to immediately begin dialing upon the experimenter's signal, but rather the driver could choose the timing of when to initiate the call. Results for this measure are not reported however.

- Participants drove three circuits of the track for each of the six telephone dial designs they used, for a total of 12 calls with each telephone dial design.

- The following measures were taken during driving, driving while telephoning, and driving while adjusting the radio: rate and duration of head movements, rate of steering wheel reversals, range of speed, reaction time to the subsidiary task, lane position, latency to begin the task.

Major Findings:

- The 4 x 3 push-button dial-in handset mounted on the dash and the horizontal push-button dial mounted on the dash had less lane movement (3.28" and 3.22" respectively), compared to the other four telephone dial designs (3.64" -4.16").

- Rotary dialing time (16.0 seconds) was significantly longer than push-button dialing times (11.1-12.5 seconds).

- Drivers made significantly fewer head movements when using the horizontal push-button dial pad, whether dash (.30 times per second) or visor mounted (.17 times per second), than when using any other push-button dial (.41 - .44 times per second).

- Drivers reported that they were most uncomfortable about dialing while driving.

- About 42% of the drivers most preferred the 4 x 3 dial-in-handset mounted on the dash configuration. About 67% of the drivers least preferred the 6 x 2 dial-in-handset configuration.

- When asked to rate on a difficulty scale from one to ten, the difficulty of various activities which might be performed while driving, dialing was given the highest rating of the telephoning tasks (4.7, where 1 was "no difficulty at all", and 10 was "so difficult I would never do it while driving"). Writing something down and reading a map were rated more difficult than dialing (7.7 and 7.9 respectively).

- Hearing the telephone ring, and conversing on the telephone were rated the least difficult of the tasks associated with cellular telephones, 1.3 and 1.8 respectively.

Author's Conclusions:

- The design of the telephone dial design used did not have a great impact on driver control of the automobile.

- Of the performance measures used, only lane position demonstrated a significant difference between the horizontal dialing pad and the other configurations, but the magnitude of this difference was small (about 5" on the road).

- Differences found in the rate of head movement did not appear to affect driving control.

- Questionnaires administered after the driving portion of the study was complete indicated that the drivers who volunteered for the present study reported concern that the dialing task may interfere with the driving task.

- These drivers most preferred the 4 x 3 dial mounted on the dash and least preferred the 6 x 2-type dial-in-handset.

Critical Assessment:

- It is not clear whether the small differences in driver performance found between some of the dialing types and locations are great enough to translate into practical safety decrements on the road.

- While allowing drivers to decide when the cellular telephone task should be attempted may have indicated the subject's ability to assign priorities, it also reduces experimental control over the nature of each task combination. In fact, participants' success in assigning priorities was not reported.

- Results pertaining to a 6 x 2 vertical array may not be useful, since no phones appear to be built with this design. Using the 6 x 2 arrangement in this study may have artificially increased the necessity to look at the dial, since people might be able to find buttons by touch alone within the traditional 4 x 3 pattern.

- Subsequent studies, (e.g. Brookhuis et al., 1989; and Alm & Nilsson, 1990) have shown greater swerving during the dialing task. However, these were simulator studies in which precise lane keeping may have been perceived as less important.

- The author mentions in the introduction that "latency to begin the task [dialing] was an effective measure of driver strategy." Results of this latency measure however are never reported, which is somewhat surprising given the emphasis put upon it in the introduction.

McKnight, A. & McKnight, A. (1993). The effect of cellular phone use upon driver attention. Accident Analvsis & Prevention, 25(3), 259-265.

Type of Study: Laboratory research / driving simulator.

Keywords: hand-held cellular telephones, driver attention

Author's Abstract:

In this study, 150 subjects observed a 25-minute video driving sequence containing 45 highway traffic situations to which they were expected to respond by manipulation of simulated vehicle controls. Each situation occurred under five conditions of distraction: placing a cellular telephone call, carrying on a casual cellular telephone conversation, carrying on an intense cellular telephone conversation, tuning a radio, and no distraction. All of the distractions led to significant increases in the proportion of situations to which subjects failed to respond.

However, significant age differences of non-response appeared. Among subjects over age 50, non-responses increased by about one-third under all of the cellular telephone distractions. The response rate of younger subjects increased by a lesser degree except under intense conversation. Results were not influenced by gender or prior experience with cellular telephones. The authors conclude that older drivers might reduce their accident risk during attention-demanding traffic conditions by avoiding use of cellular telephones and that other drivers might do so by refraining from calls involving intense conversation.

Sample and Methods:

- 150 drivers, equally divided between males and females:
  - 45 young drivers (17-25 years)
  - 56 mid-age drivers (26-49 years)
  - 49 older drivers (50-80 years)

- Experienced cellular telephone users made up one-third of the sample, including a third of the young, half of the mid-age, and slightly over a tenth of the older subjects.

- More male drivers (40%) had cellular telephone experience than female drivers (30%).

- Drivers were required to place calls by manually dialing numbers on a keypad located close to the driver's line of sight.

- Subjects "drove along" in an open loop simulator with videotaped situations of actual traffic. These scenes totalled 25 minutes of driving and included 45 situations requiring a response of vehicle control input, e.g., route changes, turning vehicles, roadside construction, etc.

- The conversation component of the telephoning task involved both simple conversations (e.g., gathering demographic information, chit-chat on what the subject did the previous weekend), and complex conversations (i.e., math problems of the form 2+3+4+l/2+3+4= ?) or short term memory problems that required the subject to listen to a list of 5 or 6 digits and then answer whether certain digits were in that list.

- Driver performance was recorded on videotape for later analysis. Steering and turn signal use were directly visible to the data-recording video camera, and acceleration and braking were recorded by displays that registered control application and recorded for later analysis.

- Subjects responded to 45 traffic situations that required the driver to alter speed or direction under five distraction conditions: no distraction, radio tuning, placing a call, simple conversation, or intense conversation.

- The dependent measure was whether or not drivers responded to each of the 45 traffic situations encountered under different distraction conditions.

Major Findings:

- Subjects failed to respond to simulated highway traffic situations significantly more when any of the four distractions (tuning radio, placing a call, casual conversation, intense conversation) were present as opposed to no distraction while driving.

- Engaging in an intense cellular telephone conversation or tuning a radio while driving yielded the greatest distraction to the driver. Both were about equally distracting.

- Intense cellular telephone conversations and radio tuning had the greatest increase in the proportion of non-responses, expressed in percentage change from the no distraction condition, 29% and 28% respectively. Placing calls and carrying on casual conversation yielded a lower percentage change from the baseline or no distraction condition, 20% in both cases.

- Prior experience with cellular telephones appeared to have no significant effect upon driver performance for all levels of distraction.

- Gender differences were also nonsignificant across all distractions collectively.

- Subjects in the older age category (50-80 years) failed to respond to traffic situations more often than other subjects. Compared to the no distraction situation for this age category, non-response was greatest when placing calls (33%), next during casual conversation (27%) and lastly during intense conversation (25%), expressed in percentage change terms.

- Within the young group, conversation-related distractions produced effects that were smaller than the older group but still significant. The increases (percent change) in non-response were 52% for radio tuning, 33% for intense conversation, and 23% for casual conversation.

- Among mid-age subjects, the only cellular telephone distraction yielding a significant effect was intense conversation, with a 14% increase in non-response. The smaller relative increase among the mid-age group may be attributable in some part to this age group's high non-response rate when no distraction was present. Radio tuning yielded an 18% increase that was also significant.

- When comparing the older group with the two younger groups combined, the age differences seen in failing to respond to traffic situations are significant for cellular telephone calling and casual cellular telephone calls, but not for intense cellular telephone calls.

Author's Conclusions:

- The effect of cellular telephone use upon the attentional responses of drivers could well constitute a greater threat to safety than its interference with vehicle control. Attentional processes play a far greater role in automobile accidents than does vehicle control.

- The three tasks associated with the use of cellular telephones - placing calls, causal conversations, and intense conversations - all led to significant increases in the likelihood of a failure to respond to highway traffic situations.

- The greatest overall deficit in ability to respond to highway traffic situations while being distracted was experienced by older subjects.

- Except among older subjects, the performance decrement associated with cellular telephone calls seems to be no worse than that which occurs when tuning a radio, and is considerably less distracting than radio tuning for the youngest age group.

- The effect of cellular telephone use upon the operation of automobiles is not confined to the direct interference involved in attempting to handle the cellular telephone equipment and is therefore not a concern that will disappear with widespread adoption of “hands-free” systems.

- In attention-demanding situations, drivers might lower their accident risk by avoiding calls, particularly those involving intense conversation. Among older drivers whose attention-sharing abilities might already be in decline, any use of the cellular telephone during such situations seems potentially hazardous.

Critical Assessment:

- The study simulated “hands-free” operations of cellular telephones with manual dialing on a keypad placed close to the driver’s line of sight. These results may show less degradation of performance than other studies which have included manual dialing and less proximity between the keypad and the driver’s line of sight.

- Subjects were asked to respond to the traffic situations on the video tape as they would if they were actually driving. The lack of actual situation motivation and vehicle feedback may have yielded less reaction than actual driving.

- It was not clear from the description of the methodology how the dependent measure was scored for analysis, whether it was recorded by some electronic means, or by a human observer. If an observer tallied incidents of non-response, it is not known whether the observer was blind to the distraction conditions that were presented to the subjects during all trials.

- Using a global non-response as the dependent measure is not an ideal choice for performance measurement. A non-response is an all-or-nothing measure. On the other hand, drivers may indeed be altering their driving performance in more subtle but still meaningful ways.

- Lateral position variation is a common measure of driver performance used in other studies. However, given the open-loop simulator methodology, this measure was impossible to obtain since small steering wheel movements would not translate as lane position variation on the videotape for the observer to score.

- The intense conversational materials were of the “intelligence test” variety and this may not be relevant to normal cellular telephone communications.

Nilsson, L. (1993). Behavioural research in an advanced driving simulator: Experiences of the VTI system. Proceedings of the Human Factors and Ergonomics Socity 37th Annual Meeting, 612-616.

Type of Study: Driving simulator.

Keywords: hands-free cellular telephones, headway, rear-end collision, age differences, simulation

Author's Abstract:

The VTI driving simulator is described briefly, and aspects such as controllability, realism, and motion sickness are discussed. The experience of using a simulator is accounted for. As an example, a study of cellular telephone effects on driver behaviour is reported, focusing on methodological aspects. The paper ends with an extensive literature list containing behavioral studies performed in the simulator.

Sample and Methods:

- Forty Swedish drivers who had been licensed at least five years and who drove at least 10,000 km per year participated. Twenty were below 60 and twenty were 60 or older.

- The VTI Simulator, the simulator of the Swedish Road and Traffic Research Institute, was the research apparatus. This simulator allows variation of six separate systems: vehicle characteristics, moving base, visual, sound, vibration, and temperature.

- Young and elderly participants were randomly assigned to a cellular telephone or control condition. Those in the cellular telephone condition had some training on the cellular telephone task, and all participants practiced driving in the simulator, although criteria are not specified.

- The driving task required participants to catch up to and follow another car 16 times. Four of the cars ahead braked, four activated the right turn signal, and eight just drove.

- Participants were to respond to the car ahead in the following ways: when it braked, they should brake as fast as possible; when it activated its right turn signal, they should activate their left turn signal.

- A hands-free cellular telephone was used. Subjects had to receive calls only.

- The telephoning task consisted of eight incoming calls in which participants engaged in the Baddeley Working Memory Span Test.

- Driving performance was measured by brake reaction time, headway, speed, and lateral position.

- The NASA-TLX rating scale was used to measure the subjects' workload.

Major Findings:

- Collapsed across age, participants had slower reaction times for braking when they were on the cellular telephone. Also, collapsed across cellular telephone use and non-use, older participants had slower reaction times for braking.

- Headway decreased as a function of cellular telephone use. Also, a main effect for age was seen where older drivers allowed greater headway than did younger drivers.

- When using the cellular telephone, elderly subjects drove at slower speeds than younger subjects. Younger drivers also approached the car ahead 11.5 km/h faster than the older drivers did.

- Steering ability, i.e., lateral position and its variation, was not influenced by cellular telephone use or between age groups.

- Subjects who simultaneously talked and drove later rated the workload aspects of mental demand, time pressure, effort, and frustration higher than did subjects who only drove. However, subjects who only drove rated their performance higher. Younger subjects also rated the "effort" dimension of workload higher than did elderly subjects.

Author's Conclusions:

- Drivers' ability to react quickly in a car following situation was impaired when they were talking on the cellular telephone. The prolongations of reaction time imply stopping distances that are increased by 8 meters for young drivers and 21 meters for elderly drivers, when driving at 50 km/h.

- Neither young nor elderly drivers compensated for the longer reaction time by increasing the headway. The distance to a car ahead was even shorter than for control group drivers.

- Drivers estimated their workload to be higher when driving and conversing over the cellular telephone. Yet, they did not pace the dual task of driving and conversing to keep the workload level constant.

- It is likely to assume that the risk for an accident may increase when using a cellular telephone during car following, due to increased driver reaction times, shorter headway, and inadequate management of the increased workload for the dual tasks of driving and conversing.

Critical Assessment:

- As an illustration of driving simulator methodology, this article successfully examines methodological issues, but it breaks little new ground in understanding effects of cellular telephone use on driving behavior.

- Implicitly, the author leaves a number of possibilities open-ended: a) drivers could learn to compensate for their cellular telephone use by modifying their driving behavior; b) drivers who "paced themselves" could learn to manage the multiple cognitive demands of both driving and talking on the cellular telephone; and c) aspects of the quality of both tasks will decline when they are performed simultaneously.

- The author acknowledges that speed level was constrained by the experimental design, which made it impossible to overtake the car ahead. Since the speeds of the cars driving ahead imposed restrictions on speed choice, this study does not show a range of differences in reaction time and headway that may be found at speeds other than 50 km/h.

Nilsson, L., & Alm, H. (1991). Elderly people and mobile telephone use--effects on driver behaviour? Proceedings of the Conference Strategic Highway Research Program and Traffic Safety on Two Continents. Gothenburg, Sweden, and DRIVE Project V1017 (BERTIE, Report No. 53), March 1991.

Type of Study: Driving simulator.

Keywords: hands-free cellular telephones, age differences, brake reaction time, lateral position, speed

Author's Abstract:

The effects of a cellular telephone conversation on driving were studied in the advanced driving simulator at VTI. Twenty subjects, 10 men and 10 women, between 60 and 71 years and 20 subjects, also 10 men and 10 women, between 23 and 58 years participated in the study. The road the subjects drove could be characterized as "easy." It was straight and not expected to cause the subjects any problems with speed choice and steering strategy.

The workload imposed on the subjects by the driving task was thus supposed to be very low. The cellular telephone task included handling of the cellular telephone and a conversation, containing a working memory part and a decision part. The handling task consisted of pushing the hands-free button to activate the cellular telephone when it was calling. During the conversation the subjects were asked to listen to pre-recorded sentences and for each sentence to judge if they experienced it as "sensible" or "nonsense." After a number of sentences they were required to recall the last word in each sentence, in the order they were presented.

Sample and Methods:

- Twenty licensed drivers, 10 males and 10 females, ages 60 to 71 years with a mean age of 65.9 years participated. All drove at least 10,000 km per year and had been driving at least 5 years.

- Half of the subjects were assigned to an experimental condition and the others were assigned to the control group. Subjects in the experimental group drove and performed the cellular telephone tasks consisting of receiving calls only, while subjects in the control group only drove.

- Whenever age was used as a variable in the analysis, data for young drivers was added from an earlier study (see Alm & Nilsson, 1990).

- The apparatus used was the VTI Driving Simulator.

- A hands-free cellular telephone mounted on the instrument panel was used for the cellular telephone tasks.

- All subjects received practice driving in the simulator on a 20 km long, straight road. The actual test route was 80 km long.

- A red square appeared on the left shoulder of the road to simulate an abruptly emerging event on the traffic scene. Participants were instructed to brake as soon as they saw the square.

- During the practice session, all subjects had an opportunity to experience the visual stimulus (red square) to which they had to brake as fast as possible. Subjects in the experimental condition received practice on the cellular telephone task as well.

- The cellular telephone was mounted on the instrument panel to the right of and at the height of the steering wheel. When a driver answered the cellular telephone by pressing the hands-free button, a tape recorder was activated and "read" the cellular telephone task to the driver. The presented cellular telephone tasks and the participants' answers were recorded on a second tape recorder.

- The Baddeley et al. (1985) Working Memory Span Test was chosen for the cellular telephone task. It contained a working memory part and a decision part.

- Eight cellular telephone calls were presented to drivers in the experimental group. Calls occurred at eight randomly chosen locations along the route. At four randomly chosen positions, the red square appeared in connection with the cellular telephone calls. For two of these four occasions (again randomly chosen) the visual stimulus appeared 1 second after the cellular telephone had rung, while for the remaining two occasions the visual stimulus appeared 30 seconds after the ring signal.

- The following driver performance measures were taken: speed (km/h), lateral position on the road (meters), variation in lateral position (meters), brake reaction time (seconds), number of correct sentence judgments (sensible/ nonsense), and number of correctly recalled last words (in the order of presentation).

- Drivers' subjective workload was measured by the Task Load Index (NASA-TLX).

Major Findings:

- The mean brake reaction time for the four simulated danger situations (red square stimulus) was calculated for each subject.
  - Regardless of age, use of the cellular telephone while driving resulted in longer brake reaction times compared to driving without using the cellular telephone.
  - Regardless of cellular telephone use or non-use, older drivers had longer brake reaction times than younger drivers.

- Mean absolute lateral position was recorded for the 0-500 meter and 0-2500 meter distances after the initiation of each cellular telephone call. The 500 meter segment covered the distance during which drivers had to activate the cellular telephone, while the 2500 meter segment corresponded to the entire cellular telephone task.
  - No effect of cellular telephone use on mean lateral position was found.
  - When the 0-500 meter distance was considered, the "no effect" result obtained for the elderly drivers was in agreement with the result for the young drivers. However, when the 0-2500 meter distance was considered, the young participants drove significantly more to the right while performing the cellular telephone task, compared to young drivers that only drove.

- Variation in lateral position was also recorded and analyzed.
  - Elderly drivers varied their lateral position more when they activated the hands-free function while driving compared to elderly drivers that only drove.
  - When the distance covering completion of the entire cellular telephone task was considered, the variation in lateral position was larger for elderly drivers who used the cellular telephone while driving than for elderly drivers who only drove.
  - During the phase of driving when the hands-free function had to be activated (0-500 meters), the effect of the cellular telephone was influenced by age, i.e., elderly participants varied their lateral position more than the younger participants.
  - The effect of cellular telephone use was influenced by age during performance of the entire cellular telephone task (0-2500 meters). The variation in lateral position increased for the elderly drivers compared to the elderly driving only condition, while it decreased for the younger drivers compared to the younger driving only condition.

- NASA-TLX ratings were used to analyze drivers subjective workload.
  - Elderly drivers who performed the cellular telephone task while driving rated mental demand higher than elderly participants who only drove.
  - Independent of their age, drivers who were engaged in the cellular telephone task rated mental demand and effort higher, were less pleased with their performance, and were more frustrated than drivers in the respective control groups.
  - Younger drivers reported more frustration than elderly drivers when they used the cellular telephone while driving.

- Mean speed values were calculated from initiation of the hands-free function and 80 seconds forward, covering the entire cellular telephone task. Corresponding calculations were made for drivers in the control group.
  - For every cellular telephone call, mean speed for elderly participants using the cellular telephone was lower than the mean speed for elderly participants who only drove.
  - Independent of age, participants drove more slowly (9.2 km/h on average) while using the cellular telephone compared to those that only drove.
  - Independent of cellular telephone use, the elderly participants drove on average 4.7 km/h faster than the younger participants.

- Performance on the Working Memory Span Test showed that young drivers made significantly more correct judgments and more correct recalls compared to the elderly drivers.

Author's Conclusions:

- Both cellular telephone use and age have a negative impact on drivers' ability to react quickly to a suddenly appearing event.

- Young, experienced drivers' brake reaction time on an easy road while engaged in a cellular telephone conversation coincides with that for elderly experienced drivers, driving on the same road but without using a cellular telephone.

- A cellular telephone conversation seems to have a more severe effect on elderly as opposed to younger drivers' tracking ability. While young drivers move to the right on the road and keep a more steady course, elderly drivers increase their variation in lateral position. Thus, elderly drivers using a cellular telephone while driving, run a greater risk to intrude into the wrong lane or to leave the road.

- Drivers do not try to keep up a constant level of workload. Instead of reducing the demands added from the secondary cellular telephone task, they seem to work harder to cope with the new situation.

- Although elderly drivers decreased their speed while using the telephone, they still drove faster than the young drivers. This finding may be due to the simulator environment's tendency to create "speed blindness."

- As elderly drivers usually are aware of their reduced capacities and receptive to procedures and devices that would make them safer and better drivers, it may be worthwhile to inform them about obtained behavioral effects and suggest strategical solutions.

Critical Assessment:

- The "suddenly appearing event" is a needed element in the study of the impact of cellular telephone use on driver behavior because it comes closest to simulating an emergency situation, an instance when drivers' responses may be most crucial. Future studies should strive to increase the realism of the event, i.e., to use a stimulus other than a red square, and should necessitate simultaneous tracking and brake reaction maneuvers.

- The authors did not report reaction time differences for one second and 30 seconds after initiation of the cellular telephone call. Workload may be higher at one second, the time of the ring, as opposed to 30 seconds into the task, which may be reflected in differential reaction times depending on the timing of the cellular telephone task.

- The driving task used was an "easy" road with no interaction from other traffic. This may not be a realistic representation of actual traffic conditions.

- There was no analysis of easy versus hard workload. Cellular telephone use may have a stimulating or alerting effect for boring roadways.

- No analysis of intense versus light conversation was reported, which in other studies has shown a significant effect on driver performance.

- No analysis was made of placing a cellular telephone call, especially dialing, a task which may be more critical or detrimental than receiving a cellular telephone call or holding a conversation.

- The findings related to speed are opposite to findings in other similar studies. Usually, older drivers drive slower than younger drivers. Although the finding in the present study may indeed be due to "speed blindness" as proposed by the authors, this unique finding deserves closer analysis.

Pachiaudi, G., & Chapon, A. (1994). Carphone and road safety. XIVth International Technical Conference on the Enhanced Safety of Vehicles, No. 94-S2-0-09, Munich, Germany.

Type of Study: Driving simulator.

Keywords: hands-free cellular telephones, speed variability, self-report

Author's Abstract:

The aim of the present study was to experimentally assess the potential risk on road safety when using a hands-free cellular telephone while driving and maintaining interactive conversation. This exploratory research was carried out on an interactive driving simulator and was based on about 40 routes performed by 17 subjects. In a first step, the observation of speed variations induced by the use of a cellular telephone brought two types of reaction into prominence: 1) no effect, and 2) a more rigid driving behaviour. The latter is shown by a speed increase or decrease, or by a longer period of oscillations around the required speed, or even by a total loss of speed control.

These reactions were compared to answers to a questionnaire asking for the causes of difficulties encountered and how the driving task was disturbed by phoning while driving, and vice versa. This comparison allowed us to see how subjects managed the dual task; in most cases, they used a time sharing strategy during which the main task, i.e., driving, was often perturbed by the second one, i.e., phoning.

Sample and Methods:

- Seventeen drivers participated.
  - 9 were 18-35 years old.
  - 8 were 45 years or older.

- Participants received a call and held a cellular telephone conversation while driving on a simple route in a driving simulator. Subjects were required maintain vehicle speed at either 90 or 130 kph. The nature of the conversation was not described.

- A hands-free cellular telephone was used although the model type was not specified.

- Variation in vehicle speed was used as the dependent measure.

- Subjective measures were also collected through post-study questionnaires. These questionnaires focused on the possible causes of difficulties encountered during the conversation, the tendency to alter driving behavior while telephoning, and the difficulty in telephoning while driving.

Major Findings:

- In 18 out of 39 instances of concurrent telephoning and driving, no speed modification could be detected when comparing the speed variation before the call and during conversation. Among these instances:
  - Some drivers, after initial stabilization [the time period allowed for stabilization was not specified by the authors], kept a constant speed.
  - Others had some difficulty stabilizing the speed as seen by symmetric and steady oscillations of about 15 to 20 kph, but these findings were not statistically significant with regard to cellular telephone use or driver age.
  - A few others had significant difficulty stabilizing the speed as seen by oscillations of more than 50 kph, though again, no differences were found with regard to cellular telephone use or driver age.

- In 21 out of 39 cases, it seemed that there was a conflict between the two tasks of driving and telephoning, and driving often lost its status of prime task. This principle of "behaviour stiffening", i.e., doing one task or the other alternately, in relation to speed was observed in several ways:

– A steady increase of speed (about 30 kph) without any attempts to correct it.
– An increase of the period of speed oscillation (e.g., from 60 seconds to 100 seconds or from 90 seconds to 160 seconds)
– A loss of speed control, leading to oscillations whose amplitude could be over 80 kph.

- These findings, however, did not reach statistical significance.
– Multiple choice questionnaires gauged participants' impressions of the dual-task experience.
– Younger participants reported feeling more difficulties than the older participants.
– The main causes of difficulty that participants reported were "noise" and "dual task."
– 50% of participants reported that they would slow down from a speed of 130 kph while telephoning. 33% of participants reported that they would slow down from a speed of 90 kph while telephoning.
– Older participants reported NOT being disturbed by telephoning while driving much more than the younger participants. However, no significant age differences in performance were found.

Author's Conclusions:

- Of the seventeen participants in the sample, only two showed no change in their speed and did not report feeling any trouble while telephoning.

- Nine participants decreased their speed while telephoning and the remaining six participants experienced mental overload which would have resulted in a degradation of performance.

- In view of these results, more systematic investigations of the various elements found in the driving situation, such as lane keeping, speed, reaction time, eye direction should be performed. Age and practical experience of cellular telephone use should be taken into account in this further stage.

Critical Assessment:

- This study would have been strengthened by using validated cognitive tasks within cellular telephone conversations to establish a quantifiable mental workload level, and to reduce learning effects.

- Additional driving performance measures besides speed variation could have shown task tradeoffs and changes in driving performance better than speed variation alone.

- While the authors' interpretation of "behaviour stiffening" is interesting, they also note that no significant differences were found between the cellular telephone and control conditions, or between age groups. Additionally, percentages of responses are given for the subjective measures without determining significance. In the absence of significant results, the authors' firm conclusions that drivers experienced "mental overload" or a "conflict provoked by the increase of mental load" seem premature.

- The 40 routes driven and used to analyze the data were done by 17 subjects. The authors do not describe which of the 17 subjects drove what number of routes. 40 is not a multiple of 17; therefore, each subject did not drive the same number of routes.

- The nature of the cellular telephone conversation was not described.

Parkes, A. M. (1991). Drivers business decision making ability whilst using carphones. In Lovessey, E. (Ed.), Contemporary Ergonomics. Proceedings of the Ergonomic Society Annual Conference (pp. 427-432). London: Taylor & Francis.

Type of Study: On-road research, Laboratory research

Keywords: cellular telephones, dual tasks, cognitive interference

Author's Abstract:

This paper reports the first stage of analysis of drivers abilities to make decisions while using cellular telephones in a moving vehicle. Results show that subjects have difficulty remembering and interpreting complex information. It is concluded that there is a need for improved customer support and greater functionality of future cellular telephone systems, if full system potential is to be achieved.

Sample and Methods:

- 24 drivers (15 male, 9 female), ranging in age from 18-50.

- Cellular telephone conversations consisted of a hybrid test whose development was influenced by the Watson-Glazer Critical Thinking, Wechsler Adult Intelligence Scale, Wechsler Memory Scale and Hodgkins Differential Aptitude tests. The resultant test consisted of seven sections: numerical and verbal memory, simple arithmetic, numerical reasoning, inference, deduction and interpretation. Participants were introduced to a sample of the test material prior to actual testing.

- All participants completed four experimental conditions over two testing sessions.
  - Two conversation conditions were conducted while driving: driver to passenger (DP); and cellular telephone to office (CO). Two other conversation conditions were conducted in a laboratory: stationary phone to office (TT); and face-to-face (FF).
  - The experimenter took the role of the person on the other end of the telephone. During the DP condition, this experimenter was in the front seat of the car. In the CO condition a second experimenter sat in the back seat to give directions while the conversation was held over the cellular telephone with the first, remote experimenter.

- Before starting either driving condition, the participant was shown a map of the route to be followed, and completed a short familiarization drive in the car. The route involved a mixture of suburban and rural roads.

- Participants received calls only and the design of the cellular telephone was not reported.

Major Findings:

- Participants' scores on the critical thinking test were highest for face-to-face conversations, followed by stationary telephone to office conversations, followed by driver-to-passenger conversations, and finally, cellular telephone to office conversations.

- Differences were found between the driver to passenger (DP) condition and cellular telephone to office (CO) condition for the following sub-scores:
  - Verbal memory decreased by 25%.
  - Numerical memory decreased by 21%.
  - Interpretation decreased by 23%.

- Differences between the stationary telephone to office (TT) condition and the cellular telephone to office (CO) condition were found for the following sub-scores:
  - Verbal memory decreased by 21%.
  - Numerical memory decreased by 20%.
  - Interpretation decreased by 19%.

Author's Conclusions:

- It seems that the combination of the driving task with the cellular telephone results in difficulty in remembering verbal or numerical data, and in making correct interpretations from background information.
- The lower scores cannot be solely attributed to the dual demands of the driving task, as scores in the driver to passenger condition were not significantly different to those produced in the laboratory in single task conditions. Videotape analysis suggests that the experimenter-as-passenger naturally made allowances for traffic movements and maneuvers when administering the test.
- Some reservation should be placed on notions of the development of the future "office on the move."
- Users of cellular telephones need to be realistic in terms of what they can and should be used for.
- Suppliers could help the situation by providing explicit advice to customers about the potential difficulties of holding, or being drawn into, complex business negotiations while on the move.
- Suppliers should further investigate the possibility of increasing the functional capability of cellular telephones. The "hands-free" facility is a major advance, but other features such as the proposed "intelligent answerphone" should be pursued. Systems that can divert, record, and interrupt messages appropriately may prove cost effective for many business people of tomorrow.

Critical Assessment:

- This study assumes people are single channel information processors. Further studies should examine the mutual interference between driving and telephoning within a broader, more parallel framework.
- The present study would have benefited from simultaneous measures of driving performance. This addition may have better illustrated drivers' attentional tradeoffs between the driving and cellular telephone tasks.
- The experimenter-as-passenger arrangement used in the DP condition allows for the possibility of experimenter bias and/or Hawthorne effects which may skew the results.

Parkes, A. M. (1993). Voice communications in vehicles. In Franzer, S. and Parkes, A. (Eds.), Driving future vehicles (pp. 219-228). London: Taylor and Francis.
Type of Study: Review of experimental findings.
Keywords: cellular telephones, driver performance, technology development

Abstract:

A literature review was performed to explore the questions: a) Does talking on a cellular telephone affect driving performance? and b) Does driving make it difficult to use a cellular telephone in the same way as a standard fixed telephone? A limited capacity model of information processing is used to highlight tradeoffs in both tasks, as shown by the experimental findings reviewed. Problems associated with cellular telephone conversations are emphasized, both in terms of the effect on the driving task and on the conversation itself. Implications for driver adaptation as well as human factors implications for the development of future cellular telephone technology are discussed.

Sample and Methods:

- Types of studies reviewed include the following:
  - Driving simulator studies.
  - On-road driving studies.
  - Experimental social psychology studies of cellular telephone behavior.
  - Perceptual and cognitive studies relevant to the dual task of mobile telephoning while driving.

Author's Conclusions:

- Though it has been less than comprehensive so far, research into the effects of in-vehicle cellular telephone conversations has important implications not only for that application but also for the nature of future interface design.

- Priority can be given to the primary task of driving while talking on a cellular telephone, without observable decrements in performance, so long as some threshold point is not reached. Cumulatively, the literature has shown performance decrements, mainly swerving, increased reaction time in braking, decreased following distance, and inaccurate spatial perception, that become observable in association with variations in surrounding traffic, road type, driver's age, cellular telephone design, and nature of telephone task.

- Driving and communication system usage can be considered within the context of a limited capacity model of human information processing. In this model, a task may take up a proportion of available capacity, leaving a certain "spare capacity." The introduction of a second task will make demands on this limited channel and take up spare capacity of the system.

- The operational skill level component of the driving task is reasonably robust and only likely to show deterioration at times of high primary (i.e., driving) task difficulty. It might be hoped that the driver might take appropriate action in such situations and either not accept incoming calls or close down current ones.

- While drivers seem aware that holding cellular telephone conversations while driving involves them in increased workload and a certain amount of stress, drivers also seem largely unaware of the increases in their response times. Generally, drivers' lack of awareness or adjustment of their driving impairment while using a cellular telephone is analogous to the public perception of the level of impairment produced at low levels of blood alcohol.

- Many cellular telephones have sophisticated voice recognition facilities, and a large number of commands for call set-up, number dialing and call termination can be activated by voice alone. Such voice input, allowing truly hands-free and more importantly, eyes-free operation, is to be encouraged if it can be demonstrated that a superior manual alternative does not exist.

- Future cellular telephones may benefit from features that would be able to intervene with appropriate messages to the second party, reducing pressure on the driver to keep up the flow of conversation when encountering immediate driving task demands. This technology could help control for the fact that the remote person does not "punctuate" their speaking the same as an in-car passenger would. Cellular telephones could be linked to route guidance or collision avoidance systems to provide such an intervention. System integration is a challenge for future designers.

- The temptation to design a "mobile office" in a car should be tempered by the reality of a person's limited ability to simultaneously respond to conversation demands and driving demands.

Critical Assessment:

- This article puts safety research on cellular telephone use into a practical context by exploring mobile communication in both directions: the effects of driving on telephone behaviors and the effects of telephoning on driving. The limited capacity model of human information processing suggests that aspects of both tasks, driving and communicating, may be compromised by performing them simultaneously.

- It should be remembered that a limited capacity model of attention is just one framework in which phenomena such as driving and telephoning can be discussed. For example, improved performance at the operational/control level of driving (Brookhuis, et al., 1991) suggests that neurocognitive arousal and levels of processing views of attention are needed in the study of mobile communication.

- Parkes acknowledges that during times of high driving difficulty, drivers should not use their cellular telephones. He envisions a time when advances in technology allow the cellular telephone itself to shut off at such times. Until such advances are realized, driving conditions sometimes may change so suddenly as to not permit drivers an effective return of all attention to the driving task. Except for one study in which car-sized boxes moved into the drivers' path, requiring an emergency lane change (Stein et al., 1987; or Department of the California Highway Patrol, 1987), the literature appears to be missing comparisons of drivers' emergency response performance between cellular telephone use and non-use. Future research may explore this issue in more depth.

Petica, Stefan (1993). Risks of cellular phone usage in the car and its impact on road safety. <u>Recherche-Transports-Securite,</u> 37,45-56.

Type of Study: Review of literature and actions taken by various countries.
Keywords: cellular phones, traffic accident risk, driver attention

Abstract:

The effect of telephone communications on driving and hence on road safety have not been very clear until recently and experimental studies of the subject (which have been fairly contradictory) have not received much of a response. But the rapid increase in this type of equipment which is expected in the years to come has refocused attention onto the subject and the risks of accidents resulting from the implications of this task on the driver are starting to be considered. In order to better locate the true risk the author has analyzed the most significant variable in the situation. The major directions which this research is taking are as follows:

- examination of the socio-technical factors arising from the considerable increase in the number of carphones (four million in France by the year 2000),
- examination of several typical experimental studies of the psychological and behavioral effects this task has on driving,
- presentation of the activities of the public authorities abroad with respect to this potential hazard and the position as regards regulations in several countries,
- summary of a few facts which have emerged from the analysis of the state of the art, conclusions on risk assessment and proposals for educational, ergonomic and regulatory measures.

Sample and Methods:

- Types of studies reviewed include the following:
  - Driving simulator studies.
  - On-road driving studies.
  - Experimental social psychology studies of cellular telephone behavior.
  - Perceptual and cognitive studies relevant to the dual task of mobile telephoning.

- Actions taken by public entities reviewed include the following:
  - International survey of experts and policy-makers conducted by INRETS.
  - United States experience including the California Highway Patrol study.
  - European experience including Switzerland, Germany, Spain, Sweden, Great Britain, and France.

Author's Conclusions:

- Due to the interference that might arise when the tasks of driving and telephone communication are performed simultaneously, it should be taken into account that the probability of an accident in such cases rises significantly. The extent of risk, if principally linked to circumstances on the road, may be negligible or rise in probability two to four times.

- The increase in probability of an accident has been established for all types of users and for control, guidance and navigation activities; but its distribution varies, according to the age of the user, traffic conditions, placement and type of phone. This increase has been demonstrated from the experimental point of view by most of the studies analyzed, even though from the point of view of accident statistics there does not exist much proof. This is largely due to the difficulty involved in the actual observation of these types of accidents.

- Dialing of telephone numbers is shown to be the most dangerous, considering its characteristics: visual distraction and splitting of attention while driving with one hand. This is true even for the hands-off type of phone.

- The probability of accidents is much higher for all types of phones when problems, emergencies or conflicts arise.

- It is very difficult to discover any detrimental and secondary effects of phone usage that might be due to driving style and to the influence that this can have on behavior of other users. More research is called for.

- From the safety point of view, the presence of a car phone has certain advantages, but these advantages are due to the presence of the phone in the car, not to its utilization during driving.

- The risk of accidents is considerably decreased if the task of communication is simplified by:
  - the presence of a memory function which shortcuts the dialing procedure
  - the presence of an automatic answering system
  - the presence of a hands-off or similar system and,
  - in the future, voice recognition.

- For the mid-term, the growth in the number of car phones, as well as the actual practice of phone usage under traffic conditions might increase the number of accidents.

- A preventative and regulatory attitude on the part of the public authorities imposes itself, especially since new communication products will soon be introduced in cars. the combination and interference of the above potentially negative factors, perceived as negligible, will certainly pose new problems for road safety if certain measures are not taken. Based on the fact that other countries have already regulated car phone usage in one way or another, a similar attitude would be desirable in Europe.

Critical Assessment:

This is an early review of cellular phone issues and foreign public and governmental approaches to dealing with the potential risk of cellular phone use.

Redelmeier, D. A., & Tibshirani, R. J. (1997). Association Between Cellular Telephone Calls and Motor Vehicle Collisions. The New England Journal of Medicine, Vol. 336, Number 7,453-458
Type of Study: Epidemiologic, case-crossover design..
Keywords: cellular telephones, motor vehicle collisions, crash risk

Author's Abstract:

Because of a belief that the use of cellular telephones while driving may cause collisions, several countries have restricted their use in motor vehicles, and others are considering such regulations. We used an epidemiologic method, the case-crossover design to study whether using a cellular telephone while driving increases the risk of a motor vehicle collision.

Sample and Methods:

- The authors studied 699 Toronto drivers who had cellular telephones and who were involved in motor vehicle collisions resulting in substantial property damage but no personal injury.
- Each person's cellular telephone calls on the day of the collision and during the previous week were analyzed through the use of detailed billing records.
- The time of each collision was estimated from each subject's statement, police records, and telephone listings made to emergency services.

Major Findings:

- A total of 26,798 cellular telephone calls were made during the 14 month study period. The risk of collision when using a cellular telephone was four times higher than the risk when a cellular telephone was not being used (relative risk, 4.3: 95 percent confidence interval, 3.0 to 6.5).
- The relative risk was similar for drivers who differed in personal characteristics such as age and driving experience; calls close to the time of collision were particularly hazardous (relative risk, 4.8 for calls placed within 5 minutes of the collision, as compared with 1.3 for calls placed more than 15 minutes before the collision; P<O.OOl); and units that allowed the hands to be free (relative risk, 5.9) offered no safety advantage over hand-held units (relative risk, 3.9; P not significant).
- Thirty nine percent of the drivers called emergency services after the colision, suggesting that having a cellular telephone may have had advantages in the aftermath of an event.
- The authors also found that the relative risk of having a crash while using a cellular phone was estimated to be similar to the hazard associated with driving with a blood alcohol level at the legal limit.

Authors' Conclusions:

- The use of cellular telephones in motor vehicles is associated with a quadrupling of the risk of a collision during the brief period of a call.
- Decisions about regulation of such telephones, however, need to take into account the benefits of the technology and the role of individual responsibility.

Critical Assessment

This study is suggestive of a relationship between cellular phone use and crashes that merits further experimental inquiry, but it has several limitations as well.

Redelmeier and Tibshirani themselves point out several limitations to their study. They note that causality cannot be inferred from such a study. By way of example, they mention that emotional stress might lead to both increased cellular phone use and decreased driving ability, so that individual calls may have nothing to do with increased crash risk. They also list four weaknesses in their study.

First, only volunteer drivers participated, perhaps leading to underestimates of risk caused by riskier drivers opting out. Second, they point out that people vary in their driving behavior from day to day, though Redelmeier and Tibshirani consider the findings hard to explain in terms of such variations because of consistent findings between the whole sample and a subset of 72 subjects who remembered (up to a year later) having driven during both the hazard period and the control period.

Third, case-crossover analysis does not eliminate all forms of confounding, particularly in regard to temporary conditions, though again the article's authors believe such factors are unlikely to account for the magnitude of association observed. Finally, they point out that collision involvement did not mean the cellular phone owner was judged "at fault". This was left unspecified in the article and the authors indicate that perhaps cellular phone use merely decreases a driver's ability to avoid a collision caused by someone else.

Maclure and Mittleman (1997) point out additional limitations to the study and qualifications to its results. While they applaud the use of the case-crossover design (Maclure was the originator of this approach), they indicate that the use of pilot subject data to adjust for the "intermittency of driving" was not convincing because of possible unmeasured differences between the pilot subjects and the study subjects. They have more faith in the analysis of the 72 people who recollected driving during both periods, though they acknowledge that a relative risk result from this group may be an overestimate due to incomplete participation and faulty memory. Maclure and Mittleman indicate that the lack of a safety advantage for hands-free phones may simply be the result of too little statistical power to test for this effect. The risks associated with placing a call, the risk extinction curve over time after a call ends, and the kinds of collisions that are most likely to increase are all in need of future research, they point out.

To these caveats and critiques, the present authors add the following. While Redelmeier and Tibshirani distinguish between exact and inexact collision time estimates, no separate analysis of the 231 exact cases is reported. The distinction between exact and inexact, once made in the report, is not considered further. Determining the exact time of a collision is difficult.

Contamination across sources (e.g., driver statement is also used in a police record to indicate crash time) may have occurred. The analysis of the 72 people who remembered up to a year or so later that they were driving in both periods is similarly susceptible to memory errors. By any reckoning, the time of collision is subject to numerous sources of error.

Average call length (based on calls placed the week before the collision by this group of subjects) was 2.3 minutes, with 76% lasting 2.0 minutes or less. This suggests a positively skewed distribution with a long right tail, a distribution of mostly short (i.e., less than 2 minute) calls with some calls lasting substantially longer. The importance of this data relates to the fact that the investigators focussed their analysis on 5-minute and 10-minute-long hazard intervals prior to the collision. It is not known if the subject was actually on the cellular phone at the time of the collision.

The study contrasted a time period on the day of the collision with a comparison period on a day preceding the collision. The authors assert that this approach would identify an increase in risk if there were more telephone calls immediately before a collision than would be expected solely by chance. The key measure that was analyzed is termed "relative risk." In words, relative risk was defined as "the probability of having a collision when using a cellular telephone at any time during a 10-minute interval as compared with the probability of having a collision when not using a cellular telephone at any time during a 10-minute interval." (p. 456).

Quantitatively, relative risk is calculated as follows. The following example is an explanation of the "crude" relative risk assessment given on p.455 of the article, as explained by Redelmeier in a phone interview with one of the present report's authors. For that example, the relative risk assessment is based on the following 2 x 2 table:

	YES	NO	
Phone in Use within 10-minutes prior to Crash Day?	13	24	
Phone in Use within 10-minutes on Previous Day?	157	505	
	170	529	= 699

Relative Risk =

$$\frac{\text{\#Cases of Phone in Use on Crash Day but not on Preceding Day}}{\text{\# Cases of Phone in Use on Preceding Day but not on Crash Day}} = \frac{157}{24} = 6.5$$

Presumably, the interpretation is that the baseline risk (not observed or estimated) was the same on the crash day and the preceding day. Therefore, by this line of reasoning, the baseline risk was raised by some multiplier equal to the ratio of the observed cellular phone uses on the crash days and cellular phone uses on the preceding days. Because of the many variables that can affect crash hazard probabilities but that cannot be equated with the case-crossover study design, the authors point out that a causal relationship between cellular phone use and crashes cannot be drawn.

The implication of causality based on relative risk metrics would require very strong assumptions about the equality of baseline risk for each matched-pair in the study on all accounts except cell phone use. Such assumptions may not be plausible unless it can be assured that the situational characteristics (traffic situations, driver states, nature of cell phone use, etc.) were the same across the two days. The implausibility of this is reflected in the fact that an adjustment factor of 35% was used because the subject may not have even been driving during the control period.

The comparison of relative risk of a crash associated with cellular telephones and that associated with drivers with blood alcohol levels at the legal limit deserves special mention. While such a comparison may be appealing from the standpoint of emphasizing the potential adverse consequences of using a cellular phone while driving, it overlooks some important distinctions between the two categories of crashes. First, no causal link has been established between cellular telephone use and crashes. In contrast, the link between driving while intoxicated and crashes is far more clearly established, both in terms of the nature of the influence on driving and the magnitude of the problem.

Second, it must be recognized that cellular telephone use is a transient behavior, lasting, on the average (in this study) 2.3 minutes, with the majority of calls lasting 2 minutes or less. Intoxicated drivers, however, are impaired throughout a trip and thus exposure is likely to be considerably greater. The comparison given in the article would suggest that cellular phone use, per unit time, is actually much more hazardous than driving in an intoxicated state. This finding does not accord with what one might reasonably expect. Thus, the comparison in crash hazard exposure between cellular phone use and driving while intoxicated is specious unless more data than provided in the article are brought forth.

With regard to the lack of an apparent safety advantage of hands-free phones, we would add to Maclure and Mittleman's comment the fact that having such a feature does not mean it (i.e., the hands free feature) was in use at the time of a call. This issue is compounded by the fact that the specific "hands-free" features for a phone can vary considerably, requiring varying levels of interaction on the part of the driver for both dialing and conversation. Thus, the distinction between the two groups in this study may not be that clearcut.

Finally, a threat to the validity of any conclusions suggested by the Redelmeier and Tibshirani study resides in the nature of the study participants themselves. All 699 subjects were cellular phone owners who had a crash. But three other groups of drivers might be logically identified for comparison: cellular phone owners who did not have a crash, non-cellular phone owners who did have a crash, and non-cellular phone owners who did not: have a crash.

None of these three other groups were considered in the analysis. It is possible that the study participants represent members who are in some sense atypical of the driving population or of cellular phone owners in general. They may be extreme in the nature of their phone use (e.g., greater frequency of calls, longer calls, more intense dialogue), in their driving style (e.g., more aggressive driving with less margin for error), or even in their human abilities (e.g., less capacity to time-share the driving task and telephoning task). Thus, caution is urged in using the Redelmeier and Tibshirani study results to infer that cellular phone use, in general, is hazardous.

In summary, Redelmeier and Tibshirani's study represents a unique and suggestive investigation of the relationship between cellular telephone use and highway safety. Increasing the current level of understanding of the nature of this relationship awaits future research that helps untangle the many threads of potentially influential factors present in this study.

Serafin, C., Wen, C., Paelke, G., & Green, P. (1993). Car phone usability: a human factors laboratory test. Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, 220-224.
Type of Study: Driving simulator.
Keywords: hand-held cellular telephones, hands-free cellular telephones, voice-activated cellular telephones, lane deviation, age differences, head-up display

Author's Abstract::

This paper describes an experiment that examined the effect of cellular telephone design on simulated driving and dialing performance. The results were used to help develop an easy to use cellular telephone interface and to provide task times as input for a human performance model. Twelve drivers (six under 35 years, six over 60 years) participated in a laboratory experiment in which they operated a simple driving simulator and used a cellular telephone. The cellular telephone was either manually dialed or voice-operated and the associated display was either mounted on the instrument panel (IP) or a simulated head-up display (HUD).

The cellular telephone numbers dialed were either local (7 digits) or long distance (11 digits), and could be familiar (memorized before the experiment) or unfamiliar to the subject. Four tasks were performed after dialing a telephone number; two of the tasks were fairly ordinary (listening, talking) and two required some mental processing (loose ends, listing). In terms of driving performance, dialing while driving resulted in greater lane deviation (16.8 cm) than performing a task while driving (13.2 cm).

In addition, the voice-operated cellular telephone resulted in better driving performance (14.5 cm) than the manual cellular telephone (15.5 cm) using either the IP display or HUD. In terms of dialing performance, older drivers dialed 1l-digit numbers faster using the voice-activated cellular telephone (12.8 seconds) than the manual cellular telephone (19.6 seconds).

Dialing performance was also affected by the familiarity of numbers. Dialing unfamiliar numbers using the voice-activated cellular telephone was faster (9.7 seconds) than using the manual cellular telephone (13.0 seconds) and 7-digit unfamiliar numbers were dialed faster (8.2 seconds) than 1l-digit unfamiliar numbers (14.5 seconds). Thus, the voice-operated design appears to be an effective way of improving the safety and performance of car cellular telephone use, but the location of the display is not important.

Sample and Methods:

- Twelve licensed drivers (six men and six women), ranging in age from 20-76 years old.
  - Participants were divided into two subgroups, six younger (20-35 years old, mean = 24 years) and six older (over 60 years old, mean = 70 years).
  - Participants had never used a cellular telephone before.
  - Driving conditions in the simulator included nighttime driving on a single-lane, slightly curved road.
  - Cellular telephone designs tested were hand-held, hands-free, and voice-activated models mounted on either the instrument panel or displayed in a head-up display on the wind-shield.
  - Participants practiced dialing each type of telephone number once and practiced driving and using the cellular telephone at the same time until comfortable with the task. The tasks to perform in place of telephone conversations were also practiced, in the following order: loose ends, listing, talking, and listening. The communications tasks included "loose

ends" (how many unconnected ends are there in a capital letter), "listing" (name as many items in a category as possible in a fixed time period, e.g., "type of furniture), talking (answer the question "What did you do last week-end?"), and listening (i.e., listen to a hypothetical situation and answer multiple choice questions about it). Each task lasted about 30 seconds and all test participants were given the same materials.

- The study examined two types of cellular telephones, manual and voice-operated, combined with two types of displays, instrument panel (IP) display and head-up display (HUD). The IP display was located in the center console of the dashboard, and the HUD was positioned to the left of the driver's view.

Major Findings:

- The main disturbance in driving performance was found during periods of manual dialing while driving, as measured by standard deviation of lane position (16.8 cm versus 13.2 cm for performing a cellular telephone task while driving and 14.2 cm for driving only).
  - Voice activated dialing led to better driving performance than the manual handset dialing (14.5 cm versus 15.5 cm).
  - The driving performance of older drivers was significantly worse (15.2 cm) than younger drivers (14.2 cm).

- Dialing performance, as measured by the time it took to enter the digits of the telephone number, was affected by cellular telephone type, length of telephone number, type of telephone number (familiar versus unfamiliar), and age. Only display type did not significantly affect dialing performance.
  - Older drivers dialed 11-digit numbers faster using the voice-activated cellular telephone than the manual cellular telephone.
  - Participants dialed unfamiliar numbers faster using the voice-activated cellular telephone than the manual cellular telephone, but there was no difference for familiar numbers.
  - Participants dialed unfamiliar 7-digit numbers faster than 1l-digit numbers, but there was no difference between familiar numbers.
  - Older men dialed faster than older women, while younger women dialed faster than younger men.

- For the loose ends task (i.e., identifying structural features of letters, so that for the letter A, the answer would be "two," since two lines do not connect to other lines at the bottom of the letter), the response time for the letter G was higher than every letter except K. While older women had longer response times than younger women, older and younger men did not differ.

- 10 of the 12 drivers preferred the voice/head-up-display combination; the other two preferred the voice/instrument panel combination. The least preferred (8 of 12 participants ranked it "worst") was the manual/instrument panel combination.

Author's Conclusions:

- Compared with a manual handset, voice input with a HUD or IP display resulted in less lane position deviation for all drivers and faster dialing times for older drivers dialing unfamiliar numbers.

- Drivers preferred the voice-operated cellular telephone.

- Voice-operated designs appear to be an effective way of improving safety and performance of cellular telephone use.

- Age influenced both driving performance and dialing times, indicating that the older driver should be taken into account in the design of cellular telephones.

- In the manual/head-up-display combination, there may be location effects between the head-up-display and the handset display location, but the study of this location was restricted by hardware limitations on the simulator, so that the HUD was always positioned to the left of the driver's view.

Critical Assessment:

- Dialing time is a less relevant operational definition of safety for voice-activated cellular telephones than for manual cellular telephones, since visual attention does not need to be diverted from the road. In fact, voice dialing added only 0.3 cm of standard deviation of lane position to baseline driving, compared to 1.0 cm added for manual dialing. It is conceivable that for some drivers, saying a telephone number slowly would be less distracting than trying to say it as quickly as possible.

- Further operational definitions of driving performance besides lane position need to be studied in order to understand the effects of manual versus voice-activated dialing on driver performance.

- The practical significance of an age-related 1 cm increase in standard deviation of lane position is unclear.

- The study was conducted in a driving simulator, with its attendant interpretive problems.

- Some of the conversational materials (e.g., loose ends) have no apparent analogues in real-world cellular telephone communications.

Serafin, C., Wen, C., Paelke, G., & Green, P. (1993). Development and human factors tests of car phones. (UMTRI Technical Report No. 93-17).

Study Types: Study I – Pilot for Usability Study, Study II – Usability study, Study III – Summary and assessment of all differences between the two versions of the report.

Keywords: cellular telephone interface, cellular telephone functions, button labels, head-up display, hand-held cellular telephones, hands-free cellular telephones, voice-activated cellular telephones, lane deviation, age differences, dual tasks, cognitive interference

Author's Abstract:

This report describes three experiments to develop an easy to use car phone interface. In the first experiment, 19 people at two local secretary of state driver licensing offices gave their preferences for button labels and abbreviations. The following labels (and abbreviations) are recommended: power (Pwr), Call, End, delete (Del), memory (Mem), and recall (Rcl). Twelve drivers (six under 35 years, six over 60 years) participated in the third experiment, a laboratory study, in which they operated a simple driving simulator and used a car phone.

The phone was either manually dialed or voice-operated, and the associated display was either mounted on the instrument panel (IP) or was a simulated head-up display (HUD). Phone numbers dialed were either local (7 digits) or long distance (11 digits), and could be familiar or unfamiliar. In addition, there were four conversational tasks, two of which were fairly ordinary (listening, talking) and two of which required some mental processing (loose ends, listing).

Driver performance (voice-5.7 inches: manual--6.1 inches) and dialing times (voice-9.2 seconds; manual-l0.7 seconds) were better with the voice-operated phone than the manual phone using either the IP display or the HUD. In addition, younger drivers outperformed older drivers with regard to both driving (younger-5.6 inches; older 6.0 inches) and dialing performance (younger-7.4 seconds; older-l2.6 seconds). Thus, voice appears to be an effective way of improving the safety and performance of car phone use, but the location of the display is not important. The benefits of voice are particularly noticeable for older drivers.

STUDY I

Type of Study: Pilot for Usability Study

Sample and Methods:

- Nineteen licensed drivers (fourteen men and five women), ranging in age from 20-71 years old.
  – Participants were fluent in English.
  – Participants were recruited while waiting in line at two Michigan secretary of state offices.
  – Participants had never used a cellular telephone before.

- A computer interface was used to display a car phone keypad. Function buttons were labelled with question marks. After each function was demonstrated to the participant, the participant was asked to label the associated function key based on the demonstration. This task involved both naming the function and providing an abbreviation for that name that could be applied to the appropriate button.

- Participants devised labels for the following demonstrated cellular phone functions: power, delete, dial, end, answer, memory, and recall.

Major Findings:

- Across participants, the same labels were chosen most frequently for dial (DIAL), answer (ANSWER), memory (MEMORY), and recall (RECALL) functions.

- The most common abbreviation strategies that participants employed for labeling functions were truncation (e.g., POW for power) and vowel deletion (e.g., PWR for power).

- For the functions power, delete, and end, no consensus emerged as to the preferred label choice.

Author's Conclusions:

- Data on drivers' car phone label and abbreviation preferences was collected successfully in the secretary of state driver licensing office setting.

- No preferred label or abbreviation choice emerged for several functions.

- Results were used to develop stimulus materials for Study II.

Critical Assessment:

- While driver preferences for cellular phone button labels are an important usability issue, Study I falls outside the major focus of this literature review since no driving performance measures were taken.

STUDY II

Type of Study: Usability study

Sample and Methods:

- Twelve licensed drivers (seven men and five women), ranging in age from 22 to 53 years old.
  - All but one participant had never used a cellular telephone before.
  - Drivers were employees of the University of Michigan Transportation Research Institute (UMTRI).

- Drawings of cellular phone interfaces were presented to participants.
  - Button labels in the drawing were varied for the following functions: power, call, end, delete, memory, and recall.
  - Button functions were abbreviated according to three methods: 1., vowel deletion, 2., truncation, and 3., mixed vowel deletion and truncation. These labeling patterns were presented in counterbalanced order.

- Participants were instructed to tell what each button label abbreviation stood for and to state the function of each button. Participants were also asked to explain the sequence of buttons they would push to place a call. Participants were asked to choose a their preference for a button abbreviation method.

Major Findings:

- Among participants who were presented the interface labeled by the vowel deletion method first, two out of twelve participants mistook "DLT,"an abbreviation of "delete," for "dial tone."

- Among participants who were presented the interface labeled by the truncation method first, three participants mistook the meaning of "REC," an abbreviation of "recall," for "record" or "receive." In addition, two participants misinterpreted "POW," an abbreviation of "power," as a function to retrieve answering machine messages.

- Eleven of the twelve participants preferred the mixed vowel deletion and truncation method.

- In the “place a call” task, only one participants named the correct sequence of buttons. The most common error involved pressing “CALL” before dialing, rather than after dialing.

Author’s Conclusions:

- People are able to decode cellular phone function abbreviations better when they are encoded according to a mix of abbreviation techniques.

- Participants’ performance in abbreviation decoding and function naming was best when button labels were abbreviated with a combination of truncation and vowel deletion methods.

- The dual function of the “call” button, sending and receiving calls, was not well understood by novice cellular phone users.

Critical Assessment:

- While driver comprehension of cellular phone button labels is an important usability issue, Study I falls outside the major focus of this literature review since no driving performance measures were taken.

STUDY I I I

Type of Study: See Serafin, Wen, Paelke, & Green (1993) for a full review.

- Information from the larger report is provided here to supplement the above referenced review. The following points summarize and assess all differences between the two versions of the report.

Sample and Methods:

- Participants were screened for visual acuity at the time of recruitment.
- Lane position data is presented in standard measurements, while the same data is presented in metric units in the *Proceedings of the Human Factors* and *Ergonomics Society* version of the report.

Major Findings:

- Drivers’ glance behavior while using the phone in the simulator was analyzed. Only one participant of each age by gender cell was included in the glance analysis, and only data from the instrument panel (IP) condition using long distance telephone numbers was analyzed. This section of the report should be regarded as exploratory.

- Similarly, data on participants’ dialing patterns was included in the larger report. Again, videos of only four participants were used in the analysis, and these were only in the manual dialing condition. Pauses in dialing were counted. Among the four participants, older telephone users inserted more pauses into their dialing, while younger users tended to chunk numbers more often while dialing.

- Errors in dialing were also reported in the larger report. Since errors were rare events, they cannot be considered statistically meaningful. Counts are given of error types (13 commissions and 3 omissions), errors within each phone configuration (manual IP panel, 7 errors; voice HUD, 4 errors; manual HUD, 3 errors; and voice IP, 2 errors), and whether the participant corrected the error or not.

Stein, A.C., Parseghian, Z., & Allen, R.W. (1987). A simulator study of the safety implications of cellular mobile phone use. (Paper No. 405). Hawthorne, CA: Systems Technology, Inc.

Type of Study: Driving simulator.

Keywords: hand-held cellular telephones, hands-free cellular telephones, voice-activated hand-held cellular telephones, cellular telephone mounting location, lane position, radio tuning, age differences

Author's Abstract:

An interactive driving simulator developed by STI was used to investigate the impacts of different types of cellular telephone design, use, and mounting locations on driver performance in negotiating a simulated route. Along the route drivers were required to negotiate curves, avoid obstacles, and respond to various road signs. Data on lane position and speed were collected along the routes, making it possible to compare driver performance when no task was required (the baseline case) with performance over similar segments while dialing a cellular telephone, receiving a call, or tuning a radio. Seventy-two subjects were segregated by sex, age, and past experience with cellular telephone use in analyzing driver performance.

Sample and Methods:

- 72 participants.
  - 36 males and 36 females. 24 drivers were under 25 years old; 24 were between 25-55 years old; and 24 were over the age of 55.
  - In each young and middle age group, three of the drivers were current cellular telephone users. In the over 55 male group, only one driver was a cellular telephone user. In the over 55 female group, no current cellular telephone users were included.

- An off the shelf cellular telephone was used, but the model was not specified by the author.

- The cellular telephones were mounted on the center console and on the dashboard.

- Participants were trained to use the cellular telephone in a similar way that cellular telephone retailers train their customers, i.e., they were given an operation manual and observed a demonstration of cellular telephone operations.

- Participants were trained in the driving simulator until they reported feeling comfortable and were able to perform all required tasks without difficulty in all road conditions. A practice run was given before testing began.

- In order to create a workload representative of urban driving during peak traffic conditions, over the course of the testing session the driver was presented with 12 curves, 20 obstacles, and approximately 50 highway signs, 30 of which required driver response (depressing the horn switch or using the headlight dimmer foot switch). Whenever drivers observed the "airport" symbol sign, they were required to originate a cellular telephone call. All other cellular telephone calls were randomly originated and received on a straight section of road, a straight section of road when an unexpected obstacle was presented, and a curve.

- Each driver completed two driving scenarios in which the cellular telephone mounting location varied, dash or center console. Type of cellular telephone also varied (i.e., manual dialing/ hand-held handset; memory dialing/hands free; or voice-activated/hand-held handset).

- Subjects dialed by manually keying in the 10-digit phone number plus an enter key, by recalling a number from memory (i.e., pressing "RCL 1"), or by a voice command (i.e., lift handset and say "TRAVEL AGENT"). Placing a call, the driver heard and was required to memorize specific flight information given by a "travel agent"; this information included airline, flight number, originating airport, and destination. On an incoming phone call, the driver had to convey the memorized information.

- During a drive scenario, the subject was required to originate three cellular telephone calls, receive three cellular telephone calls, and perform the radio-tuning task three times.

- Dependent measures were as follows: speed, number of "accidents," lane position, lane position variability, and responses to road signs.

Major Findings:

- Secondary tasks did not significantly affect drivers' speed control, increase "accidents" (defined as running off the simulator road or colliding with an object), or increase "speeding tickets" (defined as travelling at least 3 mph above limit during the randomly-determined 30% of the time when a "policeman" was present). Therefore, steering control data was most useful concerning the effects of cellular telephone use on driver performance.

- On straight roadways without obstacles, the following results were found:
  - Driver's tracking ability (standard deviation of average lane position) deteriorated with manual dialing; the console-mounted cellular telephone deteriorated tracking ability more than the dash-mounted cellular telephone when manually dialing.
  - While manually dialing with a console-mounted cellular telephone, older drivers' lane tracking variability was 6 inches greater than younger drivers. This variability translates into a 1.63% probability of exceeding the lane boundary, and traffic safety may begin to be adversely affected when this probability exceeds 0.50%.
  When manually dialing a console-mounted cellular telephone, middle aged drivers had a 1.60% probability of exceeding the lane edge, while older drivers had a 7.23% probability of exceeding it.
  - When manually dialing a dash-mounted cellular telephone, mid-aged drivers had a 0.68% probability of exceeding the lane edge, while older drivers had a 1.63% probability of exceeding it.
  - Across ages and mounting locations, lane tracking variability was significantly greater for radio tuning than for memory dialing a cellular telephone.
  - Across task and mounting conditions, older drivers had a greater tracking variability than young drivers, but this difference translated into probabilities of exceeding the lane edges that were not significant in practical terms.
  - The voice-activated dialing task was no more difficult, i.e., had no greater lane tracking variability, for one age group than another. Voice-activated dialing resulted in less lane tracking variability than the radio tuning. A driver's probability of exceeding lane boundaries while dialing with voice-activation dialing was less than 0.10%.
  When receiving calls, older drivers' ability to maintain lane position was worse than middle aged drivers, and middle age drivers were worse than younger drivers. While this difference was significant, the practical probability of exceeding the lane boundary was consistently less than 0.10%.
  Similarly, when receiving calls, drivers' ability to maintain lane position was best with no secondary task, worse when tuning the radio, and worst when receiving a call with either a hand-held or hands-free cellular telephone. Again, while these differences were significant, the practical probability of exceeding the lane boundary was consistently less than 0.10%.
  - For old-age drivers, the effect of radio tuning on tracking variability reached the threshold of concern (0.50% probability of crossing lane boundary) from a trafffic safety standpoint.

- On curvy roadways without obstacles, the following results were found:
- – Manual dialing resulted in greater lane tracking variability than did radio tuning. All other dialing and answering tasks caused less lane tracking variability than the radio task.
- – Old-age drivers had significantly greater lane-tracking variability than mid-age or young drivers during manual dialing and memory dialing, but not for voice-activated dialing.

- On straight road segments with obstacles, the probability of colliding with obstacles or running off the road was calculated based on lane position variability. Actual collisions were rare. The following results were found:
- – Manual dialing performance was consistent with straight-segment-without-obstacle performance.
- – Mid-age and old-age drivers had a five-fold increase in the probability of striking the obstacle when they dialed with center console mounted cellular telephones. However, the probability of striking the obstacle only increased by one half when using the dash-mounted cellular telephone.
- – Dialing a memory-dial cellular telephone did not increase the accident probability for any age group.
- – Dialing with voice-activated cellular telephones increased mid-aged drivers' probability of running off the road.
- – When answering the cellular telephone, old-age drivers were two to five times more likely to have an accident when answering a call with the hands-free option than with hand-held.
- – Old-age drivers were 5 to 7 times more likely to be involved in an obstacle accident while tuning the radio.

Author's Conclusions:

- Consistent with other research, as a driver's age increases, any task competing for attention interacts with age to impair driving ability.

- Although manually dialing a ten-digit number can substantially increase the risk of accident involvement over that imposed by radio tuning, this risk may be reduced by appropriate cellular telephone location. Cellular telephones should be mounted in locations that are as close to the driver's line of sight as practical.

- Both voice-activated dialing and memory dialing are less hazardous than tuning a radio. In fact, for younger drivers, keying a single-digit memory location to enter a number, and then pushing the send button, was not appreciably more hazardous than the baseline condition of unencumbered driving.

- Dash-mounted cellular telephones may reduce the probability of accident involvement, compared to center console mountings. Further studies are needed to investigate the effects of other locations, such as the transmission hump, which is forward of the console and more in the driver's line of sight [but could be a further reach].

- Although hands-free operation showed no advantage over handset use when answering the cellular telephone, it could be helpful in emergency situations, since both hands could be free to respond to the emergency.

- Minimal training allows adequate carry-over from home telephone systems to the operation of cellular telephones.

- Use of voice-recognition dialing technology should be encouraged.

- The memory dialing capability of the cellular telephone should be used, but drivers should be instructed not to refer to written lists of memory locations while driving.

Critical Assessment:

- This study includes some useful descriptions of the available cellular telephone technology.

- Although part of the drivers' task involved responding to traffic signs by honking the horn, dimming the headlights, or originating a call, results are not reported as to whether drivers followed these directions. Although this part of the task may have diminished participants' sense of the study's realism, results may still have been useful in the sense that they could have shown whether drivers actually paid attention to roadway conditions in the simulator.

- As a secondary workload during cellular telephone calls, drivers were asked to memorize a script during the first cellular telephone call of a sequence and to repeat the information during the next call. The inter-trial interval was not reported, which could have a significant effect on the amount of information the individual is able to recall. Additionally, the explicit demand to learn the task allowed participants free reign in choosing encoding and retrieval strategies, whereas other studies have placed more quantifiable cognitive demands (e.g., serial addition or listing) upon participants. Therefore, the degree of interference imposed by telephoning is hard to gauge.

- No differentiation was made between data collected while dialing/answering and engaging in the ensuing conversation. Collapsing data across both tasks makes it hard to distinguish whether the dialing/answering method or the cellular telephone type had the observed effect on lane position. The effect of conversing is also obscured. Separate measurements should be made, and a fuller range of cellular telephone feature combinations should be utilized, e.g., voice-activated hands-free and memory-dialed hand-held.

- The simulator scene is described as 'a rural roadway, at dusk, under somewhat reduced visibility." However, in combination with secondary tasks, the simulation task is described as "create[ing] a workload representative of urban driving during peak traffic conditions." Urban driving has been associated with a higher workload than rural driving (Brookhuis et al., 1991). However, without physiological or secondary task measures, driving task workload is hard to quantify. Caution should be also be taken in generalizing results from computer-generated simulator displays to specific, (and different), real-world environments.

- All conclusions related to radio tuning must be viewed in light of the fact that participants were required to visually search for a particular radio frequency on the dial. This task may be comparable to tuning to a frequency to obtain airport traffic information without the benefit of search and scan features commonly found on car radios today. This methodology differs from other studies in which drivers simply matched a station that another radio played by listening and moving the dial. The radio results may be best considered as time in which visual attention was diverted, but should not be taken as representative of radio use.

- The author asserts but does not support a number of statements such as: "if a driver uses his telephone...as an electronic 'scratch pad' to record new telephone numbers, the activity is just as dangerous as the manual dialing task;" or, "in practice, however, on any given trip more time would be devoted to telephone use than radio tuning."

Tijerina, L., Kiger, S. M., Rockwell, T.H., & Tornow, C. (1995). Workload assessment of in-cab cellular phone use bv heavy vehicle drivers on the road. (NHTSA Contract DTNH22-91-C-07003).

Type of Study: On-road research with an instrumented vehicle.

Keywords: cellular telephones, commercial vehicle operation, on-road measures

Author's Abstract:

This study assessed the driver workload imposed by a cellular phone on heavy vehicle drivers under various driving conditions. Sixteen (16) professional commercial vehicle operation (CVO) licensed drivers drove an instrumented heavy truck over a 4-hour period on public roads under various conditions of ambient lighting (day or night), traffic density (light or heavy), and road type (divided or undivided). Within driving conditions combinations, cellular phone dialing, radio tuning, and communications dialogue were completed by the driver. Continuous measures were taken of visual allocation, steering and accelerator activity, speed maintenance and lane-keeping performance. Results of in-vehicle device use are presented and provide insights into useful workload measures and methods, as well as a contribution to the literature on cellular telephone system ergomatics.

Sample Studied:

- 16 professional heavy vehicle drivers. Participant ages ranged from 32-60 years old, with a mean age of 47.2 years. None were regular cellular telephone users.

Apparatus

- The test vehicle was a 1992 Volvo/White GMC conventional tractor with a sleeper and a 53 ft. 1993 Fruehauf dry freight van semi-trailer loaded to bring the gross vehicle weight to approximately 76,300 pounds.
- The test vehicle was equipped was standard engine gauges, CB radio, and AM/FM stereo radio. The vehicle was also instrumented with an array of sensors, including an automatic lane tracker, speed sensor, steering sensor, accelerator pedal angle sensor, and a storage device to capture all sensor data.
- Four video cameras and two VCR's were used to capture data on driver visual allocation, manual allocation, and the road scene ahead.
- A text message display consisting of a 7-inch diagonal VGA-compatible green-phosphor CRT was mounted on the top of the instrument panel to the right of the seated driver.
- A Motorola Model No. 190 17NAABB black cellular telephone was installed to the right of the seated driver.
- The telephone included a recall feature to dial stored numbers.
- Manual dialing was completed by pressing the "send" button.
- An on-board experimenter was present at all times.
- The test route was arranged to encompass variations in lighting (dark vs. light), road type (divided vs. undivided), and traffic density (high vs. low).
- Each driving condition phase occurred over roughly a 10- 15 minute period, about one each hour of a 4-hour run.
- Drivers were prompted to use the cellular telephone by text messages on the CRT display.
- During each of the four driving condition phases, eight est messages and two dialogues were presented.

- One dialogue had an anticipated low workload (driver required to answer biographical questions such as name, address, birth date) while the second dialogue had an anticipated high workload (questions requiring single math calculations to determine fuel needed, time required to reach a destination, etc.).

- Manual task data (auto-dial, 7-digit, and 10-digit manual cellular telephone dialing, plus radio tuning as a control condition) and cognitive task data (the two question-and-answer dialogue tasks with open-road driving as a control condition) served as measures of driver performance.

Major Findings

- 7-digit and 10-digit dialing took more glances, on average, for completion than radio tuning, with greater total time the eyes are off the road and on the device.

- Mean number of steering holds was greater during radio tuning and lo-digit dialing then for auto-dialing and 7-digit dialing.

- Smallest number of steering reversal occurred during auto-dialing compared to radio tuning, -7-digit and 10-digit dialing.

- The impact of road conditions (divided vs. undivided) on driving performance was found to be secondary to the manual task effects, but did have some impact on driving measures during cognitive task execution.

- Manual dialing did not have an effect on speed variance or lane-keeping measures.

- Mirror sampling reduced from a little over 12 percent while engaged in open road driving only to about 6 percent while drivers were engaged in a dialogue.

- No degradation of driving performance in terms of speed maintenance and lane keeping measures were noted during execution of the cognitive tasks.

Author’s Conclusions

- Driver visual allocation measures can be sensitive to variations in in-vehicle workload with heavy vehicle drivers.

- Simple biographical question-and-answer dialogue reduced the number of mirror glances professional drivers took.

- Reduced mirror glances resulted in reduced situation awareness of driving conditions to a degree.

- Drivers generally showed excellent speed control over the vehicle during in-cab use of the cellular telephones, but lane-keeping, in terms of lane exceedances and related measures, was degraded.

- This suggests that cellular telephone dialing can be disruptive to lane-keeping as a measure of drivers’ performance.

- In-vehicle device workload can degrade highly over learned vehicle control skills of lane-keeping, as well as decrease drive monitoring for crash hazards ahead.

Critical Assessment

As the authors point out, “high” traffic density for this study may have been relatively low as compared with other locations (e.g. metropolitan Washington, D.C.). Therefore, even though traffic density did not have an effect of workload measures in this particular study, traffic density may effect workload measure in other geographical locations.

This study benefitted from the use of several measures of driving performance, such as steering and accelerator activity, speed maintenance, and lane-keeping performance.

Trinkaus, J. (1990). Usage of cellular telephones: an informal look. Perceptual and Motor Skills, 71, 1375-1376.

Type of Study: Brief report, citing one systematic field observation study (The cellular marketplace: 1990. Washington, DC: Economics and Management Consultants International, 1990.)

Keywords: hand-held cellular telephones, systematic field observation

Author's Abstract:

The growth in the usage of cellular telephones by motor vehicle operators appears to be happening in the absence of any companion governmental operating directives. The result is a state of the world wherein drivers are mandated to be securely fastened to seats of defect-free vehicles, yet are permitted to drive with one hand on the steering wheel, while dividing their attention between road conditions and an interactive conversation.

Sample and Methods:

- Naturalistic observation of drivers in a north-eastern city having about 210,000 cellular subscribers. This estimate is from The Cellular Marketplace, (1990).
- 50 one-hour convenience citings were conducted during morning and evening rush hours, Monday through Friday, of vehicles moving north on a four-lane one-way road. Traffic flowed at a rate of about 1600 vehicles per hour.
- Drivers observed holding a cellular telephone were counted.

Major Findings:

- During the 50 hours of observations, two drivers were noted to be using what appeared to be cellular telephones.
- Both operators, in moving private vehicles, were holding the instrument in the left hand while the right hand was on the steering wheel.

Author's Conclusions:

- Assuming industry projections for growth of cellular subscribers to be accurate, all other things being equal, a replication of this study done five years later should yield 6 drivers using cellular telephones. While seemingly not a large number, when viewed as an indicator of the magnitude of a count of all such drivers, it assumes meaning.
- It is difficult to understand accident abatement efforts that mandate seat belts but permit drivers to drive with only one hand on the wheel.
- Cellular telephone industry growth should be accompanied by a suitable ancillary program to evolve means for the safe application of its products.

Critical Assessment:

- Counting the number of drivers holding cellular telephones does not give a true measure of cellular telephone use, given the availability of hands-free technology (although we are not sure how prevalent this technology was in or before 1990). Since hands-free designs are becoming more prevalent, the author's five-year projection is not valid.
- Two drivers were reported to hold "what appeared to be cellular telephones." In fact, did observers see anyone using a cellular telephone? Could it have been the same driver on two occasions?

- Given that two drivers were observed with hand-held cellular phones over 50 hours on a road where traffic progressed at a rate of 1600 vehicles per hour, these drivers were 2 out of 80,000 drivers. This is not significant.

- Other people besides these two hand-held cellular telephone users undoubtedly were driving with only one hand on the wheel--the author's measure of safety. In fact, one-handed driving may not be a valid measure of driving performance and/or safety. Drivers shifting in manual transmission cars come to mind in this regard, though two-handed steering for emergency swerve maneuvers is almost certainly a necessity.

- Reviewing the cited study may clarify a number of methodological points that were not included in this brief report, e.g.:
  - Was the traffic videotaped, or did observers simply record what they saw in real time?

- No measure of inter-observer reliability is given. In published field observation studies, it is generally accepted that two observers should report the same observations at least 80% of the time.

- What does this sample represent? Business people travel during rush hour and tend to use cellular telephones more. In fact, it was noted that half the vehicles were commercial.

- This article appears to rely most heavily on scare tactics.

Violanti, J. M., and Marshall, J. R. (1996). Cellular phones and traffic accidents: epidemiological approach. Accident Analvsis and Prevention, 28.

Type of Study: Epidemiological case-control accident study.

Keywords: cellular phones, traffic accident risk, epidemiology, driver inattention

Author's Abstract:

Using epidemiological case-control design and logistic regression techniques, this study examined the association of cellular phone use in motor vehicles and traffic accident risk. The amount of time per month spent talking on a cellular phone and eighteen other driver inattention factors were examined. Data were obtained from: (1) a case group of 100 randomly selected drivers involved in accidents within the past two years, and (2) a control group of 100 randomly selected licensed drivers not involved in accidents with the past ten years.

Groups were matched on geographic residence. Approximately 13% (N=7) of the accident and 9% (N=7) of the non-accident group reported use of cellular phones while driving. Data was obtained from Department of Motor Vehicles accident reports and survey information from study subjects. We hypothesized that increased used of cellular phones while driving was associated with increased odds of a traffic accident. Results indicated that talking more than fifty minutes per month on cellular phones in a vehicle was associated with a 5.59-fold increased risk of a traffic accident.

The combined use of cellular phones and motor and cognitive activities while driving were also associated with increased traffic accident risk. Readers should be cautioned that this study: (1) consists of a small sample, (2) reveals statistical associations and not causal relationships, and (3) does not conclude that talking on cellular phones while driving is inherently dangerous.

Sample and Methods:

- A case group of 100 randomly selected drivers involved in accidents within past two years (1992 -93).

- A control group of 100 randomly selected drivers not involved in accidents within past two years (1992-93).

- Groups were match on geographic residence.

- Method employed an epidemiological case-control design which focused on the presence or absence of risk factors rather than outcomes. In the design randomly assigned persons who had accidents were assigned as "cases" and those who had no accidents as "controls." Being a case or control represented the independent variable. To assess risk factors, the frequency of attention diverting driver behaviors and other factors which might affect the association between cellular phone use and accidents were measured. The presence or absence of these factors were represented as dependent variables.

- A survey was sent to each case and control subject and accident information was obtained from the Department of Motor Vehicles accident reports. Demographic information as well as 18 possible driver inattention behaviors was requested, including drinking beverages, smoking, talking with others in the vehicle, adjusting seats or mirrors, and cellular phone use. Information of phone use was measured from monthly cellular phone bills. Phone time use was categorized based on the median time per month (i.e., casual, business, intense). Sixty percent (60%) of case and 77% of control subjects responded to the survey.

Major Findings:

- Results indicated that talking more than fifty minutes per month on cellular phones in a vehicle was associated with a 5.58-fold increased risk in a traffic accident.
- Descriptive analysis indicated that cellular phone users who had accidents on average were younger, had less driving experience, and more previous accidents than non-accident subjects.
- Accident subjects spent approximately twice the number of minutes per month talking on phones than did non-accident subjects and appeared to engage in considerably more business and intense business calls.
- Talking with others in vehicle, watching scenery, and drinking beverages appeared to be the most often reported driver inattention behaviors by both accident and non-accident subjects.
- Use of a cellular phone in a vehicle while simultaneously performing other behaviors also was associated with increased odds of a traffic accident. Most significant was the combination of talking on the phone while drinking a beverage, lighting a cigarette, or taking one's hand off the steering wheel. Combined driver behaviors had lower significant odds for an accident than the use of a cellular phone alone.

Author's Conclusions:

- The combined use of cellular phones and motor and cognitive activities while driving were associated with increased traffic risk.

Critical Assessment:

- Study consists of a small sample size.
- The epidemiological case-control method is prone to potential sources of bias, although efforts were made to minimize selection bias.
- The Department of Motor Vehicles did not provide evidence that persons were actually using a cellular phone at the time of the accident and the question was not included in the survey.
- Findings suggest statistical, not causal relationship between cellular phone use and accidents.
- Reported differences may reflect driver personality or cognitive differences rather than cellular telephone effects.

Zwahlen, H. T., Adams, Jr. C. C., & Schwartz, P. J. (1988). Safety aspects of cellular telephones in automobiles. Proceedings of the ISATA Conference, Florence, Italy.
Type of Study: Closed-course test track with an instrumented vehicle.
Keywords: manual dialing, cellular telephone mounting position, lane deviation

Abstract:

Two independent studies consisting of ten young and healthy drivers each were used to investigate lateral path deviations when driving in a straight path while dialing in a long distance telephone number on a cellular telephone under four different experimental conditions (cellular telephone mounted in a high position or low position inside car, driver permitted or not permitted to look at road while dialing the cellular telephone). Findings of increased standard deviation of lateral position while dialing suggest that dialing while driving is unacceptable from a driver safety point of view. Design enhancements should be investigated to afford safer and more efficient cellular telephone use.

Sample and Methods:

- Each of the two studies used 10 participants, for a total of 20 drivers.
  - Study 1 used 10 males, mean age 23.6 years. These participants had an average of 5.9 years driving experience, and averaged driving 8,900 miles per year.
  - Study 2 used 5 males and 5 females, mean age 20.8 years. These participants had an average of 4.4 years driving experience, and averaged driving 5,400 miles per year.

- The test track was located on an unused airport runway.

- Drivers were to align the longitudinal centerline of the vehicle with the centerline of the runway and drive in the straightest path possible from a standstill to 40 MPH while dialing a cellular telephone.

- A standard push button telephone was used for the telephone tasks, however, model type was not specified by the authors. This was not a cellular telephone.

- The telephone task consisted of dialing an 11-digit long distance telephone number. Telephones were mounted in a high position (keypad vertical on the top portion of the dashboard face) or in the low position (keypad horizontal to the car seat). Subjects were to either look continuously and directly at the telephone while dialing the long distance number and concurrently maintaining vehicle position over the centerline on the roadway, or to look at the roadway as often as needed in order to maintain vehicle position while dialing the telephone number.

- The telephone number (11 digits) was read by the driver from a piece of paper located near the cellular telephone at the beginning of each run. One experimenter sat beside the driver in order to monitor the looking behavior, while a second experimenter seated in the back seat recorded the task completion time.

- Each participant completed each of the four conditions (2 mounting locations and 2 looking conditions) five times in a randomized order, for a total of 20 runs per person.

- An experimenter was present inside the vehicle with the participant during the testing session.

- Lateral path deviation was measured in inches for a distance of 675 feet. A device was attached to the rear bumper at the car's midline. This device dripped liquid dye to indicate the car's path. Every 15 feet, a measurement was taken from the centerline of the runway.

- Differences in methodology between the first and second study included use of different test vehicles (a Pontiac and a Plymouth) and different telephone manufacturers (although the telephones had identical dimensions).

Major Findings:

- Drivers were able to most closely maintain a straight path along the centerline when the telephone was mounted in the high vertical position and the test drivers were permitted to look at the runway while dialing.

- The greatest lateral deviation occurred when the telephone was mounted in the low horizontal position and the drivers were not permitted to look at the runway during dialing.

- Maximum lateral path standard deviation (38.13 inches in Study 1 and 40.69 inches in Study 2) occurred during dialing, when drivers were not permitted to look at the runway and the cellular telephone was mounted in the low position.

- The lateral path standard deviation at the dialing completion time for the four experimental conditions ranged from a low of 7.01 inches for the looking high condition to a high of 25.24 inches for the drivers not looking at the runway, low position condition.

- The position of the telephone in the vehicle as well as the visual restraints (permitted or not permitted to look at the runway) had an effect on the lateral deviation of the vehicle.

- Vehicle also appears to influence the lateral mean position. The Pontiac in Study 1 had mean values that were all on the left of the runway centerline while the Plymouth in Study 2 had mean values that were all on the right of the runway centerline.

- Cumulative distributions for the dialing completion distances in both studies appear to indicate that the completion distances are fairly normally distributed with respect to the distance required to complete the dialing of the long distance telephone number. Mean completion time (distance) for all the conditions combined in Study 1 is 8.7 seconds (510.4 feet) with a standard deviation of 1.67 seconds (97.9 feet). The mean completion time (distance) in Study 2 for all conditions combined is 9.5 seconds (557.6 feet) with a standard deviation of 1.77 seconds (103.7 feet).

- Drivers looked at the road ahead an average 2.2 times while dialing the push-button telephone when the telephone was mounted in the low position. When the telephone was mounted in the high position, drivers looked at the road ahead an average 2.9 times while dialing. When drivers were permitted to look at the road, they chose not to on 13 of the 50 runs when the telephone was in the high position. However, when the telephone was in the low position and drivers were permitted to look at the road, they chose not to on only 3 out of 50 runs.

- A combined, overall standard deviation of the lateral lane position for both studies combined was calculated to be 15.41 inches over 675 feet.

Author's Conclusions:

- Based upon the combined, overall standard deviation of lane position, one out of every 52 cars (1.9%) would laterally deviate out of the driving lane at any point in time while dialing the telephone (for a six foot wide car travelling in a 12 foot wide lane, under nearly ideal conditions). Narrower lanes or worse conditions undoubtedly would increase swerving. This estimate may be conservative, since the maximum standard deviation may be as high as

40.69 inches, which occurred when drivers were not permitted to look at the runway while dialing and the cellular telephone was mounted in the low position.

- Based on the results obtained regarding number and seconds of looks inside the car to dial the telephone number, a model to be used in the design of keypads and telephone placement is presented. This model shows that if more than four looks are required to dial the telephone number, then it is considered unacceptable from a driver safety and performance point of view, as it relates to lane exceedance probability. Also, the length of time required per look should not exceed 2.0, 1.8, 1.6, and 1.4 seconds, for 1, 2, 3, and 4 looks respectively.

- Regardless of telephone mounting position, the risk of laterally deviating out of lane while dialing the cellular telephone appears too great. Design enhancements such as different input keys near or on the steering wheel, interlock devices to prevent the use of the telephones in curves and/or heavy traffic, or voice recognition input devices, need to be investigated to afford safer and more efficient telephone use.

Critical Assessment:

- The manipulation of instructions so that drivers are not permitted to look at the road may tend to inflate results, e.g., the finding of a 40.69 inch standard deviation of lane position for the low-mounted position. While a manually-dialed telephone may compete with the roadway for a driver's attention, it does not forbid the driver from looking at the road ahead. Therefore, manipulation of instructions does not bear much similarity to events that occur in the real world of driving and telephone use.

- Additionally, how did the experimenters insure that drivers didn't even peek when they were not supposed to? It is assumed that drivers were videotaped; however, the method by which videotapes were analyzed is not explained. This information would also help to understand the results pertaining to number of looks.

- This study concentrated on effects of dialing on performance, but did not include a subsequent conversation.

- It would be interesting to learn whether the liquid dye method of recording lane position was ever validated against another measure of lane position, e.g., a videotape or an instrumented vehicle that automatically detects lane tracking. Dye that evaporates in a few minutes, though convenient, does not appear particularly reliable.

Appendix D

Glossary

CTIA – Cellular Telecommunications Industry Association. An organization which represents wireless carriers and manufacturers.

3-watt booster – For portable phones used in a car kit, raises the transmission power from 0.6 watts to 3 watts, improving reception in fringe areas.

A/B select – enables the user to select either A- or B- side carrier when roaming.

Alphanumeric memory – The ability to store names with telephone numbers.

AMPS – Analog Mobile Phone Service, the standard for cellular service in North America.

Call restriction – User feature that limits phone use.

Call timer – Tracks duration, saves last call time, and may tally total air time.

Call-in absence indicator – Indicates in the phone's display if a call was missed.

Car Phone – A cellular telephone that is permanently installed and integrated into the wiring of a motor vehicle. May be either a hands-free or a hand-held model. Also called a mobile phone.

Car-Mounting kit – Provides a cradle for portable phone in the car. It may connect to car battery and external antenna.

CDMA – Code Division Multiple Access, the second type of digital cellular system to be deployed in the United States (See TDMA).

Data interface -A way to connect either a modem with an RJ-11 jack or a PC Card modem to a cellular telephone for data and fax transmission.

DTMF – Dual-tone multifrequency, refers to the generic name for the touch-tone sounds required for communicating with machines (banking, voice mail, etc.)

Dual-mode -All digital phones work both on digital and analog systems, so they are called dual-mode.

Electronic lock – Prevents phone use; requires user to enter a personal code to unlock the phone.

FARS – Fatal Analysis Sampling System. A census of fatal accidents which result from highway crashes. Sponsored by NHTSA.

GSM – Global System for Mobile Communication. A network which generally covers a fairly broad geographic area and which offers customized travel, financial, reference and commercial information to smart-phone subscribers.

Hand held telephone – a portable model that must be held to the ear and mouth for use. May be transportable, mobile or pocket size. Generally used to describe small, lightweight units.

Hands free telephone – a model that can be used while mounted in a vehicle or placed in a bracket. May use a remote speaker or microphone to improve performance.

LCD – Liquid crystal display, the most common type of cellular telephone display. LCDs are common in watches, computers and small TVS.

LED – Light emitting diode, a small, colored light bulb used typically as an indicator light.

Li-ion – Lithium-ion, state-of-the-art battery material.

Memory effect – The loss of capacity in a nickel-cadmium battery caused by charging the battery before completely discharging it.

Mobile phone – A cellular telephone that is permanently installed and integrated into the wiring of a motor vehicle. May be either hands free or hand held models. Also called a car phone.

NAM – Numerical assignment module, the place where a phone stores its phone number. Having more than one NAM enables users to sign up with more than one carrier to cut down on roaming charges.

NAMPS – An advanced type of analog cellular service that offers some of the same features as a pager.

NASS – National Accident Sampling System. A highway crash data collection system based upon 24 Primary Sampling Units randomly selected from the 48 contiguous states.

NHTSA – National Highway Traffic Safety Administration, U.S. Department of Transportation

NiCd – Nickel-cadmium, a low-quality battery material.

NiMH – Nickel-metal hydride, a medium quality battery material.

Packet radio – A method of transmitting and receiving voice, video or other information and data which can be expressed in digital form, i.e. a series of ones and zeros, in a series of blocks or "data packets" using radio frequency communications equipment.

Pocket phone – A small. lightweight cellular telephone with an integrated battery pack.

Repeater – This refers to communications equipment which receives weak incoming signals and amplifies and retransmits or "repeats" the received incoming signal so that signal reception can be accomplished at greater distances. In a vehicle such a system might be used to improve communications when low power handheld cellular telephones are used. Future vehicles might incorporate a capability that would allow hand-held units to plug into the vehicle to achieve greater power and use of an external antenna.

Roaming – Using a cellular telephone outside the user's home system. Roaming usually incurs extra charges.

Signal strength indicator – Displays strength of radio signal, telling the user if conditions are good for calling.

Soft key – A key located below the display and linked to the bottom section of the display. It performs whatever function is listed on the display.

Standby time – Maximum time that a cellular telephone operating on battery power can be left on to receive calls.

System ID select – Restricts use to a fixed number of cellular systems identified by a five-digit system ID.

Talk time – Maximum time that a phone can transmit on a single battery charge.

TDMA – Time Division Multiple Access, the type of digital cellular system most widely implemented in North America.

Transportable Telephone -Wireless telephone with an external battery pack, usually weights several pounds. Transmission power at least 3 watts. Generally packaged in a carrying case.

Appendix E

Bibliography

American Automobile Association, Potomac, 1996 Member Survey. *Car & Travel,* May/ June, 1996.

Alm, H., & Nilsson, L. (1995). The effects of a mobile telephone task on driver behaviour in a car following situation. *Accident Analysis and Prevention*, Vol. 27 (5), pp. 707-715.

Alm, H., & Nilsson, L. (1994). Changes in driver behaviour as a function of handsfree mobile telephones. *Accident Analysis and Prevention,* Vol. 26, pp. 44 l-45 1.

Alm, H., & Nilsson, L. (1990). Changes in driver behaviour as a function of handsfree mobile telephones: a simulator study. Report No. 47, DRIVE Project V1017 (BERTIE), October. Also paper No. 175, 1991 (ISSN 0347-6049). Linkoping, Sweden: Swedish Road and Traffic Research Institute.

Boase, M., Hannigan, S., & Porter, J. M. (1988). Sorry, can't talk now... just overtaking a lorry: the definition and experimentation investigation of the problem of driving and hands-free carphone use. In E. D. Megaw (Ed.). *Contemporary Ergonomics* (pp. 527-523). London: Taylor and Francis.

Brand, J.E. (1990). Attitudes toward advanced automotive display systems: feedback from driver focus group discussions (*Technical report UMTRI-9022),* Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Briem, V., & Hedman, L. R. (1995). Behavioral effects of mobile telephone use during simulated driving. *Ergonomics,* Vol. 38 (12), pp. 2536-2562.

Brookhuis, K. A., de Vries, G., & de Waard, D. (1991). The effects of mobile telephoning on driving performance. *Accident Analysis and Prevention,* Vol. 23 (4), pp. 309-316.

Brown, I. D., Tickner, A. H., & Simmonds, D. C.V. (1969). Interference between concurrent tasks of driving and telephoning. *Journal of Applied Psychology,* Vol. 53 (5), pp. 419-424.

Cellular Telecommunications Industry Association. (1994, September 6). Mid-year results show wireless customers near 20 million mark: monthly bills drop. [Press Release].

Department of the California Highway Patrol, (1987). A special report to the legislature on the findings of the mobile telephone safety study: Senate concurrent resolution No. 8.

Drory, A. (1985). Effects of rest and secondary task on simulated truck-driving task performance. *Human Factors,* Vol. 27(2), pp. 201-207.

Evans, L. (1991). Traffic Safety and the *Driver* (pp. 282 - 309). New York: Van Nostrand Reinhold.

Fairclough, S. H., Ashby, M. C., Ross, T., & Parkes, A. M. (1991). Effects of handsfree telephone use on driving behaviour. Proceedings of the ISATA Conference, Florence, Italy, ISBN 0 947719458.

Frisbie, T. (1991). Talking mobile. *Traffic Safety,* National Safety Council, March/April 1991, Vol. 91(2), pp.26-28.

Green, P. & Brand, J. (1992). Future in-car information systems: input from focus groups (SAE paper 920614). Warrendale, PA: Society of Automotive Engineers.

Green, P., Hoekstra, E., & Williams, M. (1993, November). Further on-the-road tests of driver interfaces: examination of a route guidance system and a car phone (Report No. UMTRI-93-35). Ann Arbor, MI: University of Michigan Transportation Research Institute

Green, P. (1995). Automotive techniques. In J. Weimer (Ed.), *Research Techniques in Human Engineering* (pp. 165 - 208). Englewood Cliffs, NJ: Prentice-Hall.

Handler, S.J. (1997). Imminent domain. *Mobile Computing & Communications,* February, 1997, pp. 64-74.

Hanowski, R., Kantowitz, B., & Tijerina, L. (1995, September). Final report — workload assessment of in-cab text message system and cellular phone use by heavy vehicle drivers in a part-task driving simulator (Contract No. DTNH22-91-07003). Columbus, OH: Battelle Memorial Institute.

Hanson, B.L. & Bronell C.E. (1979). Human factors evaluation of calling procedures for the advanced mobile phone system (AMPS). *IEEE Transactions on Vehicle Technology,* Vol. VT-28, No. 2, May 1979, pp. 126-131.

Hayes, B.C., Kurokawa, K., & Wierwille, W.W. (1989). Age-related decrements in automobile instrument panel task performance. Proceedings of the Human Factors Society 33rd Annual Meeting, pp. 159-163.

Japanese National Police Agency. Study of Injury Producing Crashes during June, 1996. *Daily Automobile Newspaper*. August 17, 1996.

Kames, A. J. (1978). A study of the effects of mobile telephone use and control unit design on driving performance. *IEEE Transactions on Vehicular Technology, VT-27 (4),* pp. 282-287.

Kantowitz, B. H., Hanowski, R. H., & Tijerina, L. (1996). Simulator evaluation of heavy-vehicle driver workload II: complex secondary tasks. *Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting,* pp. 877- 881.

Llaneras, R. E., Swezey, R. W., & Brock, J. F. (1993). Human abilities and age-related changes in driving performance. *Journal of the Washington Academy of Sciences*, Vol. 83 (1), pp. 32-78.

Lipoff, Stuart (1997). PCS and Cellular: War on 5 fronts (Interview). *Mobile Computing and Communications,* Vol. 8 (2), February, 1997, p. 184.

Maclure, Malcolm (1991). The case-crossover design: a method for studying transient effects on the risk of acute events. *Amercian Journal of Epidemiology,* Vol. 133 (2), pp. 144-153.

Maclure, M. & Mittleman, M.A. (1997). Editorial: cautions about car telephones and collisions. *The New England Journal of Medicine,* Vol. 336 (7), pp. 501-502.

McClelland, J. L., Rumelhart, D. E., & Hinton, G. E. (1986). The appeal of parallel distributed processing. In D. E. Rumelhart, J. L. McClelland, & the PDP research group (Eds.), Parallel *Distributed Processing: Explorations in the Microstructure of Cognition* (Vol. 1). Cambridge, MA: Bradford.

McKnight A. J., & McKnight, A. S. (1991, January). The effect of cellular phone use upon driver attention. Washington, DC: National Public Services Research Institute. (Funded by AAA Foundation for Traffic Safety.)

McKnight, A. J., & McKnight, A. S.(1993). The effect of cellular phone use upon driver attention. *Accident Analysis &Prevention*, Vol. 25 *(3)*, pp. 259-265.

Mittleman, M.A., Maclure, M. & Robins, J.M. (1995) Control sampling strategies for case-crossover studies: An assessment of relative efficiency. *American Journal of Epidemiology*, Vol. 142 (l), pp. 91-98.

Nilsson, L. (1993). Behavioural research in an advanced driving simulator: Experiences of the VTI system. *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting*, pp. 612-616.

Nilsson, L., & Alm, H. (1991). Elderly people and mobile telephone use – effects on driver behaviour. *Proceedings of the Conference Strategic Highway Research Program and Traffic Safety on Two Continents.* Gothenburg, Sweden, and DRIVE Project V1017 (BERTIE, Report NO. *53)*, March 1991.

Nilsson, L., & Alm, H. (1991). Effects of mobile telephone use on elderly drivers' behavior - including comparisons to younger drivers' behavior. Gothenburg, Sweden, and DRIVE Project V1017 (BERTIE, Report No. 176), 1991.

Organisation for Economic Co-Operation and Development (OECD), Paris (1990). Behavioral adaptations to changes in the road transport system: Final Report, RTR/S9/89.2

Pachiaudi, G., & Chapon, A. (1994). Car phone and road safety. XIVth International Technical Conference on the Enhanced Safety of Vehicles, No. 94-S2-0-09. Munich, Germany.

Pachiandi, G., Morgillo, F., Pauzie, A., Deleurence, P., & Giulhon, V. Impact de I'utilisation du telephone de voiture sur la securite routiere. (Impact of the use of car phones on road safety), International Conference on Traffic and Transport Psychology. Approche experimentale sur simulateur de conduite - Rapport LESCO n° 9417, Oct 94 Approche experimentale en conditions reelles de circulation - Rapport LESCO n° 9510, Oct 95. ICTTP '96 paper no. TS01.07

Parkes, A. M. (1991). Drivers business decision making ability whilst using carphones. In Lovessey, E. (Ed.), Contemporary Ergonomics, Proceedings of the Ergonomic Society Annual Conference (pp. 427-432). London: Taylor and Francis.

Parkes, A. M. (1993). Voice communications in vehicles. In Franzer, S. and Parkes, A. (Eds.), *Driving future vehicles* (pp. 2 19-228). London: Taylor and Francis.

Perel, M. (1988). An analysis of pedal-related accidents using police narratives. (Unpublished manuscript available from the author.) Office of Crash Avoidance Research, National Highway Traffic Safety Administration, Washington, DC.

Perel, M. (1976). Analyzing the role of driver/ vehicle incompatibilities in accident causation using police reports. DOT-HS-801-858. Washington, DC: National Highway Traffic Safety Administration.

Petica, Stefan (1993). Risks of cellular phone usage in the car and its impact on road safety. *Recherche-Transports-Securite, 37*, pp. 45-56

Petica, S. & Bluet J.C., (1989). Rapport sur I'enquete internationale concernant le radiotelephone et la securite routiere, Rapport INRETS, DOC -126224

Peterson, C. (1995). Choosing the best cellular telephone. *Automobile*, July, p. 29.

Redelmeier, D.A. & Tibshirani, R.J. (1997). Assocaition between cellular telephones calls and motor vehicle collisions. *The New England Journal of Medicine*, Vol. 336 (2), pp. 453-458.

Serafin, C., Wen, C., Paelke, G., & Green, P. (1993). Car phone usability: a human factors laboratory test. Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, pp. 220-224.

Serafin, C., Wen, C., Paelke, G., & Green, P. (1993). Development and human factors tests of car phones. Technical Report 93-17. University of Michigan Transportation Research Institute.

Smiley, A. (1995). "Overview and methodologies of the ITS safety evaluation process." Paper presented at the ITS America/NHTSA Workshop on ITS Safety Evaluations, Reston, VA, May 1-2, 1995.

Smith, D. B., Meshkati, N., & Robertson, M. M. (1993). The older driver and passenger. In B. Peacock and W. Karwowski (Eds.), *Automotive Ergonomics*, pp. 453-472. London: Taylor and Francis.

Spelke, E., Hirst, W., & Neisser, U. (1976). Skills of divided attention. *Cognition*, Vol. 4, pp. 215-230.

Stein, A. C., Parseghian, Z., & Allen, R. W. (1987). A simulator study of the safety implications of cellular mobile phone use. Hawthorne, CA: Systems Technology, Inc. Paper No. 405 (March). Hawthorne, CA: Systems Technology Inc. (See also 31 st Annual Proceedings, American Association for Automotive Medicine, New Orleans, LA, September 1987.)

Sussman, E.D., Bishop, H., Hadnick, B., & Walter, R. (1985). Driver inattention and highway safety. *Transportation Research Record:* pp. 40-48.

Tijerina, L., Kiger, S. M., Rockwell, T. H., & Wierwille, W. W. (1995). Final report supplement -- task 5: Heavy vehicle driver workload assessment protocol (Contract No. DTNH22-91-C-07003). DOT HS 808 467 (5), Washington, DC: U.S. Department of Transportation, NHTSA.

Tijerina, L, Kiger, S., Rockwell, T. H., & Tornow, C. E. (1995a). Final report - Workload assessment of in-cab text message system and cellular phone use by heavy vehicle drivers on the road. (Contract No. DTNH22-91-07003). DOT HS 808 467 (7A), Washington, DC: U.S. Department of Transportation, NHTSA.

Tijerina, L., Kiger, S. M., Rockwell, T. H., & Tornow, C. (1995b). Workload assessment of in-cab text message system and cellular phone use by heavy vehicle drivers on the road. *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting*, pp. 1117 - 1121.

Treat, J.R., Tumbas, N.S., McDonald, S.T., Shinar, D., Hume, R.D., Mayer, R.E., Stansifer, R.L., & Castellan, N.J. (1979). Tri-level study of the causes of traffic accidents: executive summary. (Contract No. DOT HS 034-3-535). DOT HS 805 099. Washington, DC: U.S. Department of Transportation, NHTSA.

Violanti, J. M., (June, 1997) Cellular phones and traffic accident characteristics, Abstracted in *American Journal of Epidemiology*, Vol. 145 (1 1), Abstract No. 230, p.S58.

Violanti, J. M., & Marshall, J.R. (1996). Cellular phones and traffic accidents: an epidemiological approach. *Accident Analysis and Prevention*, Vol. 28, pp. 265-270.

Wang, J., Knipling, R. R. & Goodman, M. J. (1996). The role of driver inattention in crashes; new statistics from the I995 crashworthiness data system (CDS). *40th Annual Proceedings: Association for the Advancement of Automotive Medicine*, pp. 377-392.

Weimer, J. (1995). Developing a research project. In J. Weimer (Ed.), *Research Techniques in Human Engineering* (pp. 20 - 48). Englewood Cliffs, NJ: Prentice-Hall.

Wickens, C. D. (1987). Information processing, decision-making, and cognition. In G. Salvendy (Ed.), *Handbook of Human Factors* (pp. 72-107). New York: John Wiley & Sons.

Wierwille, W., W., & Tijerina, L. (in press). An analysis of driving accident narratives as a means of determining problems caused by in-vehicle visual allocation and visual workload. To appear in A. G. Gale et al. (Eds.), *Vision in Vehicles* V. Amsterdam: North-Holland.

Wierwille, W. W. & Tijerina, L. (1995). An analysis of driving accident narratives as a means of determining problems caused by in-vehicle visual allocation and visual workload. Paper presented at the Fifth International Conference on Vision in Vehicles, Glasgow, Scotland, September, 1993. (Conference proceedings, North Holland-Elsevier Press, Amsterdam, 1996.)

Zwahlen, H. T., Adams, Jr. C. C., & Schwartz, P. J. (1988). Safety aspects of cellular telephones in automobiles (Paper No. 88058). Proceedings of the ISATA Conference, Florence, Italy.

Appendix F

Human Factors (Ergonomic) Considerations

The following taxonomy was developed on the basis of materials, data and information collected for this study. It reflects a very diverse and comprehensive review of available wireless communications technologies and associated equipment (e.g., third party mounting hardware, hands-free conversion, etc.), how it is used, and how specific design features and implementation strategies might be related to the potential for distraction and hence crash risk. Many issues are as yet unresolved but, as a general rule, the greater the number of features requiring user manipulation/observation, the longer the duration of manipulation/observation required, and the more difficult a device is to manipulate (e.g., hold securely, one hand vs. two hands vs. no hands), the greater the risks associated with its use in a moving vehicle.

The consideration and application of good human factors practice in the design of in-vehicle communications systems are seen as having a significant potential for reducing the risk of a crash while using these systems. In addition, an understanding of the relevance of these features to safety within the general public may also provide an industry incentive to design the "best" possible systems, since it can serve as a basis for purchasing preferences. In this regard it is recommended that industry generated human factors design guidelines be developed to provide informed guidance to equipment manufacturers on developing ergonomically sound systems.

Driver Tasks Associated with Cellular Phone Use While the Vehicle is in Motion:

Cellular telephone use while driving can be characterized by the tasks that make up such use. While phones with more advanced features (e.g., hands-free) may modify the nature of, or eliminate some of these tasks entirely, the majority of users currently own portable phones and at one time or another are faced with the following tasks:

- Handset Pickup and Storage (answering a call, placing a call, hanging up after a call)
- Dialing (including recall of a stored number)
- Voice Communications (usually dialogue, listening, and talking)
- Associated Tasks (e.g., taking notes, referring to a calendar, reading a map).

The first may be considered trivial, especially if the location of the handset is well learned or the unit is of the hands-free variety. It is not trivial in the case of a hand-held phone that is out of reach. The dialing and voice communications tasks, on the other hand, are not trivial. These have been the focus of most of the published research in this area. As suggested in the body of this report, the communications aspect of phone use may play the dominant role in crashes, at least in the United States.

In Japan, where usage patterns may be different, research findings indicated that responding to a call is the dominant factor (see Chapter 3). With regard to associated tasks, less is known. Anecdotal information and common sense suggest that such activities are particularly risky since they would likely require the use of two hands and provide considerable opportunity for inattention to the driving task. Nevertheless, observations of drivers taking notes or checking maps while using their phones confirms the willingness of some to take these risks.

Regardless of the task being considered, it is clear that the application of good human factors design principles can reduce the adverse influence these tasks might have on a person' s ability to drive safely. The following discussion of cellular telephone "features" highlights a number of areas where such considerations can provide significant safety benefits. [1]

General Features

-*Hand-held* vs. *Hands-free* : Hands-free systems have the obvious benefit of allowing conversation while the driver has both hands on the wheel. Variations in the actions required of users of these systems (i.e., voice answer, one button press, etc.), however, suggest that the best implementation strategies for these systems are yet to be determined.

Road noise may serve to mask the communications with hands-free systems. Thus, there may be a need to enhance the ability of the driver to hear the conversation through the use of an earphone (single). Such use is illegal in most states and may itself have distraction potential if the earphone has the potential to fall or if the earphone cord is cumbersome. Cordless earphones might solve the latter problem.

-*Voice activated vs. Non-voice features:* These features are primarily related to hands-free operation and define the extent to which the user must interact with the system. A completely hands-free system requires no manipulation on the part of the driver, while less capable systems may require one or more buttons to be manipulated. Voice activated control of the volume may also be an alternative solution. Voice-activated control should reduce or even eliminate the demands of manipulation on the driver. It may nonetheless impose high cognitive demands (e.g., listening to a spoken menu of options) or induce unintended driver behaviors (e.g., taking eyes off the road scene to look at the device while speaking commands).

-*Mounting kit/base vs. no mounting kit/base:* Any implementation that minimizes the need to hold or "pocket" the phone, whether in-use or parked in a cradle is preferable since it reduces handling related distractions. Nevertheless, placement of the mounting bracket from the standpoint of convenience and length of receiver cord is also critical to ensure normal driving posture can be maintained. In addition, crashworthiness considerations must also be addressed. Future vehicles will likely move towards a uniform cellular telephone/PCS bus interface in vehicles that will allow "plug and play" hands free capabilities, perhaps integrated with ITS technology.

-*Cord vs. Non-cord:* As a general rule hand-held phones are typically operated in vehicles without being connected to the vehicle itself, although users have the option of connecting an external antenna, operating off vehicle power, or using a "cradle" which may provide these capabilities

1 Many of the human factors issues discussed in this appendix are equally relevant to a number of ITS technologies (e.g., in-vehicle information systems) currently being developed, and studies are either ongoing or planned which address many of the same considerations. Information generated by these efforts could provide useful data to support the development of human factors design guidelines for wireless communications systems.

along with hands-free operation. To the extent that cords are used, they should be of sufficient length and be placed so as not to interfere with the task of driving. For "car phones" permanently installed in a vehicle, the accessibility of the handset and length of the cord are of primary concern. Because of short cords, drivers have been observed holding a handset in conversation while leaning over and crouched at the height of the dashboard.

-*Antenna Configuration: (i.e., retractable vs. 'pop-up" antenna vs. "antenna on case" vs. non-retractable ["stubby"] antenna vs. vehicle-mounted external antenna)* As with other features requiring user manipulation, the need to manually extend an antenna on making or receiving a call is potentially distracting and may influence controllability of the vehicle, particularly when the effort requires two hands. Use of an external antenna or units with "pop-up" antenna will minimize distraction in this regard.

-*Flip-phone vs. non-flip Phone:* In recent years flip-phones have become very popular and have allowed the overall size (collapsed) of the phone to be reduced while maintaining display and keypad size. While such features facilitate storage and usability, they do require the added task of opening or "flipping" the phone for use, a task that typically requires two hands. Here again, the additional distraction and the increased manual demand have the potential to increase risk.

-*Various Logics for speed- or auto-dial (e.g., <RCL> <4><SEND> vs. <RCL> scroll down to Option 4 in stored Phone Directory, then <SEND>): As* illustrated by the examples, keypad strategies for "speed-dial" or "auto-dial" options can vary considerably. Efforts to simplify this task to minimize time required are worthwhile to the extent that they reduce both the time on task and opportunity for error.

-*Power (watts) of unit affecting ability to maintain communications and avoid dropouts:* Variations in "cell" locations, physical obstructions, and cellular telephone transmitting power capabilities can result is signal drop out, an event more frequently encountered with hand-held phones since they are generally of lower power, have a built-in antenna and are used within the metal shell of the vehicle. Observations indicate that some drivers attempt to compensate for intermittent signals by adjusting position of the hand-held phone, shifting the unit from one hand to the other or even holding the unit partially outside the vehicle window.

All of these behaviors have the potential to divert attention from the driving task and possibly interfere with control of the vehicle, particularly under emergency conditions. This problem may best be managed by the use of vehicle mounted antennas, where the process of connecting to the antenna is convenient and non-interfering. Alternate strategies of lower power hand-held units with on-board "repeaters" may also solve the problem with no hard connection to an external antenna.

-*Stowing of cell phone: (e.g., search in pocket, vs. cradle vs. loose on car seat):* The results of the Japanese study highlight the potential consequences of responding to calls while driving. Although driver actions/responses associated with the crashes cited varied, the findings are consistent with crash data in the United States. Clearly, reaching or searching for the phone can be very distracting, particularly when reaching results in movement of the steering wheel in combination with reduced attention to the driving task. This suggests significant benefits of having a convenient cradle available for holding, as well as using the phone.

— *"Hold-ability" (Based on size, texture, curvature, etc.):* Crash data also indicates that incidents can occur when a driver drops a cellular telephone. Dropping a cellular telephone usually results in a natural response to retrieve the unit, an activity that may clearly put the driver at risk. Ergonomic design consideration here can play a significant role in mitigating the potential for such an event.

Visual Display Features

The visual display features outlined below all interact to define visual and cognitive demands on the driver and serve to determine the readability of the display and the degree of attention required to obtain the displayed information. These design features in particular are in need of human factors consideration insofar as multifunction displays may require considerable attention to displayed information. It is important to optimize both the display and the presentation of information to minimize demands on the driver. Human factors research is clearly needed to establish optimal design trade-offs for a given device architecture.

-Large screen-area display vs. small screen-area display: Trends toward miniaturization have the potential to shrink the size of screens and hence reduce their readability. Careful attention to text characteristics (e.g., font, color, size), presentation style (e.g., lower case vs. caps) and format (e.g., number of lines, line length) can be particularly beneficial for small screen displays.

-Luminous display (e.g., LED) vs. backlit display (e.g., LCD): Considerable variation in ambient light conditions in vehicles, particularly bright sunlight, can significantly impair the ability of a driver to read a cellular telephone display. Since difficulty in reading a display may precipitate behavior (e.g., changing phone orientation, extended periods of inattention) which is contrary to safe driving, optimizing the readability of the display from this standpoint is also of great importance.

-1 -line vs. Multi-line displays: As wireless services increase, there is likely to be an evolution of cellular telephone display formats that incorporate more than one line of text. Multi-line presentations may result in longer glance times and more glances per transaction, potential concerns from the standpoint of attention. In addition, text characteristics, presentation style and display format all must be considered together to ensure that readability of the information is not compromised to achieve a more comprehensive presentation of information. As a possible solution, this suggests that cellular telephones have two modes of operation, one for stationary use and one for road use, designed specifically to limit the need for extensive driver attention or manipulation.

- Text font, style and presentation: As suggested earlier, font selection and case (e.g., all upper case vs. mixed upper and lower case) can both influence display readability. Similarly, presentation of the information in terms of the manner in which consecutive lines are displayed (e.g., scrolling vs. paging) can also influence readability as well as the need for user refresh.

Keypad Features

-Keypad button size and spacing: As cellular telephones get smaller the size of keypad buttons and/or their spacing is likely to be reduced. Attention to this feature is important so as to minimize eyes-off-road time while keying, to avoid the need for reentry of information, and to reduce the need to frequently verify entries where errors are perceived to be likely.

-High clutter vs. low clutter on keypads (more vs. fewer keys): Here again, as wireless devices get more sophisticated and offer more capabilities it is likely that keypads will get more cluttered, a situation that can lead to increased difficulty in accurately making key selections while driving.

Multifunction keypads are not necessarily a straightforward solution since some keying logics may place high demands on the driver.

-*Stimulus-response compatibility (e.g., up-down arrow keys arranged side-by-side are not S-R compatible; up and down arrow keys arranged one above the other are S-R compatible):* Layout and function of keys should be logical and follow user expectations to ensure that errors are kept to a minimum.

-*Keying feedback absent or present (e.g., some cellular telephones provide auditory feedback in the form. of a beep upon button depression, some have the buttons designed to provide an audible "click", and some have buttons designed to provide tactile feedback):* Regardless of the approach used, some positive feedback is necessary on key presses to reduce the need for input verification.

Auditory Display Features

-*Clarity of receiving (and sending):* Based on the quality of the audio features of the unit, the intelligibility of the communications can have significant implications for the cognitive loading of the driver. Poor audio quality is likely to require very focused attention on the part of the driver. Unfortunately, audio quality is a consequence of the combination of units communicating and therefore is not wholly under the control of the mobile user. Nevertheless, clarity of speech is an important consideration.

-*Startle potential of incoming call announcement (e.g., various types of "ring," voice announcement; "vibration" feature in flip-phones):* The startle created by a ringing cellular telephone has been identified as a possible problem by some drivers. This potential suggests that the manner in which drivers are notified of an incoming call should be examined carefully. In particular, special in-vehicle alerts should be investigated which are less likely to startle a driver. Use of vibration, a gradual increase in ring volume, or use of voice alerts may be appropriate alternatives.

-*Key press feedback (informational):* While the need for keypad feedback has been addressed above, such feedback offers the opportunity to provide the user with distinguishing information as to the keys pressed through the use of codes (e.g., number of beeps) or differentiating tones. Such feedback may reduce the need for verification of keypad entries.

Associated Tasks

In the course of a call, particularly a business call, a driver may find it necessary to carry out associated tasks. These tasks might include, for example, taking notes, retrieving information from a calendar or notebook, or scanning a map. Such behavior has obvious risks associated with it. For those drivers who link their computers or faxes to their cellular telephones, the risks are equally obvious. It is not clear what technology can do in this arena short of enhancing the driver interfaces, supporting communications with ITS technologies, and perhaps building into cellular telephones a voice recording/data recording capability for later access.

Other Considerations: Content, Environment and Human Variability

Along with the design considerations discussed above, there are a number of other factors that may interact with design so as to facilitate or impair the users' ability to operate wireless systems safely. The content or nature of communications has already been mentioned as having potential for "capturing" a driver's attention and influencing situational awareness. Other factors or interest include traffic, roadway, weather (visibility), ambient light (day/night) presence of passengers/ children in the vehicle, noise, etc., all of which can influence the workload imposed on the driver and provide additional opportunities for distraction. Predicting the influence of these environmental factors is further compounded by individual differences in ability to timeshare between the task of driving and other secondary tasks such as speaking on a cellular telephone.

Individual differences associated with circadian rhythm (i.e., effects of time of day on attention) also can play a role in one's ability to drive and use a wireless system. These issues highlight the importance of individual responsibility in selecting a "safe" wireless system and using it responsibly within their capabilities and under appropriate circumstances.

Summary

The discussion above highlights the potential importance of human factors design considerations to the safety of using wireless communications systems in moving vehicles. New light weight digital wireless systems on the immediate horizon, capable of a variety of data services, voice memo capabilities, built in phone directories capable of holding as many as 250 entries, and using color active matrix multi-line displays, have the potential to place significant demands on users. While the responsibility for safely using these systems in a moving vehicle lies with the driver, careful attention to their design by manufacturers along with careful selection of the devices and their implementation by the user will help reduce the risk of a crash.

Nonetheless, it must be emphasized that while attention to these design issues can enhance the safe use of a given wireless system, to the extent that such considerations (by facilitating usability) increase the use of the systems (e.g., frequency or duration of calls), there is a potential for a net increase in crashes due to increased use and, hence, increased exposure. It is the uncertainty of how this will play out in the future with more demanding technologies and societal pressures, that highlights the need for more accurate data collection and a greater emphasis on human factors research.