CELL PHONE USE WHILE DRIVING:
A LITERATURE REVIEW AND RECOMMENDATIONS

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December 11, 2008

Abstract

This review on behavioral, experimental, and real-world studies shows a strong relationship between cell phone use while driving and a deterioration in driving performance leading to an increased risk of collision. Although the problem of talking while driving has attracted the attention of governments at all levels, the legislative attempts to curb cell phone use by drivers have been less than successful. While automotive manufacturers develop more active safety features to avoid car accidents and minimize the harmful effects of accidents, it is equally important to develop cost-effective technological solutions that can accurately identify the driving mode of cell phone users and help stop or reduce the use of cell phones by drivers. Safety-based insurance policies, built on an integrated driving monitoring system, are also critically needed to encourage safe driving behaviors, especially for already challenged young drivers. In order to perform a better economic analysis of restricting cell phone use while driving, it is highly desirable to have accurate reporting of cell phone involvement in collisions on police reports.

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1. Introduction

Cellular telephones (cell phones) were first introduced in the United States in the mid-1980s, and their use has since experienced explosive growth. Today there are more than 262 million cell phone subscribers, representing 84 percent of the United States population. Cell phone technology has become very useful for people on the move, which is demonstrated by surveys that show that the majority of users reported using their phones while driving.

Cell phone use by drivers, although difficult to quantify, has been estimated through observational data by the federal government at six percent of drivers in 2007 (IIHS, 2006). This rate means that at any moment during the day, one million passenger vehicles in the United State are being driven by people on hand-held cell phones. Further analysis of these statistics show that women are more likely to be on their phones while driving; eight percent of women use cell phones while driving compared to five percent of their male counterparts. Also of importance, this data found that young drivers (16-24 years old) were most likely to be on their cell phones at 10 percent compared to six percent of those aged 25-69 and one percent of drivers 70 and older (see Figure 1).

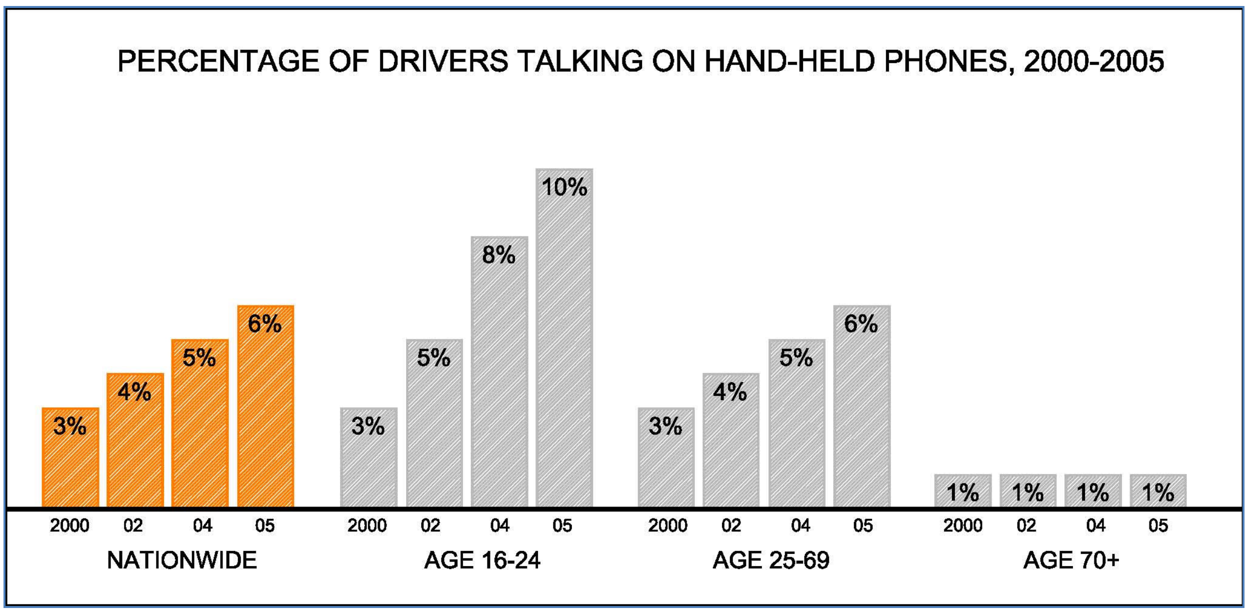

Figure 1 Percentage of Drivers Talking on Hand-Held Phones 2000-2005 (IIHS, 2006).

Public perception of the dangers of cell phone use while driving seems to coincide with common sense and experience, but common practice does not. In a survey done by Nationwide Insurance (IIHS, 2008), four out of five surveyed cell phone owners admitted to driving while distracted. Even though almost half of the surveyed people consider cell phone use to be the most dangerous distraction, 98 percent of the drivers consider themselves to be safe drivers. An interesting result of the survey was that almost two-thirds of cell phone owners say they were expected by family, friends or employers to always be reachable by phone or other communication device. Among young drivers in this survey, 40 percent said they send or read text messages along with other activities while driving in order to “remain connected” (IIHS, 2008).

Another survey of only teenage drivers conducted by State Farm Insurance, found that only 25 percent viewed cell phone use while driving as dangerous. Almost 80 percent, however, recognized that texting on cell phones while driving was risky (IIHS, 2008). The rate at which young drivers are most likely to be using cell phones while driving, along with their attitude towards the perceived risk of using such devices, is concerning because this group is already at the highest risk for collisions even without these distractions.

A survey conducted by AAA and Seventeen magazine found that 46 percent of drivers 16 and 17 years old said that they text message while driving. This is a profound statistic because 37 percent of the same teenagers said that they believed that text messaging was the most dangerous driver distraction (Quain, 2007).

2. Quantifying Cell Phone Usage and Crash Risk

Drivers' attentiveness has been a concern since the invention of the automobile. As technology increases, the number of driver distractions increases. Each year, more than 42,000 people are killed, more than 3 million are injured, and more than 6 million collisions occur on roads in the United States (IIHS, 2006). Estimates have attributed between 30-50 percent of collisions to distracted drivers, resulting in huge amount of societal cost (Cohen, 2003). Although common sense and experience tells us that using cell phones while driving is dangerous, a number of studies are devoted to quantifying the exact risk associated with using a cell phone while driving. Since the mid-1990s, around 120 studies have attempted to validate a common conception: using a cell phone while driving is a distraction and therefore increases crash risk (IIHS, 2008). The literature on this subject investigates various relationships between cell phone use and accident risk. These studies can be separated into three general groups: epidemiological studies, experimental studies, and real-world studies. Epidemiological studies examine real-world accident data and cell phone records to draw conclusions based on the relationship between the two. Behavioral and experimental studies attempt to measure some cognitive effect of cell phone use on normal driving functions such as visual attention, following distance, reaction time, and other driving tasks. Real-world studies attempt to show how real-world situations either justify or disprove the other data.

Before discussing selected studies, a summary of the general conclusions from each type of study is presented below:

(a) Epidemiological Studies: Studies that analyze the relationship between cell phone use and increased crash risk using case studies where people have been in actual accident. Researchers have concluded that the use of cell phones while driving significantly increases the risk of collision (Ontario Medical Association, 2008).

(b) Experimental and Behavioral Studies: These studies have been able to demonstrate that having a conversation on a cell phone is cognitively distracting and causes deterioration in driving performance. These studies also confirm the finding of the epidemiological studies that when driving performance is affected negatively, an increased crash risk is observed (Ontario Medical Association, 2008).

(c) Real-World Studies: These studies are observations of test subjects that are monitored while in the field. Conclusions are drawn based on the observed data and are a reflection of actual events. The real-world studies have proven that the single most dangerous driver distraction is cell phone use.

2.1 Epidemiological Studies

Epidemiological studies have attempted to measure the association of cell phone use with the risk of collision. They examine accident data and cell phone records to obtain a correlation, resulting in a relationship between cell phone use and accident risk. The following review focuses on three epidemiological studies that indicate cell phone use is associated with an increase risk of collision.

2.1.1 Cellular Phones and Traffic Accidents, 1996

In an early study in 1996, Violanti and Marshall used a case-controlled design study where they selected 100 random drivers that had been involved in crashes in the previous two years and compared them against another group of 100 randomly selected drivers who had not been involved in crashes in the previous 10 years. The study concluded that using a cell phone for 50 minutes per month resulted in a collision risk 5.59 times greater than not using a cell phone at all. In this study, the risk ratio is statistically significant, but the confidence limits were large. The obvious limitations of this study are: (1) small number of cell phone users in the sample; (2) selection bias; and (3) lack of evidence that the cell phone users were using their phones at the time of the collision.

2.1.2 Association between Cellular Telephone Calls and Motor Vehicle Collisions, 1997

Redelmeier and Tibshirani (1997) conducted the most quoted epidemiological study of cell phone use and increased crash risk in 1997. This research was a case cross-over design, where each subject served as his/her own control. The study included 699 drivers who had been involved in a collision and who owned cell phones. The authors used five-minute intervals of time before the time of the collision, and compared those against the same time on the previous day. The authors were able to conclude that the risk of collision was approximately four times higher than when the same subjects were not using their cell phones. The only significant limitation to this study is that collision times are estimated. There exists the possibility that cell phone use was a post-collision call instead of a pre-collision call. The authors made a conscious effort to eliminate calls that were precipitated by the collision by identifying 9-1-1 calls and through thorough questioning of the drivers.

2.1.3 Wireless Telephones and the Risk of Road Accidents, 2001

Laberge and Nadeau conducted an epidemiological study in Quebec in 2001. This study was based on a self-reported questionnaire from a sample of 36,079 participants, of which 35 percent had records with cellular telephone providers. Taking into account only age and year of observation, cell phone users had a 38 percent higher risk of collisions than non-users. Including additional constraints, such as miles driven and driving habits increased the relative risk by 11 percent for males and 21 percent for females. The authors also applied the case cross-over design used by Redelmeier and Tibshirani to their data. This method produced a relative risk of being in a crash while using a cell phone at 5.13 times that of a non-user. However, the authors concluded that this case cross-over design over-estimates the risk, and determined that a more realistic risk of collision is around 1.3-1.4 times that of a non-user.

2.2 Experimental and Behavioral Studies

The majority of the literature reports on experimental and behavior studies examine the impact of cell phone use on the cognitive functions necessary for driving. Many of the experimental studies have correlated how cell phone use, including hands-free devices, while driving interferes with or degrades various aspects of driving. Because of the quantity of experimental and behavioral studies, only representative research is reviewed in the following four categories: (1) Field-of-View Studies; (2) Brain Research Studies; (3) Simulator Studies; and (4) Benchmark Impairment Studies.

2.2.1 Field of View Studies

In 2003, Strayer's reseach group at the University of Utah found that drivers who use cell phones are less able to process visual information. Based on the observations of participants in a simulator, the study was able to conclude that drivers conversing on cell phones increase their risk of collisions. The researchers attributed the increase in collision risk to a theory called "Inattention Blindness". Inattention Blindness is summarized to be, "Even when participants [drivers] are directing their gaze at objects in the driving environment, they may fail to 'see' them because attention is directed elsewhere." The study also found that the use of hands-free and hand-held cell phones equally impair the driver's ability to see objects. The study found that "the disruptive effects of cell phone conversations on driving are due in a large part to the diversion of attention from driving to the phone conversation." This diversion of attention also affects the driver's ability to react to sudden event placing pedestrians and others at increased risk for injury (Strayer, 2003).

In 2005, researchers from the Japanese Automobile Research Institute further examined the findings from the University of Utah report. The authors of this report agreed with the conclusions of the earlier report, but felt that a more direct assessment of the visual attention needed to be done to identify the exact amount of diversion from what the driver is looking at to the cell phone conversation. The authors conducted experiments with drivers on a simulator using the medically known physiological response "Binocular Fusion". The results of this study show that, "engaging in hands-free phone conversation interferes with visual information processing. The increment of binocular gaze dissociation by conversing on a phone indicates that the driver's attention is diverted from the external scenery to the conversation." The purpose of the report was not necessarily to prove that speaking on a cell phone increases crash risk, but this relationship is inferred by the authors (Uchida, 2005).

Figure 2 is extracted from Wood's field-of-view study in 2006 that obtained similar results as the studies mentioned above. It demonstrates the number of errors drivers made while listening and responding to questions went up dramatically when compared against no distractions.

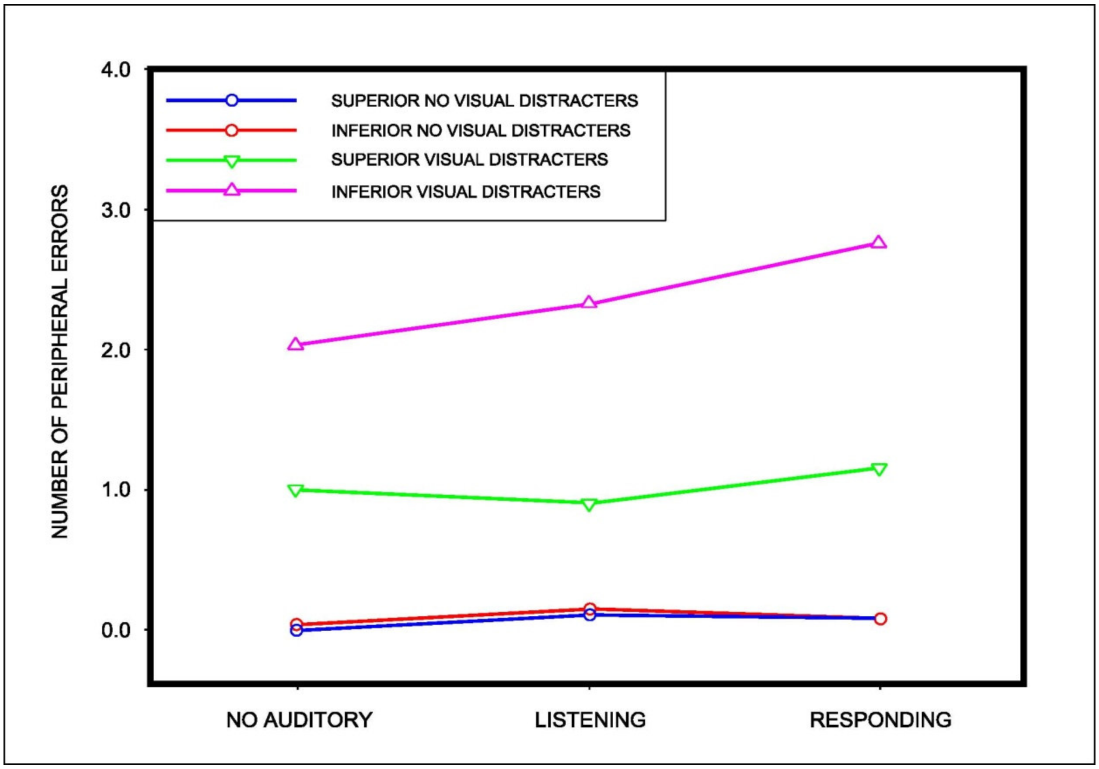

Figure 2 Number of Errors for Various Distraction Situations (Source: Wood, 2006)

2.2.2 Brain Research Studies

A 2005 Study by GM Corp., Wayne State University Medical School, and Henry Ford Hospital set a foundation for understanding how cell phone use by a driver influences the brain function. This study used Functional Magnetic Resonance Imaging (ƒMRI) and Magnetoencephalography (MEG) to locate essential brain activated structures and their corresponding dynamics. As discussed above, field-of-view studies generally depend on behavior observations to determine if the mind is focused on the road and thus fail to completely reflect what the brain may actually be doing. The authors suggest that there are situations where behavioral indicators will show that the mind is on the road, but in reality, it is not. With this understanding, the authors set out to uncover the exact neural mechanisms that are associated with distracted behaviors while driving. Putting participants in a simulator and monitoring their brain function, the authors were able to identify the major brain pathways involved in driving and distracted driving. This study set a foundation for determining and measuring how the brain reacts to distracted driving (Young, 2005).

In 2007, researchers at Carnegie Mellon University conducted a study furthering the previous study by using Functional Magnetic Resonance Imaging (ƒMRI) to investigate the impact of concurrent auditory language comprehension on the brain activity when simultaneously exposed to a simulated driving experience. Participants operated a driving simulator, either undisturbed or while listening to statements they had to identify as true or false. This auditory language comprehension was designed to mimic talking on a cell phone. The participant's brain activity was monitored during the simulations and was compared against the ƒMRI scans of the undisturbed driver's brain. The authors found that when participants experienced the dual-task condition, mental resources were taken away from areas of the brain that deal with driving tasks (see Figure 3). This occurred even though the areas of the brain that deal with driving tasks and auditory comprehension are different. The authors were able to make two conclusion based on their experimental data: (1) mental resources are diverted from driving tasks to auditory comprehension regardless of other physical tasks; and (2) the deterioration of driving performance occurs because of a competition of mental resources in the brain between driving tasks and auditory comprehension (Just, 2008).

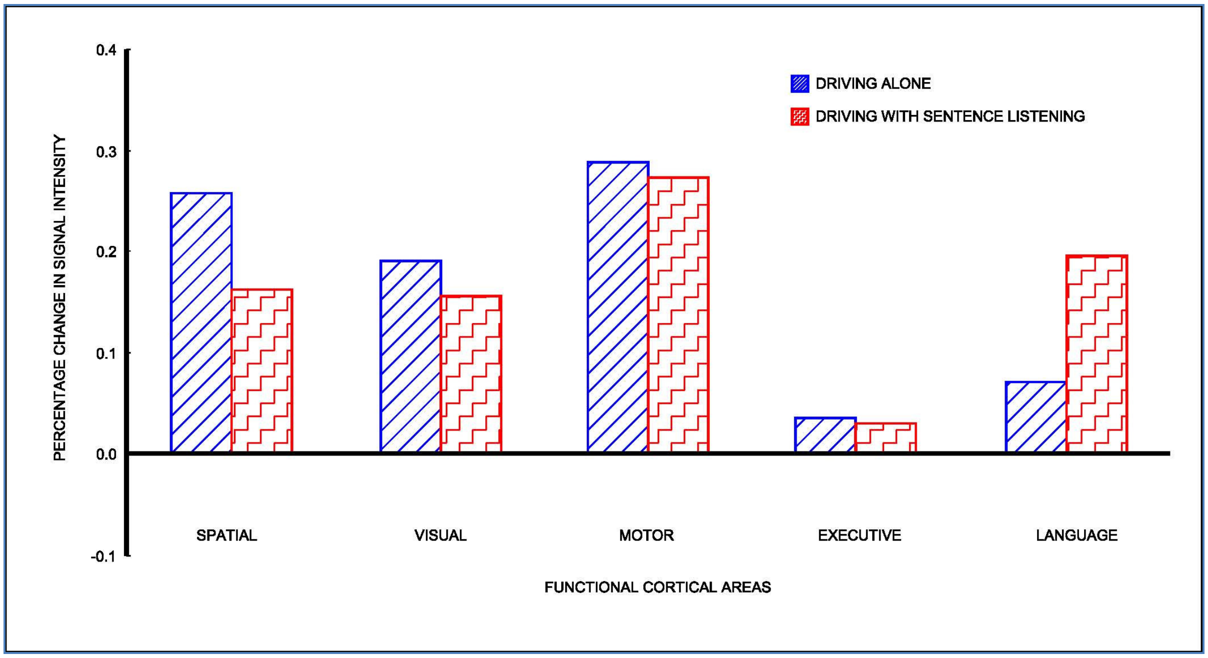

Figure 3 Percentage Change in Signal Intensity for Five Functional Groupings of Cortical Areas (Source: Just, 2008) Spatial processing areas significantly decrease with the addition of the sentence listening task.

2.2.3 Simulator Studies

In 2001, Strayer's research group at the University of Utah submitted test subjects to different levels of distractions while driving in a simulator. The researchers were able to conclude that cellular phone conversations while driving caused the subjects to react slower to stimuli and perform tasks with considerably reduced precision. Specifically, while engaged in cell phone conversations the subjects were twice as likely to miss simulated traffic signals compared to when they were not distracted. These results were also qualified by showing that talking on a cell phone was more dangerous than when the driver was subjected to common in-vehicle distractions, such as the radio and books-on-tape. The researchers also wanted to determine if the reason the subjects missed the traffic signals was because they did not see them or because they were slow to respond to them. To determine this, the researchers examined the memory of the subjects after normal driving as well as distracted driving. The results indicated clear memory impairment after having been engaged in cell phone conversations. The researchers were able to conclude that active participation in a cell phone conversation while driving disrupted driving performance by diverting attention from driving tasks to a cognitive process.

In a 2002 observational study by the Insurance Corporation of British Columbia, researchers used a complex method of identifying specific cell phone users and non-users through in-field observations, and linking these people with their driving records. This method presents some obvious limitations or uncertainty about the user classification; however, the results corresponded well with other identifying methods. The driving records of the cell phone users had higher counts of moving violation citations over the previous four years, to include speeding, alcohol, failure to use seat belts, aggressive driving violations, and non-moving violations. Although the correlation between these violations and use of a cell phone is not scientifically proven by this study, it does likely reflect a difference in lifestyle, attitude and personality of the typical cell phone users; indicating they are inherently riskier drivers (Wilson, 2003).

These simulator studies are consistent with a self-report survey conducted by the Traffic Injury Research Foundation. The authors of this report determined that people who use cell phones while driving were more likely to have received a traffic ticket in the last year, drive after drinking, and to consume greater quantities of alcohol when they drink. Again, these behavioral indicators cannot necessarily be directly linked to cell phone use; rather, they suggest a personality type who frequently uses a cell phone while driving (Beirness, 2002).

2.2.4 Benchmark Impairment Studies

Innumerable studies have been able to prove the correlation between cell phone use while driving and an increased risk of crashing when compared to normal driving. What these studies have failed to do is show a comparison to known impairment levels. There have been at least three studies that compare the cell phone driver to a drunk driver at the per-se blood-alcohol concentration limit of 0.08 wt/vol. This blood alcohol concentration has been thoroughly studied and quantified as the limit at which the average driver will become incapable of safely operating a motor vehicle. Comparing the cell phone driver to a benchmark of this caliber becomes a solid comparison and explanation to how dangerous driving while on a cell phone really is.

In a 2002 study by Burns et al., the authors designed a study to compare the impairment from hands-free and hand-held phone conversations to the decline in driving performance caused by alcohol impairment. Participants were given either an alcoholic beverage or a placebo drink and placed in front of a driving simulator that represented realistic driving tasks. The quantity of alcohol was determined from the participant's age and body mass, and was closely correlated with the legal limit of .08 mg/ml blood alcohol concentration. The results of this experiment showed a clear substantial decrease in driving performance when using a hand-held phone, in comparison to the sober condition. Driving performance under the influence of alcohol was significantly worse than normal driving, but better than driving while using a phone, leading to a conclusion that driving while talking on a phone is more impairing then driving at the legal limit of alcohol.

Strayer's research group at the University of Utah published research comparing the cell phone driver and the drunk driver in 2003, and a revised report in 2006. The purpose of their research was to provide a direct comparison of the driving performance of a cell phone driver and an alcohol impaired driver in a controlled laboratory setting. These researchers used participants who were casual drinkers and compared their own sober driving, cell phone driving, and alcohol-impaired driving to themselves. This method of control seems to be more accurate than the previous studies' process of comparing the same situations in different subjects. The researchers were able to conclude that both the intoxicated driver and the cell phone drivers' driving profiles were different from the sober base-line. Cell phone drivers exhibited a delay in their response to events, had longer following distances, took longer to recover lost speed following braking, and were involved in more traffic accidents. Drivers in the intoxicated condition exhibited a more aggressive driving profile by following closer to the vehicle in front of them and braking harder. The researchers suggest the data indicates impairment or risk from cell phone use is as great as that of the intoxicated driver, but in different ways. The authors also noted that driving impairments associated with hands-free devices and hand-held devices were not significantly different, indicating that the impairment comes from a diversion of attention from the processing of normal driving tasks.

2.3 Real-World Studies

Several real-world studies have been conducted and are being conducted to further validate the epidemiological and experimental studies. Our review indicates that the majority of these studies are funded in part by insurance companies or makers of driving performance enhancers.

The most commonly cited real-world study involved 100 cars and 42,000 hours of driving time monitored by in-vehicle cameras and sensors over a one-year period. The study was conducted by the Virginia Tech Transportation Institute in 2006, and concluded that, "secondary task distractions" were the prime factor in collisions. The single biggest distraction leading to collisions was cell phone conversations, dialing, and sending text messages. The Virginia Tech Transportation Institute is conducting another study that involves 2500 drivers and will last three years (Bunkley).

We have been able to identify several other current real-world studies that are underway. The studies are funded primarily by insurance companies, and we have been unable to obtain any information about them due to proprietary reasons (Olson, 2007; Robinson, 2008).

2.4 Police Accident Reports

Since the studies prove the hypothesis that cell phone use while driving increases crash risk, quantitative analysis of crash causation data should reflect this. This, however, is not the case. The reasons that the real-world data does not match the experimental and epidemiological conclusions are due primarily to two factors. First, three states in 2001 and six states in 2002 provided a specific space on their uniform crash reports to indicate that the use of a cell phone had been involved in the collision. In addition, even with a space available on a police report to record cell phone involvement, the box may or may not be marked. The investigating officer has multiple responsibilities at an accident scene, including tending to injured, restoring traffic flow, completing the investigation, and issuing citations for criminal violations. Officer discretion plays a part in the completion of police reports; even if evidence of cell phone use is present, the officer may or may not indicate that cell phone use was a factor in the collision. A NHTSA study of North Carolina supports this analysis. The study concluded that the underreporting of crashes that are a result of inattention due to cell phone use is substantial. The portion of crashes that were reported to be due to inattention because of cell phone use was 1.5 percent which is significantly below the estimated value obtained in more comprehensive studies of 30-50 percent (Cohen, 2003).

Second, even if the collection of this data is a requirement for every state, it would likely still be inaccurate because of the public's reluctance to report cell phone use to police. Because the risks of using cell phones while driving are becoming commonly known and more states are adopting laws to outlaw the use of cell phones while driving, the likelihood that an offender admit to using a cell phone to a police officer becomes less. In addition, a police officer's reasonable investigation time does not allow for a comprehensive investigation of every crash to include determining the use of cell phones. This is more likely to be reserved for very serious crashes where serious injury and or loss of life were present.

To help address the underreporting of crashes that are due to cell phone use, several federal agencies, national organizations, and state and local governments have worked to improve the data collection. In 2003, the national Governors' Highway Safety Association released a revised edition of the Model Minimum Uniform Crash Criteria (MMUCC), which included changes that would help record the number of crashes associated with distracted driving. The changes, which were developed with the help of

NHTSAS, the Federal Highway Administration, the Federal Motor Carrier Safety Administration, and numerous state and local agencies, define the information that should be collected at an accident scene. Included in the new criteria is that reports should include any information regarding distracted driving. The changes are designed to facilitate more accurate reporting of distracted driving, which in turn, will give policy makers and data analysts more concrete data from which to make conclusions (Sundeen, 2004).

The National Transportation Safety Board (NTSB) has also taken aim at the problem of cell phone use and its underreporting. In a press release in 2006, the NTSB acknowledged that cell phone use by driver's results in a cognitive distraction that leads to an increase in accident rates. The same press release suggested that the remaining 20 states that at the time did not have driver distraction codes on their uniform accident reports add them (National Transporation Safety Board, 2006). In 2008, the NTSB made a press release that again emphasized the dangers of cell phone use by drivers by citing research conclusion that such activity reduces driving performance. The press release also indicated that the NTSB had added cell phone restrictions by commercial drivers to its 2009 list of most wanted safety improvements (National Transportaion Safety Board, 2008).

3. Cell Phones and Teenage Driver

3.1 Teen Drivers' Collision Statistics

Teen drivers are alarmingly prevalent in the collision statistics. In 2005, 4,544 teens ages 16 to 19 died of injuries sustained in motor vehicle crashes. In the same year, almost 400,000 motor vehicle occupants in this age group were hospitalized from injuries sustained in automobile crashes. Overall in 2005, teenagers accounted for 7 percent of the driving population, but they account for 14 percent of all fatalities. Young people ages 15-24 represent 14 percent of the U.S. population, but account for 30 percent of the motor vehicle injuries. The most concerning age group is the 16-19 year olds. Drivers in this age group are three times more likely to be killed in an automobile crash than people 25-64 years old (Lynch). As shown in Figure 4, crash risk is especially high during the first 6 months of unsupervised licensure (Lee, 2007).

Understanding exactly why young drivers are so overly represented in the crash statistics is difficult to isolate, especially while the interactions between young drivers and new technology remains mostly unexplored. Even so, it is safe to conclude from the research that new drivers have difficulty with driving because of inexperience, risk-taking behavior, immaturity, and risk exposure (Lynch). Driving is a divided attention task requiring the driver to multi-task, which is a skill that one improves with experience. This is demonstrated also by figure four in the difference between the novice and learners (supervised) crash rates. The difference in crash rate is probably due to the restriction of exposure to risky situations and aid that is provided from the adult passenger assisting in much of the multi-tasking requirements.

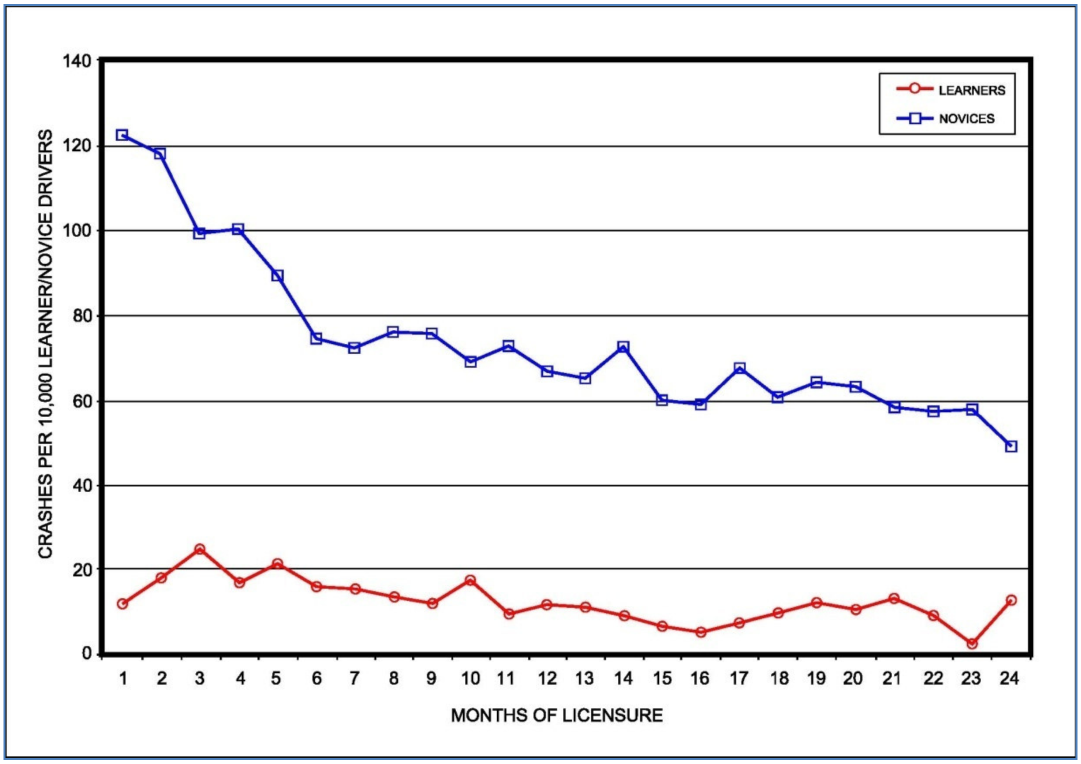

Figure 4 Crash rates for drivers under the supervision of an adult and during the first months of independent driving. (Source: Lee, 2007)

A study by the Brain Trust Alliance published in 2006 suggests a possible explanation for why young drivers are overrepresented in crashes. The researchers found that the human brain continues to develop well past childhood into early adulthood, reaching maturity at around age 25 (see Figure 5). Different parts of the brain fully develop at different times. Specifically, the prefrontal cortex and parietal lobe are areas of the brain that are still developing through adolescence and the teen years. The prefrontal cortex controls planning, working memory, organization, risk management, self restraint and emotional control. The parietal lobe controls spatial perception and vision which gives the ability to interpret location, speed and distance. The researchers concluded that understanding the brain development is valuable in understanding why young drivers are at risk and the limitations that should be placed on them to reduce the risk. Specifically, the researchers suggest that the time young drivers are under supervised driving needs to be extended to give them the time they need to comprehend the risks of driving and responses for common driving situations.

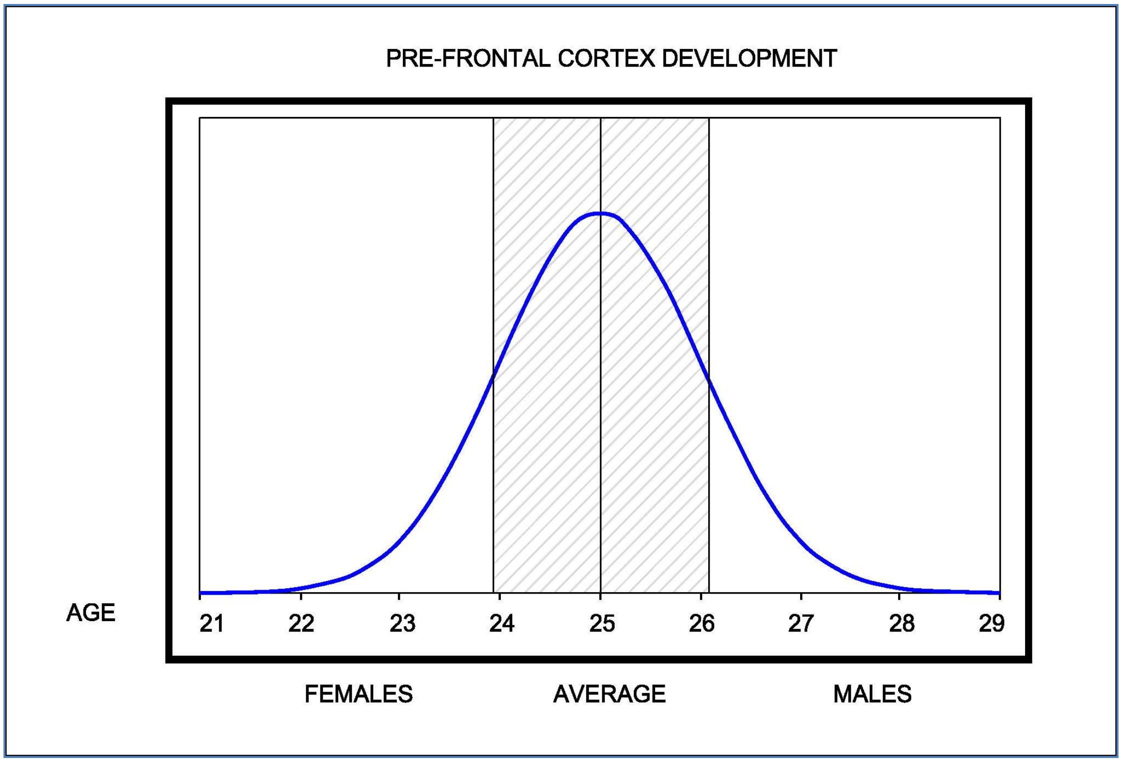

Figure 5 The development of the pre-frontal cortex in males and females.
The female pre-frontal cortex generally develops earlier than most males (Brain Trust Alliance, 2006).

3.2 Teen Driver and Cell Phone Distractions

Technological distractions that tend to distract drivers, such as making phone calls, watching videos, corresponding through email, text messaging, and selecting and listening to music, are become more prolific and are alarmingly most popular with the younger drivers. All of these technologies have the ability to distract the driver; however the cell phone has attracted the most attention. Text messaging among young driver is especially alarming since 46 percent of drivers 16-17 years old admitted to driving while texting and since it not only requires cognitive resources, but it takes eyes off the road (Quain, 2007). In a 2007 study at the University of Iowa, the researchers concluded about young drivers that, "A high rate of early adoption of new technology, peer pressure, risk-taking tendencies, poor ability to detect and anticipate hazardous situations, and underdeveloped vehicle controls kills all leave young drivers particularly vulnerable to the distractions posed by the increasing variety of infotainment systems" (Lee, 2007).

3.3 Supervised Driving and Parental Involvement

Young drivers, especially those recently licensed, who use cell phones compound their risks; intervention of some type is needed. A survey conducted by Allstate in February 2007 of parents of teen drivers found the following:

- Parents believed that it was their responsibility to teach their children driving safety (95 percent).
- Eighty-five percent of parents said supervised time behind the wheel is "very helpful" in teaching teens safe driving.
- Enforcing restrictions is parents' top choice for enforcing driving rules with their teens.

- Most parents (55 percent) said they wished they had more time to teach driving safety to their teens.

Parents have the ability to influence their teen children's' driving in ways that no one else can. The Allstate survey shows that parents feel that teaching children how to drive safely is their responsibility and wish they had more time to teach and supervise their children. Graduated Drivers Licenses, a program to facilitate more parental involvement in a newly licensed teens driving development, are becoming more common throughout the United States. These alone, however, are proving to be insufficient to reduce the increased crash rate of young drivers.

Teen driving contracts have been emphasized in many states as a way for parents to passively maintain interest in their teens' driving behavior. A teen driving contract typically is a signed contract between parent and a teen that specifies the rules, expectations, and responsibilities for safe driving. A typical safe driving agreement covers cell phone use while driving, speeding, driving at night, carrying passengers, as well as seatbelt use. The privileges set out in the teen driving contracts are designed to be reviewed periodically and may be updated depending on how the parents feel the teen is performing (Michigan Secretary of State, 2007).

4. Legislative Attempts to Prevent Driver Cell Phone Use

Although young drivers present a particularly urgent situation when it comes to cell phone use while driving, the issue is also a risky one for adult drivers. Either way, the literature and research suggest that something needs to be done to reduce the loss of life and money associated with cell phone use while driving. Numerous efforts are underway to keep drivers safe, including efforts from federal, state, and local agencies, parent groups, and schools. Governments have made various attempts through legislation to outlaw the use of cell phones while driving. This review has identified three reports on legislative efforts designed to help reduce crashes resulting from cell phone use and they are presented below:

4.1 New York State 2001 Hand-Held Cell Phone Ban

In 2001, New York became the first state to adopt a law that bans the use of hand-held cell phone devices by all drivers. Prior to the law, the rate of drivers using cell phones was observed at 2.3 percent. Immediately after to several months after the enactment of the law, the observed cell phone use dropped by approximately 50 percent to 1.1 percent. By March of 2003, the rate of cell phone use had risen back up to 2.1 percent which almost matches that of the pre-ban rate. Between December of 2001 and January of 2003, only about two percent of the traffic citations issued in New York were for cell phone use even though a survey conducted by NHTSA of New York drivers showed that 30 percent admitted to still using their phones while driving. A possibility for the decline in effectiveness is the decline in media attention and enforcement since its inception (IIHS, 2003).

4.2 District of Columbia Distracted Driving Safety Act of 2005

In July 2005, the District of Columbia enacted the Distracted Driving Safety Act which prohibits all forms of inattentive driving that result in the unsafe operation of a motor vehicle including hand-held cell phones. Prior to the law, the rate of drivers using cell phones was observed at 6.1 percent. Shortly after the law took effect, the usage rate dropped to 3.5 percent. Interestingly, when the usage rate was measured a year after the law it had risen to four percent, but was still significantly lower than the pre-ban rate. The introduction of this law also followed the typical pattern where a new law is introduced, compliance is at its highest and as time passes, the compliance drops off. Although the rise in usage a year after the introduction of the law was not as significant as that of the New York ban, it was still present. One possibility for this less significant return to pre-ban usage levels is the District of Columbia's reputation for strict enforcement (McCartt, 2007).

4.3 North Carolina Under 18 Ban of Mobile Communication Devices

In December 2006, North Carolina enacted a law that prohibited the use of any mobile communication device by drivers younger than 18 years old. Cell phone usage was observed at high schools prior to the law and five months after the law took effect. The cell phone usage prior to the law was observed at 11 percent. Cell phone usage five months after the law took effect was observed at 11.8 percent. As a control, cell phone usage in the adjacent state of South Carolina was observed over the same period of time and cell phone use there was steady at 13 percent over the observation time. Researchers conducted interviews of teen drivers in which 50 percent of the surveyed teens reported using their cell phones (post-ban) if they had driven the day prior to the survey. The conclusion of the researchers was that the cell phone law had little effect on teenage drivers' use of cell phones (Foss, 2008).

5. Distance-Based Insurance Polices

Keeping drivers safe behind the wheel is becoming an ever increasing priority as evidenced by the many new and innovative approaches to the problem. Solutions are being sought and in some cases found in areas of science, engineering, biomechanics, state-of-the-art safety designs, etc. The following review is based on a relatively new insurance concept called distance-based insurance.

Vehicle insurance is typically based on a lump sum pricing method which translates to a fixed cost for each consumer regardless of how many miles a vehicle is driven. A lump-sum insurance policy will result in the same premium across a similar demographic, assuming that other aspects such as age, gender, location, driving records, etc. are the same. Consumers will not see any reduction in price if they reduce their yearly mileage which results in lower risk. Since the risk of collision and other policy claim related losses are dependent on how many miles the vehicle is driven, it seems unfair to apply a lump-sum pricing scheme to such a complex situation (Bordoff, 2008).

In a paper written by Litman (1997) he makes a profound analogy of this situation to the sale of gasoline. If gasoline was sold by the car-year, vehicle owners would be required to make one lump-sum payment at the beginning of the year. This payment would allow the owner to fill the vehicle up with gasoline unlimited times throughout the year. Prices would be based on the average consumers' use of gasoline in his/her demographic. Litman suggests that this unlimited distribution of gasoline would perpetuate an increase in fuel usage resulting in more miles driven, overall vehicle costs, congestion, pollution and increased accident risk. Consumers who use less fuel than the average would find the system wholly unfair and unaffordable and would not use it. Consumers who used more than the average would be in favor of the system because of the benefits it offers them. This system is obviously unreasonable, and anecdotally explains the limitations of our current lump-sum insurance system.

In response to this problem, a new distance-based insurance pricing method has been suggested and is being implemented in some places. Distance based insurance policies are variable and are based on the vehicle-miles driven instead of the current practice of lump-sum policies. These policies are designed to better reflect the risk of consumers, since claims are generally proportional to miles driven (Bordoff, 2008). Figure 6 represents the average 2003 distribution of expenditures for ownership of an automobile in the United States. The percentage paid in insurance costs is 21 percent, a significant amount. The benefits of distance-based insurance policies are many, but most importantly is that they more accurately reflect the customers' mileage-based risk and give many consumers an opportunity to proportionally reduce their insurance rates.

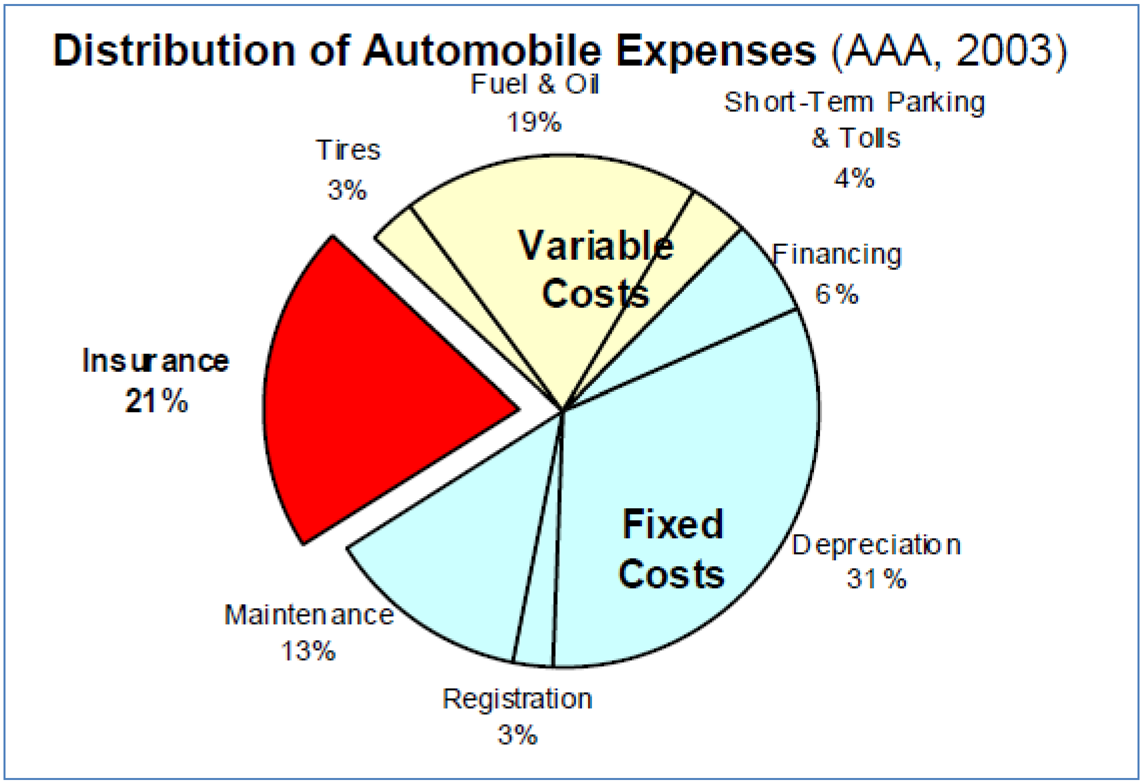

Figure 6 Average 2003 Distribution of Expenditures for Automobile Ownership in The United States. (Litman, 1997)

Similar to how distance-based insurance pricing has revolutionized the way insurance premiums are being evaluated, safety-based driving systems can revolutionize how driving habits are reflected in insurance premiums. For example, cell phone use while driving increased the risk of collision. If a driver were to voluntarily participate in a program that restricted his/her cell phone use while driving, thereby reducing his/her risk of collision, that behavior could be rewarded by a lower insurance premium. This same methodology could be applied to any risky driving practice (i.e. speeding, teen driving at night, etc.) as reported to an insurance company through reliable technological methods. This, much like distance-based policies, would more accurately reflect the consumers' safety risk and could result in lower insurance rates. Those who choose not to participate in the program would have to assume the average risk and associated premiums. This program would be a huge incentive for people to participate and subsequently drive safely.

6. Technological Methods for Improving Driving Safety

6.1. Active Safety Features through Vehicle-to-Vehicle and Vehicle-to-Infrastructure Comm.

To help avoid car accidents and minimize harmful effects of accidents, many automotive manufacturers aim to provide active safety features such as: forward-looking speed radar, autopilot systems, lane departure warnings, integration of video cameras, collision alerts, situational awareness systems, active headlights, and vehicle-to-vehicle communications to name a few. The radar-based system can be used to help avoid or mitigate the effect of front-end collisions. A number of systems focus on how to utilize wireless vehicle-to-infrastructure communications to provide early warnings to drivers about potential hazards at intersections, where 40 percent of all traffic accidents and 20 percent of crash-related fatalities occur.

Specific technologies designed to mitigate the use of cell phones by drivers are generally marketed toward the young driver because that is where the largest concern for safety is, as well as where the most potential improvements can be made. It is also the primary market because often these technologies require voluntary involvement where parents are more likely to involve their children than themselves. These devices are, relatively speaking, in their infancy. Many devices on the market seem to individually employ a portion of what is needed to be a complete and effective system, but each has its limitations.

6.2. GPS-based Driving Monitoring System

Examples of a technologies used to monitor teens and provide a possible solution for talking while driving are the wide variety of Global Positioning System (GPS)-based monitoring systems. These systems use the GNSS (Global Navigation Satellite System) network to log the vehicle's location and speed at regular intervals and allow downloading of the data for further analysis. Some advanced monitoring programs provide over-speed alerts and/or send data to a central computer or system through a wireless communication network for tracking teen drivers in real-time. It should be remarked that, in addition to the use of teen driver tracking, these kinds of GPS tracking systems have been successfully used for commercial fleet tracking and network-wide traffic monitoring. Similarly, the windshield camera produced by DriveCam Inc. can record the driving behavior and transmit digital images to a central data server for further analysis.

The above-mentioned (passive monitoring) systems, however, are not seamlessly integrated with cell phones, so none of them can actively prevent the use of cell phones even when the vehicle is in motion. They provide only an opportunity for the monitor to give post-violation advice and instruction to the teens, when it might be too late.

6.3. Cell Phone Based Context Identification

Currently, mobile phone usage is no longer limited to making and receiving calls, both GPS and accelerometer sensors have been widely supported in the next generation of mobile phones. For example, both GPS and accelerometer sensors have been installed in iPhone 3G smart phones from Apple Inc., and 50 percent of Nokia mobile phones shipped in 2009 will be GPS-enabled.

A number of studies aim to utilize embedded sensors in the next generation of mobile phones, specifically GPS and accelerometer sensors to discover and take advantage of contextual information such as user location, time of day, as well as the type of activity the user is involved in, such as walking, driving, or standing still. This contextual information can be used to alter the phone's status creating a "smart" phone that is safer and/or more user friendly.

Chen and Kotz (2000) provided a comprehensive survey on context-aware mobile computing research. They suggest that although context-awareness is a widely researched topic, there are still areas that could be further explored. The authors specifically highlight the need to further develop the awareness, communication, and use of context-based computing as having the most potential to benefit society.

The application of contextual information to cell phones is critically important because it determines what the user is doing, and thereby when to alter the phone status.

SenSay is one recent application (Siewiorek et al., 2003) that integrates contextual information with cell phone use. Combining a cell phone with sensory data, user information, and user history, the researchers were able to provide a context aware phone that improves its overall usability. For example, the phone is able to change ringer volume and vibration, and further provide dynamic phone alerts and call handling depending on the users' activity. The real-world application of this device is limited because of peripherally needed devices, but the integration of this type of context sensing devices within phones holds great potentials.

In a GSM or 3G networks, triangulation among two or more cellular towers, signal strength fluctuations, and changes to the current serving cell phone towers can be also used to estimate the context of cell phone users (e.g. study by Anderson and Muller in 2006). The result of context identification, including the speed of moving cell phones, can be used to distinguish driving vs. walking or remaining still. This contextual information can be used to prevent risky driving behaviors, such as talking while driving and texting while driving. However, as shown in a study by Smith et al. (2004), the existing cell phone-based speed estimation results are less accurate when compared to GPS-based methods. These results are exaggerated during periods of congested traffic or stop-and-go traffic on arterial streets.

This review was able to identify various devices for sale that are marketed toward teen drivers all with the purpose of monitoring and or reducing poor driving habits. These devices are tools which parents can use to monitor, advise, and teach their children long after the learner and graduated driving experiences have passed. Several companies currently offering some of these devices were contacted and asked if there were any studies or research that had been done showing the effectiveness of their products. The companies responded that studies have been done, but that the results were proprietary because they had been financed by insurance companies.

7. Economic Analysis of Restricting Cell Phone Use

Although there is sufficient data to prove that cell phone use while driving increases the risk of crashes, complete restriction of cell phones by drivers has been controversial in part because of the benefits consumers and society receive from these calls and because the exact number of crashes caused by cell phone use are unknown. Several researchers have attempted to quantity these values by comparing the total societal cost of crashes caused by cell phone use to the benefits society receives from the same. The results of three such studies are listed below:

- Hahn and Tetlock (1999): A complete ban on cell phones by drivers would result in a societal loss of $23 billion annually.
- Redelmeier and Weinstein (1999): A complete ban on cell phones by drivers would result in a societal loss of $300,000 annually.
- Cohen and Graham (2003): A complete ban on cell phones by drivers would result in a net societal loss of zero.

The Cohen and Graham study was a re-analysis of the Hahn and Tetlock study with updated estimates and more comprehensive analysis. Because the exact numbers of crashes that are caused by cell phone use is unknown and it is difficult to quantify the value of cell phone use in society, these variables needed to be estimated in the analyses. The variability between the three estimates shows how the results are highly dependent on the estimation of these variables.

In a Study by Martin et al. (2006), researchers analyzed the impact cell phone use by drivers had on traffic flow. A "car following behavior" was identified by simulated driving for both the non cell phone user and the cell phone user. The researchers then used these "car following behavior" models and through simulation and microscopic traffic modeling, were able to identify the impact that cell phone users had on the traffic stream efficiency. The research found that with different traffic conditions and varying percentages of cell phone users, cell phone usage while driving had a negative impact on traffic flow when traffic volumes were moderate or high. Converting these delays into monetary units, the researchers were able to project the cost of the delays caused by cell phone users throughout the entire United States highway network as significant.

8. Findings and Recommendations

Distracted driving has been a public concern ever since the beginning of the automobile. Cell phone use by drivers is widespread. Intuitively, one understands that cell phone use while driving is distracting and dangerous, and many studies have proven that instinct to be true. Experimental and behavioral studies have drawn an unambiguous conclusion that cell phone use by drivers results in a cognitive distraction leading to an increased risk of collision. Studies have also been able to quantify this risk as at least as dangerous as driving while impaired by alcohol at the legal limit of .08 mg/ml. Epidemiological examination of actual crash data compared against cell phone records provides confirmation that driving while using a cell phone increases the risk of collision. In the epidemiological studies reviewed in this paper, the increased risk of collision when using a cell phone while driving was found to be between 1.3 and 5.59 times greater than non-users. Real-world data, although scarce, has also confirmed that cell phone use while driving is the single largest driver distraction leading to collisions.

Studies are mounting that show an obvious correlation between cell phone use while driving and increased crash risk. The association between cell phone use and increased risk of traffic crashes seems to be validated by epidemiological, behavior, experimental and real-world studies, but the actual number of crashes directly related to cell phone use is harder to determine. Because the exact number of crashes directly related to cell phone use is unknown, the likely financial savings to United States drivers for outlawing cell phone use while driving is also uncertain.

Other important findings are listed as follows: (1) Government at all levels has tried to legislate a solution for this problem with poor results, (2) Young drivers are especially susceptible to the danger of cell phone use while driving because they are already overrepresented in the crash statistics, (3) Technology is intervening where legislation has failed to provide solutions to the problem of cell phone use while driving.

To improve driving safety in general, and to prevent talking on cell phones while driving in particular, the following initiatives and innovations are critically needed.

1) Accurate reporting of cell phone involvement in collisions on police reports

The underreporting of cell phone involvement in collisions on police reports, the best indicator of how many collisions are directly related to cell phone use, has proven to be significant. This is worrisome because many legislative efforts to stop the use of cell phones by drivers are based at least partly on this data. Legislative efforts in themselves have shown to be minimally effective to statistically ineffective in curbing the use of cell phones by drivers. Several government agencies have nonetheless continued seeking for some type of solution to this problem.

2) Technological solutions for accurately identifying driving mode of cell phone users

A wide variety of research has been devoted to mobile phone-based context identification by GPS, triangulation, or signal strength. Despite considerable research efforts, the technology remains insufficient to properly distinguish the exact mode of cell phone uses such as driving, walking, or remaining still. Even with all the available location and movement data, it is still extremely difficult to distinguish if a cell phone user is driving a car, seating as a passenger, or riding a bus or train. Inaccurate context identification could lead to problematic disabling of the communication capability when a cell phone user is not driving a car. Additional research is still needed in the area of artificial intelligence to improve the context estimation accuracy.

3) Integrated driving monitoring system

There are many products that have been designed to address the problem of cell phone use by young drivers. Some existing context based technologies are designed to passively monitor an individual's driving by recording their movements and making them available for download at another time. Some advanced monitoring technologies allow for real-time alerts to be sent to a central computer or by text message through wireless communications. These technologies can give real-time information to parents about safety concerns, but fail to provide any way of actively preventing the dangers from happening. The need for a context based solution that also allows for active prevention of cell phone use while driving is apparent.

4) Safety-based insurance policies

Distance-based insurance policies have revolutionized the way automobile insurance is evaluated. Distance-based policies are more reflective of the individual mile-based risk and result in more fitting premiums. As distance-based insurance policies have changed how we think about insurance, so can safety-based insurance policies. If a driving safety profile could be determined for an individual consumer, insurance rates could be tailored to better reflect the individuals collision risk. This method could help further reflect a driver's risk and in many cases lower the insurance premiums or be an incentive for aggressive or inexperienced drivers to drive safely.

5) Cost-effective car safety features

Automotive manufacturers are engaged in the design of safety features on vehicles, which are intended to enhance the driver's ability to avoid collisions. Some of the state-of-the-art safety features that are being explored by the automobile manufacturers are: forward-looking speed radar, autopilot systems, lane departure warnings, integration of video cameras, collision alerts, situational awareness systems, active headlights, and vehicle-to-vehicle communications. Automotive manufacturers have the objective of creating a "smart" car through the integration of technology. The "smart" call will be designed to enhance the driver's ability to avoid collisions, but the driver will still maintain control. These devices, although potentially very effective in reducing vehicle collisions, fail to address the problem of cell phone use by drivers. Automotive attempts at collision avoidance systems are also relatively expensive and in some cases are limited by participation and communication between vehicles.

The complete restriction of cell phone use by drivers seems to be unlikely because of the lack of concrete evidence showing how many crashes are caused by cell phone use, and what the cost of such a ban would be. Short of a complete restriction, a technology that would self-impose restrictions or that could be tailored to the most dangerous demographic of young drivers becomes most probable. A technological solution that is practical, effective, context-based, cost-effective, and focused on the driver's actions is critically needed.

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