CELL PHONE USE

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Executive Summary

Reports in the media claim an increased risk due to the use of cell phones while driving. This project was conducted to determine if current literature has empirically shown that cell phone use while driving significantly diminishes driving performance and increases incident risk.

Objectives

The objectives of this project were to:

- Review literature related to the impairment of driving caused by cell phone use;
- Determine if current literature has empirically shown that cell phone use while driving significantly affects driving impairment.

Scope

Research literature that relates to the use of a cell phone while operating a motor vehicle (i.e., car or truck) is limited. Studies were selected based on their empirical nature and applicability to current driving situations.

Conclusions

The scientific studies reviewed for this document indicate that engagement in a cell phone conversation while driving significantly degrades driving performance and contributes to an increased risk of vehicular incidents. Various scientific studies described vehicle control degradation as:

- A delay in brake activation three times longer than the reaction deterioration found in drivers under the influence of alcohol;
- A four-fold increase in risk associated with the use of a cell phone while driving as compared to not using a cell phone;
- The increase in the relative risk of vehicle collisions similar to the hazard associated with driving with a blood alcohol level at the legal limit;
- A diversion of the driver's attention and situational awareness from driving environment and potential hazards that may unexpectedly impact safety, during cell phone conversations;
- A compromise in the safety margin (e.g., following distance in adverse driving conditions) provided by a fully aware and responsive driver. This compromise is caused by secondary tasks that demand the cognitive engagement of the drivers, such as cell phone conversation engagement;
- The reduction in the ability to maintain lane position while operating a heavy vehicle and an increase in potential crash hazard exposures for experienced drivers who were simultaneously engaged in tasks that required the cognitive attention (e.g., cell phone conversations) of the drivers;
- No difference in the level of safety for the use of hands-free compared to hand-held design cell phones.[9]

A review of current cell phone policy is recommended based on scientific data and study results.

Literature Search Results

The design of cell phones has undergone numerous changes since their introduction into the market (e.g., smaller sizes, voice activation, etc.). The capability of humans to process information has remained relatively limited and constant. Human mental capabilities are a limiting factor in safely performing multiple tasks (i.e., driving and being a part of a telephone conversation simultaneously). Specifically involved is the human ability to:

- Receive sensory input;
- Process all sensory input correctly;
- Decide on appropriate responses;
- Respond accordingly.[2] [14]

Conversing on a cell phone is not like conversing with a passenger in the vehicle. Passengers are able to perceive the road situations and are able to vary their portion of the conversation accordingly[9].

There is also some interference from conducting a cross modal task such as being engaged in a cell phone conversation (verbal-auditory) while driving a vehicle (visual-spatial). Cross modal tasks generate interference in performance[9] [18]. The need to respond quickly and safely to multiple pieces of information (e.g., vehicle speed, conversation content, traffic, past events, etc.) exacerbates this mental limitation. A link exists between cell phone use and driving in relation to competing cognitive requirements of driving and conversing on the phone. Cell phone and other vehicle technologies decrease a driver's safety margin performance and distract drivers from their critical responsibility of vehicle control[7] (ICBC).

Types of Studies

In this report, empirical studies of cell phone use while driving are categorized as:

- Simulator
- Closed-course (Test-Track)
- Actual road
- Epidemiology

Studies selected for this report were based on experiments that generated objective measurements (e.g., lane position, accelerator angle, and reaction time). In all of the reviewed investigations, the concept of a distraction was studied as it relates to cell phone conversations. Highlights of each study, its methodology, and the results are included in this report.

Simulator studies offered the greatest control of external environmental factors (e.g., traffic changes and road conditions). In the simulator studies, real-time performance variables were monitored to determine how participants reacted to their simulated external environment. Additionally, recognition memory of the drivers was studied to determine how dual-task conditions of driving while involved in a cell phone conversation impacted the driver's memory.

Studies conducted on closed-courses or test tracks allowed greater control of potential distractions other than cell phone use (e.g., changes in traffic flow and environment). The methodology for these studies monitored, for instance, vehicle speed, brake activation, pavement position and situational awareness.

Actual road studies were conducted on actual roads with "real world" conditions. These studies equipped the test vehicle with an array of sensors to monitor, for instance:

- Lane position;
- Speed;
- Accelerator pedal angle;
- Steering.

Actual road experiments provided the least control of unscheduled distractions (i.e., traffic changes.

Epidemiological studies evaluated potential associations between cell phone use and the risk of vehicle collisions. A characteristic of these studies is use of data from "real-world" situations.

1. Simulator

This type of study recreated actual driving environments in a simulated setting. The simulator apparatuses were configured to replicate the interior compartments of actual vehicles (i.e., dashboard, pedals, steering wheels, sounds, and driving scenarios). Measures of real-time driving performance (e.g., speed, deceleration, and steering wheel rotation) were collected during these studies.

The external validity and application of simulator information has been questioned. One argument is that participants in simulator studies behave differently since they are not exposed to any real danger[1] (Alm et al.). Car driving is a learned task, repeated frequently by drivers. Given the level of realism in simulated driving, the transfer of behaviors is expected from actual driving to simulated driving.[1]

Study by Strayer, et al.

Strayer, Drews, Albert, and Johnston at the University of Utah conducted a study with two objectives. The first objective was to determine the effects of driving and conversing on a cell phone on a multilane freeway while following a pace car that would brake at random intervals. The second objective involved an assessment of the hypothesis that cell phone conversations impair driving performance by removing a driver’s attention from the visual scene [15].

Methodology

Experiments for this study were conducted in a driving simulator that functioned to “immerse” the driver in a driving environment. The simulator environment replicated the partial interior of an American sedan with, for instance, dashboard instrumentation, pedals, and steering wheel.

Additionally, the driving simulator incorporated vehicle dynamics, traffic scenarios, road surfaces, realistic scenes, and traffic conditions. Four experiments were performed in this study:

- Experiment one involved forty participants and two different driving conditions. The real-time responses of these participants were monitored under low-density driving conditions. A pace car and the subject's car were the only vehicles on the roadway. The second driving condition involved "distracter" vehicles on a highway scenario. These vehicles gave the impression of a steady flow of traffic in the left-hand lane. In both scenarios, the pace car, equipped with brake lights, would brake in a random fashion and would continue to brake until the study participant depressed their brake pedal.[15]
- Experiment two tested twenty participants. It analyzed incidental recognition memory as an estimate of the degree to which attention to visual information in the driving environment is distracted by cell phone conversations. Study participants were required to perform a simulated driving task without the previous knowledge that their memory for objects in the driving environment would be tested afterward.[15]
- Experiment three included twenty subjects. The simulated driving tasks of experiment two were repeated while the eye fixations of the participants were measured. Experiment three studied if cell phone conversations while driving reduced attention and the recognition memory for fixated objects.[15]
- Experiment four involved thirty participants and measured the perceptual memory for words that were presented during fixation on objects. This study element estimated the perceptual memory for items by the time taken by a subject to correctly report the identity of the item. The perceptual memory task provided an index of the initial data-driven processing of the visual scene. The application to a driving scenario, for instance, may be the observation of an emergency situation in the driving environment and appropriate response (s).

  This experiment differed from simulator experiments one, two and three through the use of a joystick in a pursuit-tracking task. This tracking task was done while the study participant was engaged in a cell-phone conversation. Immediately following the tracking task, the subjects performed a perceptual memory task to identify words to which they were previously exposed.[15]

Data analysis for experiment one used a Multivariate Analysis of Variance to provide a general measure of driver performance as a function of experimental conditions.[15] A univariate analysis of each dependent measure in the experiments (traffic density and cell phone conversation and no cell phone conversation) was applied to each dependent measure during the simulation.[15]

Experiment two tests the participant's ability to correctly recall billboards that were present during the simulated driving. Recognition memory performance was also calculated in experiment three. Additionally, the total fixation time was measured to ensure that the observed differences in recognition memory were not due to longer fixation times.[15] The conditional probability of recognizing a billboard, given that a subject is fixated on this billboard while driving, was also calculated. Finally, a time-varying Analysis of Covariance was conducted. The recognition probabilities for the billboard items that were fixated were statistically corrected for variations in fixation duration on a billboard-by-billboard basis.[15]

In experiment four, the rate at which a study participant identified words during no cell phone and cell phone tasks were measured. Moreover, the rate at which a subject could identify new words was measured. All words were masked randomly and revealed gradually every 33 milliseconds.[15]

Results

Experiment One:

The Multivariate Analysis of Variance showed a significant main effect for the tasks of engaging in a cell phone conversation while driving. This effect indicated that during this time, the study subject's reactions were slower when compared to only driving the vehicle. The participants tended to compensate for this sluggish behavior by increasing the distance between their vehicle and the pace vehicle.[15]

Additionally, a univariate analysis indicated that the time interval between the brake light illumination on the pace car and the subject's brake pedal depression was greater when driving while engaged in a cell phone conversation. This difference was statistically significant on highway driving conditions with the presence of other vehicles functioning as distractions.[15]

Experiment Two:

Results of this experiment indicate a breakdown of a person's visual attention. The data showed that cell phone conversation diverts a driver's attention from the driving environment to the cell phone conversation. The engagement in a cell phone conversation impairs the recognition memory of objects in the driving environment.[15]

Experiment Three:

Similar to experiment two, this experiment indicated that cell phone conversations disrupt the attention of a driver to their visual environment. This disruption still occurred when experiment subjects fixated their vision on objects in the driving environment. These drivers were less likely to form explicit memory of objects when they were engaged in a cell phone conversation.[15]

Experiment Four:

Words were identified slower for trials involving the use of a cell phone while the subject tracked the target with the joystick. This reduction in time requirements applied to words presented in previous experiments during the dual tasks of driving and engaging in a cell phone conversation. Data from this experiment indicated that cell phone conversations diminished perceptual memory of items on which the participants fixated during the completion of tracking tasks.[15]

<u>Study by Parks and Hooijmeijer</u>

Parkes and Hooijmeijer directed a driving simulator study that also investigated the impact of cell phone use and driving performance. Driving performance and situational awareness were the parameters measured in this study. Situational awareness is defined in this research as: "a person's perception of the elements of the environment within a volume of time and space, comprehension of their meaning and the projection of their status in the near future."[12]

Methodology

Static driving simulator tests were conducted on fifteen subjects. This simulation presented various elements of feedback to the driver, such as dashboard lights, engine, road, and wind noise. A route was used in the driving simulation to keep the driver's attention on the road. To increase the realism of the driving experience, oncoming traffic and cars in the rear view mirror were simulated.[12]

A hands-free type of phone was used for cell phone conversations in the experiment. Subjects of the experiment were to keep the vehicle in the middle of the lane and maintain the speed limit. Additionally, they were informed that other traffic would be present during the simulation, as would environmental changes (e.g., wind gusts).[12]

Lateral position of the vehicle and its variability were measured during the experiment. Maintenance of vehicle speed, braking distance and response time to unexpected events were also measured. The situational awareness was also used as an indicator of the driver's performance. Three levels of situational awareness were measured:

- Perception of elements in the environment;
- Comprehension of the current situation;
- Projection of future status.[12]

Results

Results from the t-test, used to analyze lateral position and braking distance, did not indicate a significant difference between driving during a cell phone conversation and without the conversation. In relation to the mean reaction time to the change in speed limit, the change on the part of the drivers while using the cell phone appeared to be slower for deceleration than when not using a cell phone.[12]

The data from the situational awareness measures utilized χ^2 analysis. Results of this analysis indicated that there were significantly more correct answers to the situational awareness questions in driving without the use of a cell phone than there were with the use of one.[12]

Limitations of this particular simulator experiment included:

- Drivers perceived and adjusted their response patterns to the safety of a simulated environment;
- Road chosen had no direct conflicts with other cars;
- Road did not have sharp curves or large junctions.

The tests of situational awareness indicated a significant difference between cell phone and no cell phone use. A notable decrease in situational awareness, due to the level of concentration demanded by the cell phone conversation, was evident in the data.[12]

Study by Alm and Nilsson

This study investigated the issue of car-following distance, referred to as headway in this study, as it relates to cell phone use while driving the vehicle. A goal of this study was to analyze the effects on reaction time, mental workload, and lateral position when participants in the study must interact with other road users. Another objective of this study was to investigate if engagement in cell phone conversations impacted the participants' choice of following distance (headway).[1]

Methodology

Forty subjects participated in this study. A complex driving task was used in this study. Similar to other simulator studies, the simulated interior was of a passenger car. The difference to other simulators was the use of a manual gearbox. The cell phone used for this study was a hands-free version.[1]

The driving simulator used a moving base system and a wide-angle visual system. Other simulation effects included vibration-generating, sound and temperature-regulating systems. All these systems operated simultaneously to give the study subjects the impression of a driving experience.[1]

The simulator was equipped to gather real-time values for objective performance measures. Performance measures analyzed in this study included choice reaction time to braking of lead vehicle, headway, lateral lane position, communication of correct judgements and subjective workload indices. Subjective workload information was measured using a simplified version of the NASA-TLX rating scale. Objective data was analyzed using a two-way ANOVA (Analysis of Variance).[1]

Results

Choice reaction time:

The ANOVA results demonstrated a significant difference in choice reaction time in braking. The subjects demonstrated a longer reaction time when involved in cell phone conversations.[1]

Headway:

Compensation by the subjects for increased reaction time would be an increase in the following distance between the subject's vehicle and the lead vehicle. An analysis of the data did not indicate an increase in the following distance. A reason given in this study for the absence of an increase relates to a subject's situational memory. Their reasoning was that a driver must be able to remember and compare reaction time in different situations based on previous experience. The researchers concluded that the headway during cell phone use was not large enough to include the increased risk caused by the slowed reaction time.[1]

Lateral Position:

Lateral position in this study referred to the participant's ability to maintain position of the vehicle in their lane. The analysis of the data from this study did not indicate an increased variability in lateral position. Reasoning given for this finding includes the frequent stream of oncoming vehicles, which required the subjects to be careful about lane position.[1]

Mental Workload:

The ANOVA of the mental workload data indicated a significant difference between engagement in cell phone conversations while driving versus no cell phone use. Study participants who used the cell phone rated the mental demand, time pressure, effort, and frustration as higher in comparison to participants that did not use the cell phone while driving. The researchers state that increased levels of workload contribute to a reduction of the driver's attention. Furthermore, they conclude that extreme levels of workload may result in the limited availability of processing resources for new information. This study suggests that using a cell phone concurrently with driving may increase the risk of an accident if something happens unexpectedly.[1]

2. Closed Course (Test-Track)

These studies presented a greater control of distractions and variables than those presented to the drivers in actual road situations did. Driving under these conditions controlled the "elements" or variables that distract drivers from vehicle control (e.g., traffic, unexpected road condition changes, etc.).

Study by Hancock, et al.

Hancock, Lesch, and Simmons used test track facilities for their study. The researchers state that during normal, non-critical driving conditions, experienced drivers perform secondary tasks (e.g., radio tuning, talking to passengers, etc.). When unexpected, emergency situations (e.g., child running in front of the vehicle) occur, skills developed and control of the vehicle by the experienced driver are adapted for the situation. However, if experienced drivers encounter a surprise when distractions are present, the combination of emergency events and distractions may lead to dangerous outcomes. In this study, it is hypothesized that the distraction caused by cell phone use while driving is contingent on the momentary difficulty of the driving experience.[6]

Methodology

Data for this study was collected on a 0.5-mile closed-loop test track. A simulated intersection was equipped with a functioning traffic light at the end of one straight portion of the test track. Inductive loops below the pavement monitored vehicle position. The vehicle was a passenger sedan with automatic transmission and instrumentation. The vehicle was equipped to monitor speed and brake activation.[6]

Tasks in the experiment consisted of number memorization and recall, distraction, and stopping. The memorization and recall task was performed on every trial. The distraction involved a simulated cell phone pad located adjacent to the steering wheel. The data for the stopping task included analysis of brake response time, stopping time, stopping distance, and stopping accuracy (compliance) as indicators of driver reaction.[6]

Each task had four conditions:

1. Control condition: Neither the distraction (cell phone) or stopping tasks were presented;
2. Distracter only condition: Only the distracter task was presented;
3. Stopping only condition: Only the stopping task was presented;
4. Distracter and stopping condition: Both the distracter and stopping tasks were presented.[6]

Analyses of Variance were calculated for each of the performance indicators. In the experiment, several dependent measures were used. These indicators involved brake response time, stopping time, stopping distance, and stopping accuracy. Distracter response time and accuracy were also measured. Response accuracy was used as an indicator of on-going, short-term memory capacity.[6]

Results

An analysis of the data collected for this study demonstrated the negative effect of cell phone use on driving performance in relation to braking. Drivers reacted more slowly when the cell phone distracted them from their driving tasks. Drivers that reacted more slowly compensated for the delayed reaction with an increase in force applied to the brake pedal.[6]

Brake Response Time:

Stopping compliance involved a complete stop at the stop line at the intersection when the red stoplight was illuminated. The brake response time data indicated that test subjects had a brake response time 0.19 seconds slower when the cell phone distraction was present. The researchers concluded that the cell phone distraction decreased the safety margin provided by a fully aware and responsive driver.[6]

Stopping Time:

Stopping time in this study was defined as the time period between the driver's first activation of the brake after the red light was illuminated and the vehicle speed decreased to zero miles per hour velocity. In trials that involved the cell phone distraction, the stopping time decreased on average from 2.57 seconds to 2.23 seconds. This decrease in time was indicative of greater braking intensity.[6]

Stopping Distance:

The results of the tests showed a significant main effect of cell phone distraction in relation to the stopping distance. The stopping distance was measured as the distance from the front of the driver's vehicle to the stopping line at the intersection. When the cell phone distraction was present the drivers stopped closer to the line versus without the cell phone (5.13 ft versus 9.45 ft).[6]

Stopping Accuracy:

This measurement gave information that related to the percentage of occasions that the driver successfully complied with the change in light status in terms of stopping before the cross line on the roadway. Compliance decreased to 80.35% when the cell phone distraction was present versus 94.64% compliance when the cell phone was absent. The researchers described this finding as one of critical importance for safety concerns.[6]

In general, this study suggests that the use of a cell phone while driving causes drivers to:

- Miss significantly more activated red lights;
- React more slowly;
- Brake more intensely.[6]

<u>Study by ICBC</u>

Insurance Corporation of British Columbia (ICBC) conducted a study to determine evidence that indicated a significant degradation of driving performance on the part of the driver when conversing on a hands-free cell phone.[7] This research study investigated the distraction caused by cell phone use during situations that required critical decisions.[7]

Methodology

An elongated closed-course was used to gather information for this study. Events used in this study included:

- Light change from amber to red;
- Pop-up targets to create the need to weave between them to avoid them;
- Left-turn task.[7]

Participants in this study were also required to respond verbally to taped messages that played in their vehicles while they drove on the closed-course. A driving task sometimes triggered the messages and sometimes it did not. The messages were "hands-free" from the perspective of the test subjects. The message types were verbal, semantic and spatial or imagery. Responses to the message were "yes" or "no" in relation to the criterion defined in the contextual phrase of the message.[7]

A 1991 Honda Accord equipped with instrumentation to record brake, acceleration, pedal movement, and continuous speed was provided for use in the experiment. Performance indicators applicable to each driving situation were measured (i.e., average deceleration or acceleration, reaction time from event occurrence to brake or accelerator pedal movement, etc.). Each of these indicators was treated as a dependent variable in a series of repeated measures analyses. An F-statistic was used to determine significance level ($p < 0.05$).[7]

Results

Traffic Signal Task:

If a subject decided to not stop for the changing lights (amber to red) and "run" the light, their initial speed to implement the decision to "run" the light was greater when the cell phone distraction was present. Additionally, when the participant decided to pass through the intersection on an amber situation, they tended to accelerate harder through the intersection than in a no cell phone distraction situation. However, if the decision to stop was made by the subjects, the likelihood of stopping was 62.6% when involved in a cell phone conversation versus 47.9% when not engaged in a cell phone conversation. These results are linked to a conservative or anticipatory behavior with the use of cell phones.[7]

Pop-up Target Task:

Results of this task indicated that the presence of cell phone messages resulted in a significant impact on deceleration prior to and speed through the weave maneuver. During the presence of cell phone distraction, study participants reduced their speed less than in tasks without a cell phone message. Subjects in the study made fewer speed adjustments and maneuvered faster when the cell phone distraction was present. Furthermore, the experiment data indicated that under wet pavement conditions, there was less speed compensation during cell phone situations for reduced maneuverability capability.[7]

Left-Turn Task:

This task generated data related to the gap acceptance for left-turns across oncoming traffic. Subjects waited for substantially larger gaps in oncoming traffic when the pavement was wet and no cell phone distraction was present. If the cell phone distraction was present, however, according to the data, the participants did not adjust their gap acceptance. The researchers describe this behavior as degradation in safety margins needed for safe vehicle operation.[7]

In general, this study stated that it provided evidence of problems associated with the division of a driver's attention during cell phone use. This study states that these problems were exacerbated by adverse driving conditions (e.g., wet pavement). The attention needed by drivers to control their vehicles in a safe manner is compromised by secondary tasks that require their cognitive engagement (i.e., cell phone use).[7]

3. Actual Road

These studies were closer to "real world" driving environments than the previously mentioned studies. This type of study increased the realism of the driving experience for the study subjects. A limitation of this type of study is the sacrifice of control of several experimental variables (e.g., traffic distraction timing, road conditions, etc.).

<u>Study by Lamble, et al.</u>

The determination of the effects on driver performance as a result of cell phone usage was the focus of this study. Specifically, this study investigated the performance of drivers in safety critical sub-tasks. This performance involved the detection of a car ahead decelerating while doing cell phone related tasks. Two tasks related to cell phone use in this study included the use of a numbered keypad (visual divided attention) and a memory and addition task (non-visual attention). This second task was used to simulate the non-visual cognitive load associated with phone conversations.[9]

Methodology

Nineteen participants and two passenger vehicles were used to collect driver performance data. A repeated measure, Analysis of Variance, was used to analyze the braking reaction time data. The braking reaction time was defined as the time between the start of the lead vehicle's deceleration and the subject's brake response, measured by the initial depression of the brake pedal.[9]

The driver's use of controls, speed, and between-vehicle separation were measured. Cameras were used to monitor the road scene in front of the car, and the driver's face, eyes and hand movements on the console. Experimenters were seated in the passenger seats. The experimenter in the rear passenger seat provided the cognitive information needed for the memory task while the other experimenter was responsible for attaining the correct headway and speed prior to beginning each trial and engaging the cruise control to maintain the speed.[9]

Conditions or situations tested during this study were a control task, a phone-dialing task, and a cognitive task. The data collection involved testing in blocks of ten trials of the same condition. The three blocks were repeated a total of three times, always starting with a control task, resulting in thirty trials for each of the three conditions.[9]

For the dialing task, the driver, while controlling the vehicle, entered integers given by the second experimenter into a keypad mounted on the dashboard, just to the right of the steering wheel. In the cognitive task, while their vehicle was still following the lead vehicle, the driver was to add the last two integers called out by the experimenter. The subject was instructed to brake as soon as they noticed the lead vehicle decelerating in each trial.[9]

Results

This study indicated an average increase of 0.48 seconds in brake reaction time **during** the phone dialing tasks and 0.50 seconds **during** the cognitive tasks. This increase in reaction time connects with a closing of headway and a decrease in the margin of safety between vehicles. Lamble states that this delay in brake activation is three times **greater** than reaction deterioration found in another study for drivers under the influence of alcohol.[9]

Furthermore, these study results represent optimum performance of alerted drivers in a dual task scenario (e.g., driving while using a cell phone). The subjects of this study were instructed to keep their foot positioned above the brake pedal. The results in this study do not include normal motor response of moving the foot from the accelerator to the brake pedal (approximately 0.2 seconds). Therefore an additional delay should be expected for non-experimental situations due to a possible reduction in alertness.[8 11]

<u>Study by Tijerina, et al.</u>

Drivers of heavy vehicles may differ from the general driving public in relation to their driving experience and training. This study involved professional heavy-vehicle drivers under actual driving conditions. Objectives of this study examined the workload imposed by a text messaging system and cellular phone use on drivers of heavy vehicle under various actual driving conditions.[16]

Methodology

All sixteen drivers in this study had their commercial driver's license and between six and thirty-five years of experience (average experience was 21.6 years) driving truck and long trailer combinations. Each driver had no more than three moving violations and/or one "at fault" accident within the three years preceding the study. The test subjects had no Driving Under the Influence violations within three years preceding the study.[16]

The vehicle used in the study was instrumented to monitor, for instance:

- Lane position;
- Speed;
- Steering;
- Accelerator pedal angle.

Furthermore, video cameras were used to capture data on the driver's visual allocation and the road scene ahead of the vehicle. A time stamp was provided for all the data collected during the study.[16]

Text messages were presented to the drivers by a ride-along observer. Additionally, the ASPEN voice answering system was used during the experiments. Prerecorded questions were presented to the driver with this system, which also recorded the driver's verbal response.[16]

The test route for the study included:

- Dark versus light lighting types;
- Divided versus undivided road types;
- High versus low traffic density types.

This study required the vehicles to travel along a prescribed route with the on-board experimenter present. The drivers were to respond to various cognitive tasks while the vehicle traveled along the prescribed route.[16]

The experimental design and analysis conducted separate analyses for:

- Visual task data related to the text messages;
- Manual task data related to the task of cell phone dialing ;
- Cognitive task data related to responding orally to set questions.

Each analysis used a four factor (task, lighting, road type and traffic) coupled with subjects Analysis of Variance. Log transform was used to stabilize variance and normalize the data prior to analysis.[16]

The dependent indicators were analyzed in separate univariate Analysis of Variance. The dependent indicators for this analysis were the visual allocation indicators, steering and accelerator pedal measures, and speed and lane position variations.[16]

Results

Data for visual allocation indicators analyzed for the Cognitive Task indicated that a non-visual task, such as voice communications, impact the driver's visual allocations. For instance, the time spent mirror sampling dropped from 0.124 seconds to 0.047 seconds and 0.039 seconds when biographical and arithmetic dialogues were presented to the drivers. This reduction in mirror sampling is linked to a reduction in the heavy vehicle driver's situational awareness.[16]

The data indicated degradation for control of lane position with the response to high attention tasks conducted in the cab (e.g., reading of and responding to text messages). The greatest variability in lane keeping was associated with the reading of two and four lines and ten digit phone number messages. The test vehicles were driven beyond the lane boundaries during eighteen percent of the trials that involved reading tasks.[16]

Overall, the drivers in this study demonstrated required speed control; however, their ability to maintain lane position was reduced. The researchers suggested from this study that devices requiring the cognitive attention of drivers in the cabs of heavy vehicles increase the mental workload for experienced drivers and potentially increase the crash hazard exposure, if these devices are used by the driver while vehicle is being driven.[16]

4. Epidemiological

Study by Redelmeier and Tibshirani

A study conducted by Redelmeier, M.D., and Tibshirani, Ph.D. was designed to determine whether using a mobile phone while driving increases the risk of a motor vehicle collision. It used an epidemiological approach to determine potential association between the use of a cell phone and vehicle collision risk in real-world environments.[13]

Methodology

The case-crossover design was used in this study. This study involved 699 drivers that had cell phones and were in motor vehicle accidents that resulted in substantial property damage without personal injury. Study participants cell phone calls were analyzed through the use of detailed billing records. Each participant's cell phone calls on the day of the collision and during the previous week were analyzed.[13]

Each person functioned as their own control, such that confounding of data due to age, sex, visual acuity, training, personality, driving record, and other fixed characteristics was eliminated. The pair-matched analytic approach was used to contrast a time period on the day of the accident with a comparable period on a day preceding the accident. This contrast allowed the case-crossover analysis to identify an increase in risk if there were more cell phone calls by the driver immediately before the vehicle accident than would be expected solely as a result of chance.[13]

The sample size was calculated to provide an 80% chance of detecting a doubling or halving of collision rates. Relative risks were estimated with methods of matched-pairs studies on the basis of exact binomial tests and conditional logistic-regression analyses. Modifications of the relative risks were assessed by comparing different subgroups, with particular attention to the pre-specified contrast between hand-held cellular telephones and models that leave the hands free. All P values were two-tailed, and all relative risks were computed with 95% confidence intervals.[13]

Results

Results of this study indicated that there was a four-fold increase in risk associated with the use of a cell phone while driving as compared to not using a cell phone. The authors indicate that this relative risk of vehicle collisions is similar to the hazard associated with driving with a blood alcohol level at the legal limit. Additionally, the study suggested that the use of hands-free design was not safer than the use of hand-held design cell phones.[13]

Study by Violanti and Marshall

Another epidemiological study, by Violanti and Marshall, examined the statistical association between traffic accidents and cell phone use. The hypothesis of this study was that increased use of cell phones while driving was associated with an increased probability of traffic accidents.[17]

Methodology

The method used for this epidemiological research involved a case-control design. In this design, individuals with accidents were considered "cases" and those without accidents were considered the study's "controls." To obtain information on driving behavior not available through Department of Motor Vehicle records, it was necessary to conduct a mail survey with each case and control subject.[17]

The "case" group consisted of a random sample of 100 New York State resident drivers who had a record of an accident in 1992-1993. A random sample of 100 New York resident drivers, accident-free within the previous ten years before the study, composed the "control" group.[17]

From a review of the monthly cell phone billings, cell phone use was measured by the number of minutes per month that each driver actually talked on the phone in the vehicle. Descriptive and multivariate analyses were used to test the study's hypothesis.

Descriptive analysis results suggested that a higher percentage of the "case" group subjects averaged more minutes per month talking on the cell phone and had a higher average of personal, business and intense business cell phone calls than "control" group.

As the amount of time spent talking on a cell phone increased, the chances of a vehicle accident also increased, was used as the hypothesis for the multivariate analysis. The statistically non-significant variables were eliminated and only variables that might potentially confound the association between cellular phone use time and vehicle accidents were retained in the final logistic regression model.

Results

The descriptive analysis suggested that drivers who had accidents (case group) spent approximately double the time per month talking on their cell phones as drivers without accidents (control group). Additionally, the case subjects were involved more in business and intense business calls.

The Multivariate analysis indicated modest evidence that involvement in cell phone conversations by the driver was associated with increased odds of having a vehicle accident. Moreover, males who used a cell phone more than 50 minutes per month had a significant increase in odds of a vehicle accident. Subjects with 26-40 years of driving experience had the greatest chance of having an accident due to cellular phone use time.

Examples of limitations of this type of study include:

- Lack of direct evidence that persons were using a cellular phone at the time of the accident;
- Potential sources of bias (i.e., no response to questionnaire);
- No admittance to cell phone use at time of accident.

The researchers for this study state that their findings suggest a statistical association between cell phone use while driving and accidents. They also state that the amount of time spent in cell phone conversations while driving appears to be associated with increased odds of vehicular accidents.

Reference List

1. Alm, H. and Nilsson, L. (1995). *The effects of a mobile telephone task on driver behavior in a car following situation.* Accident Analysis and Prevention, Volume 27 (5), pages 707-715.

2. Bailey, Robert W. (1982) *Perception, Problem Solving, and Decision Making*. Human Performance Engineering, Chapter 7, Pages 107-129. Prentice Hall.

3. Brookhuis, K. A., de Vries, G., and de Ward (1991). *The Effects of Mobile Telephoning on Driving Performance.* Accident Analysis and Prevention, Volume 23, Number 4.

4. Cain, Alasdair, Burris, Mark (1999). *Investigation of the Use of Mobile Phones While Driving*, Prepared for the Center for Urban Transportation Research, College of Engineering, University of South Florida. http://www.cutr.eng.usf.edu/its/mobile_phone.htm

5. Fairclough, S. H., Ashby, M. C., Ross, & Parkes, A. M., (1991). *Effects of handsfree telephone use on driving behavior.* Proceedings of the ISTA Conference, Florence, Italy

6. Hancock, P. A., Lesch, M., Simmons, L. (2002). *The distraction effects of phone use during a crucial driving maneuver.* Accident Analysis and Prevention, Article in Press, May 8, 2002. http://ww.sciencedirect.com

7. Insurance Corporation of British Columbia Driver Distractions Research (2001). *Hands free cell phone study*. http:/www.icbc.com [January 25, 2001]

8. Johansson, G., Rumar, K., (1971) *Driver's brake reaction times*. Human Factors Volume 13, pages 23-27.

9. Lamble, D., Kauranen, T., Laakso, M., Summala, H., (1999). *Cognitive load and detection thresholds in car following situations: safety implications for using mobile (cellular) telephones while driving.* Accident Analysis & Prevention, Volume 31, pages 617-623.

10. McKnight, A. J., and McKnight, A. S., (1993). *The effect of cellular phone use upon driver attention.* Accident Analysis and Prevention, Volume 25 (3), pages 259-265.

11. Olson, P. L., Sivak, M., (1986) *Perception - response time to unexpected roadway hazards.* Human Factors, Volume 28, Pages 91-96.

12. Parkes, Andrew, Hooijmeijer, Victor (2001). *The influence of the use of mobile phones on driver situation awareness.*

13. Redelmeir, M.D., Donald A., Tibshirani, Ph.D., Robert J. (1997). *Association between Cellular-Telephone Calls and Motor Vehicle Collisions*. The New England Journal of Medicine, 336, 7, pages 453-458. http://content.nejm.org

14. Sanders, Mark S. and McCormick, Ernest J., (1987). *Human Factors in Engineering and Design*, Chapter 3, Pages 43-74, McGraw-Hill Publishing Company.

15. Strayer, David, Drews, Frank, Albert, Robert, & Johnston, William, (2003). *Cell Phone Use Can Lead to Inattention Blindness Behind the Wheel.* Journal of Experimental Psychology:Applied, March 2003.

16. Tijerina, Louis, Kiger, Steven M. et al. (1995). *Workload Assessment of In-Cab Message System and Cellular Phone Use by Heavy Vehicle Drivers on the Road*, **39** Human Factors and Ergonomics Society 39th annual Meeting, pages 117-121.

17. Violanti, J. M., and Marshall, J. R. (1996). *Cellular Phones and Traffic Accidents: An Epidemiological Approach*. Accident Analysis and Prevention, 28, 2

18. Wickens, C. D., (1992). *Engineering Psychology and Human Performance*, 2nd ed. HarperCollins Publishers, New York.