CELLULAR PHONE DISTRACTED DRIVING: A REVIEW OF THE LITERATURE AND SUMMARY OF CRASH AND DRIVER CHARACTERISTICS IN CALIFORNIA

October 2014

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RSS-14-248

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
October 2014	Final Report	

4. TITLE AND SUBTITLE
Cellular Phone Distracted Driving: A Review of the Literature and Summary of Crash and Driver Characteristics in California

5a. CONTRACT NUMBER
5b. GRANT NUMBER TR1016
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
California Department of Motor Vehicles
Research and Development Branch
P.O. Box 932382
Sacramento, CA 94232-3820

8. PERFORMING ORGANIZATION REPORT NUMBER
CAL-DMV-RSS-14-248

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
California Office of Traffic Safety
2208 Kausen Drive, Suite 300
Elk Grove, CA 95758-7115

10. SPONSOR/MONITOR'S ACRONYM(S)
OTS

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT

13. SUPPLEMENTARY NOTES email: research@dmv.ca.gov

14. ABSTRACT The present study reviews the literature on cell phone-distracted driving including the effectiveness of legislative efforts to reduce the behavior. It also reports results of descriptive analyses characterizing crashes and drivers involved in police-reported, cell phone-distracted crashes in California. Cell phone use in the U.S. is widespread and increasing. People tend to support legislative efforts to limit the use of cell phones while driving despite the fact that many continue to engage in the behavior. Empirical and observational research consistently shows a negative impact of cell phone use on driving performance and crash risk. The present study extracted data from the Statewide Integrated Traffic Records System database pertaining to crashes that occurred between 2003 and 2011 in California. These data were examined at two levels: crash and driver. Crash analyses revealed that most crashes did not involve inattention. When they did, non-cell phone inattention was more common than cell phone inattention and hand-held cell phone use was more commonly associated with crashes than hands-free. The most common primary crash factor for cell phone-related fatal/injury crashes was traveling at an unsafe speed. A larger percentage of cell phone-related fatal/injury crashes occurred during the workweek than on the weekend, and more occurred in the afternoon than in the morning or night. Driver analyses revealed that 21 to 30 year-old drivers accounted for the largest percentage of drivers involved in cell phone-related fatal/injury crashes. Males accounted for more cell phone-related fatal/injury crashes than females. Finally, drivers reported as using a cell phone at the time of fatal/injury crashes were more likely to be found at fault, and were slightly more likely to be found at fault than those using hands-free devices.

15. SUBJECT TERMS Cell phone, cellular phone, distracted driving, inattention, hand-held, hands-free, age, sex, time-of-day, part-of-week

16. SECURITY CLASSIFICATION OF: Unclassified			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Douglas P. Rickard
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified	None	44	**19b. TELEPONE NUMBER (*Include area code*)** 916-657-5768

PREFACE

This report presents the results of an exploratory investigation of drivers involved in cell phone-related crashes in the state of California. It was prepared by the California Department of Motor Vehicles Research and Development Branch and funded by the National Highway Traffic Safety Administration through a grant administered by the California Office of Traffic Safety (Grant DD 1402). The findings, opinions, and conclusions expressed herein are those of the authors and may not represent the views and policies of the California Office of Traffic Safety, the State of California, or the National Highway Traffic Safety Administration.

ACKNOWLEDGMENTS

This project was conducted under the general direction of Dr. Bayliss Camp, Research Manager II, Driver Competency and Safety Unit, and Dr. Scott Masten, Research Manager II, Alcohol/Drug Projects Unit. Sukhvir Brar, Research Program Specialist II, accumulated published literature on distracted driving, and Douglas Rickard, Associate Governmental Program Analyst, helped to create the data tables and figures and format the final report.

EXECUTIVE SUMMARY

Background

In the U.S. in 2012, 415 people were killed in crashes in which at least one driver was using a cell phone. During the same year, cell phone involved crashes were also responsible for an estimated 28,000 injuries. The present study a) reviews research studies on the consequences of cell phone use on driver performance and crash risk, b) reviews the effectiveness of state-based legislative efforts to reduce cell phone-distracted driving, and c) uses descriptive analytic techniques to characterize crashes and drivers involved in police-reported, cell phone-distracted motor vehicle crashes in California from 2003 through 2011.

Cell phone use in the U.S. is widespread and increasing. Research using observational and self-report methodology has found that people largely support legislative efforts to limit the use of cell phones while driving despite the fact that many people continue to engage in the behavior. This is troubling in light of meta-analyses of empirical investigations that consistently show a negative impact of cell phone use on driving performance and crash risk. Driving while using a cell phone has been shown to increase driver reaction time, reduce travel speed, and increase headway distance. Further, crash-risk studies have estimated that cell phone use increases the risk of crashing by roughly threefold.

Washington D.C. and 15 U.S. states/territories have banned hand-held cell phone use while driving. Texting while driving is prohibited in Washington D.C. and 46 U.S. states/territories. Research efforts to examine the effectiveness of this legislation have produced mixed results. Legislation banning the use of hand-held cell phones while driving seems to have a negligible to small positive impact on the behavior, while texting bans may, in some cases, actually lead to more dangerous “covert” texting behavior.

The present study attempts to better understand cell phone-distracted driving in California through descriptive analyses that identify characteristics of crashes, drivers, and trends across time (2003 to 2011) for crashes in which police reported inattention involved the use of a cell phone.

Method

Data pertaining to crashes that occurred between 2003 and 2011 were extracted from California's Statewide Integrated Traffic Records System (SWITRS) database. Only data from crashes involving a driver were included. These data were examined at two levels: crash and driver. At the crash level, each crash was only counted once, even if there were multiple drivers involved in the event. Further, inattention was only recorded for the most impairing cell phone type distraction reported for all drivers involved. At the driver level, each driver involved in the crash was counted once. Frequencies and percentages were tabulated to examine characteristics of crashes and drivers. At the crash level, this included total crashes per year by type of inattention, fatal/injury crashes per year by type of inattention, fatal/injury crashes where inattention was reported across all years, fatal/injury crashes by cell phone type inattention and primary crash factor across all years, fatal/injury crashes involving cell phone use across all years comparing weekdays to weekends, and fatal/injury crashes involving cell phone use across all years comparing time of day when the crash occurred. At the driver level, this included age by year, sex by year, age by sex, type of cell phone use by age group across all years, and type of cell phone use by at-fault verdict for crashes resulting in injury or fatality across all years.

Results

Crashes

- Most crashes did not involve inattention. When inattention was involved, non-cell phone-related inattention was more commonly reported than cell phone-related inattention. Hand-held cell phone use was more commonly associated with fatal/injury crashes and crashes overall than was hands-free use.

- The most commonly reported primary crash factors for cell phone-related fatal/injury crashes were 1) traveling at an unsafe speed, 2) improper turning, 3) traffic signal and signs, 4) driving under the influence alcohol and/or drugs, and 5) automobile right-of-way.

- A larger percent of cell phone-related fatal/injury crashes occurred during the workweek than on the weekend, and a larger percent occurred in the afternoon/evening hours rather than during the morning or night hours.

Drivers

- Drivers 21 to 30 years of age accounted for the largest percentage of all drivers in cell phone-related fatal/injury crashes. Drivers of other age groups, including those less than 18 years of age, accounted for a smaller percentage of cell phone-related fatal/injury crashes.
- Males were involved in more cell phone-related fatal/injury crashes than females. The proportional representation of the two sexes remained relatively stable across time, while the total number of drivers involved in fatal/injury crashes declined across time for both sexes.
- Across age groups, drivers using hand-held cell phones were involved in more fatal/injury crashes than hands-free or cell phone (other) use. However, the relative proportions of drivers using hands-free to hand-held and cell phones (other) involved in fatal/injury crashes increased slightly as a function of age.
- Drivers reported as using a cell phone at the time of a fatal/injury crash were more likely to be found at fault than drivers who were not. In addition, drivers using hand-held devices were slightly more likely to be found at fault than those using hands-free devices.

Conclusions and Future Research

Because the present analyses were descriptive in nature no strong conclusions can be drawn. It remains unknown at this time whether or not the observed differences and trends are statistically significant. Further, no information is provided regarding the pre-crash driving records of the drivers involved in these distracted driving crashes. Future research should apply more advanced statistical techniques (e.g. regression modeling) in order to identify statistically significant differences and trends and incorporate information obtained from individual driver records. Ultimately, this future work could more decisively determine if California's cell phone law is working and provide a strong basis upon which to build action-specific recommendations.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

TABLE OF CONTENTS (continued)

LIST OF FIGURES

INTRODUCTION

Background

Distracted driving is defined generally as engaging in any voluntary activity that diverts attention away from the roadway (GHSA, 2011). Researchers estimate that between 13% and 50% of all crashes involve at least one distracted driver (Ranney, Mazzae, Garrott, & Goodman, 2000; Stutts, Reinfurt, Staplin, & Rodgman, 2001; Sussman, Bishop, Madnick, & Walter, 1985**;** Wang, Knipling, & Goodman, 1996), though a recent naturalistic study found that 78% of crashes, and 65% of near-crashes, were attributable to some form of driver distraction (Dingus et al., 2006). Of all principal sources of driver distraction, cell phone use has been the focus of an increasingly large volume of work over the past 30 years (McCartt, Hellinga, & Braitman, 2006). This attention appears warranted given recent findings from the National Highway Transportation Safety Administration (NHTSA, 2014a): 3,328 people were killed and 421,000 injured in distraction-affected motor vehicle crashes in the U.S. in 2012. Of those killed, 415 (13%) were involved in crashes in which at least one driver was using a cell phone at the time of the crash. Such crashes were also responsible for an estimated 28,000 injuries.

The contention that phone use impairs driving ability is not new. Results to that effect were first published in the late 1960s (i.e., Brown, Tickner, and Simmonds, 1969), yet it wasn't until the early 2000s that law makers began to limit driver use of wireless communication devices. Although the force and effect of these regulations vary by state, the underlying goal of cell phone legislation remains arguably uniform: To reduce the prevalence of cell phone-distracted driving. The effectiveness of this legislative agenda is the subject of the current investigation, and a review of the impact of cell phone laws in various U.S. states is provided below. Additionally, this investigation sought to characterize drivers (e.g., age, sex) who were involved in police-reported, cell phone-distracted motor vehicle crashes in California from 2003 through 2011, as well as to identify trends in police-reported crashes involving cell phone use over that period. This effort is supplemented by cell phone use statistics, as well as a review of empirical studies that demonstrate the consequence of cell phone use on driver performance and crash risk.

Cell Phone Use in the United States

Subscriber and Use Statistics

Cell phone use has increased markedly over the last two decades. In 1997 there were 55 million subscriber connections in the U.S., representing a wireless penetration rate[1] of approximately 20% (CTIA, 2013). As of December 2012, the number of subscriber connections surpassed 326 million. This equates to a wireless penetration rate of 102%, meaning that many U.S. residents now have active wireless connections to more than one device (CTIA, 2013). Furthermore, cell phone subscribers in the U.S. used 2.3 trillion voice minutes and sent 2.2 trillion text messages in 2012, compared to only 62.9 billion voice minutes used and an indeterminate number of text messages sent in 1997[2] (CTIA, 2013).

Survey Findings of Driver Cell Phone Use & Attitudes

Advances in computing architecture and processing power have led to a significant influx of web-based applications designed to enhance user mobility (e.g., internet access, navigation tools). It is therefore unsurprising that cell phone use within an automobile has become commonplace. For instance, the American Automobile Association (AAA, 2008) found that over half of survey respondents had used a cell phone while driving at least once in the past 30 days, and that one in seven reported texting at least once during that same time period. In a 2010 study conducted by the Insurance Institute for Highway Safety, over 40% of those surveyed used their cell phone while driving "at least a few times per week," with 19% reporting daily use. A 2011 survey commissioned by NHTSA found that men and women were equally likely to make or accept phone calls, as well as to read/send email or text messages (Tison, Chaudhary, & Cosgrove, 2011). This study also found that nearly 80% of respondents reported answering incoming calls (with 66% continuing the conversation as they drove), and that the perceived importance of the call was the cardinal determinant of whether or not it was answered. When asked under what conditions drivers would *not* use a cell phone, 54% indicated bad weather, with 25% citing heavy traffic. Drivers under the age of 25 were found to be 2-3 times more likely than older drivers to text or use email, which is congruous with prior research in which the

[1] Calculated as the number of active wireless units divided by the U.S. and its territorial population.
[2] The number of text messages sent in 1997 is unknown because the keyboard function had yet to be fully developed and integrated into mobile devices.

majority of teen respondents (73%) reported texting while driving "at least some of the time" (Nelson, Atchley, & Little, 2009).

The 2011 NHTSA survey also asked respondents to provide their opinion on the safety implications of using a cell phone while driving. More than half indicated that cell phone use had no effect on their driving behavior, even though 90% reported that they would feel "very unsafe" if they were the passenger of a cell phone-distracted driver. Similar results were obtained in a more recent NHTSA survey (Schroeder, Meyers, & Kostyniuk, 2013), in which 50% of respondents believed that cell phone use had no impact on their driving behavior, despite the majority of those surveyed (74%) voicing support for a ban on driver use of hand-held cell phones. Furthermore, a 2013 study conducted by State Farm found that 74% of those surveyed "strongly agreed" with, "…a measure that would prohibit drivers from text messaging/e-mailing." This survey also found that nearly half (44%) of respondents were "extremely likely" to support the implementation of in-vehicle technology that would prohibit motorists from receiving and responding to texts and e-mails while driving.

Observational Studies of Driver Cell Phone Use

Surveys of self-reported distracted driving behavior, like those mentioned above, consistently demonstrate an interesting contradiction: Drivers use their cell phones even though most support legislation that would make doing so illegal. Consequently, the frequency of cell phone use may actually be under-reported in such surveys (GHSA, 2011). In order to calculate a more valid estimate, researchers need to observe motorists as they behave in the real-world. Investigations of this kind typically involve watching drivers at pre-determined intersections, noting whether they are using a cell phone, and then extrapolating those findings to generate a population parameter estimating the overall rate of driver cell phone use (NHTSA, 2010).

The National Occupant Protection Use Survey (NOPUS) provides the only nation-wide, observation-based data on driver use of electronic devices. One purpose of this survey is to determine the probability of cell phone use among motor vehicle operators. Results from the most recently published iteration (2012) estimated that at any given daylight moment in the U.S., approximately 5% of motorists (660,000 drivers) were using a hand-held cell phone (Pickrell, 2014). This figure nearly doubled to 9% (1.18 million drivers) when including the use of hands-free phones or other mobile devices (Pickrell, 2014). Consistent with prior research (e.g., Cazzulino, Burke, Muller, Arbogast, & Upperman, 2014; Lee, 2007), young drivers (16 – 24 year olds) were found to be the most likely to engage in this behavior.

The Impact of Cell Phone Use on Driver Performance

Driver Distraction as it Relates to Attention

Motor vehicle operators often divide their attention between relevant and distracting stimuli. Sources of distraction, be they visual, auditory, manual, and/or cognitive, all compete for attentional resources that are needed to perform the driving task (Collet, Guillot, & Petit, 2010a, 2010b; GHSA, 2011; Strayer, Watson, & Drews, 2011). This sharing of attention becomes problematic when considering that human operators are limited in their ability to perform multiple tasks simultaneously. According to multiple resource theory (Wickens, 1984, 2002, 2008), human operators possess separate "pools" of attentional resources that become depleted as the number of tasks (or their difficulty) increase. Furthermore, limitations in dual-task performance become more significant when separate yet concurrent tasks require the same perceptual modality (e.g., visual vs. auditory) and/or neural processing code (e.g., spatial vs. verbal).[3] Viewed from this perspective, the risk in using a cell phone while driving becomes evident; both tasks require the same perceptual modality (visual), processing code (spatial), and, in the case of hand-held phones, operator response (manual). Multiple resource theory has been validated in several experiments (e.g., Horrey & Wickens, 2003; Sarno & Wickens, 1995**;** Wickens, Dixon & Ambinder, 2006; Wickens & Seppelt, 2002), and is generally consistent with other popular models of resource-based attention (e.g., Kahneman, 1973).

Research Methodology

A number of techniques have been developed to evaluate the driving performance of cell phone-distracted motorists (e.g., surveys, simulators, observational, and field experiments). The selection of one method over another typically involves a trade-off between experimental control, and the ability to generalize the findings of a given study beyond its sample. For instance, driving simulators afford considerable control over the testing environment, though

[3] "Perceptual modality" refers to bodily organs (e.g., eyes, ears) responsible for the intake of sensory information, while "neural processing code" refers to the transduction of a physical stimulus (e.g., photonic output of a light source) into neuronal activity within various locations of the brain.

performance under such highly artificial conditions may not be representative of how one drives in the real world. Given the volume and variety of cell phone-distracted driving studies, a recounting of each is beyond the scope of this document. Instead, results from recent meta-analyses, which combine the findings of separate yet thematically similar studies, are provided below.

Meta-Analyses

Caird, Scialfa, Ho, and Smiley (2004) reviewed 84 articles published between 1969 and 2004 concerning the effects of cell phone use on driver performance. One goal of this analysis was to determine if conversing on a cell phone (either hands-free or hand-held) influenced driving behavior. This investigation found that cell phone-distracted motorists drove more slowly than cell phone-free motorists, and that the former exhibited an increase in reaction time to critical events[4] by an average of 230 milliseconds (the equivalent of 20 feet while driving 60 mph). It was also found that use of hands-free phones produced similar deficits to driver performance compared to hand-held phones.

Horrey and Wickens (2006) reviewed 23 studies published between 1991 and 2004 and concluded that use of either hands-free or hand-held cell phones increased reaction time to critical events by approximately 130 milliseconds. Significant increases in reaction time were also demonstrated when drivers engaged in phone conversation compared to more experimentally-contrived analogs (e.g., mental arithmetic, digital span task). Lane-keeping and other tracking tasks appeared to be less affected by cell phone use, and performance deficits associated with cell phone-distracted driving were roughly equivalent to those exhibited during conversation with passengers.

A review of 125 studies by McCartt, Hellinga, and Braitman (2006) found that the most common cost associated with cell phone use was slowed reaction time. No gender differences were identified, though increases in reaction time among cell-phone distracted motorists were greater for older drivers (ages 50 to 80). Results were mixed with respect to phone type; some experiments found no difference in driving performance when comparing hands-free to hand-held phones, whereas others found use of the latter to be more detrimental to speed and lane-

[4] Typically defined as any event requiring immediate action by the driver in order to avoid a crash.

maintenance. Cell phone-distracted drivers performed significantly worse when engaged in complex conversations, and when the attentional demands of the driving environment (e.g., traffic volume) were high. This review also found that motorists tend to adapt their driving behavior when using a cell phone, which typically manifests in a reduction in speed and an increase in headway distance.

Caird, Willness, Steel, and Scialfa (2008) analyzed the results of 33 cell phone-related driving studies published between 1969 and 2007. This investigation found that use of either hands-free or hand-held cell phones increased driver reaction time by approximately 250 milliseconds. Lateral control, lane-tracking, and headway distance did not appear to be as affected by cell phone use, though cell phone-distracted motorists typically drove slower than their cell phone-free counterparts. Reaction time was not moderated by conversation target (i.e., someone inside the vehicle compared to someone outside), which led the authors to conclude that talking on a cell phone incurs the same deficits to driver performance as talking to a passenger.

Common among all the meta-analyses reported above is the finding that cell phone use (either hands-free or hand-held) resulted in a significant increase in driver reaction time. Lateral control and other tracking-related tasks did not appear to be as affected, though cell phone-distracted motorists were found to drive slower and increase their headway distance more than cell phone-free motorists. In sum, these results indicate that cell phone use incurs several deficits to driving performance. The question then becomes whether these deficits represent a significant increase in the likelihood of crashing.

Cell Phone Use and Crash Risk

Methodological Issues in Estimating Crash Risk

Estimating the impact of cell phone use on crash risk is problematic for several reasons. Automobile crashes are typically multi-causal events (NHTSA, 2008), thus making it difficult to attribute the occurrence of a given crash solely to cell phone use. Furthermore, the Telecommunications Act of 1996 (Telecommunications Act of 1996, 47 U.S.C. §151) prohibits the dissemination of cell phone use data to third parties without the customer’s consent. As a result, empirical studies estimating the crash risk of distracted motorists are often left to rely on police reports to determine if cell phone use was a contributing factor. These data are historically unreliable (NSC, 2012), and without witnesses, or an admission of guilt by the distracted driver, a police officer will likely be unable to determine if cell phone use was the primary cause of a crash (McCartt, Hellinga, & Braitman, 2006). Investigations of cell phone-distracted driving must take this into account, and strive to obtain and compare appropriate measures of exposure independent of those provided by police reports (GHSA, 2011).

Crash Risk Studies

Research efforts conducted *outside* of the U.S. have been permitted to use the billing records of crash-involved drivers to verify cell phone use. For instance, two separate studies (Redelmeier & Tibshirani, 1997; McEvoy et al., 2005) found that cell phone use during the 10-minute period preceding a crash was associated with a 4-fold increase in the likelihood of crashing. No gender or age differences were identified, and crash rates were roughly equivalent when comparing use of hands-free to hand-held phones. Elvik (2011) conducted a meta-analysis of 12 studies published between 1996 and 2011. To the knowledge of the authors, this work represents the only attempt to combine the results of studies enumerating the crash risk of cell phone-distracted drivers. The investigations reviewed in this analysis employed various methodological techniques, including case-control/crossover designs, sample surveys, naturalistic observation, and induced exposure. Using the best available data, the odds ratio for cell phone-distracted drivers was 2.86, which equates roughly to a 3-fold increase in the odds of crashing compared to cell phone-free drivers. It should be noted, however, that the majority of studies included in this analysis utilized self-reported surveys and police records to determine if and when a cell phone was in use. As mentioned above, and as noted by Elvik, this is problematic given the lack of reliability inherent in these particular reporting procedures.

Under ideal circumstances researchers would have access to billing records and video-captured performance data obtained during naturalistic (i.e., real-world) driving. When analyzed in tandem, these data would serve to identify the exact moments during which a cell phone was in use, and what actions the driver was engaged in (other than cell phone use) prior to crash or near-crash involvement. The only study to date that has employed this methodology was conducted by Fitch and colleagues (2013), wherein they evaluated the crash risk of drivers resulting from use of one of three types of cell phones: hand-held, portable hands-free, or integrated hands-free. The results showed that cell phone calls accounted for 10.6% of the total drive-time of the study (8,240 hours). Inputting and sending a text message required an average of 35 seconds, and resulted in drivers removing their eyes from the roadway for approximately 23 seconds. The amount of time spent looking away from the roadway was significantly greater when inputting and sending a text message compared to all other visual-manual subtasks identified in this study (e.g., reading a text, dialing a phone number). Furthermore, it was found that *talking* on a cell phone, irrespective of type, was *not* associated with a significant increase in crash risk. However, crash risk *was* found to increase significantly as a result of the visual-manual subtasks required of hand-held cell phone use (i.e., reaching for and physically manipulating/holding the phone).

Extant Cell Phone Laws

The U.S. and its Territories

Hand-held cell phone use, and by extension, texting, has been identified as one of the most dangerous non-driving activities undertaken by motorists. Current law reflects this; as of May 2014, 12 U.S. states, Washington D.C., Puerto Rico, Guam, and the U.S. Virgin Islands have banned all drivers from using hand-held cell phones (GHSA, 2014). This law is currently considered primary enforcement in each of these localities, meaning that an officer can stop and cite a driver solely for using a hand-held cell phone. Texting while driving is currently prohibited in 43 U.S. states, Washington D.C., Puerto Rico, Guam, and the U.S. Virgin Islands, and is considered a primary enforcement offense in all but 5 states in which this legislation has been enacted (GHSA, 2014).

California

California Vehicle Code (CVC) mandates that drivers use hands-free equipment when talking on a cell phone (CVC§23123). Offenders are penalized a base fine of $20 for a first violation, and a base fine of $50 per subsequent violation.[5] Each conviction is maintained on the individual's driving record, though no negligent operator ("neg-op") points are assessed. These base fine penalties also apply to drivers found in violation of California's texting laws, which as of 2009, prohibit the use of hand-held cell phones to read, write, or send a text message, email, or other text-based communication (CVC§23123.5). Drivers under the age of 18 are prohibited from

[5] With additional fees these fines can be 2-3 times higher depending upon the locality of the infraction.

using cell phones, regardless of type, to perform any action other than contacting emergency services (CVC§23124).

As noted above, California is one of a number of states that currently prohibit drivers from using hand-held cell phones. Unfortunately, California is one of only a few states to have empirically evaluated the effectiveness of this legislation. Similar analyses have been conducted in New York, Washington D.C., North Carolina, and Michigan, the results of which are provided in greater detail below.

Studies of Cell Phone Law Effectiveness

New York

On November 1, 2001, New York's cell phone ban became the first statewide attempt to limit driver use of wireless, hand-held communication devices. The codifications therein permitted motorists to manipulate, dial, and converse on a hand-held cell phone, but required that such actions only be undertaken when the vehicle was no longer in motion (or if emergency assistance was needed). The implementation of this law followed a "phased-in" approach, whereby enforcement and monetary penalization became more stringent with time.[6]

McCartt, Braver, and Geary (2003) sought to evaluate the immediate impact of this legislation, and to that end conducted naturalistic observations of driver hand-held cell phone use[7] in four metropolitan areas in New York. Two cities in Connecticut, a state which at that time had yet to enact any cell phone restrictions, were also chosen to serve as "no-law" control locations. Three separate observations were attempted at each of the six locations, one pre-law and two post-law,[8] and the rate of cell phone use among motorists during these three periods was compared. This analysis showed that the pre-law rate of cell phone use in Connecticut was marginally higher (0.6 percentage points) compared to New York. One month following the ban, this difference more

[6] Only verbal warnings were issued to offenders by law enforcement up to a month after this legislation was implemented. From December 2000 through February 2001, fines for violating this law could be waived if the offender provided proof of purchase of hands-free equipment. Subsequent to this period, fines were no longer waived.

[7] Unless otherwise noted, cell phone "use" describes subjects observed holding the phone to their ear.

[8] Pre-law observations were made from September through October 2001. Post-law observations were made in December 2001, and again in March 2002.

than doubled (1.6 percentage points higher). Four months subsequent the ban, overall cell phone use in the New York locations had decreased by 52%.

McCartt and Geary (2004) then conducted a follow-up study on the short-term effectiveness of this legislation approximately 16 months after it was enacted. Using the same locations in both states, this investigation found that cell phone use in New York decreased from 2.3% before the ban was enacted, to 1.1% immediately following its inception. Sixteen months later, this figure rose to 2.1%. In comparison, cell phone use in Connecticut was calculated at 2.9% during pre-law observations, as well as immediately after the ban was enacted. Sixteen months later, cell phone use in Connecticut increased slightly to 3.3%. These findings indicate that the immediate benefits of the ban (i.e., reduction in cell phone use) were not sustained among the targeted population, as demonstrated by the rate of cell phone use in New York returning to near-baseline (i.e., pre-law) levels less than 2 years after it was implemented. To account for these findings, McCartt and her colleagues noted that the state of New York did not aggressively campaign for motorists to comply with this ban, nor did it consistently penalize those found in violation. As a result, any potential long-term benefit afforded by this law may have been severely limited (NHTSA, 2014b).

To address these concerns, McCartt, Hellinga, Strouse, and Farmer (2010) evaluated the long-term impact of New York's cell phone ban in April 2009. Similar to previous efforts, drivers at controlled intersections in both New York and Connecticut were observed, and the rate of hand-held cell phone use among these motorists was recorded and compared. This investigation found that the rate of cell phone use among drivers in the New York locations had reached 3.7%, which was 76% higher than the short-term, post-law use rate found by McCartt and Geary (2004). Poisson regression models were used to show that despite this overall increase, the observed rate of hand-held cell phone use among drivers in New York (3.7%) was still 24% *lower* than predicted by the models if the law had not been enacted (4.91%). In other words, hand-held cell phone use in New York increased after the ban, but at a rate much lower than predicted had the ban not been implemented.

Washington D.C.

Effective July 1, 2004, Washington D.C.'s cell phone ban prohibited all drivers from talking on hand-held cell phones. The immediate impact of this law was evaluated by McCartt, Hellinga, and Geary (2006), wherein they compared the rate of cell phone use in selected D.C. districts to comparable "no-law" control locations in both Maryland and Virginia. Pre-law observations of cell phone use were made in March 2004, and post-law observations were made the following October. Results showed that hand-held cell phone use in the D.C. locations decreased, from a pre-law rate of 6.1%, to 3.5% four months after the ban was enacted. The rate of cell phone use among drivers in the control locations varied during this epoch, decreasing marginally in Maryland (6.3% to 5.7%) while increasing significantly in Virginia (4.7% to 6.2%). Relative to observations made in Maryland and Virginia, hand-held cell phone use among D.C. motorists in the targeted locations decreased by approximately 50% four months after the ban was implemented.

In 2007, McCartt and Hellinga analyzed the short-term effectiveness of Washington D.C.'s cell phone ban 16 months after it was implemented. Following the protocol of McCartt, Hellinga, and Geary (2006), observations were made of drivers in D.C., Maryland, and Virginia, and the rate of hand-held cell phone use among these motorists was compared. This investigation found that relative to pre-law measures, the rate of cell phone use increased in both Maryland (6.3% to 8%) and Virginia (4.7% to 6.5%). After a marked decrease immediately following the ban, driver cell phone use in D.C. also increased 16 months later (3.5% to 4.0%) though this figure remained significantly lower than pre-law measures (6.1%). In an effort to evaluate the sustainability of this result, McCartt et al. (2010) observed driver hand-held cell phone use in D.C., Maryland, and Virginia in April – June 2009. Poisson regression models were used to predict the long-term use rate in absence of the law (7.41%), which, as this analysis revealed, was 43% *higher* than the observed use rate (4.22%). In other words, similar to New York, overall hand-held cell phone use among D.C. motorists increased after the ban was implemented (relative to immediate and short-term, post-law figures), but at a much lower rate than predicted had the ban not been enacted.

North Carolina

On December 1, 2006, the state of North Carolina enacted legislation prohibiting the use of cell phones by drivers under the age of 18. These restrictions were added to the state's graduated driver licensing program in an effort to heighten public awareness and parental oversight. To assess the impact of this law, Foss, Goodwin, McCartt, and Hellinga (2009) observed hand-held cell phone use among teen drivers at 25 high schools in North Carolina. Observations were also made at eight high schools in South Carolina, an adjoining state which at that time had yet to enact such restrictions. Data were collected at each location during the 2 months preceding the ban, and at 5 months following its inception. Cell phone use among the targeted populations was compared, and telephone interviews were conducted to evaluate public awareness of the new legislation. Surprisingly, cell phone use among teen drivers in both North and South Carolina increased marginally 5 months after the ban was enacted (by 0.8% and 0.1% respectively). The rate of increase in post-law cell phone use among teen drivers in North Carolina was 11% higher relative to the increase in South Carolina, though this difference was not statistically significant.[9] Even more surprising was that awareness of the law by parents of teen drivers in North Carolina *decreased* over time, from 45% prior to its implementation, to 39% 5 months later.

Goodwin, O'Brien, and Foss (2012) then conducted a follow-up study of the longer-term effect of North Carolina's cell phone ban 2 years after it was enacted. This investigation utilized the same experimental protocol as Foss et al. (2009), whereby observations of hand-held cell phone use by teen drivers were made at a number of high schools in both North and South Carolina. Analyses showed that overall cell phone use in North Carolina decreased from 11% before the law was enacted, to 9.7% 2 years following its inception. Use of cell phones by teen drivers in South Carolina also decreased during this period, from a pre-law rate of 14.5% to 12.1% 2 years later. The difference in post-law cell phone use between the two states was not statistically significant, indicating that North Carolina's cell phone legislation was unsuccessful in effectively reducing the rate of cell phone use among the targeted population. Moreover, additional analyses revealed a 39% *increase* in the likelihood that teen drivers in North Carolina were observed physically manipulating their phone.[10] This finding, coupled with the overall decrease in phone *use*, led the authors to postulate that teen drivers in North Carolina began texting more frequently as their propensity to converse on their phone decreased.

Laws prohibiting drivers from using hand-held cell phones have produced varied results**.** In New York and Washington D.C., long-term use rates were higher compared to immediate and short-term, post-law figures, but they remained significantly lower than expected had these prohibitions not been enacted. North Carolina's ban marginally reduced cell phone use among teen drivers, but at the (postulated) expense of increased texting. Of these results, the findings of

[9] After adjusting for differences in vehicle type, driver sex, and passenger presence.
[10] "Physically manipulate" refers to observations made of drivers interacting with their cell phone, but *not* placing it to their ear.

the North Carolina study are arguably the most concerning, given the limitations of human information processing noted earlier in this document. Most U.S. states currently prohibit texting while driving, though few have attempted to evaluate the efficacy of these prohibitions. One such effort was recently conducted in Michigan, the results from which are provided below.

Michigan (texting)

On July 1, 2010 the state of Michigan implemented a statewide ban prohibiting drivers from using cellular phones to read, write, or send text-based communications. This law was evaluated in a study by Ehsani et al. (2014), which examined the interaction between driver age[11] and three levels of injury[12] resulting from crashes that occurred both before and after the ban was implemented (2005 through 2012). Time series analyses of crash rates for each age group were conducted after adjusting for state gasoline prices and unemployment level, as well as the crash rate of a comparison population (65 to 99 year olds) for which this law was presumed to have little impact. Driver licensing and crash data used in these analyses were obtained from the University of Michigan Transportation Research Institute (UMTRI).

Investigators predicted that Michigan's texting ban would significantly reduce the frequency of all injury types for drivers aged 16 to 50. Unfortunately, these predictions were not supported by the data; in fact, results indicated small but significant *increases* in both crash trends and rates for fatal/disabling and non-disabling injury crashes. Coupled with a decrease in the least severe crash type over that period (i.e., possible injury/property damage only), these findings suggest, as do the authors, that drivers began texting in such a way as to avoid detection by law enforcement. Referred to in the literature as "concealed" or "covert" texting (Gilbert et al., 2010), this behavior is considered riskier than "normal" texting in that it typically involves holding the phone much lower below the line-of-sight of outside observers, often in the driver's lap, the center console, or the passenger's seat (Farris, 2011; Gauld, Lewis, & White, 2013, 2014;). Manipulating the phone in this way effectively forces the driver to look away from the road at eccentricities much greater than would be required if the phone were placed on the steering wheel or dashboard. Driving in this manner – without persistent visual feedback from the roadway – is exceedingly dangerous (Zwahlen, Adams, & DeBald, 1988), as was demonstrated in an earlier simulator study conducted by Hildreth, Beusmans, Boer, and Royden

[11] 16, 17, 18, 19, 20-24, and 25-50 years.
[12] Fatal/disabling injury; non-disabling injury; possible injury/property damage only.

(2000). This investigation examined driver behavior in the absence of visual feedback, and found that baseline steering performance was maintained for approximately 4 seconds when motorists were prevented from viewing the roadway. Performance degraded significantly, however, when this interval was exceeded. These findings are alarming, especially when considered jointly with the results of Fitch et al. (2013) which demonstrated that drivers removed their eyes from the roadway for an average of 23 seconds when attempting to input and send a text message.

California

California's cell phone ban went into effect on July 1, 2008, and its impact on traffic safety has been evaluated using a variety of data. For instance, in 2009 the Highway Loss Data Institute (HLDI) compared collision claim frequencies in California to adjacent control states[13] both before and after California's ban went into effect (2006 -2009). If the ban was successful in reducing cell phone-distracted driving, it would be reasonable to expect the frequency of collision claims in California to be lower after the ban was implemented, and for the post-law trend in collision claims to decline more sharply in California compared to control states. Regression analyses indicated, however, that the trend in claim frequency over the 1-year, post-law period in California was similar to control states, and that no significant change in the frequency of collision clams was exhibited in California when compared to pre-law levels (Figure 1).

[13] Arizona, Nevada, and Oregon.

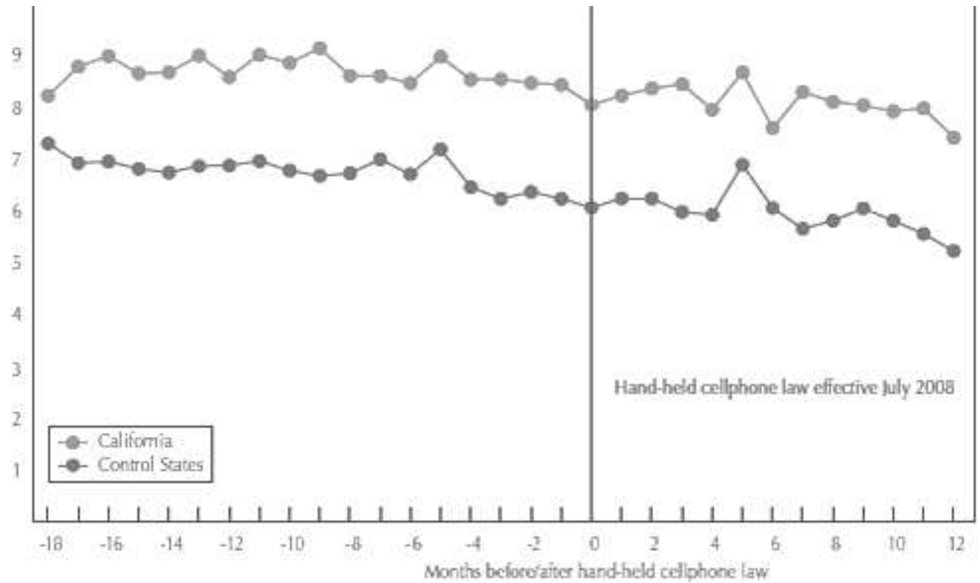


Figure 1. Monthly collision claim frequencies per 100 insured vehicles pre/post hand-held cell phone law (adapted with permission from HLDI, 2009).[14]

The Highway Loss Data Institute (2010) then evaluated California's texting ban by comparing collision claim frequencies in California to those in adjacent control states[15] both before and after the law was enacted in January 2009. The reasoning inherent in this analysis was the same as that of HLDI's earlier evaluation of California's cell phone ban – that success of this prohibition would be demonstrated by both a reduction in post-ban collision claims in California (relative to pre-law figures), and the collision claim trend in California declining more sharply after the ban compared to control states. Unfortunately, regression analyses again failed to demonstrate a significant decrease in crash claims in California after the ban was implemented (Figure 2).

[14] These figures represent only models that were 10 years old or younger; collision coverage is not mandatory, though most lenders require collision coverage on new models.
[15] Arizona, Nevada, and Oregon.

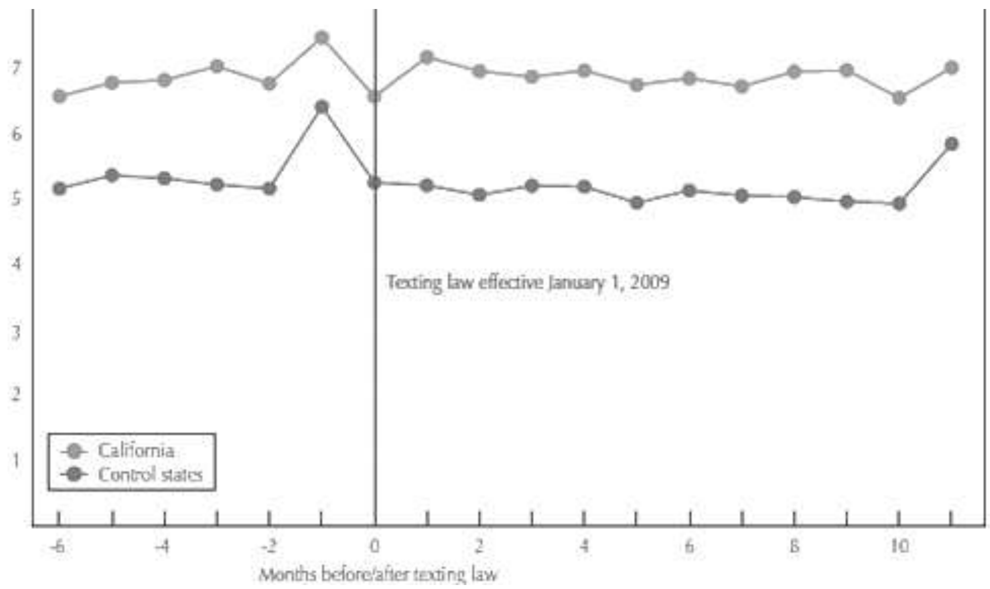


Figure 2. Monthly collision claim frequencies per 100 insured vehicles pre/post texting law (adapted with permission from HLDI, 2010).[16]

In fact, additional analyses revealed that California's texting ban was associated with a significant *increase* in crash claims in California when compared singly to Oregon and Nevada.[17] These findings led the authors to suggest that California's texting ban may have had the unintended consequence of encouraging covert texting, thus bolstering the results of both the North Carolina and Michigan studies. Notable limitations in both HLDI studies should be considered, however, before such conclusions are drawn. For instance, these evaluations utilized crash claim frequencies to characterize the traffic safety impact of both laws. In doing so, one assumes that changes in claim frequency are (1) a valid indictor of the bans' effectiveness, and (2) directly attributable to the implementation of the bans rather than to some uncontrolled variable (e.g., vehicle miles traveled, U.S./state economic factors, weather). The inclusion of adjacent control states helps to account for some of this variance, but the inherent quasi-experimental design of these investigations precludes causal assertions otherwise afforded by rigorous laboratory investigation.[18]

[16] These figures represent only models that were 10 years old or younger; collision coverage is not mandatory, though most lenders require collision coverage on new models.
[17] Similar results (i.e., a significant increase in post-ban crash claims) were found in other states with texting prohibitions (e.g., Louisiana and Minnesota) when they were compared to adjacent, no-law control states.
[18] In fairness, evaluations of the impact of traffic safety legislation cannot be conducted in the laboratory. As such, studies of this kind are naturally limited in their ability to control for confounding variables.

As noted above, both HLDI studies were limited in that they used crash claim frequencies to characterize the effectiveness of California's cell phone and texting bans. These data are in no way specific to distraction-affected crashes, and therefore may not represent the most appropriate metric by which to evaluate these laws. Some investigations have, instead, utilized cell phone-distracted crash data to estimate the impact of cell phone prohibitions. One such effort was recently conducted by the Safe Transportation Research and Education Center (SafeTREC) at the University of California, Berkeley, wherein statewide traffic fatality and injury counts were tabulated in 6-month increments from January 2005 through December 2010 (Ragland, 2012). Descriptive analyses of fatalities and injuries resulting from crashes involving distracted driving, including cell phone use, compared the total counts of the fatalities and injuries for the 2-year periods before and after the ban.[19] A marked post-ban decrease in the total number of fatalities/ injuries resulting from crashes where use of both hand-held (47%/50%) and hands-free phones (48.5%/23.6%) was reported. Furthermore, these descriptive analyses suggested that the ban seemed to have saved 70-80 lives, and prevented approximately 5,000 injuries, in the 2 years following its inception. Unfortunately, no mention (or cited reference) as to how these particular figures were derived was provided.

These findings were used to suggest that California's cell phone legislation had, "…a positive impact on reducing traffic fatalities and injuries" (OTS, 2012). However, the reader should be cautioned that several plausible alternative explanations could account for the reported positive impact. For example, simply calculating the percent change in the total number of fatalities/injuries resulting from crashes involving cell phone use pre and post-ban fails to consider that the total vehicle miles traveled in California decreased by 3.5% in 2008 compared to 2007, the single largest statewide decline since 1974 (Traffic Counts, 2014). In addition, inspection of California's traffic census data also revealed that annual traffic volume decreased each year from 2008 through 2011.[20]

Conflicting results regarding driver cell phone use, the crash risk resulting therefrom, and the efficacy of legislation aimed at reducing both, are common within the distracted driving literature. In fact, two recent studies on the effectiveness of California's cell phone ban (Burger,

[19] Pre-law period: July 2006 through June 2008; post-law period: July 2008 through June 2010.
[20] 2008-2009: -0.6%; 2009-2010: -0.2%; 2010-2011: -1.1% (data from 2010 through 2011 are based on the Traffic Data Branch's Estimated Monthly Vehicle Miles of Travel Report published by the California Department of Transportation).

Kaffine, and Yu, 2014; Stewart, 2014) reached vastly different conclusions despite using similar analytical techniques on the same kind of data.[21] Thus, rather than attempting to characterize California's cell phone and texting laws as either "successful" or "unsuccessful", researchers should be tasked more with identifying those who violate these prohibitions, thus allowing for the implementation of interventions targeted specifically at those individuals.

The Present Study

The present study attempts to better understand cell phone-distracted driving in California through descriptive analyses that identify characteristics of crashes, drivers, and trends across time (2003 to 2011) for crashes in which police reported inattention involved the use of a cell phone.

[21] Both used variants of regression analysis to estimate the impact California's cell phone ban on traffic crashes. The former found no reduction in post-ban crashes associated with the law, whereas the latter found a 43% decrease in crash likelihood.

METHOD

The California Highway Patrol maintains the Statewide Integrated Traffic Records System (SWITRS). This database contains information gathered at the scenes of crashes that occurred within the state of California. The database contains information pertaining to crash characteristics including the presence and type of driver inattention, and driver demographic information. The present study utilized this database, extracting crash and driver data pertaining to crashes that occurred between 2003 and 2011.

Types of inattention were categorized as “cell phone hand-held”, “cell phone hands-free”, “other inattention”, and “cell phone (other)”. The category “cell phone (other)” exists because, in 2003, a new coding procedure was adopted by the California Highway Patrol. The new codes distinguished between “cell phone hand-held” and “cell phone hands-free”; however, for some time following adoption of the new codes, the old code, which did not distinguish between “cell phone hand-held” and “cell phone hands-free”, was still in limited circulation. If this older code was used to report a crash, cell phone involvement may have been recorded more generally as “cell phone (other)”.

Because the present study focused specifically on distracted driving, data were only extracted if the crash involved a driver and the vehicle type was not a bicycle or pedestrian. Data were examined at two levels: Crash and driver. At the crash level, each crash was only counted once, even if there were multiple drivers involved in the event. Further, inattention was only recorded for the most impairing cell phone type distraction reported for all drivers involved. Hand-held cell phone use was considered most impairing followed, in descending order, by hands-free cell phone use, other cell phone use, other inattention, and no inattention reported. Thus, if a crash occurred that involved two drivers where one driver was using a hand-held cell phone and the other driver was using a hands-free cell phone, only the hand-held cell phone use would be represented at the crash level. However, at the driver level, both types of distraction would be represented. At the driver level, each driver involved in the crash was counted once. Thus, at the driver level each crash could involve more than one driver.

Frequencies were tabulated to examine characteristics of crashes and drivers involved in crash events where police reports indicated inattention was involved. At the crash level, the following frequencies/percentages were tabulated:

- Total crashes per year by type of inattention,
- Fatal/injury crashes per year by type of inattention,
- Fatal/injury crashes where inattention was reported across all years,
- Fatal/injury crashes by cell phone type inattention and primary crash factor across all years,
- Fatal/injury crashes involving cell phone use across all years comparing weekdays to weekends, and
- Fatal/injury crashes involving cell phone use across all years comparing time of day when the crash occurred.

At the driver level, results are presented only for fatal/injury crashes because the distributions of fatal/injury crashes were nearly identical to those that included total police reported crashes. For drivers involved in fatal/injury crashes where cell phone use was reported, the following frequencies/percentages were tabulated:

- Age by year,
- Sex by year,
- Age by sex,
- Type of cell phone use by age across all years, and
- Type of cell phone use by at-fault verdict across all years.

RESULTS

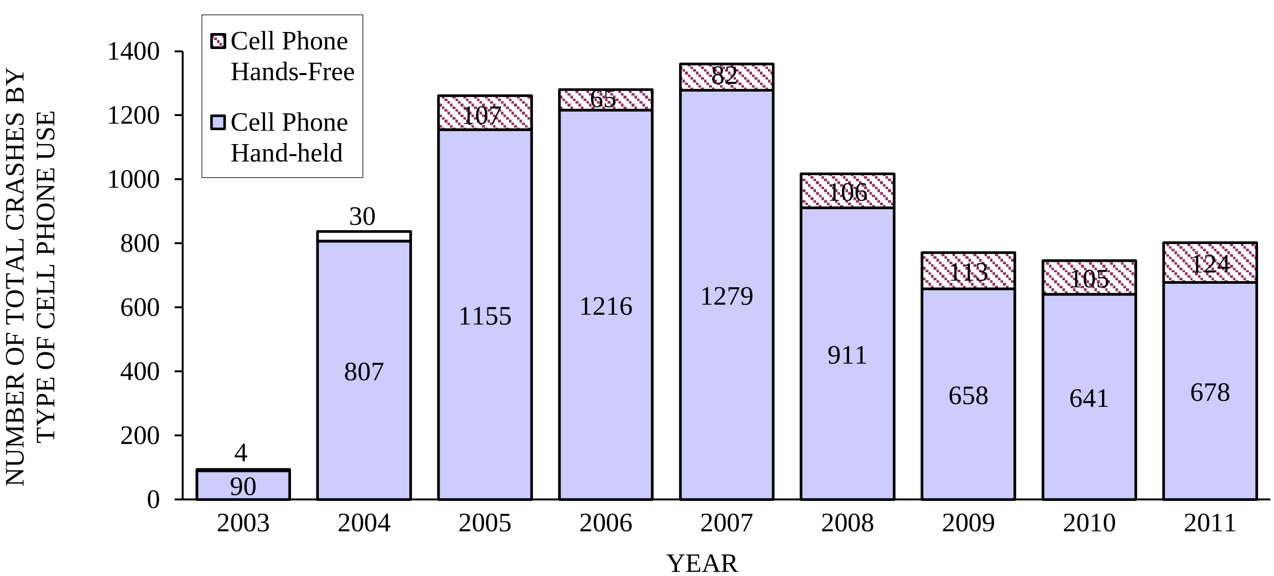
Crashes

Tables 1 through 3 and Figures 3 through 8 display descriptive data depicting characteristics of inattention-related crashes. Table 1 shows percentages of total crashes for each year by type of inattention involved. Figure 3 further narrows these comparisons by focusing only on hand-held vs. hands-free cell phone use. The figure also includes total crashes involving cell phone use of each type, superimposed over the color-coded bars. As shown in Table 1, it is noteworthy that, across time, the involvement of hands-free cell phone use was negligible (rounding to 0%), and the involvement of hand-held cell phone use was small (ranging from 0.02% to 0.26%). Involvement of other forms of inattention was higher (ranging from 5.66% to 7.96%). However, for the vast majority of crashes (91.80% to 94.14%), no form of inattention was reported. This can also be seen in Figure 3. The bottom bar of the figure shows that, across time, 0.18% to 0.29% of total crashes involved cell phone-related inattention. Of these cell phone-related crashes, hand-held cell phone use was considerably more frequent than hands-free cell phone use. When examining the total number of crashes involving cell phone use in Figure 3, it is interesting that they appear to drop off in 2008.

Table 1

Percent of Total Crashes by Type of Inattention from 2003 through 2011

INATTENTION		2003	2004	2005	2006	2007	2008	2009	2010	2011
CELL PHONE HAND-HELD	%	0.02	0.15	0.22	0.24	0.26	0.20	0.16	0.15	0.17
CELL PHONE HANDS-FREE	%	0.00	0.01	0.02	0.01	0.02	0.02	0.03	0.03	0.03
CELL PHONE (OTHER)	%	0.23	0.06	0.03	0.02	0.01	0.01	0.00	0.00	0.00
OTHER INATTENTION	%	7.96	6.84	6.97	6.59	6.30	6.12	6.07	5.72	5.66
NO INATTENTION REPORTED	%	91.80	92.95	92.76	93.15	93.41	93.65	93.75	94.09	94.14



% of total crashes	0.25%	0.22%	0.27%	0.27%	0.29%	0.23%	0.19%	0.18%	0.20%

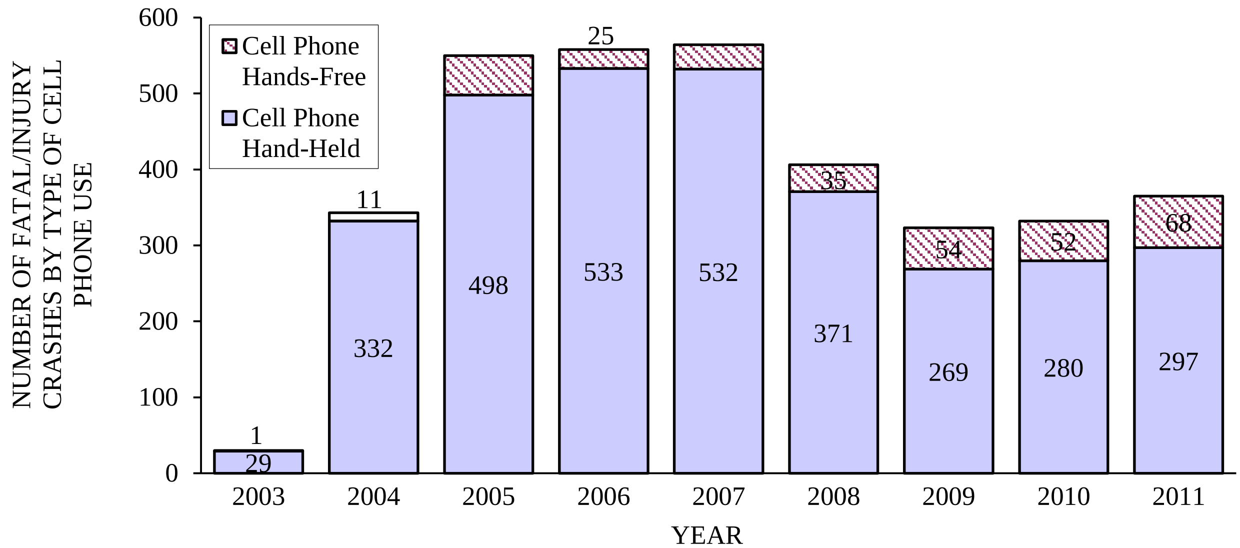
Figure 3. Total Crashes Involving Cell Phone Use from 2003 through 2011.

Results were similar when crashes that resulted in fatality or injury (fatal/injury) were examined in isolation. Table 2 and Figure 4 apply the same layout as Table 1 and Figure 3, but their data only correspond to fatal/injury crashes. As shown in Table 2, involvement of hands-free cell phone use was negligible, again rounding to 0%, and involvement of hand-held cell phone use was again quite small (ranging from 0.01% to 0.28%). Involvement of other forms of inattention was slightly higher (ranging from 6.37% to 8.76%) and, for the vast majority of crashes (90.95% to 93.40%), no form of inattention was reported. This is also reflected in Figure 4. The bottom bar of Figure 4 shows that, across time, 0.20% to 0.31% of fatal/injury crashes involved cell phone-related inattention. Similar to Figure 3, the total number of fatal/injury crashes involving cell phone use in Figure 4 appear to drop off, beginning in 2008.

Table 2

Percent Fatal/Injury Crashes by Type of Inattention from 2003 through 2011

INATTENTION		2003	2004	2005	2006	2007	2008	2009	2010	2011
CELL PHONE HAND-HELD	%	0.01	0.16	0.25	0.28	0.28	0.22	0.16	0.17	0.19
CELL PHONE HANDS-FREE	%	0.00	0.01	0.03	0.01	0.02	0.02	0.03	0.03	0.04
CELL PHONE (OTHER)	%	0.27	0.07	0.03	0.01	0.01	0.00	0.00	0.00	0.00
OTHER INATTENTION	%	8.76	7.59	7.76	7.44	7.00	6.79	6.82	6.57	6.37
NO INATTENTION REPORTED	%	90.95	92.17	91.94	92.26	92.68	92.97	92.98	93.23	93.40



% of total fatal /injury crashes	0.29%	0.23%	0.30%	0.30%	0.31%	0.24%	0.20%	0.21%	0.23%

Figure 4. Fatal/Injury Crashes Involving Cell Phone Use from 2003 through 2011.

Of these cell phone-related fatal/injury crashes, hand-held cell phone use was more frequently noted than hands-free cell phone use. Table 3 and Figure 5 depict this information, collapsing across years. Again, the pattern is similar. No form of inattention was noted for the majority of fatal/injury crashes (96.55%). When cell phones were involved, hand-held cell phone use was noted more frequently than hands-free cell phone use. By and large, these observations are consistent with Fitch et al. (2013) who found that talking on a cell phone alone was not associated with increased crash risk. Rather, crash risk increased for hand-held cell phone use, presumably due to the visual-manual subtasks of reaching for and manipulating the phone.

Table 3

Fatal/Injury Crashes where Inattention was Reported from 2003 through 2011

INATTENTION	*N*	%
TOTAL	124742	100.00
CELL PHONE HAND-HELD	3141	2.52
CELL PHONE HANDS-FREE	330	0.26
CELL PHONE (OTHER)	830	0.67
OTHER INATTENTION	120441	96.55

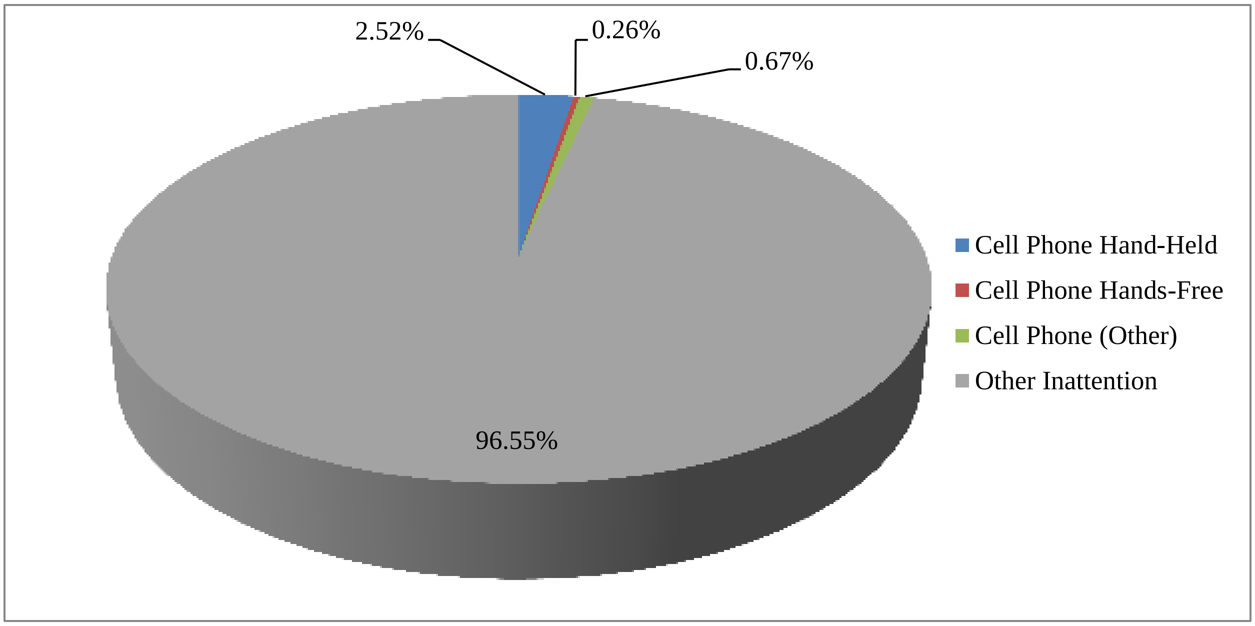


Figure 5. Percent of Fatal/Injury Crashes where Inattention was Reported from 2003 through 2011.

Figure 6 shows counts of fatal/injury crashes where cell phone use was involved by type of cell phone inattention for each primary crash factor from 2003 through 2011. The most common primary crash factor was traveling at an unsafe speed. This was followed by improper turning, traffic signals and signs violation, driving under the influence of alcohol or drugs, and automobile right-of-way violation. Other crash factors (e.g., impeding traffic, following too close, falling asleep) were categorized as "other" because their total counts were very small or were not represented at all. For each of the top five factors, the relative proportions of each type of cell phone use involved were similar to Tables 1 and 2 and Figures 3 and 4 in that hand-held cell phone use was dominant, followed by cell phone (other) and, lastly, hands-free cell phone use.

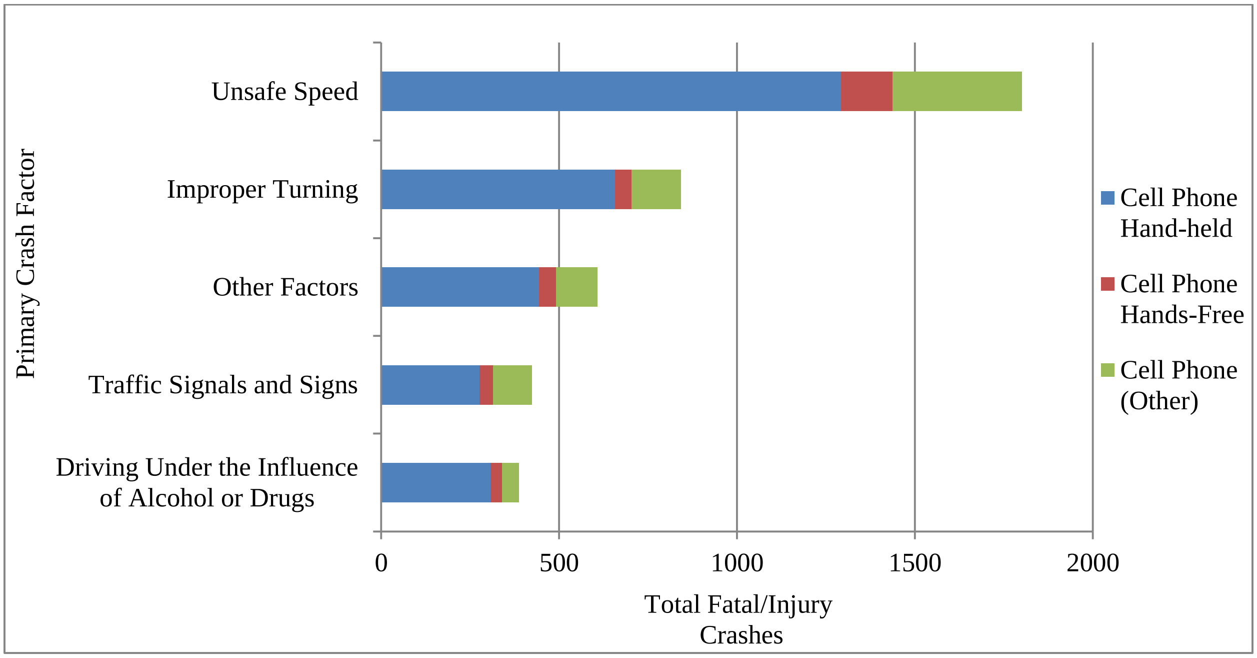


Figure 6. Fatal/Injury Crashes by Type of Cell Phone Use and Primary Crash Factor from 2003 through 2011.

Crash characteristics were also examined for fatal/injury crashes involving cell phone-related inattention by part-of-the-week and time-of-day. As depicted in Figure 7, cell phone inattention while driving was a factor in more fatal/injury crashes during the work week (Monday through Friday) than on the weekend (Saturday and Sunday). Fatal/injury crashes involving cell phones were categorized according to the time of day they occurred. Crashes that occurred between 5:00AM and 12:59PM were categorized as "Morning" crashes, those that occurred between 1:00PM and 8:59PM were categorized as "Afternoon/evening" crashes, and those that occurred between 9:00PM and 4:59AM were categorized as "Night" crashes. Figure 8 shows that the largest percentage of cell phone-related fatal/injury crashes occurred during the afternoon/evening, followed by the morning. The smallest percentage of fatal/injury crashes occurred during the night.

Although the descriptive nature of the present analyses precluded any tests of statistical significance, one might speculate as to why the visual trends emerge. For example, it is reasonable to assume that it is more difficult to use a cell phone while driving if it is dark, therefore resulting in less cell phone use while driving during night hours. Further, the afternoon/evening encompasses more non-work hours than the morning, thus presenting more driving opportunity and, hence, more opportunity for driving while using a cell phone.

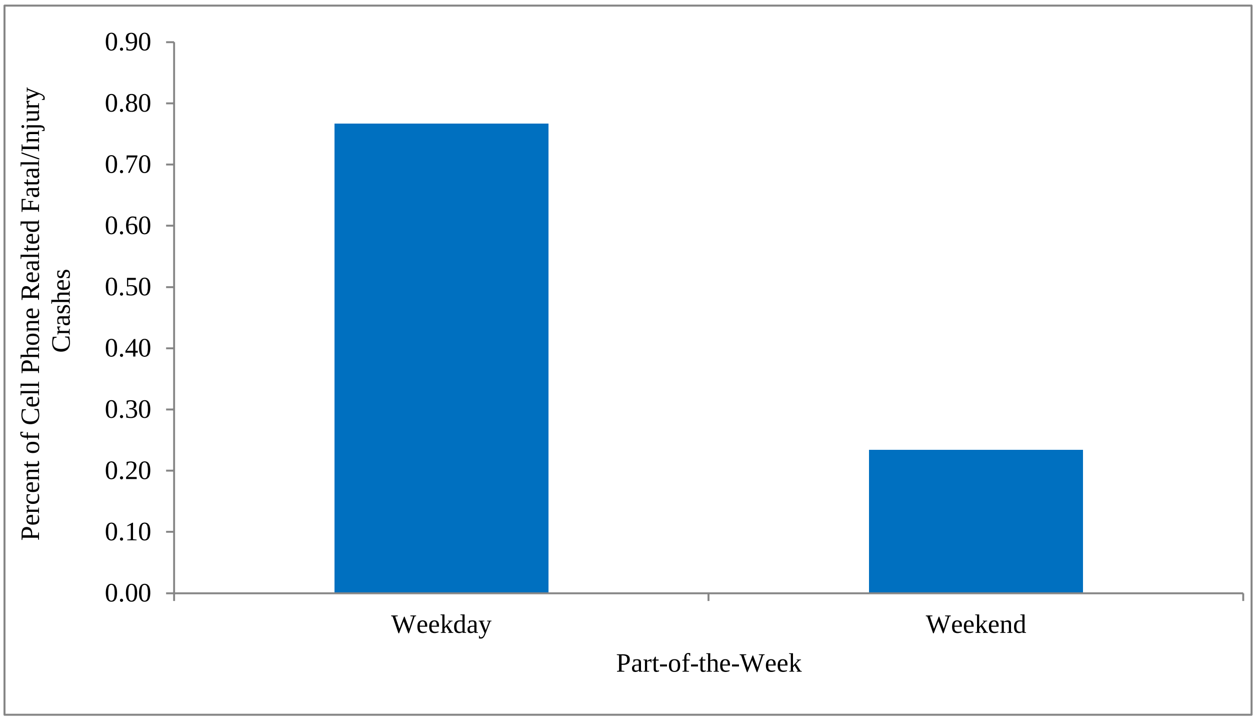


Figure 7. Percent of Fatal/Injury Cell phone-related Crashes by Part-of-the-Week from 2003 through 2011.

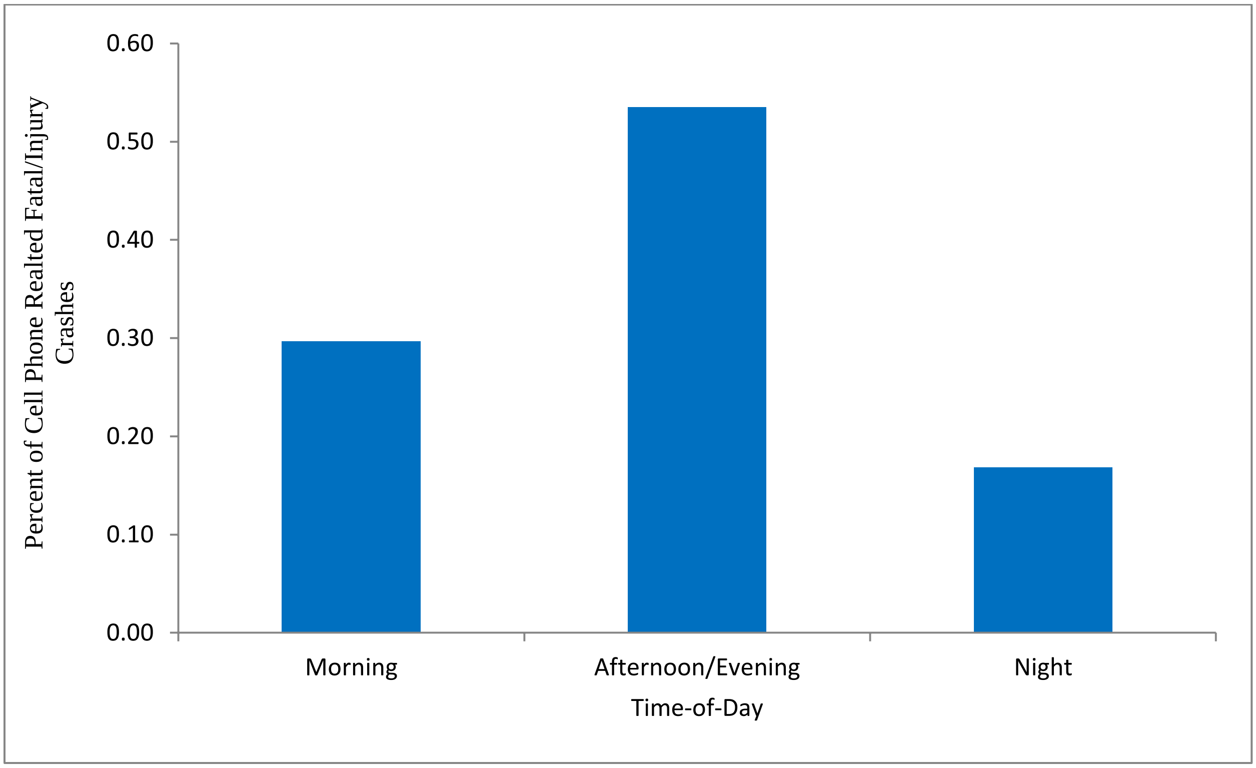


Figure 8. Percent of Fatal/Injury Cell phone-related Crashes by Time-of-Day from 2003 through 2011.

<u>Drivers</u>

Tables 4 through 8 and Figures 9 and 10 display descriptive data depicting characteristics of drivers involved in fatal/injury crashes where cell phone use was reported. Table 4 shows total counts and percentages of drivers involved in fatal/injury crashes where cell phone use was noted as a function of age from 2003 through 2011. Figure 9 graphically displays the associated percentages. The vertical line perpendicular to the x-axis year of 2008 represents the year that cell phone and driving regulations were implemented in California. As can be seen in Figure 9, there appear to be three distinct groups. Persons 21-30 years old represent one group, accounting for the largest percentage of drivers involved in cell phone-related fatal/injury crashes. Further, this group's percentage appears to increase over time, accounting for around 30% in 2003 and rising to around 45% by 2011. A second group, comprised of drivers 18 to 20 years of age, 31 to 40 years of age, and 41-50 years of age appear to cluster together and vary in a non-linear way across time, accounting for between 12% and 25% of cell phone-related fatal/injury crashes. A third group, comprised of drivers under 18 years of age, 51-60 years of age, 61-70 years of age, and 71 years of age or greater also appear to cluster together. This group appears to be stable across time, accounting for between 0% and 10% of cell phone-related fatal/injury crashes.

Table 4

Drivers Involved in Fatal/Injury Crashes while using Cell Phone by Age from 2003 through 2011

AGE		2003	2004	2005	2006	2007	2008	2009	2010	2011
UNDER 18	*N*	48	47	43	47	27	15	12	14	5
	%	8.14	9.81	7.05	8.12	4.67	3.71	3.74	4.23	1.40
18-20	*N*	78	88	120	85	101	62	68	40	49
	%	13.22	18.37	19.67	14.68	17.47	15.35	21.18	12.08	13.69
21-30	*N*	164	138	177	169	191	153	123	135	158
	%	27.80	28.81	29.02	29.19	33.04	37.87	38.32	40.79	44.13
31-40	*N*	143	81	117	116	112	79	52	62	63
	%	24.24	16.91	19.18	20.03	19.38	19.55	16.20	18.73	17.60
41-50	*N*	90	78	93	104	80	56	41	42	44
	%	15.25	16.28	15.25	17.96	13.84	13.86	12.77	12.69	12.29
51-60	*N*	51	33	34	44	48	28	17	28	25
	%	8.64	6.89	5.57	7.60	8.30	6.93	5.30	8.46	6.98
61-70	*N*	14	10	19	11	14	5	7	9	12
	%	2.37	2.09	3.11	1.90	2.42	1.24	2.18	2.72	3.35
71+	*N*	2	4	7	3	5	6	1	1	2
	%	0.34	0.84	1.15	0.52	0.87	1.49	0.31	0.30	0.56
TOTAL	*N*	590	479	610	579	578	404	321	331	358
	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

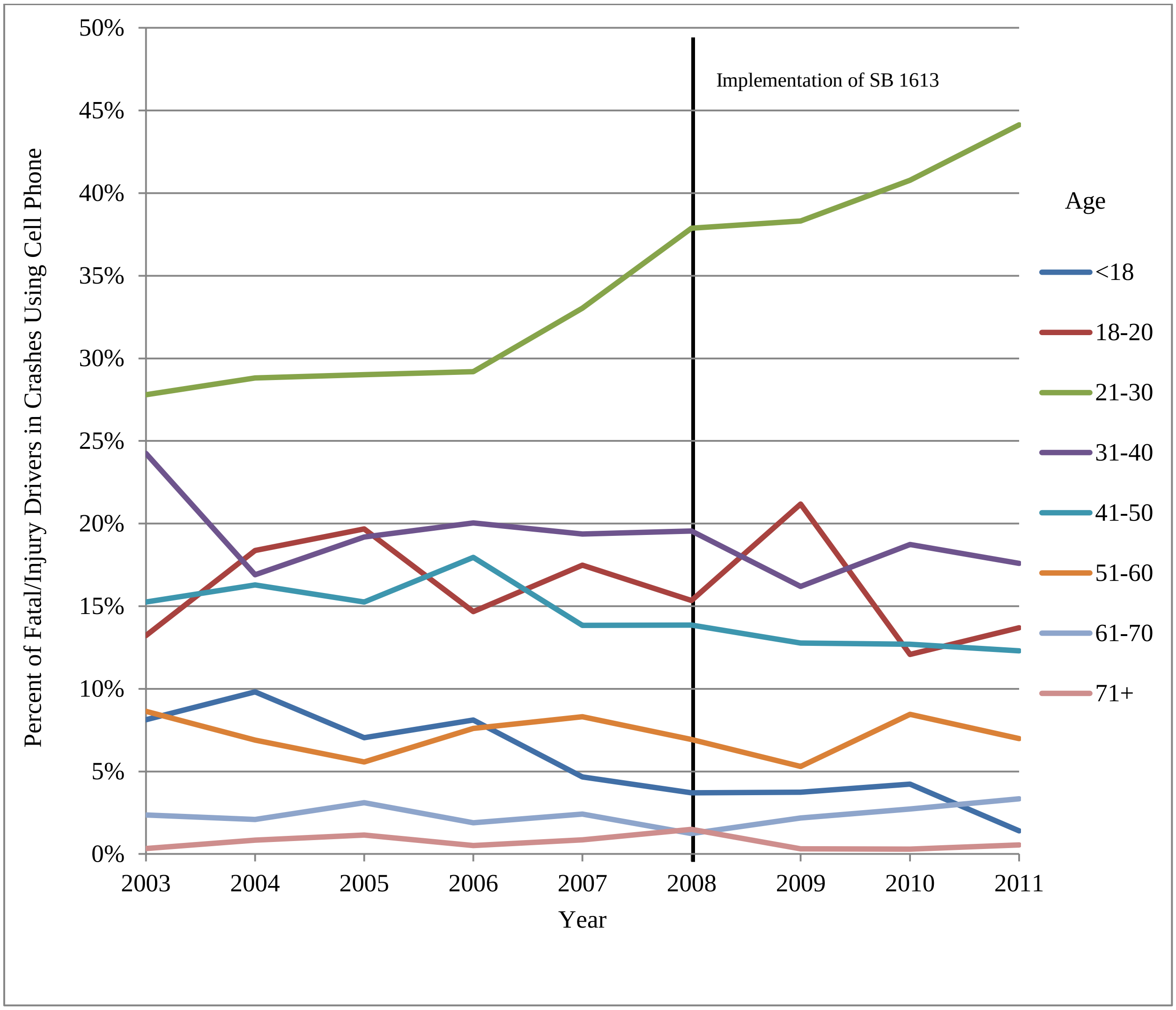


Figure 9. Percentage of Drivers Involved in Fatal/Injury Crashes while Using Cell Phone by Age from 2003 through 2011.

Table 5 shows total counts and percentages of drivers in fatal/injury crashes involving cell phones by sex. Percentages are also displayed graphically in Figure 10. Males show higher cell phone-related crash counts and account for a greater percentage of crashes across all years except 2009, when the sexes were roughly equivalent. This is consistent with past research (Harrington & McBride, 1970) demonstrating that males have higher crash risk than females. As can be seen in the total counts in Table 5, cell phone-related crashes for both sexes decrease beginning at about 2008. This could be the result of the cell phone law or other factors such as reduced exposure associated with the recession.

Table 5

Frequency and Percentage of Drivers Involved in Fatal/Injury Crashes while using Cell Phone by Sex from 2003 through 2011

SEX		2003	2004	2005	2006	2007	2008	2009	2010	2011
FEMALE	*N*	256	229	267	240	259	185	161	149	157
	%	43.39	47.81	43.77	41.45	44.81	45.79	50.16	45.02	43.85
MALE	*N*	334	250	343	339	319	219	160	182	201
	%	56.61	52.19	56.23	58.55	55.19	54.21	49.84	54.98	56.15
TOTAL	*N*	590	479	610	579	578	404	321	331	358
	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

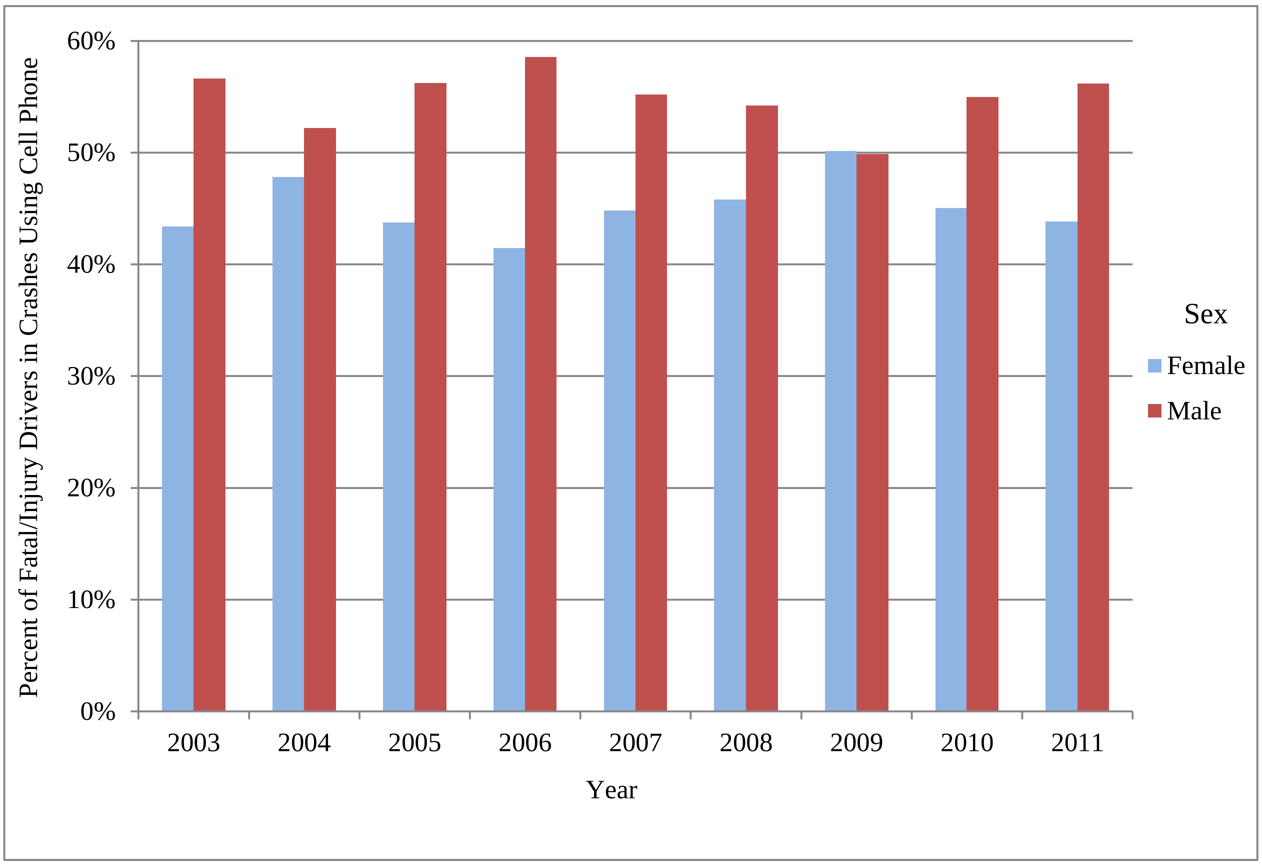


Figure 10. Drivers Involved in Fatal/Injury Crashes While using a Cell Phone by Sex from 2003 through 2011.

Table 6 shows total counts and percentages of drivers in fatal/injury crashes involving cell phones by sex and age group. Consistent with Table 5 and Figure 10, across age groups, males continue to show higher cell phone-related crash counts and account for a larger percentage of crashes than females. Further, similar to the trends observed in Table 4 and Figure 9, the 21-30 year-old groups was involved in more cell phone-related crashes and accounted for a greater percentage of the total than any other age group. As discussed earlier, this may be due to a higher number of miles traveled by this age group compared to teens and seniors (Brar & Rickard, 2013).

Table 6

Frequency and Percentage of Drivers Involved in Fatal/Injury Crashes while using Cell Phone by Age and Sex from 2003 through 2011

			SEX			
	TOTAL		FEMALE		MALE	
AGE	N	%	N	%	N	%
UNDER 18	258	6.07	125	48.45	133	51.55
18-20	691	16.26	330	47.76	361	52.24
21-30	1408	33.13	670	47.59	738	52.41
31-40	825	19.41	348	42.18	477	57.82
41-50	628	14.78	241	38.38	387	61.62
51-60	308	7.25	127	41.23	181	58.77
61-70	101	2.38	44	43.56	57	56.44
71 & ABOVE	31	0.73	18	58.06	13	41.94
GRAND TOTAL	4250	100.00	1903	44.78	2347	55.22

Table 7 shows total counts and percentages of drivers in fatal/injury crashes involving cell phones by type of cell phone use and age group. Consistent with the tables and figures presented above, drivers using hand-held cell phones were involved in a greater number of fatal/injury crashes compared to those using hands-free cell phones.

Table 7

Frequency and Percentage of Drivers Involved in Fatal/Injury Crashes while using Cell Phone by Age and Type of Cell Phone Use from 2003 through 2011

	TOTAL		CELL PHONE USE					
			CELL PHONE HAND-HELD		CELL PHONE HANDS-FREE		CELL PHONE (OTHER)	
AGE	*N*	%	*N*	%	*N*	%	*N*	%
UNDER 18	258	6.07	179	69.38	6	2.33	73	28.29
18-20	691	16.26	529	76.56	41	5.93	121	17.51
21-30	1408	33.13	1058	75.14	114	8.10	236	16.76
31-40	825	19.41	583	70.67	69	8.36	173	20.97
41-50	628	14.78	435	69.27	59	9.39	134	21.34
51-60	308	7.25	214	69.48	30	9.74	64	20.78
61-70	101	2.38	67	66.34	13	12.87	21	20.79
71 & ABOVE	31	0.73	20	64.52	6	19.35	5	16.13
GRAND TOTAL	4250	100.00	3085	72.59	338	7.95	827	19.46

When examined as a function of age, percentages for hand-held cell phone use and cell phone use (other) appear to be relatively stable across the age groups. However, percentages for hands-free cell phone use appear to increase as a function of age.

Table 8 shows total counts and percentages of drivers in fatal/injury crashes by type of cell phone use and fault. The data presented in this table indicate that drivers reported to be using a cell phone at the time of a fatal/injury crash were more likely to be found at fault than drivers who were not using a cell phone. In addition, drivers who were using hand-held cell phones were slightly more likely to be found at fault than those using hands-free cell phones. While it is obvious that cell phone use was associated with being found at fault in fatal/injury crashes, this does not rule out the possible role of bias. In other words, being found at fault for a fatal/injury crash could be due, in part, to a general assumption of culpability when cell phone use is involved. The present data cannot directly or indirectly address this possibility.

Table 8

Frequency and Percentage of Drivers Involved in Fatal/Injury Crashes while using Cell Phone by Type of Cell Phone Use and At-Fault Verdict from 2003 through 2011

			AT-FAULT			
	TOTAL		YES		NO	
CELL PHONE USE	*N*	%	*N*	%	*N*	%
CELL PHONE HAND-HELD	3085	72.59	2911	94.36	174	5.64
CELL PHONE HANDS-FREE	338	7.95	305	90.24	33	9.76
CELL PHONE (OTHER)	827	19.46	763	92.26	64	7.74
GRAND TOTAL	4250	100.00	3979	93.62	271	6.38

DISCUSSION

The results of the descriptive analyses presented above render the following observations as they relate to crashes and drivers:

Crashes

- Most crashes did not involve inattention.
- Inattention other than cell phone-related inattention was reported most often.
- When cell phone-related inattention was reported, hand-held cell phone use was reported more often than hands-free cell phone use.
- The most commonly reported primary crash factors for cell phone-related fatal/injury crashes were 1) traveling at an unsafe speed, 2) improper turning, 3) traffic signal and signs, 4) driving under the influence, and 5) automobile right of way.
- More cell phone-related fatal/injury crashes occurred during the workweeks than on the weekends.
- More cell phone-related fatal/injury crashes occurred during the afternoon/evening than during the morning and the fewest cell phone-related fatal/injury crashes occurred during the night.

Drivers

- Drivers 21 to 30 years of age accounted for the largest percentage of all drivers involved in cell phone-related fatal/injury.
- Males accounted for more involvement in cell phone-related fatal/injury crashes than females, likely due to their generally higher crash risk. The proportional representation of the two sexes remained relatively stable across time, while total crash counts declined across time for both sexes.

- Across age groups, hand-held cell phone use accounted for more fatal/injury crashes than hands-free use or cell phone (other) use. However, the relative proportion of hands-frees fatal/injury crashes to hand-held and cell phone (other) crashes increased as a function of age. Determining the reasons behind this trend is beyond the scope of the present study.
- Drivers reported as using a cell phone at the time of a fatal/injury crash were more likely to be found at fault than drivers who were not reported as using a cell phone. In addition, drivers who were using hand-held cell phones were slightly more likely to be found at fault than those using hands-free cell phones.

Conclusions and Future Research

As noted earlier and depicted in Figures 3 and 4, it is interesting that total cell phone-distracted driving crashes, as well as fatal/injury cell phone-distracted driving crashes, appear to drop off in 2008. These findings might be indicative of the efficacy of California's cell phone law that went into effect in 2008, though causal inferences are unwarranted given a myriad of confounding variables (e.g., decline of the U.S. economy, reduced driving exposure). Given this, as well as the descriptive nature of the present data, any pattern(s) found within this report should be interpreted with caution.

As was shown in Table 7, when examined as a function of age, percentages for hand-held cell phone use and cell phone use (other) appeared to be relatively stable across the age groups; however, percentages for hands-free cell phone use appeared to increase as a function of age. The lower levels observed in the under 18 age group could be partially attributable to California law, enacted in 2008, which prohibits anyone under the age of 18 from using a cell phone while driving regardless of whether the type of use is hand-held or hands-free. However, this cannot explain the linear trend across age groups over 18 years of age. Because these data are descriptive in nature, no inferential or causal conclusions can be drawn, but one could speculate that this age-related trend may be attributable to a combination of two age-related factors: traffic law compliance, and cognitive decline. Traffic law compliance tends to increase as a function of age; older adults are more likely to wear seatbelts and less likely to speed (Centers for Disease Control and Prevention, 2014). Most relevant to the present trend, McCartt, Braver, Geary (2003) found that compliance with New York's hand-held cell phone and driving restrictions was particularly high among older adults. Taken together, older adult compliance with

California hand-held cellphone law could explain part of why the percentage of fatal/injury crashes increase as a function of age in Table 7. In other words, because older adults, as a group, are less likely than other age groups to drive while using a hand-held cell phone, they are also less likely than other age groups to be involved in fatal/injury crashes while engaging in such behavior. In addition, cognitive processing resources tend to decrease as a function of age and attentional processes are particularly affected (Watson, Lambert, Miller, & Strayer, 2011). This is especially relevant when considering that distracted driving is theorized to increase crash risk by dividing attentional resources (Watson, Lambert, Cooper, Boyle, & Strayer, 2013). With hands-free cell phone use, which is legal for drivers over the age of 18, the source of distraction is primarily cognitive in nature because the visual-manual subtasks of hand-held cell phone use are eliminated. It follows that, as attentional resources decline with increasing age, the impact of cognitive distraction on driving performance that is generated by concurrent hands-free cell phone use while driving would also increase. Thus, age-related cognitive decline could also partially explain why the percentage of fatal/injury crashes involving hands-free cellphone use increases as a function of age. While these interpretations are plausible, it should again be stressed that they are speculative in nature and based only on descriptive analyses. What's more, for all age groups, hand-held cell phone use was the dominate type of cell phone use involved in fatal/injury crashes. Further, testing these interpretations would require taking into account total miles traveled for each age group as well as baseline rates of behavioral engagement in each type of cell phone use for each age group.

The observations detailed above represent characteristics of cell phone-distracted crashes and drivers from visual inspection of frequencies and percentages only. Thus, it remains unknown at this time whether or not the observed differences and trends are statistically significant or if California's cell phone laws are effective deterrents of crash involvement. In addition, nothing is known about the pre-crash driving records of the drivers involved in these distracted driving crashes. As a follow-up to the present study, a subsequent project is currently being planned. This follow-up study will apply more advanced statistical techniques (e.g. regression modeling) in order to identify statistically significant differences and trends. This future study will also examine prior driving record data for drivers involved in cell phone use distracted crashes obtained from DMV's Driver Record Master and apply these data as predictors of future crash involvements. These approaches will allow for stronger conclusions to be drawn concerning the characteristics of cell phone-distracted crashes and drivers and the factors that predict cell phone-distracted driving behavior in California. The information presented both in the current study and future effort will assist traffic safety administrators and researcher in determining whether California's cell phone law is working and aid in providing a strong basis upon which to build action-specific recommendations.

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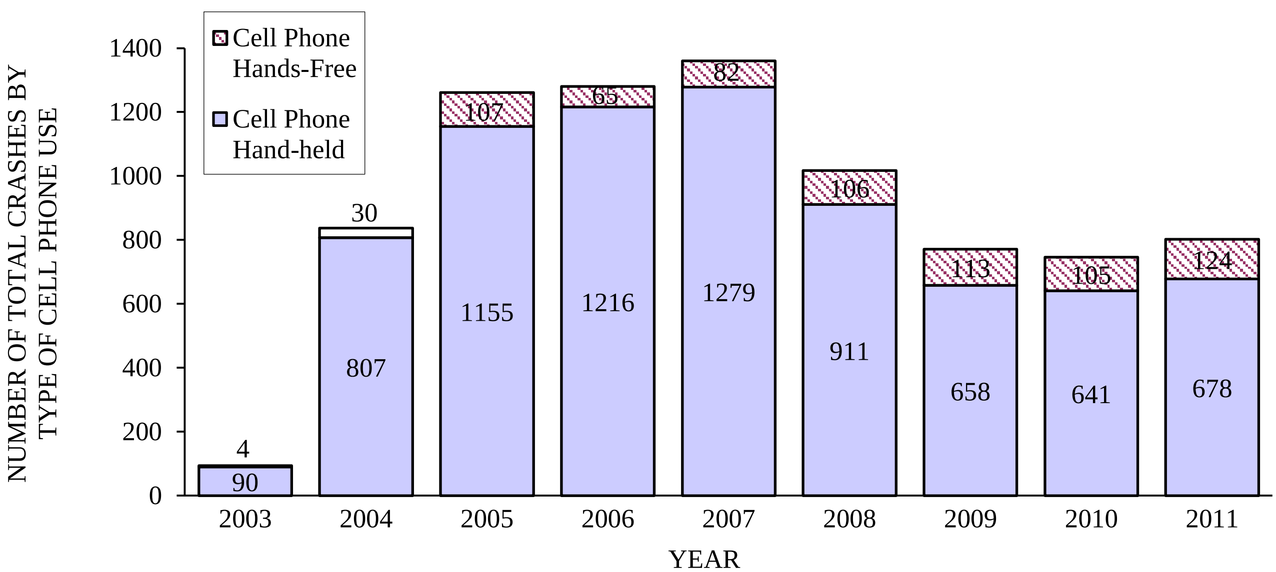
Table 1

Percent of Total Crashes by Type of Inattention from 2003 through 2011

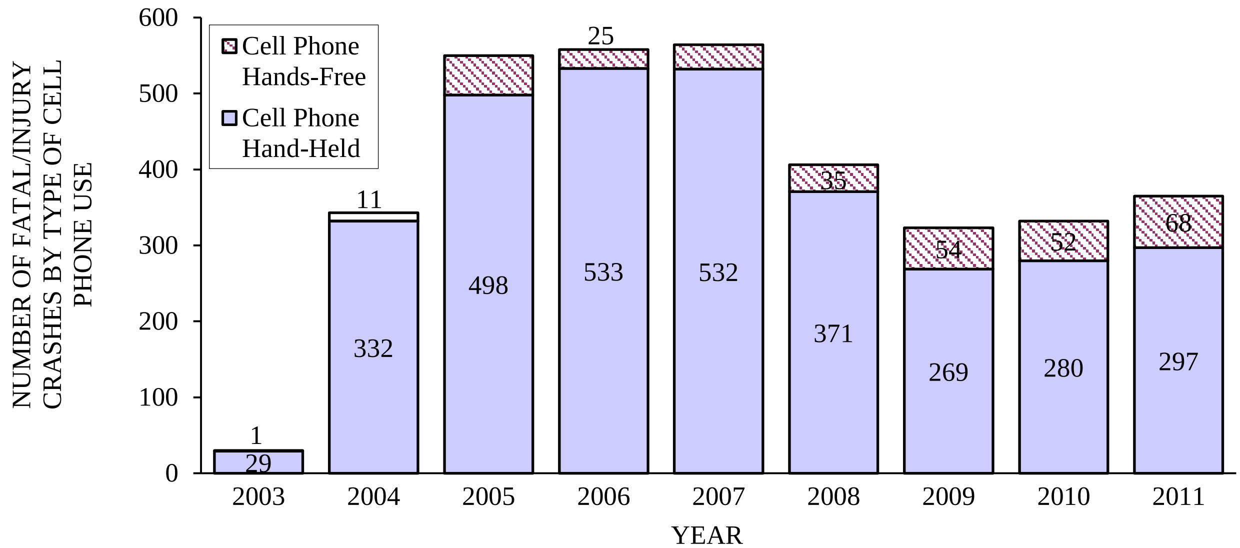
INATTENTION		2003	2004	2005	2006	2007	2008	2009	2010	2011
CELL PHONE HAND-HELD	%	0.02	0.15	0.22	0.24	0.26	0.20	0.16	0.15	0.17
CELL PHONE HANDS-FREE	%	0.00	0.01	0.02	0.01	0.02	0.02	0.03	0.03	0.03
CELL PHONE (OTHER)	%	0.23	0.06	0.03	0.02	0.01	0.01	0.00	0.00	0.00
OTHER INATTENTION	%	7.96	6.84	6.97	6.59	6.30	6.12	6.07	5.72	5.66
NO INATTENTION REPORTED	%	91.80	92.95	92.76	93.15	93.41	93.65	93.75	94.09	94.14



% of total crashes	0.25%	0.22%	0.27%	0.27%	0.29%	0.23%	0.19%	0.18%	0.20%

Figure 3. Total Crashes Involving Cell Phone Use from 2003 through 2011.

Results were similar when crashes that resulted in fatality or injury (fatal/injury) were examined in isolation. Table 2 and Figure 4 apply the same layout as Table 1 and Figure 3, but their data only correspond to fatal/injury crashes. As shown in Table 2, involvement of hands-free cell phone use was negligible, again rounding to 0%, and involvement of hand-held cell phone use



% of total fatal /injury crashes	0.29%	0.23%	0.30%	0.30%	0.31%	0.24%	0.20%	0.21%	0.23%

Figure 4. Fatal/Injury Crashes Involving Cell Phone Use from 2003 through 2011.

Of these cell phone-related fatal/injury crashes, hand-held cell phone use was more frequently noted than hands-free cell phone use. Table 3 and Figure 5 depict this information, collapsing across years. Again, the pattern is similar. No form of inattention was noted for the majority of fatal/injury crashes (96.55%). When cell phones were involved, hand-held cell phone use was noted more frequently than hands-free cell phone use. By and large, these observations are consistent with Fitch et al. (2013) who found that talking on a cell phone alone was not associated with increased crash risk. Rather, crash risk increased for hand-held cell phone use, presumably due to the visual-manual subtasks of reaching for and manipulating the phone.

Table 3

Fatal/Injury Crashes where Inattention was Reported from 2003 through 2011

INATTENTION	*N*	%
TOTAL	124742	100.00
CELL PHONE HAND-HELD	3141	2.52
CELL PHONE HANDS-FREE	330	0.26
CELL PHONE (OTHER)	830	0.67
OTHER INATTENTION	120441	96.55

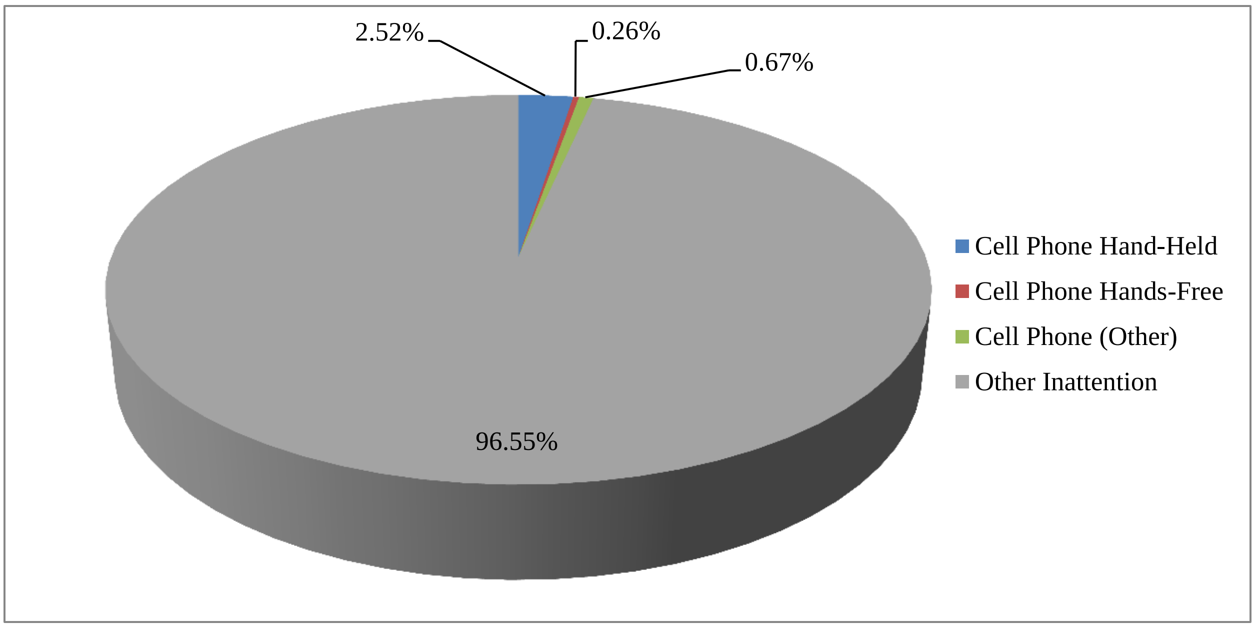


Figure 5. Percent of Fatal/Injury Crashes where Inattention was Reported from 2003 through 2011.

Figure 6 shows counts of fatal/injury crashes where cell phone use was involved by type of cell phone inattention for each primary crash factor from 2003 through 2011. The most common primary crash factor was traveling at an unsafe speed. This was followed by improper turning, traffic signals and signs violation, driving under the influence of alcohol or drugs, and automobile right-of-way violation. Other crash factors (e.g., impeding traffic, following too close, falling asleep) were categorized as "other" because their total counts were very small or were not represented at all. For each of the top five factors, the relative proportions of each type