Distracted Driving and Crash Responsibility in Fatal USA Collisions 1991 – 2015

by

Carlina Marchese

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Abstract

Distracted driving occurs when the driver engages in a secondary activity (e.g., cell phone use, eating) that affects the performance of the primary task of driving. Distracted driving has been associated with driver errors and increased crash risk. This study examined the association between driving distractions and risk of fatal crash responsibility.

The first objective of this study was to determine the prevalence of distracted driving in fatal collisions (by sex and age) from 1991 – 2015. The second objective was to establish the most prevalent type of distraction during this time period. The third objective was to examine the association between distracted driving and crash responsibility in fatal crashes from 2010 – 2015.

Driver distraction was first included in the Fatality Analysis Reporting System (FARS) database in 1991 as part of the unsafe driver action (UDA) variable. In 2010, driver distraction was revised and captured independently of the UDA variable. We computed proportion of drivers coded with at least one distraction by sex for each of the years (1991-2015; n = 86,656) and age by sex for this entire time period. We generated and compared frequencies for each distraction identified (e.g., cell-phone use; audio controls). To estimate the association between distracted driving and crash responsibility, drivers (aged 20 years or older, blood alcohol of zero, drug negative) of passenger type vehicles involved in a fatal USA crash between 2010 – 2015 (n = 27,241) were included in a case-control design. Having one or more unsafe driving action (UDA) was used as a proxy measure for crash responsibility. Cases had at least one UDA recorded; controls had no UDAs reported. We computed adjusted odds ratios (OR) and 95% confidence intervals of committing an UDA (distracted relative to non-distracted) for male and female drivers at several ages via logistic regression.

Between 1991 and 2015, prevalence of distracted driving fluctuated between 6% (1995; male drivers) and 12% (2009; female drivers) depending on year and driver's sex. While young drivers, especially males, had the greatest number of fatal crashes involving distraction; proportionally, the percentages were similar for males and females. This proportional difference was most pronounced for drivers aged 20-35 and 50-75. The most commonly identified distraction in fatal collisions from 1991 – 2015 was activity related to cell phones (e.g., talking, manipulating, or other cell phone related). Driving distracted increased the odds of crash responsibility (i.e., one or more UDAs), especially for middle-aged drivers (age 45 OR: 2.35; 95% CI: 2.06, 2.67).

Despite educational campaigns, distracted driving continues to be a persistent factor in fatal crashes. It is likely the data presented here underestimates the prevalence of, and risk associated with distracted driving due to the difficulty in coding distraction post-crash. Given the role of distractions in fatal crashes, their prevention should continue to be addressed as a public health issue.

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Dedication

I dedicate this work to my grandparents. Grazie mille for coming to this frozen foreign country with negative money, no English, and a positive attitude to build a better life for your family. I hope it was worth it. I hope I made you proud.

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List of Abbreviations

CI	Confidence interval
DWI	Driving while intoxicated
FARS	Fatality Analysis Reporting System
NCSA	National Center for Statistics and Analysis
NHTSA	National Highway Traffic Safety Administration
OR	Odds ratio
RR	Relative risk
UDA(s)	Unsafe driver action(s)
WHO	World Health Organization

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Chapter 1: Introduction

Driving is a demanding task, however, sometimes drivers engage in another activity while driving. Regan (2007) defines distracted driving as a driver engaged in a secondary activity which affects the performance of the primary task of driving. Distraction can include a wide variety of behaviours and activities, such as but not limited to changing car controls, using a cell phone, daydreaming, and having a conversation. Frequencies of distracted driving, as well as evidence regarding sex, age, awareness of distraction costs, compensatory behaviours, passengers, protective and negative effects of distraction will be discussed.

Frequency of Distracted Driving

Self-reported frequency. The 2012 National Survey on Distracted Driving Attitudes and Behaviours surveyed Americans on various distracted driving activities (*n* = 6,016; Schroeder et al., 2013). Talking to other passengers in the vehicle was most frequent, with 79.5% of respondents reporting this behaviour at least sometimes, followed by adjusting the radio with 68.4% at least sometimes. Almost half of respondents reporting eating or drinking at least some of the time (47%), with another 25.6% of respondents indicating they do this rarely. Making or accepting phone calls was quite frequent, with 39.6% reported doing this at least sometimes, and another 19% reported engaging in it rarely. About 35% (35.5%) talk or interact with children while driving and approximately one-quarter (24.6%) of respondents change CDs, DVDs, or tapes, at least sometimes. A slightly larger percentage of respondents reported reading text messages or emails at least sometimes (14.1%) compared to sending text messages or emails (10.3%). Another 9.2% reported personal grooming, and 1.3% read a book while driving, at least sometimes (Schroeder et al., 2013).

Cell phone distraction frequency. Researchers of a representative self-report sample, similar in age, gender, and geography to the USA census, found that almost 60% of drivers performed a cell phone-related distraction while driving within the past 30 days (Gliklich, Guo, & Bergmark, 2016). Over two-thirds of respondents read text messages or emails, and approximately 18% send text messages or emails at least some of the time while driving in the past thirty days (Gliklich et al., 2016). While Schroeder and colleagues (2013) found slightly higher frequency rates (10.3% sending and 14.1% reading text messages or emails), both studies found higher frequencies of reading rather than sending messages. Another American sample of young drivers 17 – 28 years old found that 89.8% reported calling someone and 63% reported sending a text message while driving (Weller, Shackleford, Dieckmann, & Slovic, 2013). On at least half of their driving trips, 33.7% reported talking and 21.5% reported texting. Of those with internet access on their phone, 17% accessed websites while driving at least once and 22.4% accessed software applications (Weller et al., 2013). Kann and colleagues (2016) found that 41.5% of high school students who drove a car had texted or emailed while driving at least one day during the previous 30 days. In a sample of 726 college students in the state of New York, 85% self-reported talking on a cell phone while driving, 80% reported reading text messages, and 68% reported sending text messages while driving (Terry & Terry, 2016). In 2014/2015, 6% of Ontario teenagers self-reported texting while driving at least sometimes, a lower proportion than 27% found two years earlier in 2012/2013 (Tucker, Pek, Morris, & Ruf, 2015).

The authors of a telephone survey found that 48% of 16 – 18 year olds texted while driving, and 68% talked on the phone while driving, at least once per trip (Carter, Bingham, Zakrajsek, Shope, & Sayer, 2014). Cook and Jones (2011) found that 74.3% of university students reported texting while driving at least a few times per month, and 21.7% reported texting while driving multiple times each day. A survey of American university students found 91% of students reported phoning and/or texting while driving, out of a sample of almost 5,000 students (Hill et al., 2015). Ninety percent (90%) reported talking on their cell phone while driving, and 90% reported texting while driving. Almost all students (98%) observed drivers of other vehicles using their cell phone (Hill et al., 2015). These studies demonstrate high reported frequencies of cell phone distraction in young drivers.

Observed frequencies. Stutts and colleagues analyzed the driving behaviour of 70 participants aged 18 – 65+ from North Carolina or Pennsylvania with cameras in their vehicles, for a total of 207 hours of driving data (Stutts et al., 2003). All participants manipulated vehicle controls, and 91.4% manipulated audio controls. Eating/drinking/spilling was quite frequent, with 71.4% of participants engaging in this distraction during their approximate 3 hours of observation. Just over one third (34.3%) of participants used a cell phone while driving, and 7.1% engaged in smoking-related activities. Interestingly, up to 16.1% of the total time that the vehicle was in motion participants were engaged in potentially distracting activities (excluding conversing). The eating/drinking distraction took the largest amount of the total time (Stutts et al., 2003).

In an observational study of 3,650 students leaving San Diego State University, 11% (n = 403) were observed using a cell phone (Cramer et al., 2007). Cramer demonstrated this was statistically higher ($p < .001$) than the findings of 8% of cell phone use among drivers who appeared to be 16 – 24 in the 2004 National Occupant Protection Use Survey (Glassbrenner, 2005). In 2015, researchers of the National Occupant Protection Use Survey observed 3.8% of Americans driving with a cell phone to their ear (Pickrell et al., 2016). This translates into at least half a million cell phone distracted drivers at any given daylight moment in the United

States (Pickrell et al., 2016). Understandably, observed frequencies of distraction (at a point in time) are lower than self-reported frequencies (during a specified time period) due to the nature of the data collection format.

Frequencies in crashes or near-crashes. Crashworthiness Data System (CDS) is a sample of crashes with at least one passenger vehicle that has been towed from the scene of the crash. Using 1995 – 1999 weighted CDS data, Stutts and Hunter (2003) found that 8.3% of drivers were identified as distracted in crashes (Stutts & Hunter, 2003). However, if the unknown attention status category is excluded, the proportion distracted would rise to 12.9% (Stutts & Hunter, 2003). They found that the most frequent driver distraction was outside person object or event (29.4%), followed by adjusting radio, cassette or CD (11.4%), and other occupants in the vehicle (10.9%; Stutts & Hunter, 2003). In Australia, just under 4% of collisions causing injury or death to the driver were found to have distraction as a contributing factor (Lam, 2002). Wireless devices, internal distractions, and passenger-related secondary tasks (mostly conversations) were the secondary task distractions that contributed to the highest percent of crashes, near crashes (events that require rapid, evasive maneuvers), and driving incidents (less severe incidents) in a naturalistic driving study (Dingus et al., 2006). Teen drivers (aged 16 – 19 years old) were observed in 412 rear-end crashes captured by in-vehicle cameras (Carney, Harland, & McGehee, 2016). The teenage drivers were observed in a distracting behaviour in 76% of the rear-end crashes. Cell phone distraction was the most frequent at 18%, followed by attending to a location outside the vehicle (17%), and attending to passengers (16%; Carney et al., 2016). Other distractions included: attending to another vehicle or its passengers (11%), singing/dancing to music (10%), attending inside vehicle unknown (9%), personal grooming (8%), reaching for an object (6%), operating in-vehicle controls/devices (4%), eating or drinking (2%), attending to person outside vehicle (2%), using an electronic device (2%), smoking-related (1%), and talking to self (1%; Carney et al., 2016).

Table 1

Summary of Cell Phone Distracted Driving Frequencies

Type of Cell Phone Use while Driving Frequencies	Minimum Reported	Maximum Reported
Self-Reported Talking	10%[1]	90%[2,3]
Self-Reported Texting	6%[1]	90%[2]
Observed Cell Phone Use	6%[4]	34%[5]
In Crashes	2%[6]	18%[7]

[1]Tucker et al., 2015; [2]Hill et al., 2015; [3]Weller et al., 2013; [4]Pickrell et al., 2016; [5]Stutts et al., 2003; [6]Stutts & Hunter, 2003; [7]Carney et al., 2016

Table 1 displays the discussed range of frequencies of cell phone use while driving. Self-reported talking and texting while driving have the largest range and highest maximum reported frequencies. The lowest self-reported talking and texting while driving frequencies came from a younger sample of teenagers (Tucker et al., 2015), compared to a wider range of young drivers aged 18-29 included by Hill and colleagues (2015) and 17-28 included by Weller and colleagues (2013). It should be noted that the study by Tucker and colleagues (2015) was conducted in Canada, with 98% of participants residing in Ontario, where cell phone distracted driving is prohibited. At the time of the study, distracted driving fines in Ontario were $280 (Ontario Ministry of Transportation, 2015), considerably higher than the $20 fine in California (Hands Free Info, 2018), the location of Hill's study. Observed frequencies are considerably lower than self-reported frequencies as the cell phone use must be identified at a certain moment in time. Stutts and colleagues (2003) reported higher observed frequencies, likely due to the in-vehicle cameras that where utilized, in comparison to Pickrell's (2016) roadside observations of vehicles stopped at an intersection. The roadside observer may fail to notice cell phones that are held inconspicuously, such as if the phone is held low near the driver's lap. Lastly, in crash cell phone use while driving varied to a lesser extent. Carney and colleagues perhaps hold a more accurate representation as they used in-vehicle cameras, whereas Stutts and Hunter (2003) reported from a database of previous crashes. The wide range of frequencies of cell phone use while driving is the result of varied methodologies, but also indicative of the complexity of the issue.

Sex

Frequency of distracted driving by sex. Evidence comparing distraction in males and female drivers is far from confirmatory. A self-report study of university students from four states found that females had greater odds than males of talking on a cell phone while driving, $OR = 2.54$, $p < .001$, 95% CI [1.77, 3.63] (Seo & Torabi, 2004). American observational data indicated that from 2006 – 2015, the percentage of females that used a handheld cell phone while driving was about 2% higher than males (Pickrell, Li, & KC, 2016). An observational study at an American university reported that compared to males, females had 1.51 times greater adjusted odds (adjusted for passengers, time, vehicle type, and parking structure) of using their cell phone while driving (Cramer, Mayer, & Ryan, 2007). Male university students reported a lower number of dangerous driving incidents (driving mishaps such as running a red light, or almost hitting something) due to texting while driving on a self-report questionnaire, compared to females (Quisenberry, 2015).

Carney and colleagues (2016) did not find a significant difference between sexes in their naturalistic study of young drivers (16 – 19 years old) in the frequency of distraction in rear-end crashes. A sex difference may not have been found due to the smaller sample size of 314 drivers engaged in a distraction while driving, the strict age range, or due to the specific involvement of rear-end crashes. Public Health Ontario conducted an online survey for youth (16 – 19 years old) and young adults (20 – 24 years old; N = 2,000), but found that reading and sending text messages while driving was not associated with sex (Ontario Agency for Health Protection and Promotion (Public Health Ontario), Berenbaum, Keller-Olaman, & Manson, 2015).

Males self-reported a significantly higher amount of general risky driving behaviours than did females (Rhodes & Pivik, 2011). In an online 5-point Likert-type scale (1= Almost Never…5 = Almost Always) survey of Ontario teenagers aged 16 – 18 years old, males reported engaging in texting while driving slightly more often than females, $m = 1.78$ vs. $m = 1.70$ respectively on, $p < .05$ (Tucker, Pek, Morris, & Ruf, 2015). A follow-up study was conducted two years later, with individuals aged 14 – 19 years old. Again, the authors found that texting while driving was more frequent in males, over females, $m = 1.35$ vs. $m = 1.28$ respectively, $p < .05$. This may be representative of a sex difference, or may display the tendency for females to answer in a socially desirable manner, as distracted driving laws were in place in Ontario at the time of the survey. Yet, there was no sex difference in the frequency of talking on the phone while driving (Tucker et al., 2015). In distracted driving fatalities, the proportion of males increased over time from 70.3% in 1999 to 74.0% in 2008 (Wilson & Stimpson, 2010).

Sex differences in distraction effects. In a simulator study of adults (aged 30 – 40) using hand-held and hands-free cell phones, females were found to have a longer brake reaction time in avoiding critical rear-end collisions than males (Li, Yan, Wu, Radwan, & Zhang, 2016). However, males reacted slower when there was a larger initial headway distance from the leading vehicle. Females tended to brake more quickly and had larger maximum deceleration rates. This allowed females to keep a larger safety margin distance from the leading vehicle.

Risk was perceived differently by males; they tended to take more risks than females, such as reducing the safety margin between the hazard and the vehicle (Li et al., 2016).

A phone distraction study using a closed-loop track found a main effect for sex in the stopping distance while distracted, with females stopping closer to the line than males (Hancock, Lesch, & Simmons, 2003). Interestingly, there was also an interaction between sex and stopping accuracy. Stopping accuracy was measured as the percent of occasions the driver was able to obey the changing light and successfully stop before the cross line. At baseline, females had higher stopping accuracy than males, but under the distraction condition, females scored much lower than males. Females suffered a considerable amount from baseline to distraction condition (approximately 25% lower), compared to males who displayed about an 8% decrease in the distraction condition (Hancock et al., 2003).

Age

Frequency of distracted driving by age. The authors of a self-report study found that younger age was associated with higher cell-phone related distraction while driving (r = - .46, p < .0001; Gliklich, Guo, & Bergmark, 2016). This is supported by previous self-report research, where teenage drivers (aged 16 – 20) reported higher frequencies of risky driving, which includes distracted driving, compared to adults (aged 25 – 45; Rhodes & Pivik, 2011). From 2006 – 2015, handheld cell phone use (i.e. holding phone to their ear) in drivers was consistently highest in the age group 16 – 24, compared to those 25 – 69, or those 70 and older, based on observational data (Pickrell, et al., 2016). However, the overall downward trend for handheld cell phone use in the youngest age group led to similar rates as those aged 25 – 69 by 2015 (4.6%, 4.0%, respectfully). Drivers observed visually manipulating handheld devices was highest in those aged 16 – 24 consecutively from 2007 – 2015; in 2006, the 25 – 69 age group was slightly higher at 0.5%, compared to 0.4% (Pickrell et al., 2016). Adults aged 25- 69 saw a four-fold increase in observed manipulation of handheld devices from 2006 (0.4%) to 2015 (2.1%). However, those 16 – 24, had a much larger increase; by 2015, the rate had increased to 4.9%, over twelve times the rate (0.4%) in 2006 (Pickrell et al., 2016).

Weller and colleagues (2013) found that younger drivers (17 – 22 years old) were more likely to send or receive text messages while driving on at least half of their trips compared to the older drivers (aged 23 – 28), $p < .01$. However, Weller et al. (2013) also found that older drivers were more likely than younger drivers to talk on a cell phone while driving on at least half of their trips, $p < .03$. Quisenberry (2015) recently found that the frequency of texting while driving decreased as age increased $r = -.261$, $p < .05$. However, age did not have a significant correlation with the amount of dangerous distracting driving incidents that happened. Each age group was equally likely to have similar amounts of dangerous distracting driving incidents, despite texting while driving decreasing with age (Quisenberry, 2015).

Age differences in distraction effects. Greenberg and colleagues (2003) found that teen drivers were riskier drivers at baseline compared to the adults (aged 35 – 66), and when engaged in distractions those secondary tasks had a larger effect on them. While distracted, teenage lane violation rate was 56% higher than adults (aged 35 – 66). Teenagers missed almost four times as many traffic events ahead of them than did adults (53.8% for teens vs. 13.6% for adults; Greenberg et al., 2003).

Comparisons across age groups. An early study examining simultaneous cell phone use and driving found that drivers in the oldest age group (46 – 80) had a higher level of deficit in responding to traffic signals compared to those in the younger (17 – 25) and middle (26-45) aged groups (McKnight & McKnight, 1993). Schreiner, Blanco, and Hankey also found that older adults (mean age 56.6 years old) were more likely to fail to identify forward and peripheral lights when performing a secondary task distraction, compared to younger drivers (mean age 23.4 years old; 2004). The oldest drivers (aged 60 – 71) were most affected by a hands free phone task in a simulator study measuring driving performance by average speed, speed variance, average lane position, lane position average, steering deviations, and reaction time to peripheral signals (Shinar, Tractinsky, Compton, 2005). The authors of a simulator study found that, despite instructions to maintain the speed limit, older drivers (aged 60 – 75) engaged in a distraction drove slower than middle age (30 – 45) or younger drivers (under 25; Horberry, Anderson, Regan, Triggs, & Brown, 2006).

Older drivers compared to younger drivers. Consistent with those findings, Reimer and colleagues found that older drivers (aged 51 – 66) performing a hands free phone task drove significantly slower than the younger drivers aged 19 – 23, $F(1, 35) = 20.94$, $p < .001$ (Reimer, Mehler, Coughlin, Roy, & Dusek, 2011). Compared to younger drivers (aged 25 – 36), older drivers (aged 55 – 65) had slower brake reaction times driving on a closed-loop test track when distracted by a phone task, $F(1, 30) = 9.82$, $p < .01$. However, both older and younger drivers had slower brake reaction times while distracted, in comparison to baseline, $F(1, 30) = 41.6$, $p < .01$). Older drivers tended to brake harder than younger drivers, $F(1, 30) = 4.45$, $p < .05$, possibly to compensate for a slower reaction time. There was also an interaction of age and stopping distance. Under the distraction condition, older drivers suffered on measures of vehicle control and stopped much closer to the target, whereas there was little difference for the younger drivers in the distraction condition, compared to no distraction (Hancock et al., 2003). Similarly, a Japanese study reported a main effect of age for reaction times of drivers engaged in a mental calculation distraction, with the oldest age group (aged 61 – 64) having the longest reaction times

(Makishita & Matsunaga, 2008). However, Strayer and Drews (2004) found that older adults (aged 65 – 74) did not differ from younger adults (aged 18 – 25) in driving deficits resulting from a hands free phone conversation on a simulator.

Middle aged drivers compared to older drivers. Thompson and colleagues (2012) compared middle aged drivers (aged 40 – 64) to elderly drivers (aged 65 – 89) on roadways in Iowa, while distracted by a mathematical addition task. Videos of the drive were reviewed by a certified driving instructor to identify at-fault safety errors. The elderly drivers drove slower, and made fewer steering deviations of ≥ 6° during the distraction condition, compared to middle aged drivers. Elderly drivers also drove slower at baseline. While driving and engaged in the addition task, elderly drivers were found to have more at-fault safety errors than middle aged drivers, $p = .013$ (Thompson et al., 2012). Both elderly and middle aged drivers drove slower and had greater speed variability during the distraction condition. There were also notable differences between the age groups. From baseline to the distraction condition, middle aged drivers had significant increases in the number of steering deviations of ≥ 6°, steering variability, and lateral acceleration variability. Elderly drivers from baseline to distraction condition had significant increases in gas pedal hold and steering frequency (Thompson et al., 2012).

With age, it is challenging to untangle the influence of driving experience, making it difficult to draw conclusions regarding the effect of age on distracted driving performance (Regan, Lee, & Young, 2008). Younger drivers may be better at driving while engaged in a secondary task, but they engage in distractions while driving more frequently, which increases their risk (Regan et al., 2008). Older drivers may suffer more driving performance decrements from engaging in a distraction while driving compared to younger and middle aged drivers (Regan et al., 2008), but they may engage in fewer distracting behaviours.

Crashes and near-crashes. The extensive *100-Car Naturalistic Driving Study* included drivers 18 – 64 years old, and found that inattention-related crash and near-crash events had a negative relationship with age (Dingus et al., 2006). The rate of events for the 18 – 20 age group varied up to four times higher than older age groups (Dingus et al., 2006). Stutts and Hunter (2003) found that young drivers aged 20 or younger were more likely to be distracted at the time of a crash compared to older age groups. An Australian study of traffic crashes in New South Wales from 1996 – 2000 found that the highest frequency of cell phone distracted crashes causing injury or death was the age group aged 25 – 29 (Lam, 2002). With the exception of those aged 30 – 39, other distraction-related crashes causing death or injury were lower with greater age (Lam, 2002). In an analysis of fatal crashes in the USA from 1999 – 2008, distracted drivers in fatal crashes were more likely to be younger (Wilson & Stimpson, 2010). The percentage of young drivers in distracted driving fatal crashes aged 16 – 29, ranged from 37.7% in 2003, to 39.8% in 2006 (Wilson & Stimpson, 2010). For those aged 30 – 49, it ranged from 33.2% (2008) to 35.8% (2003); and the 50 and older age group ranged from 25.1% (2002) to 27.8% (2004/2005/2008; Wilson & Stimpson, 2010).

Awareness of Distraction Costs to Driving Performance

In a survey, 46% of university students believed they were capable or very capable of talking on a cell phone while driving, yet felt only 8.5% of other drivers were capable (Hill et al., 2015). University students in a qualitative study stated that texting while driving is so quick and easy that people do not recognise its dangers, and continue to engage in it (Watters & Beck, 2016). The university students felt that they were able to “calculate” the risk when texting and driving, and remain in control (Watters & Beck, 2016). A study of 12 young drivers aged 20 – 24 tested drivers on their awareness of distraction effects over time (Kidd & Horrey, 2010).

Within a two-week period, participants completed four sessions on a closed-loop track, each consisting of three blocks of 10 laps. They found that drivers' estimates of their driving performance while distracted was not accurate, and did not become more accurate over time with increased sessions (Kidd & Horrey, 2010). Drivers estimated that they were more impaired than they actually were while distracted on both a lane keeping and speed control task (Kidd & Horrey, 2010).

Horrey and colleagues (2010) conducted a study of 20 young drivers (*m* = 22 years) and 20 older drivers (*m* = 64 years) who drove a vehicle equipped with sensors around a closed loop track, with tasks of lane keeping, speed control, and stopping (Horrey, Lesch, Melton, 2010). They found that there was no significant relationship between the drivers' own estimation of their distraction and their actual distraction effects. In the stopping task hands-free device condition, there was one significant relationship between estimated and actual distraction effects, but it was negative (Horrey et al., 2010). This indicates that those who predicted they had the smallest distraction effects on stopping, actually had the largest. When broken down by sex and age, young males who estimated their driving performance to be higher, actually scored lower than others; females did not have significant relationships (Horrey et al., 2010). The authors of a computer based multi-tasking study found that those with the worst performance did not accurately predict larger decrements, as well (Finley, Benjamin, & McCarley, 2014). Finley and colleagues found that participants generally anticipated lower performance while engaged in two tasks simultaneously, proportionate to the degree of task difficulty, yet most participants over-estimated the dual-task cost. Although this study utilized a computer task, and a distracting n-back auditory task, it confirms the above findings of the driving-related research (Finley et al., 2014).

Compensatory Behaviours

Researchers have investigated whether distracted drivers use compensatory behaviours (e.g., slowing down, increasing headway, pulling over, waiting for red light), to offset the attention lost due to distracting activities. An American telephone survey reported that 64% of responders will use some type of compensatory behaviour to send a text message, while 35% will simply continue to drive while sending a message (Schroeder, Meyers, & Kostyniuk, 2013). A small percentage of driving responders (6.2%) will pull over to send a text message, 6.5% will use a voice command feature, 7.8% will make a passenger send the message, and 43.5% of responders wait until a stop sign or red light to send a text message (Schroeder et al., 2013). Alternatively, when answering a telephone call while driving, only 41.2% will use a compensatory behaviour (3% pull over first, 7.5% pull over after answering, 14.2% give the phone to a passenger, 16.% tell the caller they will call back), while the remaining 57.9% continue to drive throughout the phone conversation (Schroeder et al., 2013).

The authors of a German study found that drivers do not compensate by engaging in distracting activities at a stop, compared to while the vehicle was moving (Vollrath, Huemer, Teller, Likhacheva, & Fricke, 2016). Horrey and colleagues (2010) tested drivers on a closed-loop track to determine whether drivers adjusted the time they performed a distracting task based on the varying demands of the road (e.g., a narrow curved stretch of road, straight stretch of road). Contrary to expectations, there was no tendency for drivers to perform a distraction task during areas of lower demand on the driving track. Despite being able to perform the distraction tasks at any time, the drivers did not attempt to compensate for the distraction by performing it at a time of low driving demand. However, drivers tried to protect the driving task by switching their focus between the driving task and the distraction (Horrey et al., 2010).

A simulator experiment found that compared to driving only, drivers reading a text message had a slower mean speed, and even slower speed while writing a text message while driving (Yannis, Laiou, Papantoniou, & Gkartzonikas, 2016). Other studies have found that participants drive slower when in a distraction condition (Horberry et al., 2006; Thompson et al., 2012). Yannis and colleagues also found that texting-distracted drivers maintained a larger headway (Yannis et al., 2016). In simulated rear end collision avoidance tasks, drivers using a cell phone did have some compensatory behaviours to avoid the collision in certain conditions, such as a larger maximum deceleration rate and shorter reaction time (Li, Yan, Wu, Radwan, & Zhang, 2016). However, these compensations were not enough to the lower collision risk to match that of distraction free driving (Li et al., 2016).

Effect of Passengers

Attending to passengers was the third most frequent distraction found in teenage rear-end crashes (Carney et al., 2016). Heck and Carlos (2008) conducted a survey of over 2,000 California high school seniors, and found that 38.4% of respondents had been distracted by a passenger. The most popular passenger distractions were passengers talking/yelling (44.7%), followed by fooling around (22.4%). A small amount of passenger distraction (7.5%) was reported as intentional distraction, such as attempting to use the vehicle controls or physically touching the driver (Heck & Carlos, 2008).

However, the authors of an observational study at an American university found that drivers with passengers were less likely to use a cell phone than drivers without passengers (1.8% vs. 12.1%, $p < .001$; Cramer et al., 2007). The authors of a study in Berlin found that 15.1% of drivers driving alone were distracted, but only 6.9% of drivers with passengers were engaged in a distraction (Vollrath, Huemer, Teller, Likhacheva, & Fricke, 2016). The proportion of distracted driving fatalities in the U.S. who were driving alone increased from 60.4% in 1999, to 65.5% in 2008 (Wilson & Stimpson, 2010).

Conversing with passengers may be perceived as causing the same distraction effects as a phone conversation, but the evidence suggests otherwise. Mean eyes-off-road time was significantly longer for drivers engaged in cell phone use, compared to drivers attending to passengers (4.0s vs. 2.5s, $p < .001$; Carney et al., 2016). Drivers attending to passengers did not have significantly longer response times compared to drivers not engaged in other behaviours (2.2s vs. 2.1s; Carney et al., 2016). The authors of a meta-analysis found that compared to passenger distraction, cell phone distraction studies had significantly higher odds of finding a detrimental relationship with driving performance, $OR = 3.38$, 95% CI [1.36, 8.44] (Ferdinand & Menachemi, 2014).

The authors of a qualitative study found that undergraduate students said they may text and drive if they were driving alone, but if they had others in the vehicle, they would pass their phone over to have their friend answer the text message (Watters & Beck, 2016). Additionally, in-vehicle recorders captured passengers warning the teenage driver of the imminent crash in 32% of rear-end collisions (Carney et al., 2016).

Protective Effects

A study of 27 participants using a driving simulator found a protective effect of secondary tasks in lane keeping (Medeiros-Ward, Cooper, & Strayer, 2014). The secondary task consisted of listening to a list of single digit numbers and verbally saying the last number they heard (0-back condition) or the second last number (2-back condition; more difficult). Driving conditions were divided into 3 conditions of wind entropy: low (no wind), medium, and high, progressing in difficulty. In the high wind entropy condition, as the secondary task progressed (no secondary task to 0-back to 2-back condition) the lane position variability increased. Counterintuitively however, in the low wind condition, as the secondary task progressed in cognitive workload (no secondary task to 0-back to 2-back condition), lane position variability actually decreased. The no secondary task condition was significantly higher in lane position variability than the 0-back and 2-back condition, $t(26) = 4.10$, $p < .01$, $t(26) = 7.28$, $p < .01$, respectively. Additionally, the 0-back condition had higher variability than the 2-back condition, $t(26) = 4.41$, $p < .01$ (Medeiros-Ward et al., 2014).

This counterintuitive reduction in lane variability with cognitive distraction has been found in other studies. This finding has been documented as early as 1991. Twelve participants who had not used a cell phone were tested on the road with a driving instructor (Brookhuis, de Vries, & de Waard, 1991). They found that compared to driving alone, driving while engaged in a telephone (addition) task had a significant decrease in swerving on a quiet roadway (Brookhuis, et al., 1991). A review of cell-phone distraction studies was conducted to investigate the effect of conversations on driving performance (Horrey & Wickens, 2006). The authors found that although there was a significant negative effect on reaction time, the effect on lane keeping was much smaller and nonsignificant for the unweighted means (Horrey & Wickens, 2006).

Atchley and Chan (2011) found that drivers on a simulated monotonous drive who engaged in a late verbal task (verbal task on the last of five time blocks) actually had better lane-keeping, compared to those with no verbal task, and those who were continuously engaged in a verbal task throughout the drive, $F(1,42) = 10.57$, $p < .001$. University students in a driving simulator ($n = 18$) were found to have lower lane variability when engaged in a cognitive auditory task (reordering numbers), compared to the drive-only condition, $F(2, 34) = 4.21$, $p =$

.02 (He & McCarley, 2011). Jamson and Merat (2005) found lane variability decreased as the distracting surrogate in-vehicle information system auditory task demand increased, but the opposite was true for the visual task. Liang and Lee (2010) found that lane maintenance also improved during a cognitive navigational task on a simulator. Similarly, Becic and colleagues (2010) found that drivers on a simulator engaged in a story-retelling task had lower lane variability, compared to driving only. Horrey and Simmons (2007) found that university students distracted by an arithmetic task had less lane variability than driving only, $t(17) = 5.8$, $p < .001$. Lower lane variability was also found in drivers of a simulator distracted by both a signal detection task, $F(1, 35) = 12.77$, $p < .01$, and simulated cell-phone conversation, $F(1, 35) = 16.62$, $p < .001$ (Beede & Kass, 2006). Medeiros-Ward and colleagues (2014) suggest this improvement in lane variability may be explained by the hierarchical control theory, which states inner loop performance (which is largely automatic and requires minimal attention) suffers when attention is given to the task, and improves with less attention.

Negative Effects

A meta-analysis was conducted on the association between driving performance and secondary tasks, including but not limited to cell phone use, passengers, smoking, eating, and listening to music (Ferdinand & Menachemi, 2014). A total of 350 analyses from 206 studies were included from 1968 to 2012. For the majority of studies, the secondary task was cell phone use (47.1%) or passenger distraction (14.3%). The authors found that 80% of studies found a statistically significant detrimental relationship between distractions and driving performance (Ferdinand & Menachemi, 2014). It also reported that studies which examined cell phone use had statistically higher odds of finding a harmful relationship while driving, compared to studies examining other distractions including the presence of passengers, music, in-vehicle information systems, and other (Ferdinand & Menachemi, 2014). A separate meta-analysis found that reading/typing text messages while driving unfavourably affected eye movements, reaction time, stimulus detection, lane positioning, headway, speed, and collisions (Caird, Johnston, Willness, Asbridge, & Steel, 2014). Rumschlag and colleagues (2015) also concluded that texting while driving impairs simulated driving performance. Horrey and colleagues reported that drivers made one driving error every five times they performed a distraction task (2010).

Brake Reaction and Response Times. A naturalistic driving study utilizing a closed-loop track measured driving performance while driver's completed a mental arithmetic task on a hands-free or hand-held cell phone (Horrey et al., 2010). The authors found that while performing the phone task, drivers had slower brake reaction times, compared to baseline (Horrey et al., 2010). Hancock and colleagues also found that participants on a test track had a slower brake reaction time when distracted, compared to non-distracted, (0.71s versus 0.52s) $F(1, 30) = 41.6, p < .01$ (Hancock et al., 2003). McNabb and Gray reported increases in brake reaction time in simulated driving while texting (2016).

Carney and colleagues examined naturalistic driving data of teenage drivers involved in rear-end collisions (2016). There were 412 rear-end crashes analyzed, of which 76% of the drivers were seen engaging in a distracting behaviour (Carney et al., 2016). Significantly longer response times were observed in drivers using a cell phone, operating in-vehicle controls, or attending outside the vehicle, compared to drivers not engaged in potentially distracting behaviours ($p < .05$). Drivers who were operating/looking at a cell phone had longer response times (3.4s) compared to talking/listening to a cell phone (2.8s). Drivers operating/looking at a cell phone produced response times 25% slower than drivers not engaged in distracting behaviours. Additionally, over half (51%) of drivers using a cell phone crashed without reacting to the collision by braking or steering (Carney et al., 2016). Horrey and Wickens conducted an early meta-analytic study reviewing the impact of cell phone conversations on driving (2006). They found that cell phone conversations had a significant effect on response time, with a weighted effect size of 0.50, CI [0.36, 0.60] (Horrey & Wickens, 2006).

Lane Position. Drews and colleagues found that there was a statistically significant increase in driving errors in lane keeping, while talking on a cell phone, compared to a passenger, $t(39) = 2.1$, $p < .05$, (Drews, Pasupathi, & Strayer, 2008). As previously mentioned, Medeiros-Ward and colleagues found that drivers on a simulator distracted by a cognitive number n-back test had different lane position variability depending on wind entropy (2014). If the cognitive workload increased without wind, there was actually a decrease in lane position variability. However, in the high wind entropy condition, as cognitive workload increased, lane position variability also increased (Medeiros-Ward et al., 2014).

Stopping. While engaged in a distraction, drivers on a test track stopped significantly closer to the cross line at a red light, $F(1, 31) = 27.36$, $p < .01$ (Hancock et al., 2003). Drivers stopped about 5ft closer to the line while distracted (5.1ft versus 9.8ft), which is a large safety margin difference. Additionally, without distraction, 94.6% of trials were successful in stopping before the cross line at a red light, but with distraction, this number dropped significance to just 80.4%, ($F(1, 25) = 18.35$, $p < .01$; Hancock et al., 2003). This is further supported by Horrey and colleagues who found that drivers using a cell phone on a closed loop track made more errors on a stopping task, compared to baseline (2010).

Eyes off of the Road and Hands off of the Wheel. A naturalistic driving study was conducted on 70 drivers in North Carolina and Philadelphia testing distraction’s effect on the percent of time the driver had no hands on the wheel, and the percent of time the driver’s eyes were directed inside the vehicle (instead of out towards the road; Stutts et al., 2003). They found statistically significant negative effects (high percentages of hands off the wheel/eyes directed inside vehicle) for the following distractions: dialing or answering a cell phone/pager, preparing to eat/drink, eating/drinking/spilling, manipulating music/audio controls, reading/writing, grooming, manipulating vehicle controls, reach/lean/look for/etc., and other internal distraction. There was no significant difference found for having music/audio on, smoking, all types of occupant distraction (baby, child, and adult), conversing, and external distraction. While talking/listening on a cell phone/pager drivers had a higher percentage of no hands on the wheel time, while lighting or extinguishing a cigarette caused drivers to have a higher percentage of time of eyes directed inside the vehicle (Stutts et al., 2003).

Carney and colleagues found that drivers operating/looking at a cell phone had eyes off the road time 400% longer than drivers not engaged in distracting behaviours (2016). On average, the potentially distracting behaviours took the drivers' eyes off the road for more than two seconds (Carney et al., 2016). Looking away from the forward roadway just before the conflict, was involved in 65% of near crashes and almost 80% of crashes in a naturalistic driving study (Dingus et al., 2006). Dingus and colleagues believe that the driver's eyes off of the forward roadway contributes to the negative impact of secondary task distractions (Dingus et al., 2006).

Risk of Collisions. An increased risk of collision due to distraction has been found in driving simulator, naturalistic, and retrospective studies. Strayer and Drews found that drivers using a cell phone on a simulator were statistically more likely to crash, compared to when they were not distracted, $p < .02$ (2004). This is confirmed by another simulator study whose authors found that texting while driving leads to increased crash accident probability and driving errors (Yannis et al., 2016).

An increased risk of collision has also been found in naturalistic driving studies. Klauer and colleagues (2014) utilized the natural road and had participants' vehicles equipped with special cameras and sensors. For novice drivers (aged 16 – 17), the following distractions were significantly associated with an increased risk of a crash or a near crash: dialing a cell phone, reaching for a cell phone, texting, reaching for an object other than a cell phone, looking at roadside objects, and eating (Klauer et al., 2014). But for experienced drivers (aged 18 and above), only cell phone dialing was associated with an increased risk, however, texting was not assessed (Klauer et al., 2014). Simmons, Hicks, and Caird (2016) separated cell phone use into locating or answering a cell phone, dialing, talking, and texting or browsing in six naturalistic driving studies. The authors of this meta-analysis found that dialing, locating or answering, and texting or browsing was associated with higher odds of crash or near crash risk compared to talking on a cell phone while driving, $OR = 2.72$, $p < .001$, 95% CI [1.78, 4.17] (Simmons et al., 2016). It is noteworthy that the cell phone tasks with higher risk require the driver to take their eyes off of the road (Simmons et al., 2016).

Redelmeier and Tibshirani (1997) conducted an early study on cellular telephone calls and motor vehicle crashes using 699 Ontario drivers in a case-crossover analysis. Cell phone billing records were utilized to contrast cell phone use 10 minutes immediately prior to the crash, and the same time on the day before the crash. Cell phone use immediately prior to a crash was associated with a risk of collision four times higher, $RR = 4.3$, $p < .001$, 95% CI [3.0, 6.5] than for the same drivers not using their cell phones (Redelmeier & Tibshirani, 1997).

A small case-control study using Oklahoma police accident reports reported an increased odds ratio for a driver fatality of 2.11, CI {1.64, 2.71] if a cell phone was present in the vehicle (Violanti, 1998). Further, if the cell phone was in use, the odds of a driver fatality were drastically increased *OR* = 9.29, CI [3.70, 23.14]. However, these results should be considered with skepticism as the cases of crash fatalities with a cell phone in the vehicle or with a cell phone in use were very low, *n* = 65, and *n* = 5, respectively (Violanti, 1998). A retrospective epidemiological study that linked Québec crash data with cell phone company data found a dose-response relationship between the frequency of cell phone use, and crash risk (Laberge-Nadeau et al., 2003).

Lam (2002) conducted a study analyzing motor vehicle collisions in Australia and found that the risk of crash causing injury/death to the driver was increased by in-vehicle distractions for all drivers, except those in the 40 – 49 year old age group. In-vehicle distractions included: attending to passengers, adjusting audio/music, lighting or smoking a cigarette and other distractions in the vehicle. Hand held phones only caused significant increase to driver injurious crash risk for those aged 25 – 29 years old (Lam, 2002). Just under 4% (3.8%) of collisions causing injury or death to the driver were found to have distraction as a contributing factor in Australia (Lam, 2002). Elvik (2011) estimated an increased odds ratio of 2.86 CI [1.72, 4.75] for accident involvement when a cell phone was used, compared to not used in an international meta-analysis.

While the association of distraction and increased crash risk continues to mount, only one study to our knowledge has addressed whether distraction increases the odds of a driver being responsible for causing the crash. This Canadian epidemiological study used crash data and a crash culpability scoring tool to determine whether cell phone use increases crash culpability

(Asbridge, Brubacher, & Chan, 2013). Cell phone use increased the odds of a culpable crash by 70%, compared to no cell phone use (*OR* = 1.70, CI [1.22, 2.36]). This relationship was persistent for drivers aged 26 – 65, males, non-impaired drivers, fully licenced drivers, injury and non-injury crashes. However, this association did not remain for younger drivers (aged 16 – 25), older drivers (aged 66 – 80), females, suspected impaired drivers, and drivers without a full licence (Asbridge et al., 2013).

Fatalities and Distracted Driving

Due to the various impairments of distracted driving, it is important to investigate its role in fatal collisions. Ferdinand and Menachemi (2014) found in their meta-analysis of driving performance and secondary tasks that only 3% (*n* = 11) of studies focused on fatalities. There has been very little research on the relationship between distractions and traffic-related injuries and fatalities (Ferdinand & Menachemi, 2014).

Wilson and Stimpson (2010) studied trends in fatal crashes from distracted driving from 1999 – 2008 using the Fatality Analysis Reporting System (FARS) database. Distracted driving as a proportion of all fatalities increased from 10.9% (*n* = 4,563) in 1999, to 15.8% (*n* = 5,870) in 2008. There was a decrease in distracted driving fatalities between 2003 – 2005, reaching a low of 10.5% of all driving fatalities. However from 2005 – 2008, there was a 28.4% increase in fatal collisions related to distracted driving; in 2008, distracted driving fatalities accounted for 15.8% of all driving fatalities. The demographics of drivers became increasingly likely to be male, Caucasian, younger, and driving alone (Wilson & Stimpson, 2010). Using cell phone subscriber data, they predicted that over 16,000 additional distracted driving deaths occurred in 2001 – 2007, as a result of the vast increase in texting after 2001 (Wilson & Stimpson, 2010).

More research should be done on the associations between injuries, fatalities, and distracted driving (Ferdinand & Menachemi, 2014).

Future Research

In 2010, the Canadian Association of Emergency Physicians recommended continued research on the dangers of distracted driving (Huang et al., 2010). Further research can be done on the prevalence and frequency of distracted driving among all age groups and sex. In particular, there is a research gap concerning distracted driving in adult and older adult populations. Because age and sex may play a role in distracted driving, it is important to determine how they are related. Additional research on other predictors could assist in understanding which populations are at most risk.

Academics also agree that further research is needed on cell phone distracted driving and its dangers (Regan, 2006; Srinivas, White, & Omar, 2011). Ferdinand and Menachemi (2014) stated that very few studies have focused on injuries and fatalities involving cell phone related distracted driving. Future studies should also focus on other distractions such as eating, cigarette smoking, and vehicle information systems, as few studies have examined those (Ferdinand & Menachemi, 2014).

Relevance to Public Health Research

Public health research aims to promote health, prevent disease and health conditions, and prolong life. Public health issues change as society evolves economically, politically, technologically and socially. Driving is a very common task in Western cultures. Distracted driving is also a widespread issue, especially with the recent popularity increase of cell phones. Hence, distracted driving is becoming an increasingly important health and safety issue by not only putting the driver in danger, but passengers in the vehicle, and all other roadway users. In

2001, the Canadian Medical Association Journal published an editorial suggesting the regulation of cell phone use and other devices while driving (Todkill et al., 2001). Distracted driving knowledge such as this may be used to inform policies and change laws and regulations.

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Chapter 2: The Present Study

Objectives

In this research I aimed to investigate distracted driving in fatal collisions in the USA. The first objective was to determine the prevalence of distraction in fatal USA collisions by age and sex during the years 1991 – 2015. The second objective was to establish the most prevalent type(s) of driver distraction involved in fatal collisions. The final aim of this research was to examine the role of driver distraction and crash responsibility in fatal crashes.

Methods

Data Source and Collection

This study utilized data from the Fatality Analysis Reporting System (FARS), which is a census of all motor vehicle collisions that resulted in a fatality within the 50 states of the United States of America, Puerto Rico, and the District of Columbia (National Highway Traffic Safety Administration, 2016). A fatality is defined as a death of a motorist or non-motorist as a result of the collision within 30 days. The crash had to involve a motor vehicle travelling on a primarily public traffic way (National Highway Traffic Safety Administration, 2016). The FARS is directed by the National Center for Statistics and Analysis (NCSA), a component of the NHTSA (National Highway Traffic Safety Administration). Each state's government has an agreement with the NHTSA to provide information on fatal crashes to the NHTSA (National Highway Traffic Safety Administration, 2016).

The FARS has *FARS Analysts* who are trained state employees to gather, translate and transmit their state's data to the NCSA in a standardized format (National Highway Traffic Safety Administration, 2016). FARS analysts use a variety of state documents to code more than 100 FARS data elements. The documents used for coding include: Police Accident Reports, Death Certificates, State Vehicle Registration Files, Coroner/Medical Examiner Reports, State Driver Licensing Files, State Highway Department Data, Emergency Medical Service Reports, Vital Statistics and other State Records. FARS analysts use a coding manual to translate the information from a Police Accident Report to the FARS database. When data are entered, they are automatically checked for applicable range values and consistency. Quality checks are performed on the data before they are made available to the public. Additionally, annual classes are held for FARS analysts, as well as a system wide FARS meeting to reinforce coding practices (National Highway Traffic Safety Administration, 2016).

Utilization of the FARS

A variety of authors have utilized the FARS for a number of different research questions. Various driver and vehicle characteristics in fatal collisions have been analyzed (Bédard, Guyatt, Stones, & Hirdes, 2002; Briggs et al., 2005; Potter, Dubois, Haras, & Bédard, 2013), including those with a focus on young drivers (Frisch & Plessinger, 2007), and older drivers (Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998). Past and future trends in fatalities have been tracked (Bédard, Stones, Guyatt, & Hirdes, 2001; Mullen, Dubois, & Bédard, 2013). The impact of passengers in various populations (e.g., older drivers, teenage drivers, young drivers) in fatal collisions has been investigated (Bédard & Meyers, 2004; Chen, Baker, Braver, & Li, 2000; Lambert-Bélanger, Weaver, Mullen & Bédard, 2012; Preusser, Ferguson, & Williams, 1998). The FARS database has also been used to explore the ability to predict driving performance in the elderly (Bédard, Weaver, Dārzins, & Porter, 2008).

The impact of various substances have been investigated, such as opioid analgesics (Dubois, Bédard, & Weaver, 2010; Reguly, Dubois, Bédard, 2014), stimulants (Gates, Dubois, Mullen, Weaver, & Bédard, 2013), benzodiazepines (Dubois, Bédard, & Weaver, 2008), and cannabis (Bédard, Dubois, & Weaver, 2007). The combined effects of alcohol and drugs have also been studied with cannabis (Dubois, Mullen, Weaver, & Bédard, 2015) and benzodiazepines (Maxwell, Dubois, Weaver & Bédard, 2010). The FARS has been previously utilized to study distraction and inattention in fatal motor vehicle accidents (Tseng, Nguyen, Liebowitz, & Agresti, 2005; Wilson & Stimpson, 2010). Lim and Chi (2013) have used the FARS to investigate the impact of cell phone laws in fatal crashes.

Fatality Analysis Reporting System

The FARS is currently made up of 20 data files (Appendix A; National Highway Traffic Safety Administration, 2016). There are three main data files that have been in use since the FARS began in 1975: the Crash, Vehicle, and Person data files. The crash data file contains information about the environmental conditions and crash characteristics. The vehicle data file contains information on each motor vehicle involved in the crash, and its driver. The person data file contains information on each motorist (e.g., drivers, and passengers) and non-motorist (e.g., pedestrians and pedal cyclists) involved in the crash. The remaining 17 data files have been added in 2010, 2013, or 2014 (National Highway Traffic Safety Administration, 2016).

Distraction in the FARS

The FARS began recording distraction in 1982 as a Driver Level Related Factor, and coded as 'inattentive'. This included all types of distraction such as car or cell phone, eating, fax, DVD player, head-up display systems, adjusting vehicle controls, lighting a cigarette, painting nails, using a razor, reading, looking for an address, talking, a crash in the next lane, child passengers, an automated highway sign, approaching emergency vehicle, *et cetera*. In 2002, the FARS added a variable specific to cell phone distraction, 'Cellular Telephone in Use in Vehicle'.

In 2010, the FARS created a separate data file for distraction called the Distract data file (National Highway Traffic Safety Administration, 2016). It identifies the best attribute(s) to describe the attention of the driver prior to impact, or prior to realization of an imminent dangerous event. Each moving motor vehicle driver has at least one record, and each driver distraction is recorded as a separate record. Emotional psychological states, such as anger or depression, as well as physical conditions/impairments, such as fatigue, alcohol, and medical conditions, are not considered a distraction by the NHTSA. However, cognitive distractions such as daydreaming, lost in thought, and inattention are considered distractions. There are 18 separate distractions which can be coded, as well as an option for not distracted, not reported, or unknown if the driver was distracted. The Distract data file includes distractions due to other occupants, cellular phones, adjusting controls, eating or drinking, smoking, inattention and more (National Highway Traffic Safety Administration, 2016). A complete list of the distractions can be found in Appendix B.

Variables

Crash responsibility. Each crash has data recorded by trained FARS analysts on accident, vehicle, and person levels, using standardized methods. The FARS analysts use police records to code up to three (1975 – 1996) or four (1997 – onward) driver-related factors. Many of the driver-related factors may have contributed to the crash, and are called unsafe driver actions (UDAs; Blower, 1998). The UDAs coded by FARS analysts were used as a proxy measure of crash responsibility. Crash responsibility, as determined by the UDAs acts as the dependent variable. If a driver does not have an UDA coded, he/she is considered to not have contributed to the crash responsibility. If a driver has one or more UDAs coded, he/she is considered to have contributed to the crash responsibility. Therefore, in this study, drivers without an UDA coded were controls, and drivers with one or more UDAs coded were cases. Distracted driving was previously considered an UDA, but was coded separately after 2009. Therefore, UDAs were used in the analysis from 2010 onwards. A list of the UDAs included in the analysis can be seen in Appendix C. Unsafe drive actions have been successfully utilized as a proxy measure for responsibility by many researchers (Perneger & Smith, 1991; Blower, 1998; Bédard & Myers, 2004; Bédard, Dubois, & Weaver, 2007; Dubois, Bédard, & Weaver, 2008; Dubois, Bédard, & Weaver, 2010; Maxwell, Dubois, Weaver, & Bédard, 2010; Gates, Dubois, Mullen, Weaver, & Bédard, 2013; Dubois, Mullen, Weaver, & Bédard, 2015).

Driving history. We controlled for driving record history, as unsafe or high-risk drivers may confound the analysis. The FARS includes driving record history for the drivers' previous three years, but beginning in 2015, it was expanded to the previous five years. Driving record history includes the following variables: number of collisions, number of recorded convictions for driving while impaired (DWI; alcohol and drug impairment), speeding convictions (driving too fast or too slow), other harmful moving violation convictions, licence suspensions, and licence revocations.

Other variables. Additionally, the following variables from the FARS database were utilized: age, sex, vehicle type, year of crash, number of occupants, number of vehicles in collision, and urban/rural location. Age was recorded as the individual's age at the time of the crash, according to his/her last birthday. Until 2008, the age of the individual was recorded to age 96. Those 97 and older were all labelled as 97. In 2009, the FARS was edited to record the actual age of the individual to age 120. In 2010, a Not Reported option was added, as well. Sex was recorded as male, female, or unknown; a Not Reported option was added in 2010. The number of occupants was recorded as a physical count of the actual number of occupants in the vehicle, up to a count of 95; 96 occupants or more was recorded as 96. A *Roadway Function Class* variable was used to classify the collision as happening on either an urban or rural roadway. There are Unknown and Not Reported options for most FARS variables.

Inclusion Criteria

Prevalence inclusion criteria. All participants were drivers in the FARS database from 1991 – 2015. Only drivers from 1991 onwards were used, as distraction was first coded by FARS in 1991. Drivers aged 16 years and older were included. Passenger type vehicles, which are vehicles used primarily to carry passengers were included; this includes cars, pickup trucks, SUVs, and vans. Vehicles such as motorcycles, motorhomes, commercial trucks, farm equipment, or buses were excluded. This included just over one million individuals (*n* = 1,075,448).

Crash responsibility inclusion criteria. The crash responsibility analysis used drivers in the FARS database from 2010 – 2015, as this corresponds with the updated distraction data file. As described above, only drivers of passenger type vehicles were included. In order to be able to control for previous driving history, only drivers aged 20 years old and older were included. Drivers were included if they had a blood alcohol content of zero, and tested negative for illegal drugs.

Analysis

Prevalence analysis. The prevalence analysis included drivers of passenger type vehicles of all ages (16 years and older) from 1991 – 2015. Descriptive statistics were used to identify the prevalence rate per year, of each sex, and by age. The most frequent driving distraction was identified for the years 2010 – 2015. Descriptive statistics for the following variables will also be reported: presence of passengers, single/multiple vehicle crash, and urban/rural location.

Crash responsibility analysis. The crash responsibility analysis used a case-control design within the above specified drivers aged 20 years and over from the FARS database from 2010 – 2015. The analysis could not include data prior to 2010 because the UDAs included distracted driving until 2009, therefore, it would bias the analysis. Unsafe driver actions were used as the proxy measure for crash responsibility. Cases were coded as drivers with one or more UDAs recorded. Controls were drivers with no UDA recorded. Unadjusted and adjusted odds ratios of crash responsibility by driver distraction were calculated using logistic regression. Adjusted analyses included: age, age^2, sex, the distraction by age interaction, the distraction by age^2 interaction, and drivers' past driving histories.

Odds ratios are most frequently used in case-control studies (Szumilas, 2010). An odds ratio measures the association between a particular exposure and an outcome (Szumilas, 2010). For this study, the exposure was engaging in distracted driving, while the outcome, or dependent variable, was crash responsibility (UDAs). Odds ratios were used to determine whether the exposure of distracted driving is a risk factor for crash responsibility, and to determine the magnitude of the risk factor. An odds ratio equal to one indicates that the exposure does not affect the odds of the outcome (Szumilas, 2010). An odds ratio above one indicates that the exposure is associated with higher odds of the outcome, while an odds ratio below one indicates an association with lower odds of the outcome (Szumilas, 2010). Confounding variables were addressed in logistic regression, producing adjusted odds ratios (Szumilas, 2010).

Ethical Consideration

The FARS is coded by analysts using state documents, and FARS data are available to the public. The FARS does not contain identifying information such as names or addresses. FARS data fully conforms to the Privacy Act. I acknowledge this study to be a secondary data analysis. This database has been compiled by the National Highway Traffic Safety Administration (NHTSA). There are limited ethical concerns with this research, as it utilizes previously collected data, from a public source. Ethical approval through the Research Ethics Board is not required.

Limitations

The major limitation of this project is the case-control design. Case-control studies, such as this one, do not demonstrate causality between the variables. However, given that an experimental study of distracted driving on a road cannot be conducted for ethical and safety reasons, a case-control design was used. This study can allow us to make inferences about the relationship between distraction and fatal collisions according to Hill's aspects of association, such as the strength of association, consistency of person, place and time, coherence with existing knowledge, and consideration of alternative explanations (Hill, 1965).

Another limitation is the use of UDAs as a proxy measure for responsibility, as a responsibility variable does not exist. However, UDAs are preferred over traffic violations because UDAs do not require legal proof and may not be a chargeable offense (Blower, 1998). The validity of UDAs as a measure of crash responsibility has been tested in fatal crashes involving trucks and passenger type vehicles (Blower, 1998); the use of UDAs may also be interpreted as a strength. The FARS does not differentiate between hand-held cell phones and hands-free devices. This may have provided valuable information regarding their differences.

Prevalence rates may be affected by differences in reporting over time; increased awareness of distracted driving may lead to increased inspection and reporting. Finally, the FARS only includes collisions that have resulted in a fatality. Results from these severe collisions may not be generalizable to collisions with lesser or no injuries.

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Appendix A

Current FARS Data Files

Current FARS Data Files

Year Began	Data Files	Description
1975	Accident	Crash characteristics and environmental conditions
1975	Person	All persons involved in the crash
1975	Vehicle	Moving motor vehicles and drivers
2010	Cevent	Events which occurred in the crash
2010	Distract	Driver distractions
2010	Drimpair	Physical impairment of drivers
2010	Factor	Vehicle circumstances information
2010	Maneuver	Driver maneuvers
2010	Nmcrash	Non-motorist contributing circumstances
2010	Nmimpair	Non-motorist physical impairments
2010	Nmprior	Actions of non-motorists
2010	Parkwork	Parked and working vehicles in crashes
2010	Safetyeq	Safety equipment of non-motorists
2010	Vevent	Sequence of events with sequential event number
2010	Violatn	Violations charged to drivers
2010	Vision	Obstructions to driver's vision
2010	Vsoe	Sequence of events for each moving vehicle
2012	Damage	Areas on vehicle that were damaged
2013	Vindecode	Vehicle descriptors for all vehicles
2014	Pbtype	Crashes between motorists and pedestrians

Appendix B

Distract Data File Attribute Codes

Distract Data File: Attribute Codes and Distractions

2010 – 2011	2012 – Later	Distraction
00	00	Not Distracted (excluded)
01	01	Looked But Did Not See (excluded)
03	03	By Other Occupant(s)
04	04	By a Moving Object in Vehicle
05	05	While Talking or Listening to Cellular Phone
06	06	While Manipulating Cellular Phone
07	07	While Adjusting Audio or Climate Controls
09	09	While Using Other Component/Controls Integral to Vehicle
10	10	While Using or Reaching For Device/Object Brought Into Vehicle
12	12	Distracted by Outside Person, Object or Event
13	13	Eating or Drinking
14	14	Smoking Related
15	15	Other Cellular Phone Related
16	16	No Driver Present/Unknown if Driver Present (excluded)
--	17	Distraction/Inattention
--	18	Distraction/Careless
--	19	Careless/Inattentive
92	--	Distraction/Inattention, Details Unknown
--	92	Distraction (Distracted), Details Unknown
--	93	Inattention (Inattentive), Details Unknown
96	96	Not Reported (excluded)
97	--	Inattentive or Lost in Thought
--	97	Lost In Thought/Day Dreaming
98	98	Other Distraction
99	99	Unknown if Distracted (excluded)

Appendix C

Unsafe Driver Actions as Driver Level Related Factors in the FARS

Unsafe Driver Actions (UDAs)

Code	Unsafe Driver Action
20	Leaving Vehicle Unattended with Engine Running; Leaving Vehicle Unattended in Roadway
21	Overloading or Improper Loading of Vehicle with Passenger or Cargo
22	Towing or Pushing Vehicle Improperly
23	Failing to Dim Lights or to Have Lights on When Required
24	Operating Without Required Equipment
26	Following Improperly
27	Improper or Erratic Lane Changing
28	Improper Lane Usage
29	Intentional Illegal Driving on Road Shoulder, in Ditch, or Sidewalk, or on Median
30	Making Improper Entry to or Exit from Trafficway
31	Starting or Backing Improperly
32	Opening Vehicle Closure into Moving Traffic or Vehicle is in Motion
33	Passing Where Prohibited by Posted Signs, Pavement Markings, or School Bus Displaying Warning Not to Pass
34	Passing on Right Side
35	Passing with Insufficient Distance or Inadequate Visibility or Failing to Yield to Overtaking Vehicle
36	Operating the Vehicle in an Erratic, Reckless, Careless or Negligent Manner
37	Police Pursuing this Driver or Police Officer in Pursuit
38	Failure to Yield Right of Way
39	Failure to Obey Actual Traffic Signs, Traffic Control Devices or Traffic Officers, Failure to Observe Safety Zone Traffic Laws
40	Passing Through or Around Barrier
41	Failure to Observe Warnings or Instructions on Vehicle Displaying Them
42	Failure to Signal Intentions
45	Driving Less Than Posted Maximum
47	Making Right Turn from Left-Turn Lane or Making Left Turn from Right-Turn Lane
48	Making Improper Turn
50	Driving Wrong Way on One-Way Trafficway (Intentionally or Unintentionally)

51	Driving on Wrong Side of Two-way Trafficway (Intentionally or Unintentionally)
52	Operator Inexperience
53	Unfamiliar With Roadway
54	Stopping in Roadway (Vehicle Not Abandoned)
58	Over Correcting
59	Getting Off/Out of a Vehicle

Chapter 3: Prevalence of Distraction and Cell Phone Distraction in Fatal USA Collisions

1. Introduction

There has been a general downward trend in motor vehicle crash fatalities over the last decade, however there appears to be a slight upward trend in most recent years (National Center for Statistics and Analysis, 2017). In 2016, there were 34,439 passenger vehicle fatalities, the highest tally since 2008. Not surprisingly, 28% of those fatalities were alcohol-related and 27% were speeding-related (U.S. Department of Transportation, 2018). However, distracted driving was singled out for 9% of all fatalities (National Center for Statistics and Analysis, 2017), which may be negating the safety benefits achieved through other initiatives.

Distracted driving has become a widespread issue, especially with the recent surge in the use of cell phones and other technologies. Regan (2007) defined distracted driving as driving while engaged in a secondary activity that affects the performance of the primary task of driving. Distraction can include a wide variety of behaviours and activities. Prevalence estimates of distracted driving can vary depending on the type of distraction behaviours being examined, how distraction is operationalized, the nature of the study sample, and study design. Almost half (47%) of Americans reported eating or drinking while driving, 36% reported interacting with children, and 25% change CDs, DVDs, or tapes at least sometimes while driving (Schroeder et al., 2013). Fewer respondents reported personal grooming (9%) and reading a book (1%) at least sometimes while driving (Schroeder et al., 2013).

Forty percent (40%) of American drivers aged 16 and older reported making or accepting phone calls, 14% reported reading text messages, and 10% reported sending text messages at least sometimes while driving (Schroeder et al., 2013). Almost 60% of American drivers reported using their cell phone while driving within the past 30 days (Gliklich, Guo, &

Bergmark, 2016). Rates have been shown to be much higher in certain sub-populations, such as university students and young drivers. The prevalence of university students who reported texting while driving ranged from 6% to 90%, whereas it ranged from 85% to 90% for talking on a cell phone while driving (Cook & Jones, 2011; Hill et al., 2015; Terry & Terry, 2016; Tucker, Pek, Morris, & Ruf, 2015). Young drivers (aged 17 – 28) reported similar rates of texting (63%) and talking on a cell phone (90%) while driving (Weller, Shackleford, Dieckmann, & Slovic, 2013). Approximately 42% of high school students reported texting or emailing while driving within the past 30 days (Kann et al., 2016).

Observed frequencies are often regarded as a more accurate representation of the true frequencies, compared to those stated in self-report studies, which may be more prone to bias. However, observed distraction frequencies also varied greatly; roadside observed cell phone use ranged from 2 – 11% (Pickrell, Li, & KC, 2016; Cramer, Mayer, & Ryan, 2007). In-vehicle cameras revealed 91% of drivers manipulated audio controls, 71% engaged in eating/drinking/spilling, 46% engaged in grooming, 34% used cell phones, and 7% engaged in smoking related activities (Stutts & Hunter, 2003). In-vehicle cameras also revealed that 76% of teenage drivers (aged 16 – 19) involved in rear-end crashes were engaged in some distracting behaviour (Carney, Harland, & McGehee, 2016).

There has been conflicting evidence regarding whether more males or females engage in distracted driving. Several researchers reported that compared to males, females used a cell phone more often while driving (Cramer, Mayer, & Ryan, 2007; Pickrell et al., 2016; Seo & Torabi, 2004). However, in different studies males reported more frequent texting while driving than females (Tucker et al., 2015), and no sex differences were found by others for texting and driving (Ontario Agency for Health Protection and Promotion (Public Health Ontario), Berenbaum, Keller-Olaman, & Manson, 2015), talking on a cell phone (Tucker et al., 2015), or for general distraction in observed rear-end crashes (Carney et al., 2016).

Younger drivers had high frequencies of distracted driving in several self-report studies (Quisenberry, 2015; Rhodes & Pivik, 2011; Weller et al., 2013), observational studies (Pickrell et al., 2016), as well as in crash studies (Dingus et al., 2006; Stutts & Hunter, 2003). Distracted driving appears to be more prevalent in younger drivers, however, much of this research focuses specifically on cell phone use.

The negative effects of distraction on driving have been well-documented in the literature. Authors of a meta-analysis on driving performance and various distractions stated that 80% of studies found a statistically significant detrimental relationship between distractions and driving performance (Ferdinand & Menachemi, 2014). Others, also using meta-analytic methodologies, found that reading/typing text messages while driving unfavourably affected eye movements, reaction time, stimulus detection, lane positioning, headway, speed, collisions (Caird, Johnston, Willness, Asbridge, & Steel, 2014) and cell phone conversations negatively affected driver response time (Horrey & Wickens, 2006).

There has been little research on the associations between distraction, traffic-related injuries, and fatalities (Ferdinand & Menachemi, 2014). Wilson and Stimpson (2010) found that distraction was involved in 10.9% (1999) to 15.8% (2008) of fatal crashes. They surmised that from 2001- 2007, over 16,000 additional distracted driving deaths occurred due to the increase in texting after 2001 (Wilson & Stimpson, 2010).

The present study aims to further investigate the prevalence of distracted driving in fatal collisions. We examined prevalence of all distractions, as well as cell phone distraction. We also stratified the data according to basic demographic variables (age, sex) and crash descriptors (driving alone versus with passengers, single versus multiple vehicle crash, rural versus urban). The final aim was to identify the most prevalent recorded distraction from 2010 – 2015.

2. Methods

2.1. Data Source

We utilized data from the Fatality Analysis Reporting System (FARS), a census of all motor vehicle collisions that resulted in a fatality within the 50 states of the United States of America, Puerto Rico, and the District of Columbia (National Highway Traffic Safety Administration, 2016). A fatality is defined as the death of a motorist or non-motorist within 30 days following a crash involving a motor vehicle travelling on a primarily public traffic way (National Highway Traffic Safety Administration, 2016).

The database contains more than 100 data elements coded by FARS analysts in a standardized format using a variety of state documents (e.g., Police Accident Reports, Death Certificates, State Vehicle Registration Files, Coroner/Medical Examiner Reports, State Driver Licensing Files, State Highway Department Data, Emergency Medical Service Reports, Vital Statistics and other State Records; National Highway Traffic Safety Administration, 2016).

There are three main data files that have been in use since the FARS began in 1975: the Crash, Vehicle, and Person data files. The crash data file contains information about the environmental conditions and crash characteristics. The vehicle data file contains information on each motor vehicle involved in the crash, and its driver. The person data file contains information on each motorist (e.g., drivers, and passengers) and non-motorist (e.g., pedestrians and pedal cyclists) involved in the crash.

2.2 Distraction within the FARS

The coding of driver distraction in FARS was introduced in 1982 as a driver-related factor attribute, and coded as ‘inattentive’. This included a wide array of distractions such as a car or cell phone, fax, DVD player, adjusting vehicle controls, lighting a cigarette, head-up display systems, reading, eating, a crash in the next lane, using a razor, painting nails, talking, looking for an address, an automated highway sign, child passengers, approaching emergency vehicle, *et cetera*. Because the inattentive attribute is quite broad, it does not indicate the specific source(s) of driver distraction. In 2002, the FARS added a variable ‘Cellular Telephone in Use in Vehicle’, which captures distraction by hand-held and hands-free cell phones.

In 2010, the FARS created a separate data file for distraction called the Distract Data File (National Highway Traffic Safety Administration, 2016). It identifies the best attribute(s) to describe the attention of the driver prior to impact, or prior to realization of an imminent dangerous event. Regardless of whether they were distracted or not, each moving motor vehicle driver has at least one record, and each driver distraction is recorded as a separate record. Emotional psychological states, such as anger or depression, as well as physical conditions/impairments, such as fatigue, alcohol, and medical conditions, are not considered a distraction by the NHTSA (National Highway Traffic Safety Administration, 2016). There are 18 separate distractions that can be coded, as well as an option for not distracted, not reported, or unknown. The Distract Data File includes distractions due to other occupants, cell phones, adjusting controls, eating or drinking, smoking, inattention and more. The Distract Data File includes several elements that are general or ambiguous (National Highway Traffic Safety Administration, 2016). A complete list of the distractions can be found in Appendix A.

2.3 Additional FARS variables used

In addition to the inattentive attribute and the distractions listed in the Distract Data File, we used the following variables: age, sex, year of crash, vehicle type, number of occupants, urban/rural location, and number of vehicles involved in the collision.

2.4 Inclusion/exclusion criteria

We included all drivers aged 16 years and older, with identifiable sex (male or female), recorded in the FARS database from 1991 – 2015, to capture 25 years of data. We limited our analyses to passenger type vehicles (as defined by NHTSA), which are used primarily to carry passengers (e.g., cars, pickup trucks, SUVs, and vans; National Highway Traffic Safety Administration, 2016). Vehicles such as motorcycles, motorhomes, commercial trucks, farm equipment, and buses were excluded.

2.5 Analytical plan

We reported the prevalence of overall distraction for the years 1991 – 2015, and stratified according to age, sex, and crash descriptors (presence of passengers, single or multiple vehicle crash, and rural or urban location). Cell phone distraction was examined in more details for the period 2002 – 2015. Finally, we presented the distractions recorded in the more detailed distraction data file for the period 2010 – 2015.

3. Results

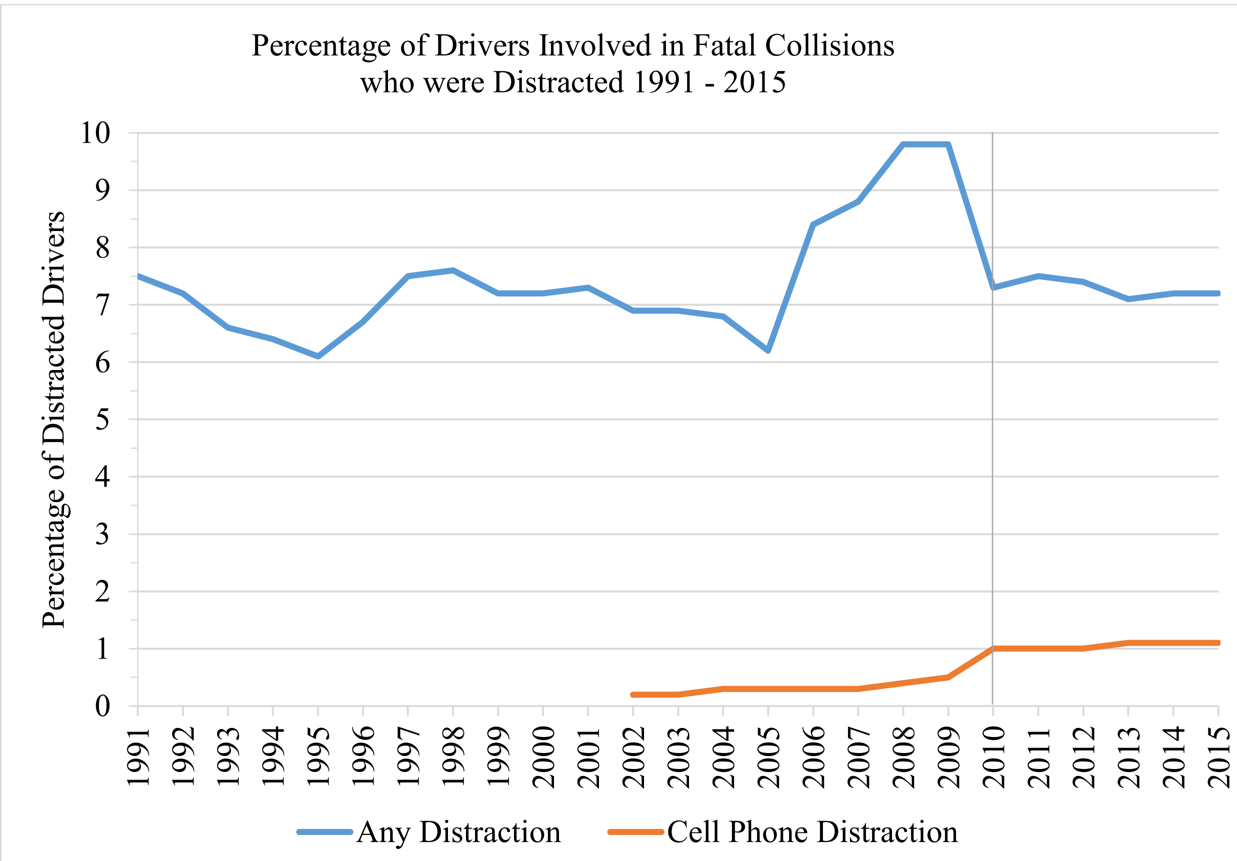
From 1991 to 2015 there were 1,477,888 people involved in crashes. Selecting only drivers of vehicles in-transport reduced this amount to 1,326,505. After excluding vehicles other than passenger type vehicles we had 1,088,843 drivers. Of these, there were 1,082,948 drivers with identifiable sex and 1,075,448 aged 16 and older; these records form the basis of the analyses we presented below.

3.1 Overall Distraction 1991 – 2015

For the period 1991 – 2015, there were 79,003 drivers coded as distracted (7.34% of all drivers in fatal crashes). Over the 25-year period the proportion of distracted drivers ranged from a low of 6.1% (1995) to a high of 9.8% (2008, 2009; Figure 1; Cell phone distraction is discussed in section 3.2). The vertical line in Figure 1 represents the beginning of the FARS Distract Data File.

Figure 1

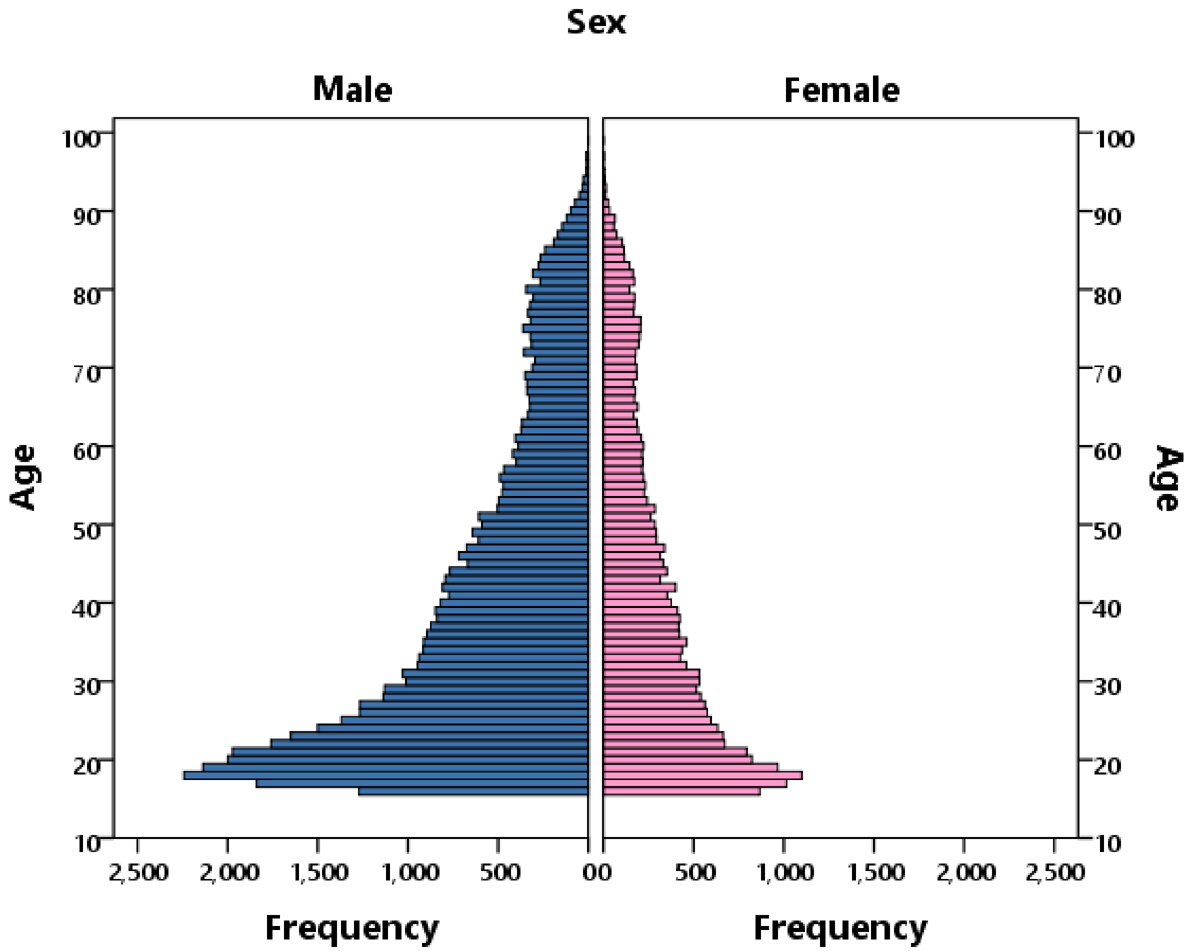
Percentage of Drivers Involved in Fatal Collisions who were Distracted, 1991 – 2015



About two thirds of the distracted drivers (n = 53,380; 67.6%) were male. The higher prevalence of male distracted drivers can be seen in Figure 2. Distraction was most prevalent in younger ages, with an increase in the oldest ages, as well.

Figure 2

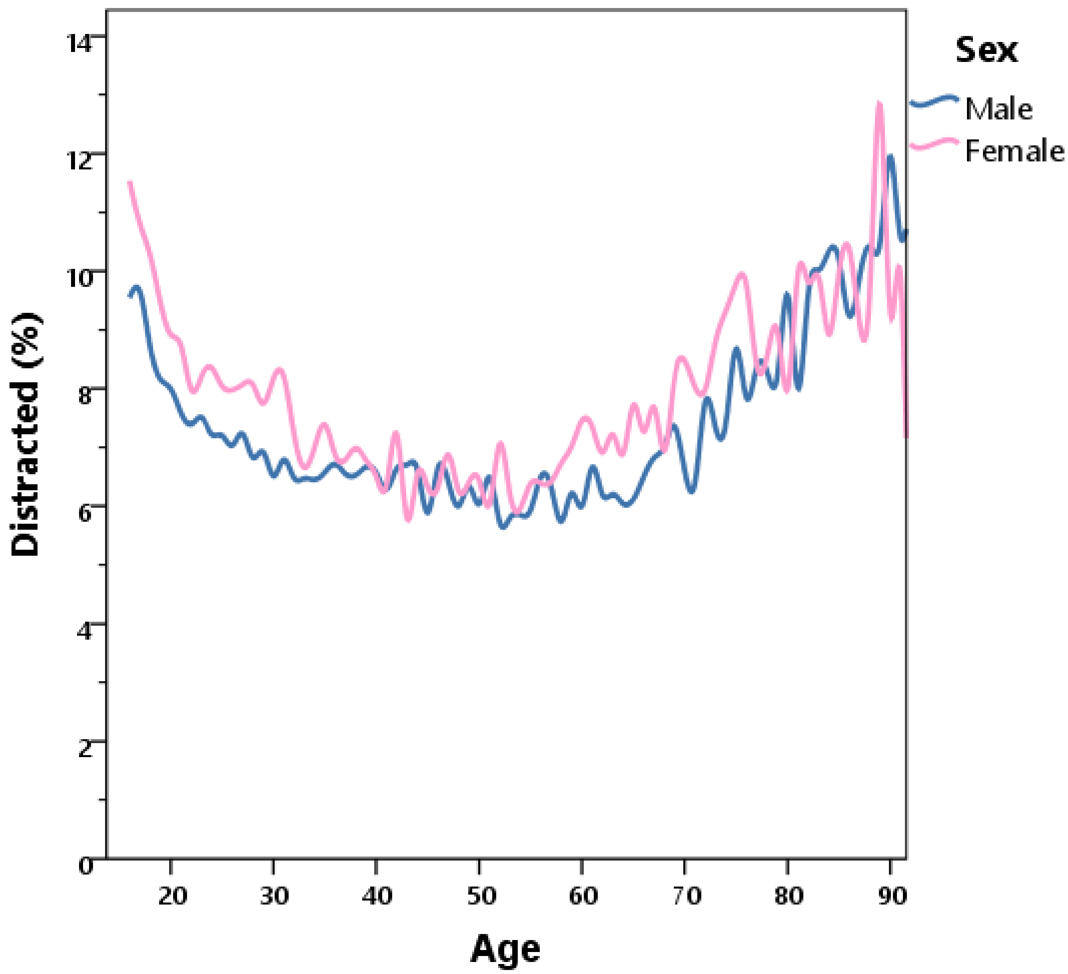
Age Distribution (by Sex) of Distracted Drivers in Fatal Collisions, 1991 - 2015



Although there were more male distracted drivers, the overall percentages of distraction within sex, males (7.1%) and female (7.8%), were similar. However, the percentage of distracted female drivers appeared higher than the percentage of distracted males among younger drivers (see Figure 3). The percentage of distracted drivers by age was U-shaped; middle aged drivers were the least likely to be reported as distracted.

Figure 3

Percentage of Drivers in Fatal Collisions (by Age and Sex) who were Distracted, 1991 – 2015

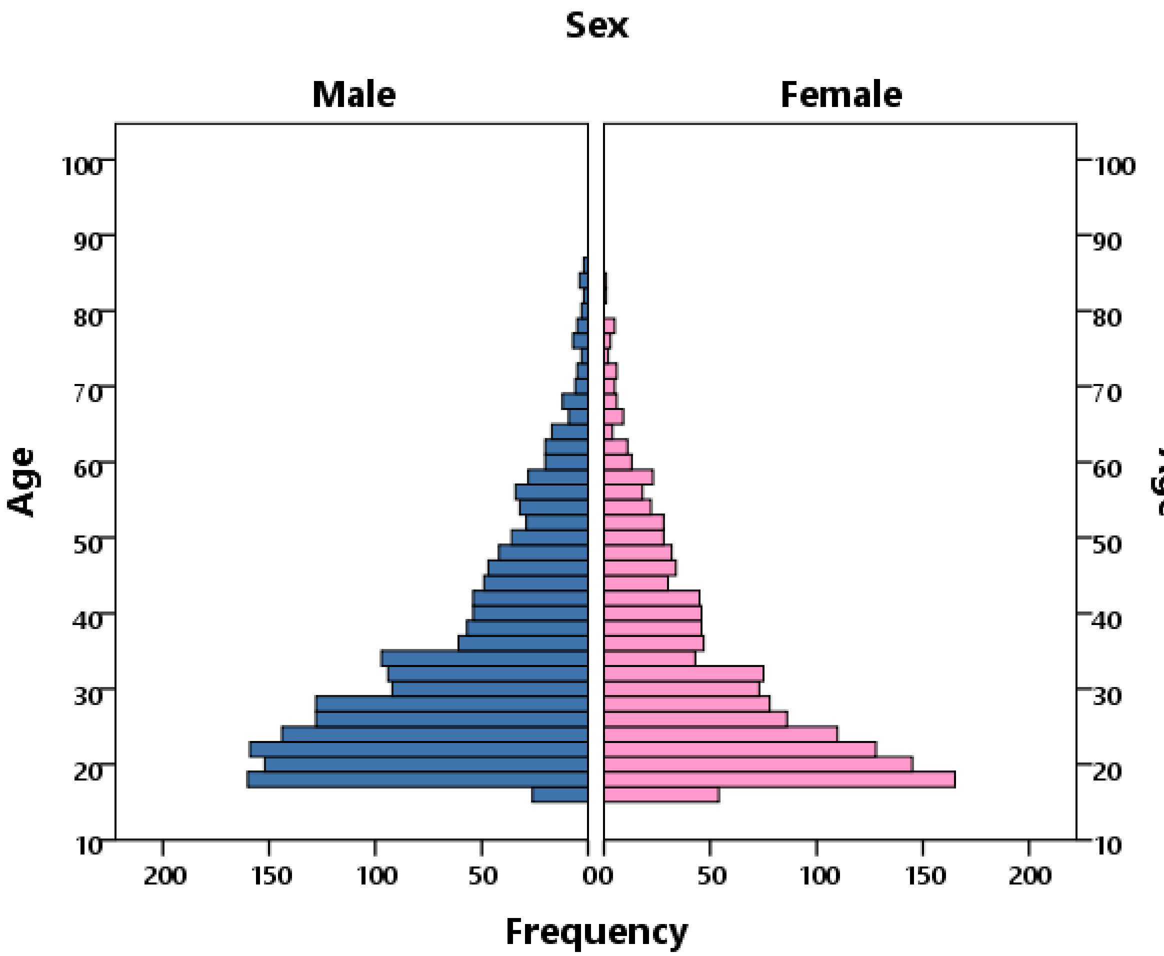


3.2 Cell Phone Distraction 2002 – 2015

From 2002 – 2015 3,240 drivers in fatal crashes had a code indicating cell phone-related distraction. Over 50% of those drivers (n = 1,818, 56.11%) were male. Since the recoding of cell phone distraction in 2010 until 2015, 1,132 drivers were distracted by cell phones. A steady increase in cell phone related distraction can be seen in Figure 1. Cell phone distraction rose from 0.2% (2002) to account for 1.1% (2015) of drivers involved in fatal collisions (Figure 1). A frequency distribution by age and sex can be seen in Figure 4. Cell phone distraction is more prevalent in younger ages.

Figure 4

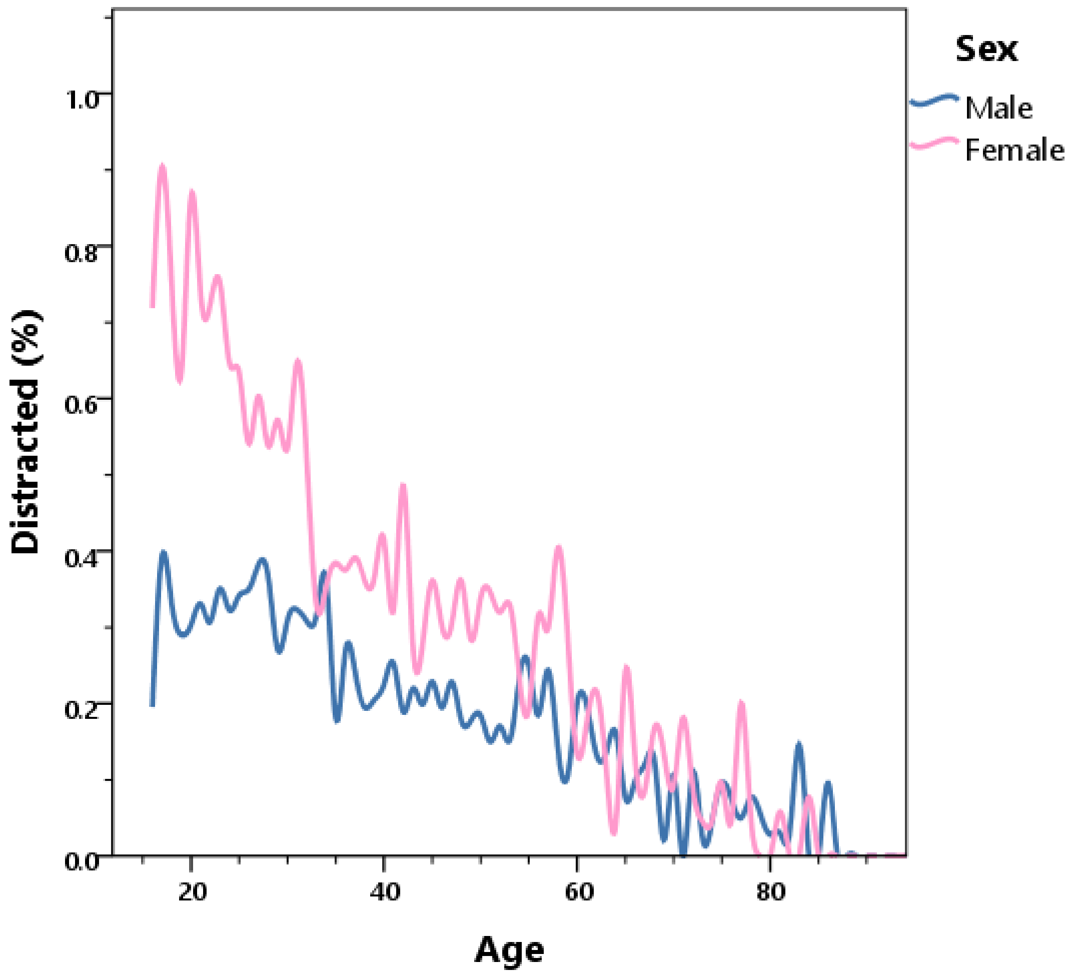
Age Distribution (by Sex) of Cell Phone Distracted Drivers in Fatal Collisions, 2002 – 2015



There is a negative relationship between age and frequency of cell phone distraction: as age increases, the number of drivers distracted by cell phones decreases. This trend occurs in both males and females. The percentage of male versus female drivers distracted by cell phones can be found in Figure 5. The percentages for females are notably higher than for males until older age.

Figure 5

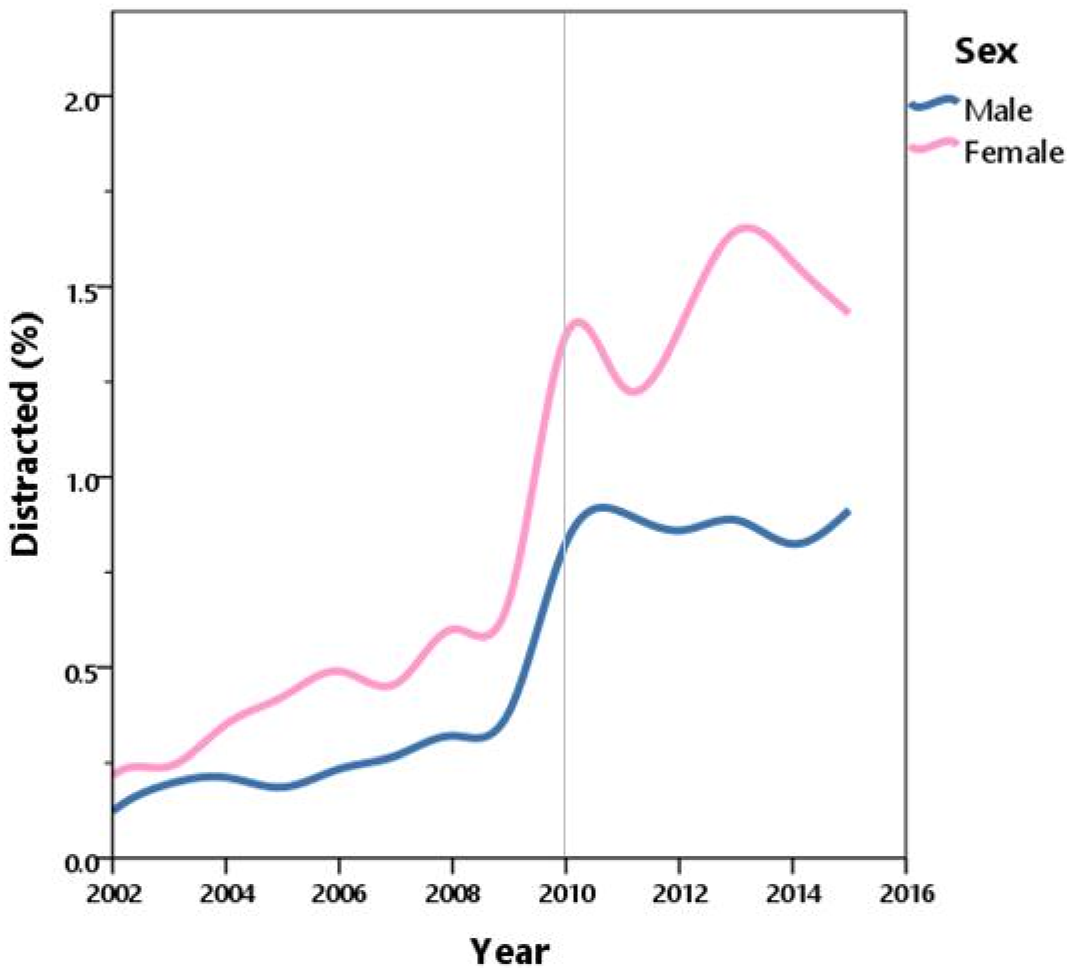
Cell Phone Distraction in Fatal Collisions by Age and Sex, 2002 – 2015



Cell phone distraction trends by sex over time can be seen in Figure 6. Although the raw frequencies were higher for males (see Figure 4), the percentage of female distracted drivers were consistently higher than males from 2002 – 2015. The vertical line represents the change in FARS coding in 2010 for cell phone use.

Figure 6

Cell Phone Distraction in Fatal Collisions over Time (by Sex), 2002 – 2015



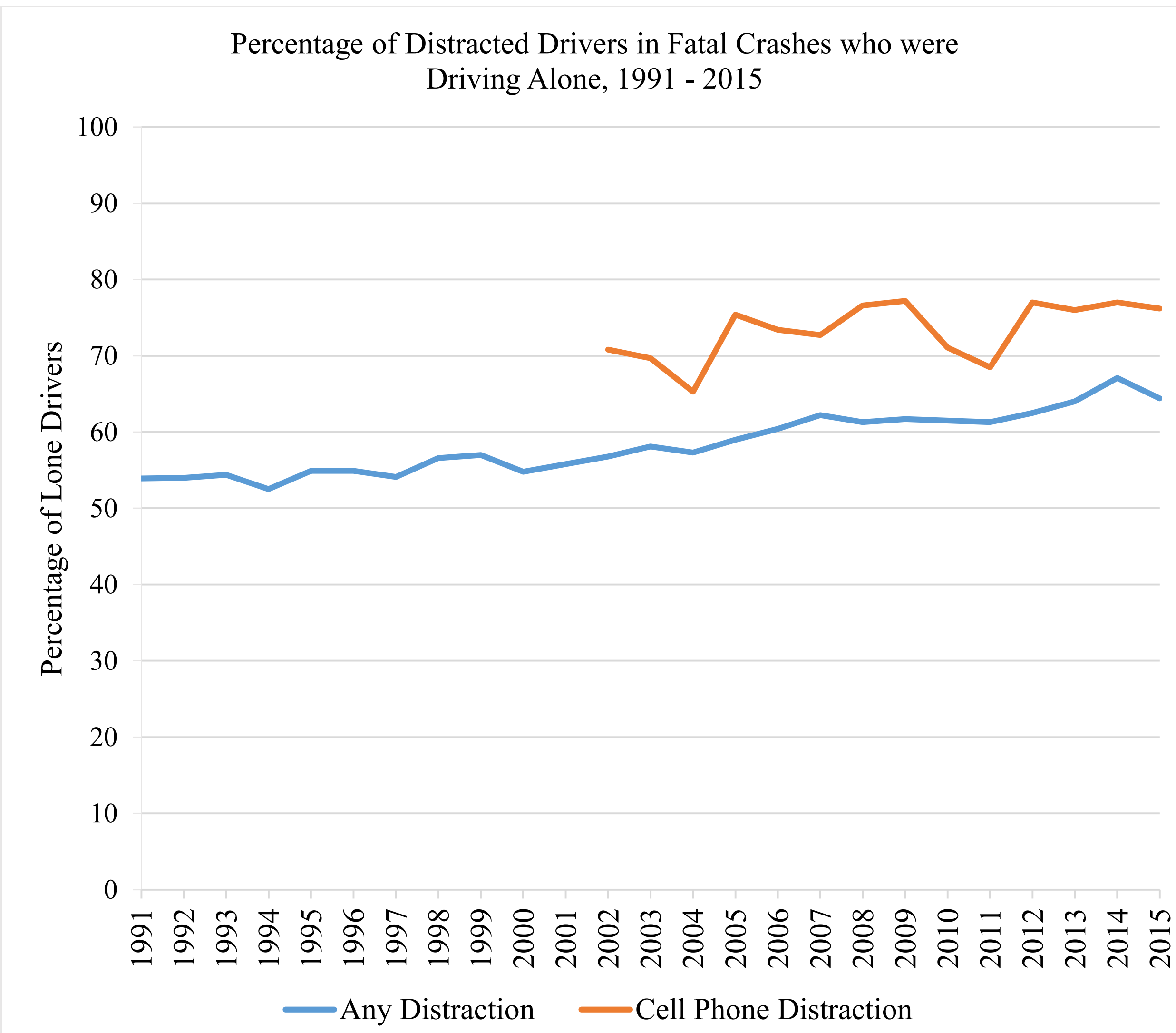
3.3 Crash Descriptors of Distracted Drivers

We examined three key crash descriptors using only the population of distracted drivers (Figures 7 – 9). The percentages of distracted drivers driving without passengers versus with passengers were examined over time. The percentage of distracted drivers (from any distraction) that were driving without passengers ranged from 52.5% (1994) to 67.1% (2014). The percentage of distracted drivers driving alone increased from approximately 55% to 65% over the 25-year period. The percentage of distracted and cell phone distracted drivers driving without passengers can be found in Figure 7.

The percentage of lone drivers is higher among cell phone distracted drivers than among drivers distracted by any distraction. The percentage of cell phone distracted drivers driving without passengers ranged from 65.3% (2004) to 77.2% (2009). The percentage of cell phone distracted drivers driving without passengers also showed a slight increase over time (Figure 7).

Figure 7

Percentage of Distracted Drivers in Fatal Crashes who were Driving Alone, 1991 – 2015

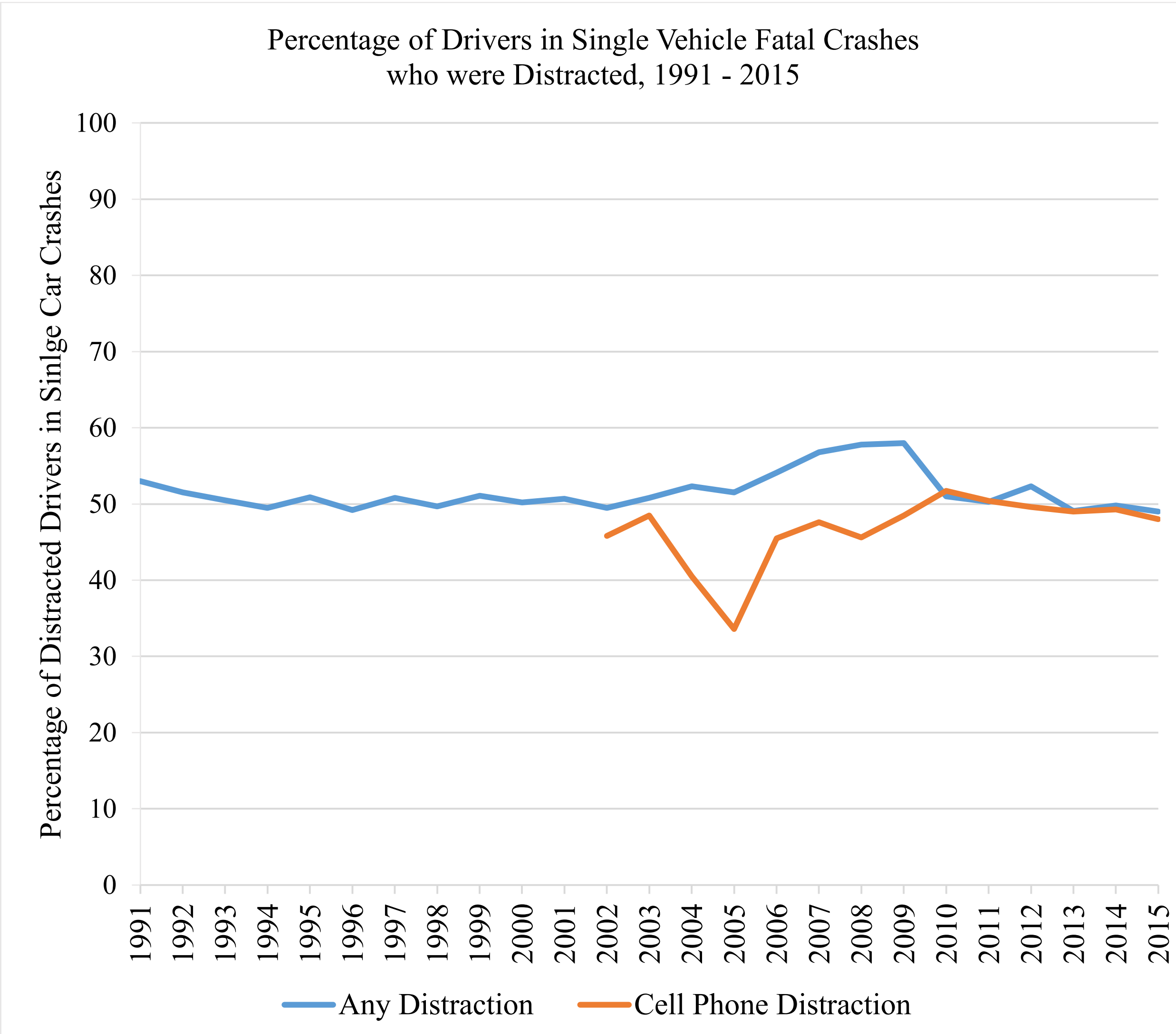


The percentages of distracted drivers involved in single versus multiple vehicle crashes were examined over time. The percentage of distracted drivers (by any distraction) involved in fatal single vehicle crashes ranged from 49.0% (2015) to 58.0% (2009). Over the 25year period, single car crashes accounted for approximately 52% of distracted drivers (Figure 8).

The percentage of cell phone distracted drivers in single vehicle crashes showed a slight overall increase; single vehicle crashes ranged from 33.6% (2005) to 51.7% (2010). Cell phone distraction trends were similar to overall distraction in single vehicle crashes from 2010 – 2015 (Figure 8).

Figure 8

Percentage of Drivers in Single Vehicle Fatal Crashes who were Distracted, 1991 – 2015

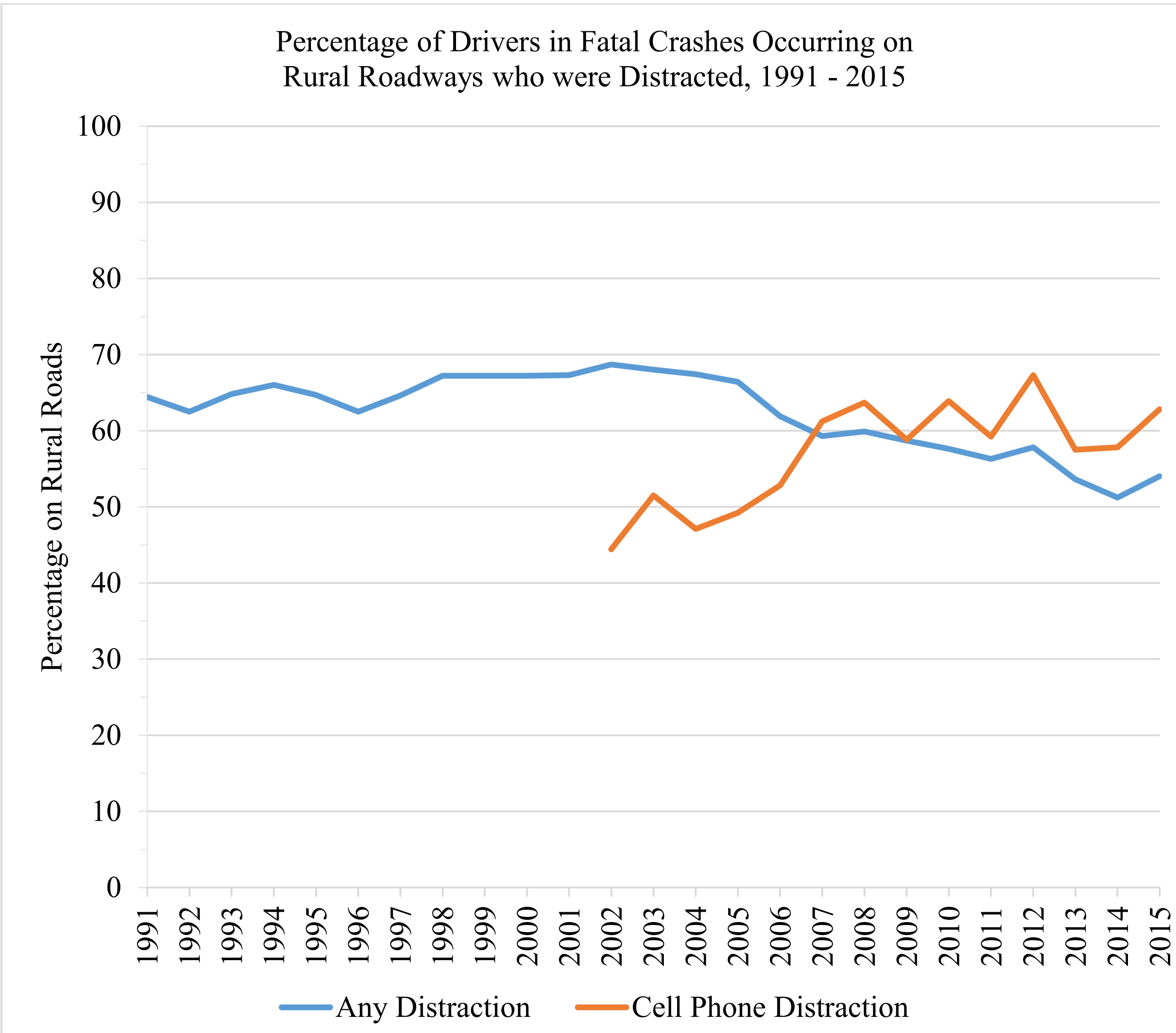


The percentages of distracted drivers in fatal crashes occurring on rural roadways were calculated. The percentage of distracted drivers of fatal collisions on rural roadways ranged from 51.2% (2014) to 68.7% (2002). Overall, the percentage of drivers distracted by any distraction decreased on rural roadways; therefore, there was an increase on urban roadways. Contrary to any distraction, cell phone distraction increased on rural roads over time. Rural location trends for distraction and cell phone distracted drivers can be found in Figure 9.

Interestingly, the percentages of cell phone distracted drivers on rural roadways increased over time; this is the opposite trend noted for all distractions on rural roadways. Rural roadway (versus urban roadway) cell phone distraction crashes was lowest at first recording in 2002 (44.4%) and peaked in 2012 at 67.3% (Figure 9).

Figure 9

Percentage of Drivers in Fatal Crashes Occurring on Rural Roadways who were Distracted, 1991 – 2015



3.4 Recorded Distractions 2010 – 2015

There were over 15,000 distractions recorded from 2010 to 2015. 'Inattention, details unknown' was the most frequently coded distraction at 1.84%. It was closely followed by 'Distraction, details unknown' which was coded for 1.56% of drivers involved in fatal crashes.

The most prevalent distraction, excluding those ambiguous in nature, was cell phone-related distractions which accounted for 1.07% of drivers involved in fatal collisions. This included three codes: while talking or listening to cellular phone (0.31%), while manipulating cellular phone (0.25%), and other cellular phone related (0.51%). Frequencies and percentages of all distractions from the Distract Data File can be found in Table 1. The total is less than the sum of frequencies due to 263 cases with two or three distractions.

Table 1

Prevalence of Drivers Coded with Distractions 2010 – 2015 (n = 15,365)*

Distractions	Frequency	Percentage of Reported Distracted Drivers	Percentage of All Drivers
Inattention (Inattentive), Details Unknown	3,877	25.23%	1.84%
Distraction (Distracted), Details Unknown	3,291	21.42%	1.56%
Other Distraction	1,182	7.69%	0.56%
Other Cellular Phone Related	1,070	6.96%	0.51%
Distraction/Inattention	1,016	6.61%	0.48%
Lost In Thought/Day Dreaming	931	6.06%	0.44%
Distracted by Outside Person, Object or Event	922	6.00%	0.44%
By Other Occupant(s)	854	5.56%	0.41%
While Talking or Listening to Cellular Phone	642	4.18%	0.31%
While Manipulating Cellular Phone	525	3.42%	0.25%
While Using or Reaching For Device/Object Brought Into Vehicle	364	2.37%	0.17%
While Adjusting Audio or Climate Controls	251	1.63%	0.12%
Eating or Drinking	226	1.47%	0.11%
Careless/Inattentive	166	1.08%	0.08%
While Using Other Component/Controls Integral to Vehicle	135	0.88%	0.06%
By a Moving Object in Vehicle	81	0.53%	0.04%
Smoking Related	78	0.51%	0.04%
Distraction/Careless	31	0.20%	0.01%

*Includes 263 cases with 2 or 3 distractions

4. Discussion

The aim of this study was to present the prevalence of overall distractions in fatal collisions over time, stratifying these results according to age, sex, and crash descriptors, and to identify the most frequent distraction involved in these fatal crashes.

4.1 Overall Distraction 1991 – 2015

The overall prevalence of distracted drivers in fatal collisions was 7%. Our findings are in line with those found in Australia; 4% of crashes causing injury or death to the driver involved distraction (Lam, 2002). The Australian data are similar to the FARS, and includes distractions within the vehicle and outside the vehicle (Lam, 2002). From 1999 – 2008, distracted driving accounted for 10% - 16% of all traffic fatalities in the United States (Wilson & Stimpson, 2010).

Regarding all distractions, the percentages within sex were similar for both males and females, but there were more distracted male drivers than females. This trend is in line with the findings of an increasing proportion of male distracted drivers over time (Wilson & Stimpson, 2010). Regardless of sex, the frequency of distracted and cell-phone distracted drivers was highest for younger drivers. The frequency of distracted driving decreased as age increased. The percentage of distracted elderly drivers was high, however the frequency was low. Finding the highest prevalence in younger drivers is consistent with previous studies (Rhodes & Pivik, 2011; Weller et al., 2013; Jonah, 2014; Quisenberry, 2015; Glicklich et al., 2016; Pickrell, et al., 2016). Crash and near-crash studies have also found distracted drivers to be younger in American (Dingus et al., 2006; Wilson & Stimpson, 2010), and Australian studies (Lam, 2002).

4.2 Cell Phone Distraction 2002 – 2015

Since the beginning of cell phone activity recording in the FARS, cell phone distraction steadily increased from 0.2% to account for over 1% of drivers involved in fatal collisions. Cell phone distraction accounts for almost 15% of reported distractions from 2010 – 2015. Male drivers had a higher frequency for cell phone distraction; however, the percentage of female drivers distracted by a cell phone was consistently higher than the percentage of male cell phone distracted drivers. Wilson and Stimpson also found more males to be distracted than females in fatal collisions (2010). Although the literature is mixed, several studies have found a higher percentage of females to be cell phone distracted while driving (Cramer et al., 2007; Pickrell et al., 2016; Seo & Torabi, 2004). As with any distraction, the frequency of cell-phone distracted drivers was highest for younger drivers.

4.3 Crash Descriptors of Distracted Drivers

The percentage of distracted drivers driving alone (versus with passengers) increased over the 25-year time period. There was also a slight increase in the percentage of cell phone distracted drivers driving alone; therefore, there was a decrease in distracted drivers driving with passengers. Our findings are consistent with a Canadian study that found electronic device use higher in drivers without passengers (Jonah, 2014). Slightly more than half (52%) of distracted drivers were involved in single vehicle crashes (versus 48% of distracted drivers in multiple vehicle crashes). While distraction in general decreased on rural roads (1991 – 2015), the percentage of cell phone distracted drivers increased on rural roads (2002 – 2015). This mirrors the previous recorded increase in distracted drivers on urban roads from 1999 – 2008 (Wilson & Stimpson, 2010), and electronic device use was found to be higher at urban, compared to rural sites (Jonah, 2014).

4.4 Recorded Distractions 2010 – 2015

From 2010 – 2015 the most prevalent distraction was cell phone distraction, which is consistent with a teenage rear-end crash study (Carney et al., 2016). This represents a departure from American crash data from 1995 – 1999 where 'outside person, object or event' was the most prevalent distraction (Stutts & Hunter, 2003). However, a likely explanation for this discrepancy is that cell phones were not as prominent during the 1990s.

4.5 Limitations

There are a few limitations to this study. We enforced a strict definition of distraction, and used drivers that met certain inclusion criteria in fatal crashes. FARS data only include crashes that resulted in a fatality, and the prevalence of distraction in fatal crashes cannot be generalized to non-fatal crashes. The prevalence of non-fatal crashes with a distracted driver is likely to be much higher than fatal crashes. There is some evidence distracted drivers engage in compensatory behaviours, for example, maintaining a larger headway, driving slower, or waiting until a stop sign (Li, Yan, Wu, Radwan, & Zhang, 2016; Schroeder et al., 2013; Yannis; Laiou, Papantoniou, & Gkartzonikas, 2016). These compensatory behaviours may reduce the impact of a crash, rendering it non-fatal.

From 1991 – 2001, distraction was captured in one all-encompassing variable. In 2002, cell phone use in vehicle was added. In 2010, the Distract Data file was added, which allowed for coding of a variety of distractions. Several of these FARS distraction codes are general or ambiguous, therefore, it was not identified what caused the driver to be distracted.
Prevalence estimates reported here likely underestimate the actual population prevalence. At the scene of the crash, it may be difficult for police officers to determine if distraction was a factor, especially in crashes with severe and fatal injuries to those involved. There is no road-side test, such as a breathalyzer, to assess distraction post-crash. Additionally, we did not include drivers under the age of 16, to better control for age given that minimum driving age varies by state; this eliminates any distracted drivers aged 14 or 15 in our analysis.

5. Conclusion

From 1991 – 2015, approximately 7% of drivers in fatal collisions were distracted. The most prevalent identifiable distraction was cell phone use. The majority of the distracted drivers were male. However, the percentage of female cell phone distracted drivers was greater than the percentage of male cell phone distracted drivers. The frequency of distracted drivers was highest in younger ages for all distractions and cell phone distraction. This research supports further education about distracted driving and the role distraction can play in fatal collisions. In the future, researchers should continue to use the Distract Data File to track prevalence over time and identify new emerging trends. Researchers should also assess the potential of distraction to cause a fatal collision.

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Chapter 4: The Impact of Distraction on Fatal Crash Responsibility

1. Introduction

1.1 Prevalence of distracted driving

Distracted driving is defined as being engaged in a secondary activity that affects the performance of the primary driving task (Regan, 2007). Distraction can include a wide variety of secondary activities, such as texting, talking on the phone, or eating. A survey of American drivers in 2016 found that 56% of drivers said they would search for a location in a navigation system, 55% would engage in a phone call, and 32% would text while driving occasionally or often (National Safety Council, 2016).

Distracted driving prevalence estimates vary greatly based upon study design, type of distraction, measures of distraction, and driver characteristics. For these reasons, prevalence estimates range anywhere from 1% of drivers reading while driving (Schroeder et al., 2013) to 90% using a cell phone while driving (Hill et al., 2015). Viewing maps while driving was self-reported by 43% of American adults; 48% self-reported reading texts and 33% self-reported writing texts while driving (Gliklich, Guo, & Bergmark, 2016). Texting while driving ranged from 74% (Cook & Jones, 2011) to 90% (Hill et al., 2015) while talking on a cell phone while driving ranged from 85% (Terry & Terry, 2016) to 90% (Hill et al., 2015) in university students. High rates of cell phone distraction have also been recorded in young driver populations (Weller, Shackleford, Dieckmann, & Slovic, 2013) and teenagers (Tucker, Pek, Morris, & Ruf, 2015; Kann et al., 2016). Observed distraction frequencies of cell phone use while driving ranged from 2% to 34% (Stutts et al., 2003; Cramer, Mayer, & Ryan, 2007; Pickrell, Li, & KC, 2016). Distracting behaviours were observed in 76% of drivers in rear-end crashes (Carney, Harland, & McGehee, 2016).

1.2 Negative effects

Distracted driving has been associated with various negative effects on driving. Over 80% of studies in a meta-analysis found a statistically significant detrimental relationship between distraction and driving performance (Ferdinand & Menachemi, 2014). Compared to passenger distraction studies, those that examined cell phone use had higher odds of finding a harmful relationship (Ferdinand & Menachemi, 2014).

Distracted drivers have been found to have a slower brake reaction time in both simulated driving (McNabb & Gray, 2016) and while driving on a test track (Hancock, Lesch, & Simmons, 2003; Horrey, Lesch, & Melton, 2010). They also had 25% slower response times in real rear-end crashes (Carney et al., 2016). Both lane keeping errors and lane position variability have been shown to increase in studies using a driving simulator (Drews, Pasupathi, & Stayer, 2008; Hosking, Young, & Regan, 2007; Medeiros-Ward, Cooper, & Strayer, 2014). On test tracks, distracted drivers stopped significantly closer to the cross line at a red light (Hancock et al., 2003), and had significantly more errors on a stopping task (Horrey et al., 2010). A naturalistic driving study found that distraction had a significant negative effect on hands off of the wheel and eyes off of the road time (higher percentages of each) for various distractions while driving (Stutts et al., 2003). Eyes off the road time was 400% greater for drivers texting (Hosking et al., 2007) and operating/looking at a cell phone (Carney et al., 2016). Looking away from the forward roadway just before the conflict, was involved in 65% of near crashes and almost 80% of crashes in a naturalistic driving study (Dingus et al., 2006). The effects of distraction have also been compared to other sources of impairment such as alcohol. Cell phone drivers had greater impairment than drunk drivers (BAC = 0.08) when controlling for driving difficulty and time on task (Strayer, Drews, & Crouch, 2006). Cell phone distracted drivers had slower reactions, and tried to compensate by increasing following distance. Meanwhile, alcohol impaired drivers drove more aggressively, for example, following more closely and braking harder (Strayer et al., 2006).

1.3 Distraction and Increased Risk of Crash

Early studies have found a dose-response relationship between frequency of cell phone use and crash risks (Laberge-Nadeau et al., 2003). An international meta-analysis estimated an almost threefold increase in crash risk (OR = 2.86, *CI* = 1.72, 4.75) when a cell phone was used (Elvik, 2011). Authors of a meta-analysis of naturalistic driving and cell phone distraction found an increased risk of crashes, near crashes, or safety-related conflicts when dialing, locating a phone, or texting while driving; however they did not find an increased risk when talking on a phone (Simmons, Hicks, & Caird, 2016). An Australian study found that inside vehicle distractions (e.g., adjusting controls, smoking, attending to passengers) were associated with increased risk of crash causing injury/death for all drivers except those in the 40 – 49 age group (Lam, 2002).

Driving simulator studies have also found an increased probability of crashes if the driver was texting (Yannis et al., 2016) or using a cell phone while driving (Strayer & Drews, 2004), compared to non-distracted. A Canadian case-crossover analysis found that the risk of collision when cell phones were used 10 minutes prior to a crash was four times higher ($RR = 4.3$, $p < .001$, 95% CI = 3.0, 6.5) than at the same time the previous day (Redelmeier & Tibshirani, 1997). These findings have been replicated in an Australian study, where cell phone use up to 10 minutes prior to a crash was associated with 4 times higher odds of crashing ($OR = 4.1$, 95% CI = 2.2, 7.7), compared to a 10 minute interval 24 hours, 72 hours, and one week prior (McEvoy et al., 2005). A small scale preliminary study on cell phone distraction in fatal collisions reported a statistically significant increase for a fatality when a cell phone was present in the vehicle (*OR* = 2.11, 95% CI = 1.64, 2.71) and when the phone was in use (*OR* = 9.29, 95% CI = 3.70, 23.14; Violanti, 1998).

In 2015 alone, there were 3,196 distraction-related fatal crashes in the United States, accounting for 10% of total crashes (National Center for Statistics and Analysis, 2017). Those crashes claimed the lives of 3,477 people and injured an estimated 391,000 more (National Center for Statistics and Analysis, 2017). The World Health Organization (WHO) stated that by 2030, road traffic crashes are projected to be the fifth leading cause of death in the world, up from ninth in 2004 (WHO, 2011). The threat of distracted driving to road safety is likely to increase and evolve as electronic device technologies and in-vehicle communications systems continue to advance and gain popularity (WHO, 2011).

1.4 The Present Study

Although the association between distraction and driving errors and crash risk is established, few studies have investigated the association between distraction and crash responsibility. One Canadian study found that cell phone use while driving increased crash culpability (*OR* = 1.70, 95% CI = 1.22, 2.36; Asbridge, Brubacher, & Chan, 2013). We investigated the association between distraction and unsafe driver actions preceding fatal crashes using a census-level data source, controlling for other potential confounders (i.e., age, sex, previous driver history, alcohol, and drugs). Utilizing passenger-type vehicles, we hypothesized that the odds of committing an unsafe driver action preceding a fatal crash would be higher for distracted drivers compared to non-distracted drivers.

2. Methods

2.1 Data Source

The Fatality Analysis Reporting System (FARS), utilized for this study, is a census level database containing information about fatal motor vehicle crashes within the 50 states of the United States of America, Puerto Rico, and the District of Columbia since 1975 (National Highway Traffic Safety Administration, 2016). To be included in FARS, the crash must: a) involve a motor vehicle travelling on a primarily public traffic way; and b) have at least one fatality within 30 days of the crash. The FARS analysts use a variety of state documents (e.g., police accident report, death certificates, vehicle registration files, coroner reports, medical service reports, and more) to code over 100 data elements in a standardized format. The FARS began with three main data files; the accident, vehicle, and person data files. The accident data file contains information about crash characteristics and environmental conditions, while the vehicle data file contains information on each moving vehicle and its driver. The person data file contains information about all people involved in the crash, including motorists and non-motorists. A 'Distract Data File' containing more detailed information on driver distraction has since been added to the FARS (National Highway Traffic Safety Administration, 2016).

2.2 Distraction in the FARS

In 1982, the FARS began coding for distraction as the driver-related factor *inattention.* Inattention included a variety of distractions such as a car or cell phone, reading, eating, fax machine, shaving, and painting nails, amongst many others. The FARS began capturing hand-held and hands-free cell phone use in 2002, with *cellular telephone in use in vehicle.* In 2010, these distraction variables were removed as driver-related factors, and formed the basis of the 'Distract Data File' added to the FARS. This file collects information regarding the best attributes to describe the attention of the driver prior to the impact, or prior to the driver's awareness of an impending dangerous event. There are 18 codes for distraction attributes (e.g., eating or drinking; manipulating cell phone; talking or listening to cell phone; smoking related; adjusting controls; distracted by an outside person, object, or event) as well as options for unknown if distracted, not reported, and not distracted. Each driver distraction is recorded as a separate record, and every driver involved in a fatal crash has at least one record, even if they were not distracted. The NHTSA does not consider physical conditions/impairments, such as fatigue or medical conditions, and emotional psychological states, such as depression or anger, to be distractions (National Highway Traffic Safety Administration, 2016).

2.3 FARS Variables Used

If a driver had one or more distraction attributes, as per the 'Distract Data File,' they were coded as distracted. Other variables used in this study include: age, sex, drug test results, alcohol test results, drivers' past driving records, unsafe driver actions, and vehicle type.

2.4 Proxy Measures of Responsibility – Unsafe Driver Actions

As noted, the FARS analysts use police crash records to code up to four driver-related factors, the majority of which are considered to be unsafe driver actions (UDAs) that may have contributed to the crash (Blower, 1998). Unsafe driver actions were used as a proxy measure of crash responsibility, the dependent variable, for this case-control study. The cases are those drivers who have one or more UDAs coded, whereas controls are drivers who do not have any UDAs coded. Unsafe drive actions have been successfully utilized as a proxy measure for responsibility by many researchers (e.g., Perneger & Smith, 1991; Blower, 1998; Maxwell, Dubois, Weaver, & Bédard, 2010; Dubois, Mullen, Weaver, & Bédard, 2015).

2.5 Driver History

To help control for poor driver history, we included the following variables: number of crashes, number of license suspensions or revocations, number of driving while intoxicated (DWI) convictions, number of speeding convictions, and number of other moving violation convictions. Prior to 2015, the time frame for these driving history variables was three years; beginning in 2015, it was expanded to the previous five years.

2.6 Inclusion and Exclusion Criteria

This study used drivers from the FARS database from 2010 – 2015, as this time frame corresponds with the introduction of the 'Distract Data File' which captured distraction data separately from the driver-related factors variable (i.e., distraction and responsibility coded separately). We included male and female drivers of passenger type vehicles (e.g., cars, pickup trucks, SUVs, and vans; n = 211,090), aged 20 and older (to control for previous driver history; n = 193,128). To help isolate impairment due to distraction drivers were only included if they had a blood alcohol content of zero, and tested negative for illegal drugs (n = 27,241). We excluded motorcycles, commercial vehicles and records with missing sex data.

2.7 Analytical Plan

Descriptive statistics were used to examine age, sex, and UDAs for distracted and non-distracted drivers. We compared the two groups using a t-test with a Satterthwaite approximation for age, as this test does not assume or require homogeneity of variance, and using Pearson's Chi-square test for sex and UDAs. We used logistic regression models to calculate both unadjusted and adjusted predicted odds and odds ratios of crash responsibility. The unadjusted model examined the difference in UDAs reported by distracted or non-distracted drivers. The full model controlled for demographic variables, age interactions, and driver history and specifically included: any distraction, sex, age, age^2, the any distraction by age interaction, the any distraction by age^2 interaction, as well as previous driver history variables. Age squared was included in the model to account for a non-linear relationship with unsafe driver actions. We report logistic regression coefficients, predicted odds and odd ratios, at several ages (every 5 years from 20 through 80) with 95% confidence intervals for each. SPSS 25 was used for all analyses.

3. Results

In total, there were 27,241 drivers of passenger type vehicles between 2010 – 2015, of which 2,400 were coded as distracted (8.81%). The mean age of the drivers was 49 (*SD* = 19.92), and just under two-thirds (64.9%) were male. Compared with non-distracted drivers, distracted drivers had a lower mean age and a larger proportion of distracted drivers were of female sex, and had one or more previous crashes, speeding or other moving violations. The full results can be seen in Table 1.

Table 1

Descriptive Statistics for Non-distracted and Distracted Drivers

Variable	Non-distracted *n* = 24,841	Distracted *n* = 2,400	χ^2/t*	*p* Value
Age, mean (SD), year	49.28 (19.88)	46.18 (20.06)	7.24	< .001
Male, # (%)	16,212 (65.26%)	1,481 (61.71%)	12.15	< .001
Driving Record**				
Crashes, # (%)	2,776 (12.27%)	325 (15.19%)	15.30	< .001
DWI, # (%)	277 (1.12%)	36 (1.52%)	2.96	.085
Speeding, # (%)	3,787 (15.38%)	445 (18.81%)	19.19	< .001
License suspension, # (%)	2,166 (8.80%)	224 (9.47%)	1.20	.273
Other conviction, # (%)	3,589 (14.56%)	390 (16.48%)	6.25	.012
Any of the above, # (%)	8,478 (34.43%)	942 (39.81%)	27.53	< .001

*Chi-square values presented for all variables, except for age, where the F-statistic is presented.
**One or more driving convictions in the past three years, or past 5 years since 2015.

The five most frequently reported UDAs by all drivers are displayed in Table 2. The top unsafe driver action was “failure to yield right of way”, which also had the greatest difference between distracted and non-distracted drivers (16.1% versus 10.2%, respectively). Distracted drivers had a greater proportion of any UDA reported compared to the non-distracted drivers (53.6% versus 37.9%, respectively). Distracted drivers had statistically higher frequencies of the following UDAs: “failure to yield right of way”; “failure to keep in proper lane/improper lane usage"; "failure to obey actual traffic signs, traffic control devices or traffic officers, failure to observe safety zone traffic laws"; and "over correcting". There was not a significant difference between distracted and non-distracted drivers for "making improper turn". For distracted drivers only, the top four UDAs were the same as all drivers in fatal collisions; the fifth most frequent UDA was replaced by "following improperly".

Table 2

Top 5 Unsafe Driver Actions

Unsafe driver action	Non-distracted (*n* = 24,841)	Distracted (*n* = 2,400)	χ^2	*p* Value
Failure to yield right of way, # (%)	2,524 (10.2%)	387 (16.1%)	81.57	< .001
Failure to keep in proper lane/improper lane usage, # (%)	2,531 (10.2%)	306 (12.8%)	15.39	< .001
Failure to obey actual traffic signs, traffic control devices or traffic officers, failure to observe safety zone traffic laws # (%)	1,224 (4.9%)	208 (8.7%)	61.44	< .001
Over correcting, # (%)	985 (4.0%)	161 (6.7%)	40.87	< .001
Making improper turn, # (%)	686 (2.8%)	55 (2.3%)	1.83	.177
Any UDA reported, # (%)	9,409 (37.9%)	1,286 (53.6%)	226.40	< .001

The unadjusted OR of any unsafe driver action occurring was 2.31 (for distracted relative to non-distracted drivers, 95% CI = 1.52, 3.50).

Table 3

Adjusted Odds Ratios with 95% CI for the Full Model Predicting Unsafe Driver Actions

Variable, Referent	B (95% CI)	Adjusted OR (95% CI)	*p*
Any Distraction, none	-0.395 (-0.959; 0.169)	0.67 (0.38; 1.18)	.170
Sex, Male	0.145 (0.091; 0.200)	1.16 (1.10; 1.22)	< .001
Age	-0.064 (-0.072; -0.057)	0.94 (0.93; 0.95)	< .001
Age^2	0.001 (0.001; 0.001)	1.00 (1.00: 1.00)	< .001
Any Distraction × Age	0.052 (0.027; 0.076)	1.05 (1.03; 1.08)	< .001
Any Distraction × Age^2	-0.001 (-0.001; 0.000)	1.00 (1.00; 1.00)	< .001
Prior Driving Record, none			
Crashes			
One	-0.019 (-0.105; 0.068)	0.98 (0.90; 1.07)	.667
Two	0.076 (-0.121; 0.274)	1.08 (0.89; 1.32)	.447
Three or more	0.201 (-0.192; 0.593)	1.22 (0.83; 1.81)	.317
DWI			
One	0.004 (-0.271; 0.279)	1.00 (0.76; 1.32)	.932
Two	0.272 (-0.422; 0.966)	1.31 (0.66; 2.63)	.442
Three or more	0.058 (-1.286; 1.402)	1.06 (0.28; 4.07)	.976

Speeding			
One	0.007 (-0.077; 0.091)	1.01 (0.93; 1.10)	.872
Two	0.106 (-0.054; 0.265)	1.11 (0.95; 1.30)	.194
Three or more	-0.022 (-0.252; 0.208)	0.98 (0.78; 1.23)	.852
License suspensions			
One	0.261 (0.136; 0.386)	1.30 (1.15; 1.47)	< .001
Two	0.254 (0.060; 0.448)	1.29 (1.06; 1.57)	.010
Three or more	0.161 (-0.025; 0.346)	1.17 (0.98; 1.41)	.090
Other convictions			
One	0.122 (0.033; 0.211)	1.13 (1.03; 1.23)	.007
Two	0.180 (0.015; 0.345)	1.20 (1.02; 1.41)	.032
Three or more	0.109 (-0.106; 0.324)	1.12 (0.90; 1.38)	.322
Constant	0.554 (0.371; 0.738)	1.74 (1.45; 2.09)	< .001

Figure 1

Predicted Odds of an Unsafe Driver Action by Distraction and Driver Age

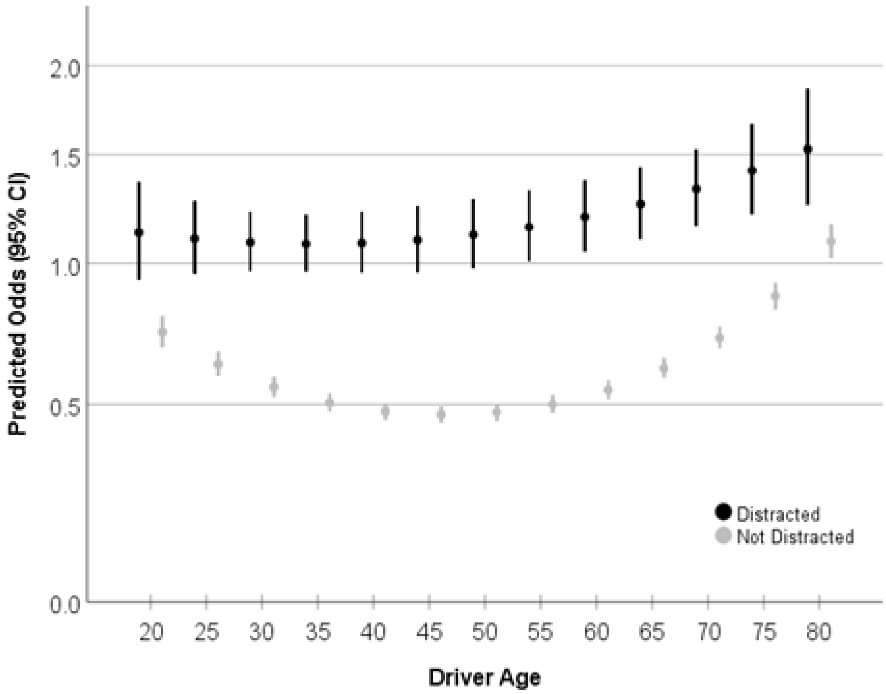
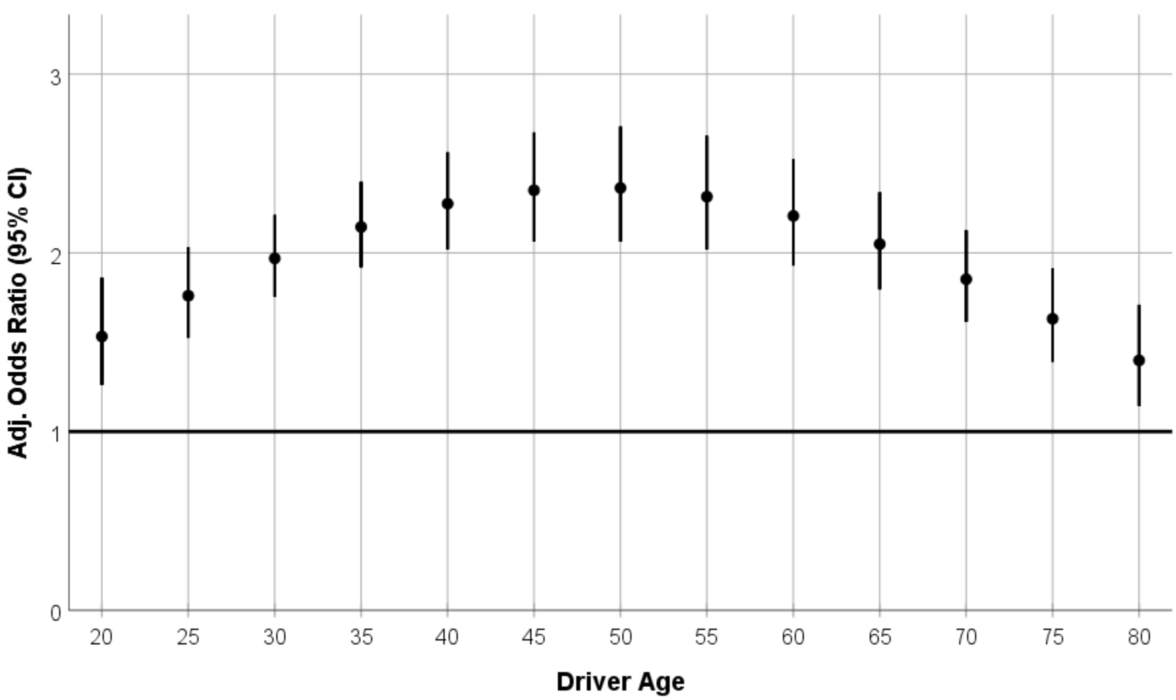


Figure 2

Adjusted Odds Ratios of Committing an UDA by Driver Age



The adjusted model is presented in Table 3. Higher odds of an UDA were reported for younger adults, older adults, females, those with previous licence suspensions, and those with other convictions. Distracted drivers had higher odds of having an UDA reported (see Figure 1 for predicted odds; Figure 2 for odds ratios; Table 4 for predicted odds and odds ratios). At each age, distracted drivers have higher odds of committing an UDA, compared to non-distracted drivers, but the ratio is dependent upon age (Figure 2). Distraction had the greatest impact on driver responsibility for middle aged drivers at age 45 (*OR*: 2.35; 95% CI: 2.06; 2.67) and age 50 (*OR*: 2.36; 95% CI: 2.06; 2.71). The smallest odds ratios were observed for the youngest, age 20 (*OR*: 1.53; 95% CI: 1.26; 1.86), and oldest, age 80 (*OR*: 1.40; 95% CI: 1.14; 1.71) drivers.

Table 4

Predicted Odds and Odds Ratios of any Unsafe Driver Action by Distraction and Age

Age	Predicted Odds (95% CI)		*OR* (95% CI)
	Non-distracted	Distracted	
20	0.74 (0.68; 0.80)	1.13 (0.94; 1.37)	1.53 (1.26; 1.86)
25	0.63 (0.59; 0.67)	1.10 (0.96; 1.27)	1.76 (1.52; 2.03)
30	0.55 (0.52; 0.58)	1.09 (0.97; 1.22)	1.97 (1.75; 2.21)
35	0.50 (0.48; 0.53)	1.08 (0.97; 1.21)	2.15 (1.92; 2.40)
40	0.48 (0.45; 0.50)	1.09 (0.96; 1.22)	2.28 (2.02; 2.56)
45	0.47 (0.44; 0.49)	1.10 (0.97; 1.25)	2.35 (2.06; 2.67)
50	0.47 (0.45; 0.50)	1.12 (0.98; 1.28)	2.36 (2.06; 2.71)
55	0.50 (0.47; 0.53)	1.16 (1.01;1.32)	2.31 (2.02; 2.65)
60	0.54 (0.52; 0.57)	1.20 (1.05; 1.37)	2.21 (1.93; 2.53)
65	0.61 (0.58; 0.65)	1.26 (1.10; 1.44)	2.05 (1.80; 2.34)
70	0.72 (0.68; 0.76)	1.33 (1.16; 1.53)	1.85 (1.61; 2.13)
75	0.87 (0.82; 0.92)	1.42 (1.21; 1.66)	1.63 (1.39; 1.91)
80	1.09 (1.02; 1.17)	1.53 (1.26; 1.86)	1.40 (1.14; 1.71)

4. Discussion

Distracted drivers compared to non-distracted drivers had greater odds of committing four out of the top five UDAs. The U-shaped curve typically associated with driver age and crash outcomes (McGwin & Brown, 1999; Tay, 2006) was observed. Distracted drivers displayed a gentler u-shaped curve of age and crash relationship. The predicted odds were highest for the youngest (aged 20) and older drivers (aged 55+). The predicted odds for committing any UDA were higher for distracted drivers, compared to non-distracted drivers at all ages.

Crash responsibility odds ratios by distraction were statistically significant for all driver ages examined. Although distraction affects crash responsibility at all ages, the impact varied by age and was greatest for middle-aged drivers (age 45: OR = 2.35 95% CI = 2.06, 2.67; age 50: OR = 2.36, 95% CI = 2.06, 2.71). Because an odds ratio is equal to the quotient of the predicted odds, middle-aged drivers effectively had the largest odds ratios because they have the lowest predicted odds while non-distracted, whereas their predicted odds when distracted is equivalent to that of younger drivers. Asbridge and colleagues (2013) also found that the odds of a responsible crash were highest for middle-aged drivers, but did not reach statistical significance at all ages. However, they did not find cell phone use to statistically increase crash responsibility in all age groups (Asbridge et al., 2013). While Asbridge and colleagues (2013) found a similar pattern in the crash responsibility odds ratios according to age, their smaller sample size likely is responsible for the lack of statistical significance. There are other notable differences in Asbridge and colleagues (2013), such as their use of propensity matched drivers, use of injury and non-injury crashes, and use of cell phone distraction only.

Some previous studies have found a much stronger association between cell phone use and crash risk (Redelmeier & Tibshirani, 1997; Violanti, 1998; McEvoy et al., 2005). The effect of distraction on crash responsibility that we have observed is smaller, a difference possibly due to misclassification (discussed further as a limitation below). This reduction in the size of the effect may also be due to the restriction of our analyses to fatal crashes, inclusion of other forms of distraction (i.e., besides cell phones), and use of crash responsibility, not crash involvement as the outcome. Further, two of the aforementioned studies did not control for driver characteristics such as blood alcohol content or drugs (Redelmeier & Tibshirani, 1997; McEvoy et al., 2005). Also, Violanti (1998) defined a fatality only as a driver who was killed, and had a very small sample size of drivers using a cell phone at the time of the collision ($n = 5$).

4.2 Strengths and Limitations

Within the responsibility analysis, we used UDAs as a proxy measure of crash responsibility. The use of UDAs is preferred to traffic violations because traffic violations are not charged without sufficient evidence, and not all unsafe actions are chargeable infractions (Blower, 1998). Further, Blower (1998) has tested the validity of UDAs as a measure of crash responsibility in truck-passenger fatal collisions.

The results of this study suggest that distracted drivers have higher odds of being responsible for a fatal crash. In terms of the "aspects of association" that Hill (1965) discussed, our study did demonstrate reasonably good strength of association, consistency across person, place, and time, coherence with existing knowledge, and consideration of alternative explanations. Despite that, we cannot infer a causal relationship between distraction and crash responsibility based upon this study alone. However, as Hill (1965) argued in an often overlooked section of his essay (The Case for Action), it is not necessary to establish causation beyond all dispute before one takes action. Furthermore, the strength of evidence required before one takes action varies according to the context and to the relative costs and benefits of acting versus not acting. For example, Hill used the analogy to thalidomide to argue that "on relatively slight evidence [of causation] we might decide to restrict the use of a drug for early-morning sickness in pregnant women." Stronger evidence would be required, Hill argued, before one would force people to burn a fuel they do not like, or to alter their dietary habits. There are enormous potential benefits to reduction of distraction in the driving environment and a relative absence of any detriments to reducing distraction. Given that and the mounting evidence of the negative effects distraction has on driving (e.g., Horrey & Wickens, 2006; Caird, Johnston, Willness, Asbridge, & Steel, 2014; Ferdinand & Menachemi, 2014), we contend that society should act on the assumption that distraction while driving causes crashes.

A strength to this study was the large sample size, and ability to control for other variables that may contribute to crash responsibility, such as previous driver history. We were able to rule out other sources of impairment by only including those drivers that had a blood alcohol content of zero and tested negative for drugs. This acts as both a strength and limitation to the study. Our study did not consider the combined effects of distraction and alcohol or other substances, and may have resulted in an underestimation of distraction effects. The impairing effects of alcohol and distraction have been found to be synergistic when both are present while driving (Van Dyke & Fillmore, 2015).

Another limitation to this study is the case-control design, which is retrospective nature. Also, there are limitations related to the collection and reporting of distraction data in the FARS (National Center for Statistics and Analysis, 2017). There are several distraction attributes that are ambiguous (e.g., distraction/inattention, distraction-details unknown). We do not know what these distractions truly consisted of, therefore limiting our results of the most prevalent distraction, and negatively impacting future directions such as campaigns against distracted driving.

The under-reporting of factors that are difficult to observe and measure, such as distraction can be a detriment to prevention efforts (National Safety Council, 2017). Our study is also possibly limited by differential misclassification, where the incorrect identification of distracted drivers as non-distracted may have biased our results towards the null hypothesis, therefore underestimating the true effect of distraction. Police officers may have difficulty determining if a driver was distracted, especially in fatal crashes, and if there were limited witnesses. Further, technological distractions may become damaged as a result of the crash, rendering it impossible to detect whether it was in use. FARS data are mostly based upon police accident reports, and are collected after the crash, providing opportunity for human error. Police crash reports vary by jurisdiction, as does the distraction reporting field, which creates the potential for inconsistencies (National Center for Statistics and Analysis, 2017). The National Safety Council recommended the complete standardization of crash report data across states (National Safety Council, 2017).

4.3 Implications

Our findings support the need for distracted driving education, laws and regulations. As of May 2018, texting while driving is banned in 47 states and the District of Columbia (Insurance Institutes for Highway Safety, 2018). However, talking on a cell phone while driving is banned in only 16 states and the District of Columbia. Thirty-eight states and the District of Columbia have banned the use of all cell phones while driving for novice drivers (Insurance Institutes for Highway Safety, 2018). A large problem is that none of these laws ban hands-free cell phone use, even though it is not a safe alternative (National Safety Council, 2012).

Additionally, our results suggest that distractions while driving affect drivers of all ages, not just young drivers. States should consider inclusive distraction bans (including hands-free cell phones) on all drivers, regardless of age or experience. It is important for distraction laws to be primarily enforced, in order to reduce distraction-related traffic fatalities. Primary enforcement of a law allows police officers to stop and ticket a driver if they observe an offence.

Police enforce secondary enforcement laws only when there is another, primary enforcement offence that has occurred.

Abouk and Adams (2013) found that legal bans on texting while driving reduce fatal crashes if they include all drivers and are enforced as a primary offence. However, the decrease was not sustained over time, which the authors primarily attributed to lax enforcement, but an alternate explanation is that drivers learnt to circumvent the laws as well (Abouk & Adams, 2013). Primarily enforced texting bans on all drivers led to a 3% reduction in fatalities in all age groups (Ferdinand et al., 2014). Lim and Chi (2013) found that primary enforcement of cell phone bans reduced fatal crashes for drivers aged 18 – 54, but did not for those aged 55 and older. These findings are further demonstrated by Rocco and Sampaio (2016) in finding that primarily enforced cell phone or texting bans significantly reduces fatalities, but there was not a significant reduction in fatalities with a secondary enforcement ban. High-visibility enforcement campaigns (increased law enforcement, visibility and publicity) have been found to be effective in decreasing cell phone use in Connecticut, New York, California, and Delaware (Chaudhary, Casanova-Powell, Cosgrove, Reagan, & Williams, 2012; Chaudhary, Connolly, Tison, Soloman, & Elliott, 2015).

Technology is evolving faster than regulations can be passed. This is especially problematic for use of electronic devices while driving. For example, recent technological advancements now allow people to read notifications such as incoming text messages from their fitness tracker, which appears to be only a watch. The National Safety Council recommends responding faster to emerging issues such as communications and safety technologies (National Safety Council, 2017).

5. Conclusion

The aim of our study was to investigate the impact of distracted driving on fatal crash responsibility. We used a case-control study design utilizing census-level fatal crash data. We computed odds ratios of UDAs for distracted relative to non-distracted drivers via logistic regression. We have added to the current literature by examining the role of distraction in fatal crashes, controlling for driver characteristics (age, sex, previous driving history), and excluding those who may have been under the influence of alcohol or drugs. Distracted drivers were found to have approximately double the odds of being responsible for the crash. Our findings can support laws, regulations, policy and educational campaigns to improve road safety, and save lives.

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Chapter 5: Discussion

We had three main objectives: 1) to examine the prevalence of distracted driving in drivers of passenger type vehicles involved in fatal collisions; 2) to establish the most prevalent type(s) of distraction involved in fatal collisions and 3) to investigate the association between distraction and crash responsibility. To our knowledge, this is one of few studies where crash responsibility and driver distractions beyond cell phones has been examined.

Overview of Findings

Prevalence of Overall distraction 1991 – 2015. The prevalence of distracted drivers in fatal collisions ranged from 6% (1995) to 10% (2009), with an overall prevalence of 7%. Using a dataset similar to the FARS (e.g., includes phones and distraction inside and outside the vehicle), Lam (2002) found that 4% of Australian crashes resulting in death or injury to the driver involved distraction. Lam's (2002) slightly lower numbers possibly result from a focus on driver injuries and fatalities only, whereas our study considered driver, passenger, or non-motorist fatalities.

The overall proportions of males than females who were involved in fatal collisions due to any distraction were similar. This is different from others who have reported a higher percentage of male distracted drivers involved in fatal collisions (Wilson & Stimpson, 2010).

We also found a u-shaped relationship between distraction and age. The frequency of any distractions was highest for younger drivers involved in fatal collisions. There was a high percentage of distraction among older adults, however the frequency was very low. Previous studies on distraction have also found the highest prevalence among younger drivers (Rhodes & Pivik, 2011; Weller et al., 2013; Jonah, 2014; Quisenberry, 2015; Gliklich et al., 2016; Pickrell, et al., 2016); the same is true in crash and near-crash studies in the USA (Dingus et al., 2006; Wilson & Stimpson, 2010) and Australia (Lam, 2002).

Prevalence of cell phone distraction 2002 – 2015. The FARS began coding for cell phone distraction while driving in 2002. Since then there has been a steady increase in cell phone distraction, accounting for over 1% of drivers involved in fatal collisions between 2002 – 2015. In the six-year period spanning 2010 – 2015, almost 15% of reported distractions were due to cell phone distraction ('while talking or listening to cellular phone,' 'while manipulating cellular phone,' and 'other cellular phone related'). Cell phone distraction was highest in younger drivers. We also found an interaction between sex and age. Though males had a higher overall frequency of cell phone distraction, a higher percentage of female drivers involved in fatal collisions were distracted by cell phones until older age (55+), at which point there was no difference between the sexes. Other researchers have reported similar findings in terms of sex (Seo & Torabi, 2004; Cramer et al., 2007; Pickrell et al., 2016).

Crash descriptors of distracted drivers. From 1991 – 2015, there was an increase in the percentage of distracted drivers who were driving alone when involved in a fatal collision compared to those driving with passengers; this same trend was also seen for distraction due to cell phones. Our findings are concordant with results from a Canadian study where electronic device use was higher among drivers without passengers (Jonah, 2014), and with research from the USA (Wilson & Stimpson, 2010). We found that single vehicle crashes accounted for 52% of distracted drivers (regardless of distraction source). Cell phone distracted drivers in single vehicle crashes showed a slight overall increase, with approximately half of drivers being involved in single vehicle collisions. The percentage of cell phone distracted drivers decreased on urban roadways, while the percentage of distracted drivers (any source) increased on urban roadways. This mirrors the previous recorded increase in distracted drivers on urban roads from 1999 – 2008 (Wilson & Stimpson, 2010), and electronic device use was found to be higher at urban, compared to rural sites (Jonah, 2014).

Recorded distractions 2010 – 2015. The most commonly coded distractions were ‘inattention details unknown,’ ‘distraction details unknown,’ and ‘other distraction’. Besides these ambiguous distractions without a known source, the most common recorded distraction was cell phone distraction. This finding is consistent with a teenage rear-end crash study (Carney et al., 2016). Our results differ from the most prevalent distraction of ‘outside person, object or event’ found using American crash data from 1995 – 1999 (Stutts & Hunter, 2003). This discrepancy is likely due to the rising popularity of cell phones in the new millennium, and their increased capabilities, such as email, and many social network applications.

Association between distraction and crash responsibility. Distracted drivers had greater odds than non-distracted drivers to commit four of the top five UDAs. A u-shaped curve was observed as is typically found with driver age and crashes (Tay, 2006), and crash responsibility (McGwin & Brown, 1999). Distracted drivers displayed a gentler u-shaped curve with the youngest (aged 20) and oldest ages (55+) showing the greatest predicted odds of crash responsibility. This indicates that the effect of age on crash responsibility is greatly reduced in distracted drivers, were the typical u-shaped curve is much flatter. Notably, at all ages, the predicted odds for committing any UDA was higher for distracted, compared to non-distracted drivers.

The crash responsibility odds ratios were statistically significant at all ages examined, meaning there was a difference in committing UDAs between distracted and non-distracted drivers at all ages. While distraction affects crash responsibility at all ages, its impact was greatest for middle-aged drivers (age 45: *OR* = 2.35 95% CI = 2.06, 2.67; age 50: *OR* = 2.36, 95% CI = 2.06, 2.71). This is due to middle-aged drivers being safer drivers overall, rather than much poorer drivers while distracted. While the impact of distraction is still present in younger and older drivers, the odds ratios are not as large as they are for middles-aged drivers. Compared to middle-aged, younger and older drivers that are non-distracted are less safe drivers, as seen by their higher predicted odds while non-distracted. Middle-aged drivers distracted by cell phone use also had the greatest odds of crash responsibility in a separate study (Asbridge, Brubacher, & Chan, 2013). Asbridge and colleagues (2013) found a similar pattern in that cell phone use increased crash responsibility, but not in all age groups, while our study achieved statistical significance at all ages. The lack of statistical significance for some age groups in Asbridge and colleagues (2013) may be attributable to differences in study design (e.g., use of propensity matched drivers, use of injury and non-injury crashes, and use of cell phone distraction only) but is likely due to their smaller sample size.

While our results suggest that distraction approximately doubles the odds that a driver was responsible for the crash, other studies have found a much stronger association between cell phone use and crash risk (Redelmeier & Tibshirani, 1997; Violanti, 1998; McEvoy et al., 2005). Their association may have been stronger due to the inclusion of non-fatal collisions (Redelmeier & Tibshirani, 1997; McEvoy et al., 2005), or a lack of control for alcohol or drug use (Redelmeier & Tibshirani, 1997; McEvoy et al., 2005). Although Violanti focused on fatal collisions, Violanti's definition of a fatality was only the death of the driver, whereas the FARS fatality definition includes the death of a motorist or non-motorist (Violanti, 1998; National Highway Traffic Safety Administration, 2016). Further, Violanti's results are limited by a very small sample size of drivers using a cell phone at the time of the crash ($n = 5$; Violanti, 1998).

The smaller association we found may also be due to our inclusion of only fatal crashes, the inclusion of all types of distraction, and the use of crash responsibility, not crash involvement as the outcome. These may bias our results towards the null hypothesis because distracted drivers may cause a predominance of minor rather than fatal crashes, and some distractions may not interfere with driving as much as others.

Implications

We found that distraction is prevalent in fatal collisions and was associated with increased odds of crash responsibility. As such, our findings strongly support the need for laws and regulations against distracted driving. As of May 2018, texting while driving is banned in 47 states and the District of Columbia (Insurance Institute for Highway Safety, Highway Loss Data Institute, 2018a). However, only 16 states and the District of Columbia ban talking on a hand-held cell phone while driving. All Canadian provinces and two territories have cell phone or general distracted driving legislation (Canadian Automobile Association, 2018). There is a lack of legislation against hands-free phones, which is problematic as it has the potential to imply that hands-free is a safe alternative (National Safety Council, 2012).

Texting while driving bans have been found to reduce fatal crashes if they include all drivers, not only young or novice drivers, and are enforced as a primary offence (Abouk & Adams, 2013). However, after four months the decrease was not sustained in the examined single-vehicle, single occupant crashes, likely due to lax enforcement and drivers learning to circumvent laws (Abouk & Adams, 2013). Furthermore, there is a difference when texting is treated as a primary versus a secondary offence; police officers can pull a driver over for a primary offence, but secondary enforcement laws are only enforced when there is another primary offence that has occurred. Ferdinand and colleagues (2014) found that primarily enforced texting bans on all drivers led to a 3% decrease in fatalities in all age groups. However, secondary enforcement did not lead to a significant reduction in fatalities (Rocco & Sampaio, 2016). Observed cell phone use while driving has effectively been reduced with the use of high-visibility enforcement campaigns (increased law enforcement, visibility, and publicity) in Connecticut, New York, California, and Delaware (Chaudhary, Casanova-Powell, Cosgrove, Reagan, & Williams, 2012; Chaudhary, Connolly, Tison, Soloman, & Elliott, 2015).

There are cell-phone bans beyond state legislation, such as by federal agencies. Federal employees have been banned from texting while driving in 2009 (Federal Leadership on Reducing Text Messaging while Driving, 2009), and in 2010 commercial vehicle drivers were also prohibited from texting while driving (Federal Motor Carrier Safety Administration, 2010). In the same year, the Federal Railroad Administration banned cell phone and electronic device use for all employees while working (Federal Railroad Administration, 2010) and all hand-held cell phone use was banned for commercial drivers and drivers carrying hazardous materials in 2011 by the Federal Motor Carrier Safety Administration and the Pipeline Hazardous Materials Safety Administration (Pipeline and Hazardous Materials Safety Administration, 2011). Municipal, state, provincial, and federal regulators all have a role to play in keeping our roads safe.

Our results suggest that distraction affects drivers of all ages, not just young drivers. Jurisdictions should create or revise distracted driving laws that are inclusive of all drivers, regardless of age or experience, and that include hands-free distractions. Currently, novice drivers are banned from all cell phone use while driving in 38 states and the District of Columbia (Insurance Institute for Highway Safety, Highway Loss Data Institute, 2018a). Novice drivers in British Columbia and Saskatchewan are the only drivers banned in Canada or the United States from using hands-free cell phones (Canadian Automobile Association, 2018). The primary enforcement of these distraction laws is necessary to reduce distraction-related traffic injuries and fatalities.

Technology is rapidly changing; it is evolving much faster than government regulations can be passed. This is problematic for the use of electronic devices and cell phones while driving. Cell phones have recently advanced into 'smart phones', which have countless applications such as cameras, internet, email, banking, and various social media platforms. Infotainment systems, which are touch screen systems to control the vehicle's information (e.g. navigation and temperature) and media controls, are growing in popularity in newer vehicles. Fitness trackers are a relatively new technology that records one's physical activity but may also allow people to read incoming text messages from the device, which appears to be a watch. The National Safety Council recommends responding faster to emerging issues such as communications and safety technologies (National Safety Council, 2017). For example, moving to electronic data collection would allow for timely adaptations to technological advancements (National Safety Council, 2017).

Future work should investigate simultaneous impairment by distraction and alcohol or drugs. This need for further research is demonstrated by the increase in distracted drivers who were also drinking alcohol from 1999 – 2008 (Wilson & Stimpson, 2010). Although our study focused on passenger type vehicles, further research is warranted on distraction in commercial vehicles and other non-passenger type vehicles.

Strengths

Our study is one of a few focused on distraction in fatal crashes considering crash responsibility with several sources of distraction. Further, our data are based on real life crashes;

our results are therefore not limited by the controlled environment of a simulator or test track. Another strength to our study is the large sample size. We used USA census-level data, providing information for all fatal collisions in the entire country. Few distraction studies have used census level crash data (Ferdinand & Menachemi, 2014; Lim & Chi, 2013).

Within the responsibility analysis, we used UDAs as a proxy measure of crash responsibility. The use of UDAs is preferred to traffic violations because traffic violations are not charged without sufficient evidence, and not all unsafe actions are chargeable infractions (Blower, 1998). Further, Blower (1998) has tested the validity of UDAs as a measure of crash responsibility in truck-passenger fatal collisions.

In order to ensure our results did not simply capture unsafe drivers rather than distracted drivers, our analysis of crash responsibility controlled for potential confounders, including age, sex, and previous driver history. Our inclusion criteria (confirmed negative BAC and drug test) eliminates the potential for alcohol or drug impairment to better isolate the impairment due to distraction. Our results are directly applicable to all U.S. states, and likely generalizable to other countries with similar vehicles, traffic systems and road conditions. However, the prevalence of distracted driving in fatal collisions may be lower in other countries such as Canada, as all Canadian provinces have some cell phone or distracted driving legislation in effect (Canadian Automobile Association, 2018).

Limitations

There are several limitations to our study. We used data from the FARS, which only includes fatal crashes. While our findings cannot be generalized to non-fatal crashes, our recommendations to support distracted driving legislation has the potential to decrease nonfatal distraction related crashes as well. Further studies should be designed to investigate crash culpability in non-fatal crashes. Prevalence of distraction in fatal crashes reported here may not be representative of distraction prevalence in nonfatal crashes. There is some evidence that distracted drivers engage in compensatory behaviours, such as driving slower, maintaining a larger headway, or waiting until a stop sign (Li, Yan, Wu, Radwan, & Zhang, 2016; Schroeder et al., 2013; Yannis; Laiou, Papantoniou, & Gkartzonikas, 2016). Drivers may engage in these behaviours to try and offset the negative effects of distraction. Compensatory behaviours may help to reduce the risk and impact of a crash.

Additionally, distraction was captured in one all-encompassing variable until 2001. In 2002, a cell phone in use in vehicle variable was added. Separate distractions were not captured until 2010, when the FARS was revised to include a 'Distract Data File'. The FARS 'Distract Data File' contains several general or ambiguous distractions, such as 'distraction/inattention', 'distraction/careless', 'distraction details unknown', 'inattention details unknown', and 'other distraction.' 'Inattention details unknown', 'distraction details unknown', and 'other distraction' were the three most frequently coded distractions. This shows that there are difficulties in identifying explicit distractions in fatal crashes. We do not know what these ambiguous distractions consisted of, which impacts the results of the most prevalent type of distractions. Knowing the most common specific distractions can better inform future directions such as public education, and campaigns.

Another limitation to the study is the retrospective nature of the case-control design we used. Despite the ease of access and low cost of secondary analyses, there are several disadvantages. The data are not collected for the purpose of the specific research question (Cheng & Phillips, 2014). The FARS data are collected in order to identify traffic safety problems, and evaluate safety initiatives. While our study identifies the traffic safety problem of distraction, the issue evolved much more quickly than the FARS could be updated. There may be important variables or identifying information that are not available, such as a clear crash responsibility variable. The researchers, as in our study, are not always involved in data collection, limiting the researchers' knowledge of the dataset and the documents provided (Cheng & Phillips, 2014). The FARS relies on various state documents, therefore, is subject to inconsistencies of documents across states and human error by the police officer or other professional completing the documents.

Although we removed the influence of drugs or alcohol, this also acts as a limitation to the study. There has been an increase in reported distracted drivers who were also drinking alcohol from 1999 – 2008 (Wilson & Stimpson, 2010). Furthermore, because alcohol and distraction have been found to produce a synergistic impairment when both are present while driving (Van Dyke & Fillmore, 2015) our results may present an underestimation of the true effects of distractions.

Despite our use of census-level data, the prevalence estimates reported here are likely an underestimation of the true actual population prevalence. Because the minimum driving age varies by state and to better control for age, we included drivers aged 16 years and older. Distracted drivers aged 14 and 15 were excluded from our analyses. Teenagers in 23 states can get their restricted driver's licence on their 15th birthday with an additional nine states granting licences even before the driver's 15th birthday (Insurance Institute for Highway Safety, Highway Loss Data Institute, 2018b). The minimum driving age is between 15 and 16 years old for nine states (Insurance Institute for Highway Safety, Highway Loss Data Institute, 2018b).

The National Safety Council has identified factors involving emerging technologies and factors that are difficult to observe and measure as crash data, as areas in which underreporting can be a detriment to national prevention efforts (National Safety Council, 2017). This would include driver distractions, and various hand-held or built-in vehicle infotainment systems. There are many different factors that may impact whether the police officer on scene can determine if a driver was distracted. Drivers may be reluctant to admit they were distracted and there may not be any witnesses to testify against them. Further, witnesses or those involved in the crash may have been severely injured or killed. As a result of a crash, potential technological distractions may become damaged or broken, rendering it next to impossible to detect whether it was in use. Besides a witness report, there is often no evidence after a crash for many distractions such as reaching for an object, or adjusting controls. Furthermore, human error is possible as FARS data are mostly based upon police crash reports, which are completed after the event. Police reports and the distraction reporting field both vary by jurisdiction, which creates the potential for inconsistencies (National Center for Statistics and Analysis, 2017). All of these factors may result in the misclassification of distracted drivers as non-distracted, effectively leading to the underestimation of the negative effects of distractions. The FARS as a whole is subject to misclassification errors from police officers and lack of standardization of police crash reports. To address coding issues, the National Safety Council recommended the complete standardization of crash report data across states (National Safety Council, 2017).

While the use of UDAs are preferred to traffic violations in determining the culpability of a crash, UDAs are not a perfect measure. UDAs include a variety of potentially hazardous actions (e.g., improper or erratic lane changing, making improper turn), and hazards based on the lack of actions (e.g., failure to yield right of way, failure to signal intentions). Our study determined crash responsibility on the assumption that if they committed an unsafe driver action, then they are assigned responsibility to the crash; those without a coded UDA, were deemed not responsible. Modern responsibility analyses not only label drivers culpable if they committed an unsafe action, but also drivers that should have been able to avoid the crash, but did not. These responsibility analyses include multiple mitigating factors that may have contributed to the crash, such as road and environmental conditions (Brubacher, Chan, & Asbridge, 2012; Robertson & Drummer, 1994). Drivers who crash in good weather and road conditions, with no alternative explanations for the crash, are deemed responsible. In addition to unsafe driver actions, six mitigating factors were included in the culpability scoring tool developed for British Columbia traffic collision data (Brubacher et al., 2012). The factors included road type, driving conditions (road surface, visibility and weather conditions), vehicle condition, contribution from other parties, type of collision (e.g., single vehicle, pedestrian, multi-vehicle collision), and task involved (e.g., avoiding object on road, changing lanes). The inclusion of such external factors in a responsibility analysis has the potential to impact the results. Further studies should include external factors such as driving conditions and road type in FARS responsibility analyses.

The results of our study suggest that being distracted while driving increases one's odds of being responsible for the crash. In terms of the "aspects of association" that Hill (1965) discussed, our study did demonstrate reasonably good strength of association, consistency across person, place, and time, coherence with existing knowledge, and consideration of alternative explanations. However, based upon this study alone, we cannot infer that distraction causes collisions. As professionals, our goal is to reduce deaths and injuries. Hill (1965) states that there are different standards of probable causality, before we take action. On slight evidence we may act upon the association if the harm is great, and the action is a minor inconvenience, such that if the association was not causal, no harm is done. We may need very strong evidence before acting upon an association that would create a large inconvenience to society. Given the enormous potential benefits to reduction of distractions in the driving environment and the relative absence of any detriments to reducing distractions, we ought to take action as though distractions while driving cause crashes.

Relevance

This is one of few studies to evaluate the association between any driver distraction and crash responsibility. Our findings suggest that distracted drivers have greater odds of being responsible for crashes than non-distracted drivers. Our results are relevant to the general public, safety professionals, and legislators. The general public should be aware that distraction increases their odds of being responsible for a fatal crash. The public may then use this knowledge to inform their driving choices to ultimately reduce distractions while driving. Safety professionals can use this information to shape educational materials for drivers and campaigns for the public. It would be wise to target future campaigns at cell phone use while driving. University students think they are able to engage in a distraction and still be able drive safely (Hill et al., 2015; Watters & Beck, 2016). However, studies have found that drivers are not able to accurately estimate the effects of distraction (Horrey, Lesch, Melton, 2010; Kidd & Horrey, 2010; Finley, Benjamin, & McCarley, 2014).

Conclusion

The aim of this study was to investigate the prevalence of distracted driving in fatal collisions and to investigate the impact of distracted driving on crash responsibility. We used census-level USA fatal crash data. From 1991 – 2015, 7.3% of drivers in fatal collisions were distracted. The frequency of distracted drivers ranged from 6.1% (1995) to 9.8% (2008; 2009). We identified high frequencies of distraction in young drivers, and males. We reported an increase in cell phone distraction over time, with higher frequencies in younger ages. Cell phone use was the most frequent specific distraction reported (after inattention details unknown, distraction details unknown, and other distraction). At all ages, distracted drivers had higher odds of crash responsibility compared to non-distracted drivers.

Our study is one of few to investigate the impact of distraction on crash responsibility, including both cell phone distraction and other distractions. We controlled for driver characteristics and excluded those who may have been under the influence of drugs or alcohol, thereby providing a clearer representation of the impact of distraction. Our work has added to the existing literature but additional research is required to confirm and expand on our findings, and to prevent further harm related to distracted driving. Governing bodies are well-positioned to use this information to influence their laws and regulations regarding distracted driving, and should consider a ban against any type of distracted driving that is enforced as a primary offence. It is our hope that the results of our study will caution drivers against the use of distractions while driving to thereby reduce the number of collisions and fatalities.

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