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Research Article

Distracted Driving and Risk of Crash or Near-Crash Involvement Among Older Drivers Using Naturalistic Driving Data With a Case-Crossover Study Design

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Abstract

Background: The purpose of this study was to examine the association between secondary task involvement and risk of crash and near-crash involvement among older drivers using naturalistic driving data.
Methods: Data from drivers aged ≥70 years in the Strategic Highway Research Program (SHRP2) Naturalistic Driving Study database was utilized. The personal vehicle of study participants was equipped with four video cameras enabling recording of the driver and the road environment. Secondary task involvement during a crash or near-crash event was compared to periods of noncrash involvement in a case-crossover study design. Conditional logistic regression was used to generate odds ratios (ORs) and 95% confidence intervals (CI).
Results: Overall, engaging in any secondary task was not associated with crash (OR = 0.94, 95% CI 0.68–1.29) or near-crash (OR = 1.08, 95% CI 0.79–1.50) risk. The risk of a major crash event with cell phone use was 3.79 times higher than the risk with no cell phone use (95% CI 1.00–14.37). Other glances into the interior of the vehicle were associated with an increased risk of near-crash involvement (OR = 2.55, 95% CI 1.24–5.26). Other distractions external to the vehicle were associated with a decreased risk of crash involvement (OR = 0.53, 95% CI 0.30–0.94). Interacting with a passenger and talking/singing were not associated with crash or near-crash risk.
Conclusions: Older drivers should avoid any cell phone use and minimize nondriving-related eye glances towards the interior of the vehicle while driving. Certain types of events external to the vehicle are associated with a reduced crash risk among older drivers.

Keywords: Driver distraction, Case-crossover, Naturalistic driving

Driving safety among older drivers is a growing public health challenge because the number of licensed drivers aged 70 and older has been increasing (1,2). The increase in the number of older drivers on the road has led to concerns about its impact on traffic safety.

Distracted driving occurs when drivers divert their attention away from the driving task to focus on some other activity (3). Estimates based on naturalistic driving data show 68–78% of crashes and 65% of near crashes are related to driver distraction (4,5). Studies investigating the effects of distraction on older drivers' driving performance have shown that following distance and reaction time were impaired (6–8), especially for in-vehicle distractions (9). These adverse effects in turn may lead to driving errors and increased risk of crash (10,11). Alternatively, some older drivers refrain from engaging in nondriving-related activities under certain driving conditions that may be considered more challenging and use compensatory behaviors such as driving slower or following as a greater distance which may help them deal with a competing activity while driving and lower the crash risk (6,12).

Naturalistic driving studies use video cameras to unobtrusively record the driver's behavior. In addition, naturalistic driving techniques allow researchers to study near crashes, whereas reliance on accident reports does not. Therefore, the purpose of this study is to examine the association between driver distraction due to secondary task involvement and risk of crash or near-crash involvement among older drivers using naturalistic driving data.

Methods

This study utilized data from the Strategic Highway Research Program (SHRP2) Naturalistic Driving Study, the largest naturalistic driving study conducted to date (13). Virginia Tech Transportation Institute (VTTI) was the primary contractor for the SHRP2 study.

A case-crossover study design was used to examine the association between the presence or absence of secondary task involvement and crash or near-crash involvement. This variation of a matched case–control design is appropriate when a brief exposure (ie, secondary task involvement) causes a transient rise in the risk of a rare outcome (ie, crash or near crash) (14). In a case-crossover design, the individuals serve as their own controls. This type of design controls for characteristics of the driver that may affect the crash risk but do not change over a short period (eg, gender).

Details of the SHRP2 purpose, study design, enrollment procedures, and data collection methods have been published previously (15). Briefly, the study involved a sample of drivers from six U.S. sites (Bloomington, IN; State College, PA; Tampa Bay, FL; Buffalo, NY; Durham, NC; Seattle, WA), representing a wide range of geographies, weather, state laws, road types, and road usage. The Institutional Review Board (IRB) of the National Academy of Sciences, VTTI, and the local IRBs provided oversight for the study (16). A combination of random-digit dialing and public advertising was used to recruit potential participants (15). The Virginia Tech Center for Survey Research followed-up with potential participants with a telephone call to discuss the study protocol and confirm eligibility. Individuals who were licensed drivers, drove at least 3 days per week, planned to keep the vehicle for the duration of the study, and had a mechanically sound vehicle were eligible to participate. Participants completed a standard intake process during a single in-person visit at regional study sites. Participants were enrolled from October 2011 through December 2013 and were followed-up over time for 1 or 2 years for most participants, accumulating more than 35 million miles of continuous driving data. More than 18,000 individuals were recruited for screening (15). The final SHRP2 sample included 3,541 drivers aged 16–98 years. For the current analysis, the sample was limited to drivers aged ≥70 years. This study was approved by the IRB at the University of Alabama at Birmingham and followed the tenets of the Declaration of Helsinki.

At the enrollment visit, participants completed questionnaires on demographic characteristics (eg, age, gender, education) and driving history (eg, self-reported prior crash involvement, and annual miles driven last year). The personal vehicle of each participant was installed with a data acquisition system (DAS) that captured continuous driving data anytime the vehicle was operating. Participants were instructed to drive their vehicles as they normally would while enrolled in the study. The DAS included a suite of vehicle sensors including accelerometers, global positioning system, forward radar as well as one color video camera view of the forward roadway and three additional grayscale video cameras of the rear view, view of the driver's face, and view over the driver's right shoulder. Data were transmitted to VTTI for processing (15).

The primary outcomes of interest were crash and near-crash events. Crashes were defined as events where the SHRP2 participant's vehicle had contact with any object (including other vehicles, pedestrians, cyclists, animals, trees, or buildings), at any speed, including nonpremeditated departures from the roadway where at least one tire leaves the paved or intended travel surface of the road. Near crashes were defined as any circumstance that required a rapid evasive maneuver by the study participant's vehicle or any other vehicle, pedestrian, cyclist, or animals to avoid a crash. Crash and near-crash events were identified when vehicle sensors detected (a) large changes in speed or position of the car with respect to the road, (b) activation of advanced safety systems (eg, anti-lock braking), (c) the participant pushed the critical incident button to flag an event, or (d) the VTTI analysts detected an event (17). A short window of video surrounding the possible event was reviewed to verify and classify as a crash or near-crash event (18). Crash events were further categorized according to the severity of the event and included (I) severe crashes, (II) police-reportable crashes, (III) minor crashes, and (IV) low-risk tire strike crashes. All crash events included levels I–IV and "major" crash events included levels I–III. At-fault crash status of the driver was determined by VTTI analysts and was only coded if there was observable evidence in the video that the driver committed an error that led to the event. The VTTI analysts coding crash and near-crash events were unaware of the participant's status on any variables collected at the enrollment visit.

The vast majority of the video depicts what is described as "normal driving" where crash and near-crash events do not occur. VTTI utilized a sampling procedure to identify 20,000 episodes of normal driving that were 20 s each. These episodes are considered controls, in that they represent periods of driving when a crash or near-crash event did not occur.

The primary exposure of interest was secondary task involvement. Using the four camera views, VTTI analysts reviewed the video surrounding each crash and near-crash event and the control episodes and recorded when the driver was involved in a secondary task and specified each task. For the purpose of this study, the

Table 1. Definition of Secondary Tasks

Secondary Task	Definition
Any secondary task involvement	Presence of any secondary task (including those tasks not summarized here)
Interacting with a passenger in adjacent seat	Interacting with a passenger in adjacent seat
Other external distraction, not otherwise specified	Other external distraction (eg, a nondriving-related glance to look out into a field, look at oncoming traffic on a road with a wide dividing median, look out a window when there are many possible targets for that glance, such as in a busy business district)
Talking or singing	Talking or singing
Other glances into the interior of the vehicle, not otherwise specified	Other nonspecific internal eye glance (eg, a nondriving-related glance to look in the direction of the cup holder area, look down towards the lap, look towards the center stack with no surrounding context as to what specifically is the target)
Cell phone use	Browsing cell phone, dialing hand-held, dialing hand-held using quick keys, dialing hands-free using voice-activated software, holding cell phone, locating/reaching/answering cell phone, other cell phone use, talking/listening to hand-held cell phone, talking/listening to hands-free cell phone, texting
Number of tasks	Sum the number of tasks (including those tasks not summarized here)

most frequently occurring secondary tasks were examined (Table 1). This was done because point estimates for secondary tasks that were infrequent were susceptible to imprecision. Cell phone use was infrequent, but was included given the vast literature on the increased crash risk associated with its use. In addition, the number of tasks was summed.

For the control episodes, the control window included those secondary tasks that were coded during the last 6 s of the 20-s video. For crash and near-crash events, the hazard window included those secondary tasks that were coded during the 5 s prior to the precipitating event (ie, the action that was critical for the vehicle becoming involved in a crash or near crash) to 1 s after the event start. This was done so that the exposure information collected during the control window and hazard window was the same length.

All observed crash or near-crash events that occurred during the course of the study were defined as case events. All control episodes that occurred for the same driver and occurred prior to each event were included. This was done to ensure that the crash or near-crash event did not alter or affect subsequent driving performance. Cases were excluded if a control period meeting these criteria was not available. Conditional logistic regression was used to estimate the odds ratios (OR) and 95% confidence intervals (CIs) for each secondary task. Analyses were repeated with a single-control episode. In a sensitivity analysis, only the control episodes that occurred within 6 months of the crash event were used to explore whether there were secular trends over time (eg, cell phone use increased over time). There was insufficient sample size to adjust for environmental and situational characteristics.

Results

During the study period, there were 221 crash events (among 152 drivers) and 211 near-crash events (among 134 drivers) with at least one matched control episode among older drivers. Table 2 summarizes the baseline characteristics of drivers who were involved in these events.

Secondary task involvement occurred in 40% of the normal driving trips (Table 3). The most frequently occurring secondary task was other external distraction (not otherwise specified) (13.0%), followed by interacting with a passenger in an adjacent seat (11.8%), talking or singing (3.3%), and other glances into the interior of the vehicle (2.6%). The prevalence of any cell phone use was ~1%. The association between any secondary task involvement and any crash or near-crash involvement was not statistically significant (Table 4). Cell phone use was associated with almost a fourfold increase in the likelihood of having a major crash (OR = 3.79, 95% CI 1.00–14.37). Secondary tasks coded as other glances into the interior of the vehicle were associated with an increased risk of having a near-crash event (OR = 2.55, 95% CI 1.24–5.26). Other external distractions (not otherwise specified) were associated with a decreased risk of crash involvement (OR = 0.53, 95% CI 0.30–0.94) among older drivers. Interaction with a passenger, talking or singing, and number of tasks was not associated with any type of crash or near-crash event.

Discussion

Distracted driving is a contributing factor in many traffic crashes, but little is known about the prevalence of this behavior among older adults. The SHRP2 naturalistic driving study provides unique insight into everyday driving behavior in a large sample of drivers. The current study is the first to use a case-crossover study design to examine the association between driver distraction and risk of any crash, severe crash, at-fault crash, or near-crash involvement among older adults using naturalistic study data. The results suggest cell phone use while driving occurred infrequently in the study population but was associated with a four times higher odds of crash involvement. Distractions in the interior of the vehicle were also associated with crashing.

Secondary task involvement was frequent among older drivers occurring in ~40% of the normal driving episodes, half of which involved other external distractions (not otherwise specified) or interacting with a passenger. Overall, there was no association between secondary task involvement and crash risk, which is consistent with other studies (19,20). In contrast, a prior study using SHRP2 data found that older drivers were 1.71 times (95% CI 1.24–2.36) more likely to crash when engaged in a secondary task compared to normal driving episodes (21). However, they compared specific secondary task involvement with sober, alert, attentive driving behavior in

Table 2. Baseline Characteristics of Older Drivers Involved in a Crash, Severe Crash, At-Fault Crash, or Near-Crash in SHRP2

	Any Crash (*N* = 152)	Major Crash (*N* = 101)	At-Fault Crash (*N* = 129)	Near-Crash (*N* = 134)
Age group (years)				
70–79	89 (58.6)	52 (51.5)	75 (58.1)	83 (61.9)
80–89	61 (40.1)	48 (47.5)	52 (40.3)	49 (36.6)
90–99	2 (1.3)	1 (1.0)	2 (1.6)	2 (1.5)
Gender				
Female	76 (50.0)	49 (48.5)	69 (53.5)	51 (38.1)
Male	76 (50.0)	52 (51.5)	60 (46.5)	83 (61.9)
Education				
Some high school	1 (0.7)	0 (0.0)	1 (0.8)	3 (2.3)
High school or GED	15 (10.0)	10 (9.9)	12 (9.5)	11 (8.3)
Some college	49 (32.7)	32 (31.7)	42 (33.1)	34 (25.6)
College degree or more	85 (56.7)	59 (58.4)	72 (56.7)	85 (63.9)
No. of MVCs in past 3 years				
0	115 (76.7)	77 (76.2)	96 (75.6)	97 (73.5)
1	31 (20.7)	23 (22.8)	27 (21.3)	31 (23.5)
2 or more	4 (2.7)	1 (1.0)	4 (3.2)	4 (3.0)
Miles driven last year	10,861.5 (6658.0)	10,440.2 (6349.0)	10,832.2 (6940.1)	11,119.4 (6487.8)

Note: GED = General Educational Development; MVC = Motor Vehicle Collision.

Table 3. Prevalence of Secondary Task Involvement

	Crashes		Major Crashes		At-fault Crashes		Near Crashes	
	Normal Driving Periods	Event Periods	Normal Driving Periods	Event Periods	Normal Driving Periods	Event Periods	Normal Driving Periods	Event Periods
Any secondary task involvement	40.3	37.1	44.3	44.2	39.6	36.8	42.6	43.1
Other external distraction, NOS	13.0	7.2	13.6	10.0	13.7	8.4	12.6	13.7
Interacting with a passenger in adjacent seat	11.8	9.5	13.6	8.3	11.2	8.4	12.8	7.1
Talking or singing	3.3	1.8	3.8	2.5	3.2	2.1	5.0	4.3
Other glances into the interior of the vehicle, NOS	2.6	2.3	2.4	3.3	2.2	1.6	2.6	6.2
Any cell phone use	1.1	1.8	1.2	3.3	1.2	2.1	0.9	1.0
Number of tasks								
0	59.6	62.9	55.7	55.8	60.4	63.2	57.2	56.9
1	34.3	33.5	38.6	39.2	33.6	33.2	36.4	33.7
≥2	6.0	3.6	5.7	5.0	6.0	3.7	6.2	9.5

Note: NOS, not otherwise specified.

Table 4. Association Between Secondary Task Involvement and Crash and Near-Crash Risk

	Crashes *N* = 221 Events	Major Crashes *N* = 120 Events	At-fault Crashes *N* = 190 Events	Near Crashes *N* = 211 Events
Any secondary task involvement	0.94 (0.68–1.29)	1.07 (0.70–1.62)	0.99 (0.70–1.40)	1.08 (0.79–1.50)
Other external distraction, NOS	**0.53 (0.30–0.94)**	0.73 (0.37–1.47)	0.62 (0.35–1.12)	1.10 (0.69–1.75)
Interacting with a passenger in adjacent seat	0.83 (0.49–1.40)	0.57 (0.28–1.18)	0.77 (0.43–1.39)	0.57 (0.31–1.03)
Talking or singing	0.53 (0.18–1.56)	0.56 (0.16–2.02)	0.61 (0.20–1.83)	0.93 (0.43–2.01)
Other glances into the interior of the vehicle, NOS	0.85 (0.32–2.28)	1.47 (0.46–4.66)	0.80 (0.23–2.76)	**2.55 (1.24–5.26)**
Any cell phone use	2.02 (0.62–6.65)	**3.79 (1.00–14.37)**	2.26 (0.67–7.60)	1.35 (0.29–6.40)
Number of tasks				
0	Ref.	Ref.	Ref.	Ref.
1	0.98 (0.71–1.36)	1.07 (0.69–1.64)	1.03 (0.72–1.47)	1.00 (0.71–1.40)
≥2	0.67 (0.31–1.47)	1.04 (0.41–2.66)	0.72 (0.31–1.66)	1.76 (0.96–3.09)

Notes: Values represent OR (95% CI). Findings in bold are statistically significant.
CI = confidence interval; NOS = not otherwise specified; OR = odds ratio.

a mixed effects model rather than a matched analysis. It is possible the OR was elevated in this previous study because the reference group had a lower risk of crash involvement compared to the reference group used in the current study, which included drivers who were not engaged in secondary task but could have had other impairments. Thus, our study compared any crash and near-crash risk when drivers were engaged in a secondary task with normal everyday driving behavior. In addition, from an analytic perspective, a mixed effects model would generate a different point estimate than a conditional logistic regression used in the current study. Thus, the results from the prior analysis of the SHRP2 addressed a related but different question.

The occurrence of cell phone use was about four times higher during a major crash event as that among the same drivers when they were not crash involved. This relative risk is consistent with other case-crossover studies on serious collisions resulting in property damage and injury (22,23). Our analysis did not differentiate between hand-held versus hands-free cell phone use or the various subtasks (eg, dial, talk, or text). Hand-held cell phone use has been associated with increased crash risk, particularly with the visual and manual subtasks of cell phone use (eg, using a cell phone to dial, talk, text) (24,25) whereas listening and talking on a cell phone (regardless of phone type) has not been associated with increased crash risk (5,21,24,26). While the magnitude of this effect was relatively large, the prevalence of any cell phone use among older drivers was small. This suggests that while any cell phone use may carry a high risk, the task is performed so infrequently among older drivers that the attributable risk is low. Policies that ban cell phone use while driving may not be effective in lowering collision rates in the older driver population as long as the prevalence remains low. However, in recent years, older adults have had more positive and accepting attitudes towards technology (27) and 10% of older adults self-reported that they have texted or sent email from behind the wheel (28). Trends in the acceptability and use of cell phones among older drivers should continue to be monitored.

Other external distractions (not otherwise specified) were shown to decrease the risk of crash involvement (OR = 0.53) in this sample of older drivers, similar to the 100-Car naturalistic driving study (5). It is possible that drivers who glance at events external to the vehicle (driving-related or not) are generally alert, responding to stimuli outside the vehicle (9), and are engaging in environmental scanning behavior, which is a physical measure known to improve driving performance (29,30). In a sense, describing this as a type of "distraction" may be a misnomer, as that term implies the external event was not relevant for driving when, in fact, this type of adaptive behavior may help the driver to detect unexpected stimuli while driving. Future studies are needed to identify what specific types of environmental scanning behaviors are detrimental to driving safety among older drivers.

Other glances into the interior of the vehicle were a significant risk factor for near-crash involvement, not crash involvement. This is a unique finding because most naturalistic driving studies on distracted driving combine crash and near-crash events (5,31–33), which may over- or underestimate the risk compared with estimates based on crash data alone. Similar to other external distraction, this category was used when the specific internal location of the eye glance could not be determined; however, existing research has shown that glances at objects inside the vehicle, specifically at the center mirror, radio/AC controls, and the left mirror are associated with near-crash/crash involvement (5). Improvements to the video camera quality used in naturalistic driving studies may help researchers better determine the specific location of these eye glances. In addition, as with other secondary tasks, a simple yes/no does not necessarily provide an accurate picture of the exposure. For example, this analysis did not account for the glance duration. Current literature and guidelines stress that glances away from the forward roadway longer than 2 s are considered dangerous regardless of the secondary task type (34), so it is possible this observed association may be explained by duration of the glance.

It was interesting to note that the number of near-crash and crash events was nearly the same in this SHRP2 sample. Naturalistic driving studies often report that near-crash events occur more frequently than crash events, reporting 2–10 times more frequently (17,35). It is possible the similar number of crash and near-crash events in this sample may be a consequence of the age group studied. Specifically, older drivers tend to be slow in response to a sudden event and make fewer rapid evasive maneuvers compared to younger drivers. That is, when exposed to the same sudden threat, younger drivers are more likely to successfully evade and have a near crash, whereas older drivers are more likely to fail to evade and have a crash. It is also possible that the difference in magnitude seen in this study compared to others, like 100-Car, is because different triggers and kinematic thresholds were used. The kinematic thresholds typically use a combination of parameters related to vehicle speed, lateral acceleration, longitudinal acceleration, steering changes, and yaw rate changes (36). For example, the 100-Car study used a trigger threshold of ≥0.6 g for longitudinal acceleration whereas SHRP2 used ≥0.75 g so there were more candidate events found in 100-Car. Therefore, it is important to recognize that the frequency of crash and near-crash events detected in a naturalistic driving data set depends on the kinematic thresholds employed, and the event types detected using more severe kinematic triggers will reflect more severe crashes (17).

The results of this study should be interpreted in light of several strengths and limitations. A major strength is that this is the first large-scale study using SHRP2 data to examine the association between distracted driving and crash risk using a case-crossover study design. A case-crossover study has the advantage of controlling for driver-level characteristics (measured or unmeasured) that are stable over time; however, it does not control for all forms of confounding. The analysis did not control for differences in temporary conditions related to the driver (eg, emotional stress, anger), the driving environment, road type, time of day, and weather between the hazard and control intervals. In addition, it does not capture any time-varying confounding (eg, emotional stress may lead to both increased use of a cell phone and increased crash risk). A case-crossover design assumes the control periods represent usual levels of exposure prior to a crash. Multiple control periods were matched to each crash event with replacement, so approximately half of the control periods were used more than once. When one control period was matched to each crash event, about 18% of the control periods were recycled and the results did not meaningfully change. This design also assumes there were no secular trends over time. To check this assumption, a sensitivity analysis was done limiting to control periods that were within 6 months of the crash event and the point estimates did not meaningfully change. The advantage of using naturalistic driving data is the high external validity, the ability to study driving behavior for an extended period of time, which enables systematic evaluation of long-term effects like seasonal variation, and the ability to obtain prevalence data for different types of behavior. However, it does not directly capture cognitive distraction that could take one's mind away from the driving task, such as that used in experimental studies using simulators. In addition, we examined whether a driver was engaged in secondary tasks, but did not capture complexity of the task or how frequently the task occurred.

This study demonstrates the feasibility to use a case-crossover study design in SHRP2 to examine the association between driver behavior and crash or near-crash risk. The results suggest that cell phone use elevates crash risk, other glances into the interior of the vehicle elevate near-crash risk, and glances at events external to the vehicle decreased the risk of crash involvement among older drivers. Older drivers should avoid using a cell phone and minimize nondriving-related eye glances towards the interior of the vehicle while driving. However, these individual secondary tasks did not frequently occur, which implies that eliminating these activities while driving will have minimal impact on crashes and near crashes among older drivers at the population level.

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Conflict of Interest

None declared.

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