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Road Accidents

The effects of age on crash risk associated with driver distraction

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Abstract

Background: Driver distraction is a major contributing factor to crashes, which are the leading cause of death for the US population under 35 years of age. The prevalence of secondary-task engagement and its impacts on distraction and crashes may vary substantially by driver age.

Methods: Driving performance and behaviour data were collected continuously using multiple cameras and sensors *in situ* for 3542 participant drivers recruited for up to 3 years for the Second Strategic Highway Research Program Naturalistic Driving Study. Secondary-task engagement at the onset of crashes and during normal driving segments was identified from videos. A case–cohort approach was used to estimate the crash odds ratios associated with, and the prevalence of, secondary tasks for four age groups: 16–20, 21–29, 30–64 and 65–98 years of age. Only severe crashes (property damage and higher severity) were included in the analysis.

Results: Secondary-task-induced distraction posed a consistently higher threat for drivers younger than 30 and above 65 when compared with middle-aged drivers, although senior drivers engaged in secondary tasks much less frequently than their younger counterparts. Secondary tasks with high visual–manual demand (e.g. visual–manual tasks performed on cell phones) affected drivers of all ages. Certain secondary tasks, such as operation of in-vehicle devices and talking/singing, increased the risk for only certain age groups.

Conclusions: Teenaged, young adult drivers and senior drivers are more adversely impacted by secondary-task engagement than middle-aged drivers. Visual–manual distractions impact drivers of all ages, whereas cognitive distraction may have a larger impact on young drivers.

Key words: traffic crash risk, driver behaviour, distraction, SHRP2 Naturalistic Driving Study, case–cohort

Key Messages

- Distraction by secondary task engagement imposes a higher risk for teenage and young adult drivers.
- Previously regarded low-risk secondary tasks, such as adjusting radio and climate control, increase risk for teenage and young adult drivers.
- Talking on hand-held cellphone increases crash risk for teenage and young adult drivers; general hand-held cellphone use increased risk for all age groups.
- Secondary tasks with high visual-manual demand increase crash risk substantially for all age groups.
- Interacting with passengers increases risk for teenage and young adult drivers and is observed to occur with high prevalence.

Introduction

Motor-vehicle crashes are a major public health issue in the USA; crashes caused 32 719 fatalities and 2.3 million injuries in 2013 and were the leading cause of death for the population younger than 35 years.[1] The National Highway Traffic Safety Administration considered distracted driving a dangerous epidemic on America's roadways. Fatality and injury crash statistics indicate that the youngest and oldest drivers represent the greatest crash risk relative to their driving exposure.[1] Teenagers (i.e. those 16–20 years of age) represent 6.0% of drivers but account for 9.6% of all drivers involved in fatal crashes.[2] Traffic-fatality rates for drivers 21–24 years of age (18.1 per 100 000 population) and older than 74 years of age (15.4 per 100 000 population) are 1.7 times and 1.4 times higher than those of drivers that are 35–44 years old (10.8 per 100 000 population).[1]

The reasons for this variable crash involvement across age groups may be due to unique characteristics within each group. A combination of immature brain development, inexperience and greater prevalence of risky driving behaviours could contribute to the heightened crash involvement for the younger age group.[3–5] The fatality risk for senior drivers generally increases with age, especially for those over 80 years of age.[6,7] Senior drivers' high crash rates are primarily thought to be due to the age-related declines experienced by some drivers in terms of their perceptual, cognitive and motor skills.[8–12]

Regardless of age, driver distraction caused by secondary-task engagement (i.e. the performance of competing tasks not related to managing the vehicle in traffic) is a major risk factor and distracted driving is considered a dangerous epidemic on America's roadways.[13] These competing tasks include eating, adjusting the radio, interacting with passengers and using electronic devices (e.g. cell phones) while driving, with the latter example garnering the most public attention and media interest during recent years.

Results of research assessing the impact of cell-phone use on driving performance have been mixed. The estimated prevalence of talking, dialling or texting while using a cell phone ranges from 6.29% to 10.4%.[14,15] Epidemiological studies have found that cell-phone use increases crash risk by as much as four times.[16–18] Simulation and test-track research has consistently found that, with experienced drivers, cell-phone use delays reaction to potential hazards,[19–21] increases following distances,[22] decreases visual scanning of the driving environment[23,24] and decreases lane-keeping performance.[25]

Naturalistic driving studies (NDSs) provide a unique opportunity for evaluating driver behaviour and risk by objectively collecting *in situ* driving data continuously for an extended period of time. The results from NDSs show that visual–manual tasks tend to increase safety-critical event risk, but provide no conclusive evidence with respect to talking on a cell phone.[15,26–28] A recent study confirmed that hand-held electronic devices have high use rates and risk but did not show the modification effects by age and gender.[14] Klauer *et al.*[26] reported that the risk of secondary-task engagement is higher for novice teenaged drivers compared with experienced drivers. One common issue with NDSs is that, due to the limited number of crashes that occur, it is challenging to evaluate the modification effect of age. In addition, crash-risk evaluation commonly relies on crash surrogates such as near-crash and critical incidents[15,26,29]—a method that has been shown to be prone to underestimating risk.[30]

The Second Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS) collected driving performance and behaviour data for 3542 drivers at six data-collection sites across the USA. Most participants were initially enrolled in the study for a period of either 12 or 24 months, although some dropped out earlier than scheduled, whereas others extended their participation for up to an additional 12 months. The SHRP 2 NDS data represent more than five million trips and more than 48 million vehicle-kilometres travelled. Within this data set, 1541 crashes and minor collisions were identified along with thousands of near-crashes. Whereas previous studies combined crash surrogates (e.g. near-crashes) with crashes to calculate odds ratios (ORs),[15,26–28] the SHRP 2 NDS represents the first NDS wherein sufficient data were collected to evaluate the *crash* risk of specific secondary-task engagement for drivers of different ages. The objective of this paper is to evaluate the prevalence and crash risk of distraction caused by secondary-task engagement across the full spectrum of age groups.

Methods

The SHRP 2 NDS is a large-scale observational-type cohort study. Data were collected from October 2010 to December 2013 from participants living near one of the following six data-collection sites: Buffalo, NY; Tampa, FL; Seattle, WA; Durham, NC; Bloomington, IN; and State College, PA.[31] A data acquisition system (DAS) developed by the Virginia Tech Transportation Institute was used to collect continuous driving data from each study vehicle (i.e. from ignition on to ignition off). The onboard DAS sensors collected dozens of vehicle and traffic variables, including 3D accelerometer data, global positioning system (GPS) data, forward radar and vehicle network data (if available). Four cameras continuously recorded a colour view of the forward roadway, along with greyscale views of the driver's face and driver-side roadway, the right rear window and the driver's interactions with the steering wheel and centre stack.[31] Participants received no experiment setup or instruction regarding how they should drive. This ensured the collected data reflected their natural driving behaviour.

Participants

This study comprised 3454 participants identified from the SHRP 2 NDS data, including both primary and secondary participants. Primary participants were recruited and their personal vehicles were instrumented; secondary participants were typically family members of the primary participants who regularly drove the instrumented vehicle and who granted consent for their data to be included in the data set. Participant ages ranged from 16 to 98 years of age; the distribution by age group is shown in Table 1.

All SHRP 2 NDS participants were compensated $500 per year of data collection, prorated for actual time spent in the study. All participants signed an informed-consent form that was mutually approved by the Institutional Review Boards (IRBs) of the six data-collection sites, the Virginia Tech IRB (where data are stored and protected) and the National Academies of Science IRB (project sponsor).

Table 1. Driver distribution by age groups

Age group	Age range	Number of participants	Percentage
Teen	16–20	768	22.2
Young adult	21–29	797	23.1
Middle	30–64	1020	29.5
Senior	65–98	869	25.2
(Total)	16–98	3454	100

Crash identification and severity

Using threshold values obtained through a sensitivity analysis of the vehicle sensor data (e.g. acceleration greater than 0.65 g), potential crashes were identified in the SHRP 2 NDS. By reviewing the corresponding video records, 1541 crashes were verified. The rigorous procedure ensured most of the relatively high-severity-level crashes were identified. A crash was operationally defined as any physical contact between the vehicle and another object. Four levels of crash severities were defined, from minor curb strike to severe-injury crashes.[14] The current analysis included only the 905 crashes with property damage or higher severity.

Study design and data coding

A case–cohort approach was used to evaluate the ORs of secondary-task engagement.[32] The cases are the property-damage or higher-severity crashes. The control segments, defined as short segments of non-safety-critical normal driving, were used to represent secondary-task exposure under normal driving conditions. The duration of each control segment was 6 seconds—a comparable length of time for determining the exposure to secondary-task engagement for crashes. A stratified random-sampling scheme was used to select control segments from each driver. The number of control segments for each driver was proportional to the total hours of driving data above 8 km/hour. The control segments were randomly sampled for a specific driver. It can be shown that the ORs under this sampling scheme approximate the event risk rate ratio.[26,32] The prevalence of a secondary task was calculated by the percentage of control segments with a specific task presence.

Video footage, beginning 5 seconds prior to the precipitating event until the end of each confirmed crash, was reviewed along with footage of control segments. Any

Table 2. Definition of secondary tasks

Secondary task	Definition
Overall distraction	All levels of driver distractions identified in SHRP 2 data
Overall distraction (M)	All levels of male driver distractions identified in SHRP 2 data
Overall distraction (F)	All levels of female driver distractions identified in SHRP 2 data
Overall cell use	Cell talking/cell visual–manual tasks
Cell talking	Cell-phone talking or listening, hand-held
Cell visual–manual tasks	Cell texting/ browsing/hand-held dialling/ hands–free dialling/ locating, reaching answering
Cell texting	Cell-phone texting
Cell hand-held dialling	Cell-phone dialling hand-held, including using quick keys
Cell reaching	Cell-phone locating/reaching/answering
Talking/singing	Talking or singing, audience unknown
Look outside	Looking at an object external to the vehicle/animal/ pedestrian/previous crash or incident
Interact with passenger	Interact with passenger (adult, child or age unknown) in adjacent/rear seat
Reaching	Reaching for cigar or cigarette/food-related or drink-related item/personal body-related item/other object
Drinking	Drinking from open container/with lid and straw/with lid no straw/with straw no lid
Eating	Eating with/without utensils
Operate in-vehicle device	Adjust or monitor climate control/radio/other devices integral to vehicle
Radio/HVAC	Adjust or monitor climate control/radio
Other integral device	Adjust or monitor other devices integral to vehicle

secondary tasks identified were independently coded by two trained analysts. The secondary tasks evaluated in this study were organized according to the 10 categories listed in Table 2. A battery of variables was coded for each event. Coding recorded the sequence of events that led to the crash: driver behaviours and errors, secondary-task engagement and environmental conditions, including road type, general conditions (e.g. day/night) and traffic density. Inter-rater reliability, assessed by comparing coders' assessments of secondary-task engagement to those of a senior researcher, was 91% for crashes and near-crashes and 97% for control segments.

Statistical analysis

A mixed-effect logistic regression model with driver-specific random effects was used to estimate the ORs of crash involvement associated with each secondary task. A driver-specific random effect term in the model incorporates the correlations among observations, both crashes and control driving segments, from the same driver. The model was also adjusted for potential confounding and interaction factors, including gender, SHRP 2 data-collection site, lighting condition, weather and traffic density. A fixed-effect logistic regression model was used for some strata with a limited number of events when a model failed to converge.

The OR of crash involvement for a specific secondary task was based on the contrast with sober, alert and attentive (i.e. no apparent secondary task or impairment) model driving behaviour. As such, the ORs obtained should be interpreted as the elevated risk due to engagement in each secondary task compared with the model driving behaviour. Model fitting was checked using the ratio of generalized chi-square to the degree-of-freedom (GLIMMIX procedure in SAS®) and there is no evidence of over-dispersion and lack of fit.

Results

The ORs by secondary-task type are shown in Table 3 and illustrated in Figures 1 and 2. The prevalence of secondary-task engagement is shown in Table 4.

Gender differences are limited for the safety impacts of *overall distraction*, which include all coded secondary tasks. Overall distraction increases crash likelihood for every age/gender combination with the exception of middle-aged male drivers (30–64 years old). Within each age group, the only meaningful gender difference was for the 16–20-year age group (OR of 2.39 for female vs 1.87 for male).

The most noticeable pattern is that the ORs of both overall distraction and specific secondary tasks for the 30–64-year age group are almost uniformly smaller than other age groups. Teenaged (16–20 years) and young adult drivers (21–29 years) show both higher ORs and higher prevalence across distraction types. Drivers over the age of 65 years show, in general, elevated ORs but lower prevalence.

Overall cell-phone use increases the crash likelihood for all age groups, with ORs ranging from 2.11 for middle-aged drivers to 5.72 for drivers above age 65 years. The prevalence of cell-phone use is high for teenaged drivers

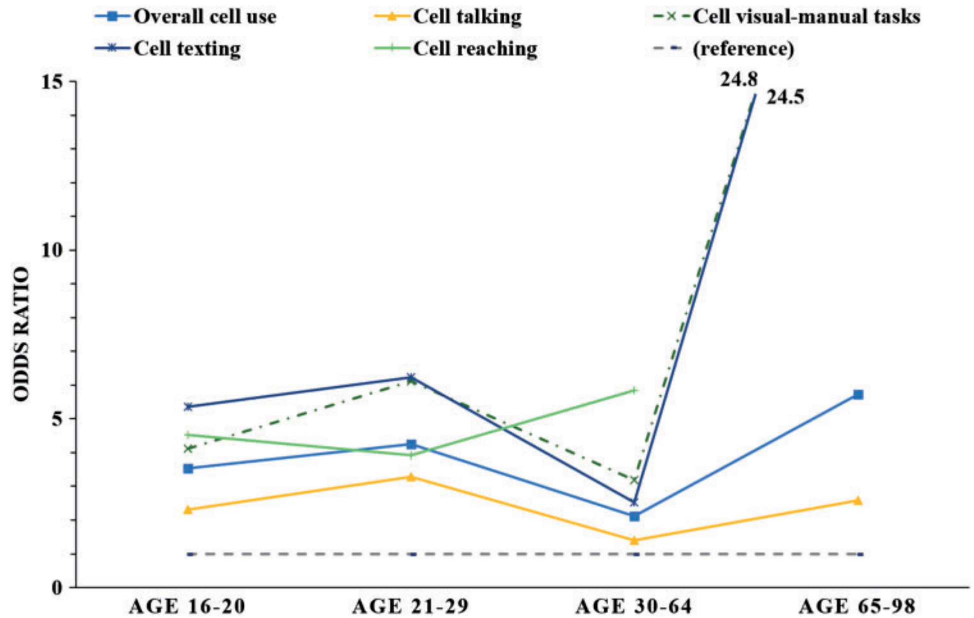

Figure 1. Odds ratios of crash involvement for cell-phone-related secondary tasks.

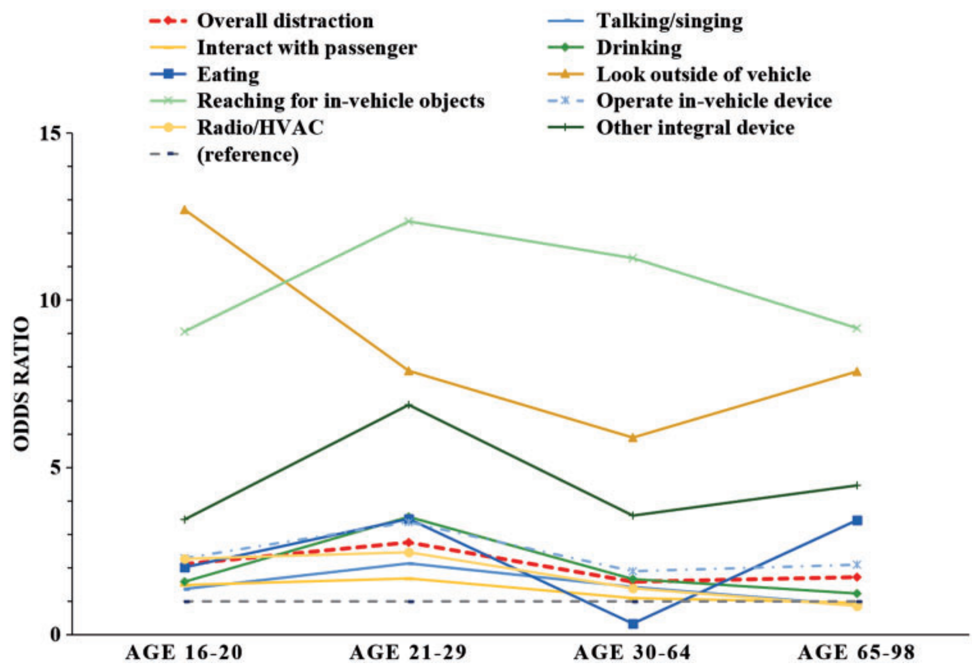

Figure 2. Odds ratios of crash involvement for non-cell-phone-related secondary tasks.

(8.52%), reaches a peak for young adult drivers (11.01%), decreases for middle-aged drivers (5.30%) and reduces to relatively trivial (0.87%) for senior drivers. Similar patterns are also observed for specific cell-phone tasks.

Cell-phone talking increases crash likelihood more than two-fold for teenage drivers (OR 2.30) and three-fold for young adult drivers (OR 3.29). The 95% confidence intervals for middle-aged and senior drivers include the neutral value of one.

Cell-phone texting increases crash odds by 5–23 times for teenaged, young and senior age groups. The 95% confidence interval for the middle-aged group includes the neutral value of one. The prevalence of texting for middle-aged drivers (1.17%) is much lower compared with the teenaged (3.32%) and young adult driver groups (3.32%). Both the OR and prevalence of cell-phone texting for drivers under the age of 30 years are high compared with other age groups (teenaged drivers' OR: 5.36, prevalence: 3.32%; young adult drivers' OR: 6.23, prevalence: 3.32%). The

Table 3. Odds ratios of crash involvement for secondary-task engagement by age group

Distraction	ORs by age group			
	Age 16–20	Age 21–29	Age 30–64	Age 65–98
Overall distraction	**2.11 (1.61–2.77)**	**2.76 (1.98–3.84)**	**1.58 (1.13–2.20)**	**1.71 (1.24–2.36)**
Overall distraction (M)	**1.87 (1.26–2.78)**	**2.85 (1.73–4.69)**	1.44 (0.91–2.28)	**1.77 (1.12–2.80)**
Overall distraction (F)	**2.39 (1.64–3.49)**	**2.76 (1.78–4.30)**	**1.77 (1.08–2.88)**	**1.69 (1.08–2.65)**
Overall cell use	**3.53 (2.42–5.17)**	**4.25 (2.78–6.49)**	**2.11 (1.16–3.83)**	**5.72 (2.14–15.29)**
Cell talking	**2.30 (1.21–4.37)**	**3.29 (1.83–5.89)**	1.39 (0.58–3.32)	2.59 (0.58–11.61)
Cell visual–manual tasks	**4.11 (2.73–6.20)**	**6.11 (3.83–9.75)**	**3.19 (1.51–6.75)**	**24.47 (6.80–88.09)**
Cell texting	**5.36 (3.40–8.45)**	**6.23 (3.61–10.76)**	2.52 (0.86–7.39)	**24.84 (4.08–151.38)**
Cell dialling	4.55 (0.51–40.30)	**36.60 (11.19–119.76)**	3.77 (0.45–31.63)	**81.51 (4.17–1594.35)**
Cell reaching	**4.51 (2.00–10.19)**	**3.91 (1.33–11.50)**	**5.84 (1.61–21.18)**	NA
Talking/singing	1.37 (0.88–2.13)	**2.14 (1.27–3.59)**	1.42 (0.73–2.76)	0.88 (0.31–2.48)
Interact with passenger	**1.48 (1.01–2.17)**	**1.67 (1.03–2.73)**	1.10 (0.65–1.85)	0.95 (0.56–1.60)
Drinking	1.58 (0.55–4.55)	**3.53 (1.20–10.36)**	1.66 (0.51–5.47)	1.23 (0.16–9.32)
Eating	2.02 (0.84–4.87)	**3.46 (1.54–7.76)**	0.32 (0.04–2.36)	**3.43 (1.15–10.20)**
Look outside of vehicle	**12.70 (6.35–25.39)**	**7.89 (3.26–19.07)**	**5.88 (2.49–13.92)**	**7.87 (3.72–16.67)**
Reaching for in-vehicle objects (not cell phone)	**9.07 (4.47–18.38)**	**12.36 (6.08–25.14)**	**11.27 (6.21–20.45)**	**9.17 (3.91–21.47)**
Operate in-vehicle device	**2.28 (1.32–3.93)**	**3.37 (1.84–6.18)**	1.89 (0.84–4.24)	2.09 (0.92–4.76)
Radio/HVAC	**2.27 (1.26–4.09)**	**2.46 (1.17–5.15)**	1.39 (0.49–3.91)	0.85 (0.20–3.69)
Other integral device	**3.44 (1.29–9.18)**	**6.86 (2.68–17.60)**	**3.57 (1.05–12.12)**	**4.46 (1.64–12.11)**

Bold text indicates statistically significant OR at the 0.05 level; NA indicates that no crash with secondary task was observed in the stratum.

Table 4. Baseline prevalence of secondary-task engagement by age group

	Age 16–20 (%)	Age 21–29 (%)	Age 30–64 (%)	Age 65–98 (%)
Overall distraction	58.46	57.35	51.60	40.49
Overall distraction (M)	58.49	58.53	50.23	40.57
Overall distraction (F)	58.42	56.40	52.91	40.38
Overall cell use	8.52	11.01	5.30	0.87
Cell talking	3.25	5.64	3.17	0.67
Cell visual–manual tasks	5.40	5.52	2.18	0.20
Cell texting	3.32	3.32	1.17	0.09
Cell dialling	0.15	0.16	0.19	0.02
Cell reaching	0.95	0.96	0.42	0.04
Talking/singing	12.12	9.97	6.27	3.55
Interact with passenger	17.81	14.77	15.01	14.99
Drinking	1.30	1.18	1.50	0.80
Eating	1.62	1.94	2.64	1.07
Look outside of vehicle	0.67	0.82	1.04	1.27
Reaching for in-vehicle objects (not cell phone)	0.87	1.04	1.33	0.96
Operate in-vehicle device	4.35	3.78	3.28	2.68
Radio/HVAC	3.62	3.10	2.54	1.81
Other integral device	0.80	0.70	0.77	0.92

prevalence of the *cell-phone dialling* and *cell-phone reaching* ranges from 0.02% to 0.96%; the ORs range from 3.91 to 81.51. The low prevalence of cell-phone dialling and reaching, and thus small sample size, could lead to the wide confidence intervals.

Talking/singing only affects young adult drivers (OR: 2.14, prevalence: 9.97%). *Interaction with passengers* increases the crash odds for drivers under the age of 30, and also has high prevalence (teenage drivers' OR: 1.48, prevalence 17.81%; young adult drivers' OR 1.67, prevalence 14.77%).

Tasks with high visual demand, including *looking outside of vehicle* and *reaching for in-vehicle objects*, show six times or greater increase in crash likelihood across all age groups (ORs range from 5.88 to 12.70). The average prevalence for the two tasks was approximately 1% (0.67% to 1.33%).

Drinking increases crash likelihood only for young adult drivers (OR 3.53). *Eating* increases crash risk for young adult drivers and senior drivers (young adult drivers' OR: 3.46; senior drivers' OR: 3.43). Note that drinking refers to what appear to be non-alcoholic beverages.

Operating in-vehicle devices significantly impacts crash risk for teenaged (OR: 2.28) and young adult drivers (OR: 3.37). Relatively simple in-vehicle tasks, such as *adjusting the radio and heating, ventilation, and air conditioning* (HVAC), only impact crash risk for teenaged (OR: 2.27) and young adult drivers (OR: 2.46). However, *operating other integrated in-vehicle devices* (e.g. adjusting rear-view mirrors or operating navigation systems) poses a much higher risk for all age groups.

Discussion

Driver distraction related to secondary-task engagement is a major contributing factor for traffic crashes. This study quantitatively assessed the safety impacts of secondary-task engagement via analysis of the SHRP 2 NDS data. The large-scale SHRP 2 NDS provides a sufficient sample size of relatively high-severity crashes to evaluate the impacts of secondary-task engagement across a full spectrum of age groups.

Results indicate that the safety impacts of secondary-task engagement vary substantially by age group and the nature of the secondary task. Specifically, teenaged and young adult drivers showed higher risk than middle-aged drivers for most secondary tasks. The results imply that driving experience and/or maturity plays a critical role in how drivers manage risk. It is also interesting to observe that risk for most secondary tasks remains high for ages 21–29 years, which implies that risk-management skills may take longer than the 9–10 years of driving experience found in previous research.[25]

Interacting with passengers increases risk for teenaged drivers and young adult drivers but not for other age groups. Previous research has shown that younger drivers' risk of being involved in fatal crashes increases with the presence of teen passengers.[33] The elevated risk and the high prevalence (teenage: 17.81%, young: 14.77%) justify intervention measures, such as graduated driver's licensing provisions for teenage drivers, safety education programmes for young drivers, etc.

Tasks that are generally considered cognitive in nature (e.g. talking on a cell phone) impact teenage and young adult drivers but not middle-aged drivers, suggesting that the experience that middle-aged drivers bring to the driving task is often sufficient to mitigate the risks associated with these sorts of cognitive distractions. Cell-phone visual–manual tasks substantially increase crash odds across all age groups.

One critical finding is that tasks generally considered as low-risk, such as adjusting ratio and climate control, increase the crash risk more than two times for teenaged and young adult drivers (OR: 2.27 and 2.46, respectively), while having little impact on middle-aged drivers. This finding further demonstrates the hazards of non-driving secondary tasks and their impact on inexperienced driver populations.

The ORs from this study associated with secondary tasks are considerably higher than those reported by Klauer *et al.*[26] This discrepancy is likely due to the different safety outcome metrics used in the two studies. Only severe crashes (e.g. property damage and injury crashes) were used in this study, whereas all crashes plus near-crashes were used in the previous study. Guo *et al.*[30] found that using all crashes as well as near-crashes tends to result in underestimation of the risk of crashes. The SHRP 2 NDS provides the first sufficient sample size of crashes to allow for the assessment of crash risk by age group.

This study provides concrete evidence that secondary-task engagement is associated with increased crash risk for teenaged, young and senior drivers, and that tasks with high visual–manual demand increase risk more across all age groups than more cognitively oriented tasks. The substantial variation among age groups suggests vulnerable drivers, including teenaged, young and senior drivers, are more susceptible to distraction risks. Secondary-task-prevalence results provide further support that policies that ban or restrict use of cell phones are appropriate, especially for teenaged and young adult drivers. Policies and vehicle design standards should be expanded to encompass drivers of all ages, as the visual–manual tasks associated with these devices substantially increase risk for all drivers.

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