NATIONAL DISTRACTED DRIVING COALITION

Driver Distraction Crash Risk in Naturalistic Driving Studies

A Literature Review

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PREPARED BY

Greg Fitch - Google

Pnina Gershon - MIT

David Zuby - Insurance Institute for Highway Safety

Scott Schmidt - Alliance for Auto Innovation

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The role of driver behavior in vehicle crashes

In 2019, there were 36,096 fatalities and 2.74 million injuries in the United States that resulted from motor vehicle crashes (NHTSA, 2020). Through the analysis of police crash reports, it has been estimated that driver behavior is a critical factor in 90% of motor vehicle crashes (Singh, 2018). This has also been found in naturalistic driving research (Dingus et al., 2016, Dingus et al., 2006), where drivers are recorded using in-vehicle cameras during the entire operation of their own vehicles for an extended period without any observer present.

Why do drivers exhibit poor driving behavior?

Drivers rarely encounter conflict scenarios. The SHRP2 naturalistic driving dataset used in Dingus (2016) recorded 35 million miles of driving, and observed around 7,000 near-crashes (as documented in the SHRP2 Insight website). That is approximately one near-crash for every 5,000 miles traveled. In other words, the feedback loop informing drivers their driving skills are poor can therefore be quite long, which reinforces the belief their bad driving habits have no consequence. Furthermore, drivers often forget about their experiences behind the wheel (Chapman & Underwood, 2000), making this behavior very hard to change once it is formed in the absence of timely feedback.

The role of driver attention in avoiding vehicle crashes

An important aspect of driver behavior is where and when drivers focus their attention. Driving requires attention to the road to:

a. avoid exposure to unfolding conflicts, and

b. execute an avoidance maneuver to prevent crashing once a conflict is encountered.

Through traffic simulation, Scanton et a., (2021) estimate many fatal car crashes occurring between 2008 and 2017 in Chandler, AZ could have been avoided had one of the involved drivers been more cautiously to avoid encountering the conflict scenario in the first place. All crashes in the simulation study were estimated to be avoided when the at-fault driver was programmed to drive cautiously, and 82% of the crashes were estimated to be avoided when the not-at-fault vehicle driver was programmed to drive cautiously. This study highlights how defensive driving and remaining aware of unfolding conflicts is a key part of safe driving.

Driver distraction

Driver distraction is defined as the diversion of attention from activities critical for safe driving towards a competing activity. This definition includes three forms of driver distraction: 1) visual distraction or looking away from the road when driving a vehicle, 2) cognitive distraction or thinking about something other than driving when driving a vehicle, and 3) manual distraction or removing hands and/or feet away from the vehicle controls when driving a vehicle. Secondary tasks performed while driving can include various amounts of these three forms of distraction. Tasks that comprise large amounts of visual-manual distraction, like inputting text characters using a keyboard, are most concerning because they involve all three forms of distraction. Naturalistic driving studies have shown drivers engage in distracting activities around 50% of the time while they are driving (Dingus et al., 2016, Fitch et al., 2013, Klauer et al., 2010). Distracting activities collectively are associated with a twofold increase in crash risk relative to model driving (OR = 2.0, 95% CI: 1.8-2.4), where drivers are alert, attentive, and sober (Dingus et al., 2016). In recent naturalistic driving studies, Gershon et al., (2022) observed an increase in distracted driving in general compared to the prevalence observed in past studies (64% vs. 50%), and drivers engaged in at least one non-driving task in 77% of the time driving with partial-automation systems (SAE Level 2) like Tesla Autopilot.

Distracted driving from cell phones

In their first study on the prevalence and crash risk of activities relative to model driving, Dingus et al. (2016) found that interacting with a handheld cell phone occurs 6% of the time, and has a crash risk that is 3.6 times higher than model driving (95% CI: 2.9 - 4.5). This risk is significantly impacted by tasks that involve substantial visual-manual interaction. For instance:

- dialing a handheld phone was found to have a risk that is 12.2 times higher than model driving (95% CI: 5.6 - 26.4);
- texting on a handheld phone has a risk that is 6.1 times higher than model driving (95% CI: 4.5 - 8.2);
- reaching for a handheld cell phone has a risk that is 4.8 times higher than model driving (95% CI: 2.7 - 8.4); and,
- other cell phone tasks like browsing and talking on a handheld cell phone have risks that are 2.7 (95% CI: 1.5 - 5.1) and 2.2 (95% CI: 1.6 - 3.1) times higher than model driving, respectively.

This study included cases where dual/triple tasks occurred in the sample window. This is important to note because the second/third task could have been a higher risk task that artificially increased the risk associated with the potentially lower risk task being investigated. That is, the higher risk task in such multi-task cases could well have caused, or been the primary contributing factor to, the crash, whether the lower risk task was present or not. The risk of individual tasks (performed in isolation) was performed in a subsequent study and the results are described further below.

Distracted driving from infotainment systems

Dingus et al. (2016) also investigated the risk of interacting with an in-vehicle infotainment system. They found that adjusting an in-vehicle radio has a risk 1.9 times higher than model driving (95% CI: 1.2 - 3.0). This provides an important comparison because both the Alliance of Automobile Manufacturers (2006) (who are now called the Alliance for Auto Innovation) and the National Highway Traffic Safety Administration (NHTSA) (2013) set manual radio tuning as the benchmark task for assessing the visual demands of a task. This was selected because of the prevalence of radio tuning in vehicles, it was available in vehicles before the digital age, and the resultant distraction was considered reasonable for a driver to experience while driving. In general, both NHTSA and the Alliance have taken the position that a task that has similar or lower crash risk when compared to tuning a radio is reasonably safe (Dingus et al., 2019, NHTSA, 2013). Dingus (2016) found that adjusting the climate controls has a risk 2.3 times higher than model driving (95% CI: 1.1 - 5.0), and adjusting non-radio/climate controls (such as using a touchscreen interface) has a risk 4.6 times higher than model driving (95% CI: 2.9 - 7.4). This higher risk relative to tuning a radio suggests touchscreen interface complexity, particularly for touchscreens existing at the time, may be a factor. However, it is important to note that adjusting the climate can help maintain a comfortable cabin temperature to maintain focus, and navigation via an infotainment system can eliminate the need to reach for a mobile device, or as was the case in the past, a paper map.

Calculating the risks of distracted driving

The above risk estimates are affected by:

- the severity of crashes included in the analysis (Dingus et al., 2019, Kidd & McCartt, 2015);
- the type of driving selected as a baseline comparison (Dingus et al., 2019); and,
- how many tasks occur alongside the task of interest (Dingus et al., 2019, Bálint et al., 2020).

Dingus et al. (2019) performed a more in-depth investigation of the analysis used in Dingus et al. (2016) by considering these factors. First, they investigated the risk of a secondary task where the task in question only occurred in isolation. Cases where multiple tasks occurred in the sample were excluded from the analysis. Secondly, they investigated the crash risk relative to “model driving” (a driver performance baseline which was described above) as well as “all driving,” where all tasks other than the task in question are included in the baseline (and used as a driver behavior baseline.). Note, model driving was found to occur 40% of the time. Finally, they calculated crash risk using all vehicle crashes (excluding tire strikes) and again with just severe crashes.

When compared to model driving, the total aggregation of cognitive secondary tasks (i.e., talking/singing alone, interacting with a passenger, talking/listening on a handheld cell phone, talking/listening on a hands-free cell phone, and dialing hands-free using voice-activated software) were associated with a small but significant increase in crash risk relative to model driving (OR = 1.25). However, no individual primarily cognitive secondary task was found to significantly increase crash risk. Combined, the cognitive tasks occurred in 20% of the driving samples. However, the individual cognitive tasks occurred to different degrees: talking with a passenger comprised 61% of all cognitive tasks (and it may have included off-road glances to the passenger since the driver had to be visibly interacting with the passenger to be annotated as talking with a passenger), talking/singing alone comprised 21% of the tasks, talking/listening on a handheld cell phone comprised 13.5% of the tasks, and using a hands-free cell phone comprised 4.5% of the tasks. The risk estimate for the combined cognitive secondary tasks was close in magnitude to the risk estimate for adjusting a radio (whose risk estimate was not significant). These findings indicate that, in general, primarily cognitive tasks are low risk and are among the lowest risk of any secondary driving tasks. Since their risk estimates were not statistically significant, a population attributable risk should not be estimated as it only applies for factors with definitive evidence in increasing crash risk. These findings support a direction that has been taken to promote natural voice interfaces as a means to enable a way to interact with technology while driving that poses acceptable levels of distraction to the vast majority of drivers.

When compared to "all driving," Dingus et al. (2019) found hands-free cell phone use was associated with a lower crash risk. The authors report there was insufficient sample size to calculate the risk of hands-free cell phone conversation relative to model driving. However, they were able to calculate its risk when case selection included samples when drowsiness and impairment were present. In doing this, talking on a hands-free cell phone significantly reduced crash risk. Overall, Dingus et al. (2019) provide evidence that cell phone conversation does not significantly increase crash risk, and hands-free cell phone conversation can lower crash risk in some cases. The presence of hands-free cell phone use in cases that involved drowsiness also suggests drivers may have been performing this task to alleviate fatigue. It is worth considering whether restricting hands-free cell phone use could have second order effects on the crash risk of drowsy driving.

Overall, studies indicate the risks of visual-manual tasks as well as cognitive secondary tasks are highly nuanced and context dependent. The research below summarizes sensitivity analyses that were performed to test the robustness of secondary task risk estimates.

Sensitivity analyses

Owens et al (2018) performed a case-crossover analysis to determine the crash risk of various secondary tasks using baseline samples matched to the driving context at the time of the crash. The dataset used was generated by the SHRP2 naturalistic driving study (Hankey et al, 2016), which also generated the data analyzed in Dingus et al. 2016 and 2019. Their results mirror those reported above. Of interest, however, is that they performed several sensitivity analyses in their assessment. They analyzed risk relative to:

a) all driving (i.e., using all matched baseline epochs where the task in question was not observed);

b) longer segments of driving (i.e., using 30 seconds rather than six seconds as the sampling window); and,

c) different selection criteria for baseline epochs (i.e., matched to crashes with respect to time of day only, without considering environmental conditions).

A summary is provided below.

Comparison to "all driving"

Just like in Dingus et al. (2019), the crash risk estimates tended to be slightly lower when compared to "all driving" than when compared to "model driving." However, the odds ratios using the "all driving" reference level were estimated with greater precision due to the greater number of crashes and baseline epochs included in the analysis.

Comparisons using 30-s samples

Instead of using a 6-second time window for each epoch, analyses were replicated using a 30-second window preceding each crash and compared to 30-second matched baseline epochs. Results were broadly similar, with texting exhibiting a similar increase in crash risk in both analyses. However, overall visual-manual tasks in the 30 seconds prior to a crash were no longer associated with a significant increase in crash risk. Furthermore, no other secondary task became significant. These results indicate the impact of secondary task workload on crash risk is short lived once the task is complete.

Comparison to previous day

Case-crossover studies performed without the benefit of naturalistic data (Redelmeier & Tibshirani, 1997; McEvoy et al., 2005) estimated that using a cell phone while driving approximately quadrupled a driver's risk of crash involvement. Owens et al. (2018) attempted to replicate their approach by sampling a single baseline epoch from each crash-involved driver 24 hours (± 10 minutes) before the crash occurred, without regard to any other matching variables (e.g., speed, traffic, weather). The authors note that, of the 900 minor, moderate, and severe crashes in the SHRP 2 study, the same driver was also driving during the comparison window in 84 (9.3%) of the crashes, which was much lower than the 50% reported by Redelmeier & Tibshirani (1997) and 33% reported by McEvoy et al. (2005). Owens et al. (2018) found the crash risk estimates generated by using the earlier study analysis methods on the newer naturalistic driving data (that also had more precision on the timing of the crash relative to secondary task engagement) were markedly different from those reported in Redelmeier & Tibshirani (1997) and McEvoy et al. (2005).

Distracted driving across age groups

Essentially, not all secondary task engagement increases crash risk in the same manner for all driver age groups. While distracted driving is risky for drivers of all ages, it is of particular concern for young drivers. According to the National Highway Traffic Safety Administration, 9% of fatal crashes in 2019 involving teen drivers were attributed to driver distraction, the highest proportion of any age group of drivers. Compared with older and more experienced drivers, young drivers are more likely to engage in secondary tasks while driving and their crash risk may be greater when doing so. Research based on SHRP2 naturalistic driving data (Gershon et al., 2017) indicates the overall tendency to engage in secondary tasks while driving is highest for the 16 to 17 age group and lowest for the 35 to 55 age group (62% and 52% respectively).

- Interacting with a passenger was the most prevalent type of secondary task for all age groups, ranging from 15% in the 35 to 55 age group and up to 22% in the 16 to 17 age group.
- Manual cell phone use (i.e., dialing, texting, or browsing) was highly common among drivers in age groups 16 to 25. The prevalence of cell phone dialing among the teens was about 2.5 times higher than the oldest age group of drivers (35 to 55 years old).
- For young drivers (16 to 25 years old), attending external distraction; manual use of cell phone including dialing, texting, or browsing; interacting with objects in the vehicle; and reaching types of secondary tasks were associated with significantly increase in crash risk (OR = 1.49, CI =1.06–2.09; OR = 1.64, CI = 1.17–2.3; OR = 2.99, CI = 1.71–5.24; OR = 3.09, CI = 1.58–6.06, respectively).
- Within the young drivers age group, the youngest age group of 16- to 17-year-old drivers, crash likelihood when engaging in cell phone including dialing, texting, or browsing was significantly elevated (OR = 1.80, CI = 1.14–2.84).
- Operating in-vehicle systems, interacting with object(s) in the car, reaching, and cell phone dialing, texting, or browsing type of tasks were significantly associated with increased crash risk among the 21- to 25-year-old drivers (OR = 3.33, CI = 1.38–8.08; OR = 3.88, CI = 1.11–13.59; OR = 4.47, CI = 1.21–16.44; OR = 2.11, CI = 1.09– 4.07, respectively). Interestingly, crash risk estimates for engaging in secondary tasks were not significant for the 35 to 55 age group.

The underlying reasons for young drivers' increased risk may include their limited driving experience, poor judgment about when to engage, long duration of eyes off the road during engagement, and underestimating the level of resources needed to maintain safe driving. For example, Simons-Morton et al., (2014) found that when teenage drivers were engaged in secondary tasks, the duration of eyes off the road was positively associated with crash risk, meaning that the longer the duration of eyes off the road the greater the crash risk, regardless of the type of secondary task. A more recent naturalistic driving study that followed teen drivers during their first year of driving indicated that manual cell phone use and reaching/handling objects while driving were associated with a significant increase in crash risk (OR=2.7, 95% CI=1.1, 6.8; OR=6.9, 95% CI=2.6, 18.6 respectively). The analysis found 41% of the crash risk caused by the manual cell phone use and 10% of the risk associated with reaching/handling objects were due to the driver looking away from the forward road (Gershon et al., 2019).

Distracted driving across driving context

Owens et al (2018) investigated the crash risk of cell phone use using a case-crossover study design. Their results reflect similar patterns to previous studies, with visual-manual tasks (particularly texting) being associated with an increased crash risk. They note their estimated risks are somewhat lower than in previous studies and speculate this was likely due to the careful matching of crashes to baseline epochs in which the same drivers were driving under similar traffic and environmental conditions, thereby inherently controlling for many individual driver-specific and situational factors which may be related to both cell phone use and crash risk.

Interestingly, the magnitude of the association between cell phone use and crash risk was generally larger for specific crash types in which the driver had a clear active role, such as rear-end crashes (in which the subject driver struck the vehicle in front of him or her, not crashes in which the subject driver was struck from behind) and road-departure crashes, especially in the case of visual-manual cell phone tasks. Notably, while the crash risk of visual-manual cell phone interaction was 1.83, the odds ratios for road departure crashes and rear-end crashes were much greater at 3.15 and 7.77, respectively. This suggests visual-manual cell phone tasks increase a driver's risk of actively contributing to a crash to a greater degree than it increases mere crash involvement, which may be influenced to a nontrivial degree by the actions of other road users. The odds ratios for handheld cell phone conversation were small and not found to be statistically significant in the driving contexts examined.

Distracted driving for commercial vehicles

Hammond et al (2021) investigated the risk of driver distraction for commercial motor vehicle drivers. A total of 43 motorcoaches, 73 motorcoach drivers, 182 trucks and 172 truck drivers participated in their study. Their dataset included more than 3.8 million miles of naturalistic data from seven fleets and 10 locations. They found handheld cell phone use increased risk more than twofold for both motorcoach and truck drivers. Further inspection showed visual-manual handheld cell phone tasks (like texting and browsing) increased risk, while talking on a handheld cell phone did not increase risk. Hammond et al (2021) also investigated the risk of hands-free cell phone use. They found it significantly decreased risk for both motorcoach and truck drivers. The authors note that hands-free cell phone use likely helped these drivers alleviate boredom and counteract fatigue.

Conclusion

In summary, complex visual-manual tasks performed on a handheld cell phone are the riskiest types of secondary tasks. They should not be performed while driving. The risk of conversing on a handheld cell phone is small and similar to tuning a radio. However, it too should not be performed while driving because of the risky visual-manual tasks typically needed to initiate a conversation (like reaching for the phone and dialing). Hands-free cell phone use was not shown to increase risk and was even shown to reduce risk in some driving contexts as well as for truck and motorcoach operators. It should be allowed while driving, particularly because of the benefits it can offer. Finally, it is worth noting that driving-mode interfaces have been recently developed for cell phones. Soon to be published research has found these interfaces lead to reduced visual-manual distraction more than current handheld interfaces, offering a safer way to enable those that do not have the latest in-vehicle interfaces to benefit from mobile technology.