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The effect of distractions on the crash types of teenage drivers

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Abstract

Teenage drivers are overrepresented in crashes when compared to middle-aged drivers. Driver distraction is becoming a greater concern among this group as in-vehicle devices, opportunities for distractions, and teenage drivers' willingness to engage in these activities increase. The objective of this study was to determine how different distraction factors impact the crash types that are common among teenage drivers. A multinomial logit model was developed to predict the likelihood that a driver will be involved in one of three common crash types: an angular collision with a moving vehicle, a rear-end collision with a moving lead vehicle, and a collision with a fixed object. These crashes were evaluated in terms of four driver distraction categories: cognitive, cell phone related, in-vehicle, and passenger-related distractions. Different driver distractions have varying effects on teenage drivers' crash involvement. Teenage drivers that were distracted at an intersection by passengers or cognitively were more likely to be involved in rear-end and angular collisions when compared to fixed-object collisions. In-vehicle distractions resulted in a greater likelihood of a collision with a fixed object when compared to angular collisions. Cell phone distractions resulted in a higher likelihood of rear-end collision. The results from this study need to be evaluated with caution due to the limited number of distraction related cases available in the U.S. GES crash database. Implications for identifying and improving the reporting of driver distraction related factors are therefore discussed.

Keywords: Driver distraction; Crash types; Young drivers; Teenage drivers; Rear-end collisions; Angular collisions

1. Introduction

Numerous factors have been related to the high crash risk of teenage (16–19-year old) drivers including risk-taking behavior, nighttime driving, driving with teenage passengers, and under the influence of alcohol (Ferguson, 2003; Williams, 2003). Teenagers (as well as the elderly) are overrepresented in terms of hospitalization from crashes related to loss of vehicular control and collisions with other vehicles (Tavris et al., 2001). Much of the literature on young drivers – commonly defined as drivers younger than 25 – is particularly relevant for examining the crash risks of teenage drivers since they reveal similar risk taking behavior (Mao et al., 1997; McKnight and McKnight, 2003). Studies on young drivers also reveal their overrepresentation in crashes occurring on the weekend and on clear, dry days (McGwin and Brown, 1999).

An important aspect of the increased risks for teenage drivers is how such risks translate into the frequency of different crash types. The three most common types of crashes for teenage drivers are: angular crashes with other vehicles, rear-end collisions, and collisions with fixed objects (NHTSA, 2003a). Rear-end collisions usually occur when vehicles are traveling in the same direction and can be attributed to very short headways and failure to brake appropriately. Angular collisions usually involve colliding with vehicles not traveling in the same direction and can be attributed to improper decision making and lane keeping. The collisions with fixed objects are different than the other two crash types because they do not involve the same potential to inflict injuries on other drivers and passengers. These differences are important when considering what factors are likely to be involved in collisions and how crash risks associated with these crash types can be mitigated.

There is very little literature on the impact of driver distraction on the crashes of teenage drivers. Driver distraction can be defined as the diversion of driver attention away from the driv-

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ing task, and it can result from factors both within and outside of the vehicle (Sheridan, 2004). Both the attentional demands placed on the driver by a secondary task and the driver's willingness to engage in that task contribute to the potential for driver distraction and thus increase the likelihood of crashes (Donmez et al., in press). A distracted driver may also make riskier decisions. As observed by Cooper et al. (2003), distracted drivers made left hand turns with smaller gap acceptance than drivers who were not distracted. Understanding how driver demographics, driver behaviors, and environmental factors interact with distraction is very important, especially when developing policies and systems to reduce the effects of these distractions. This is particularly true for young drivers, who are typically at greater risk for crash involvement when compared to drivers in other age groups (Bedard et al., 2002; Matthews and Moran, 1986). Analyzing the crash and behavioral factors of younger drivers can provide important insights into the problematic behavior of young drivers and can have a substantial impact on society.

Driver distraction can include anything that distracts a driver from the primary task of driving. Distraction types have been categorized as follows: visual (e.g. reading a map), auditory (e.g., listening to a conversation), biomechanical (e.g., tuning a radio), and cognitive (e.g. 'being lost in thought,' and 'looking but not seeing') (Ranney et al., 2000). Most distractions are actually a combination of these, thus it may be more useful to categorize distractions according to the task that drivers are engaged in while driving (rather than the combination of the forms of distractions). For example, cell phones are associated with cognitive, auditory, biomechanical, and potentially, visual distractions. Given that, it may be easier to draw conclusions, make policy recommendations, and design systems around these task-centric identified distractions.

As teenage drivers gain moderate levels of experience, they also tend to have greater crash risks related to driver distraction when compared to drivers in other age groups (Lam, 2002). One proposed explanation for this is that younger drivers appear more willing to accept new technologies and devices than other drivers. As younger drivers become confident in their driving abilities, they tend to over-estimate their ability to multitask with these devices while driving (Sarkar and Andreas, 2004). Poysti et al. (2005) also found that young drivers, from 18- to 24-years old, were more likely to use their cell phones while driving than middle-aged drivers. Clearly, as in-vehicle systems and devices become more popular, further research is needed (Olsen et al., 2005; Sarkar and Andreas, 2004).

Given that teenage drivers are over-represented in terms of crash frequency, the goal of this research is to determine how driver distraction influences the types of crashes teenagers are more likely to be involved in. Understanding this will aid our understanding of driver distraction influences on teenage drivers, their passengers, and others. It is hypothesized that different distraction types will influence the odds of teenagers being involved in certain types of crashes. This hypothesis is addressed with a multinomial logit model to predict the odds that a teenage driver will be involved in a distraction-related crash.

2. Method

2.1. Data sources

Data from the General Estimates System (GES) from the year 2003 were used for the analysis in this study. The GES data, which is part of the National Automotive Sampling System (NASS) from the National Highway Traffic Safety Administration (NHTSA), is a stratified sample of crashes that is weighted to represent national crash trends. The data include numerous crash-related factors, including detailed descriptions of the vehicles involved, the demographics of the driver(s) and their passenger(s), the distracted state of the driver(s) involved in the crashes, and the crash characteristics. Because the focus of this study is on teenage drivers (16–19) and their crash types, any individuals not in this population group were omitted from the analysis. A vehicle was labeled as a striking vehicle if it is identified as such in the GES database (as part of the vehicle's role data). Vehicles driven by teenagers that were not the striking vehicle was removed. Further, data associated with non-passenger vehicles (e.g. motorcycles and semi-trucks) was also removed.

2.2. Crash types classification

The three major crash types used for this study are angular collisions with other moving vehicles, rear-end collisions, and collisions with fixed objects, which represent 28.4%, 34.9%, and 21.0%, as calculated from all crashes, respectively. These three crash categories account for over 84% of crashes in which a teenager was driving the striking vehicle. In fact, they are the most common types of crashes for all drivers regardless of age (NHTSA, 2003b). They are therefore used as the categories for the dependent variable for the regression model.

2.3. Independent variables

Variables included in the multinomial logit model account for factors that have previously been identified as influencing teenage drivers' crash types (Chen et al., 2000; Ferguson, 2003; Jonah, 1986; Laapotti et al., 2001; McEvoy et al., 2005). These include speeding and alcohol use, as well as environmental factors such as road surface conditions, and location (urban versus rural, interstate, or intersection occurrences). Drivers were classified as speeding if the reporting officer concluded that the vehicle's speed was related to the crash occurrence. This included traveling beyond the posted speed limit or when environmental or other factors may have caused the posted speed limit to be unsafe. Poor lighting conditions have been shown to influence the situational awareness of drivers (Massie et al., 1995). Lighting was therefore included as a variable (i.e., daylight or non-daylight condition). Finally, urban and rural environments were also considered with urban classified as an area with a population greater than 50,000 people. Each of the independent variables was categorized as a binary variable (e.g., the driver either was or was not speeding).

Table 1
The frequency of crashes for teenage drivers for the three most common crash types by driver distraction category

Driver distraction category	Crash type (column)			Weighted total (row)
	Angular (34.4%)	Rear-end (42.2%)	With a fixed object (23.4%)	
Cell phone	668	2008	105	2781 (0.6%)
Cognitive	41539	82080	13183	136802 (30.4%)
Passenger	1181	1562	1407	4150 (0.9%)
In-vehicle	492	5200	5909	11601 (2.6%)
No distraction	110751	98434	84530	293715 (65.4%)
				449049 (100%)

Driver distraction was grouped into four major task-centric areas and compiled based on the driver distraction categories defined in the GES. These four areas were passenger-related distractions, cell phone-related distractions, cognitive distractions, and in-vehicle distractions. Passenger-related distractions have been studied independently and therefore merited a separate designation (Williams, 2001). Passenger-related distractions are already uniquely identified in GES and provided a direct mapping to this group. It should be noted, however, that not all crashes involving passengers were categorized as such, only those in which the passenger was clearly identified as being the source of the distraction. Cell phone distractions have also been a specific area of research with significant societal concerns, and therefore are identified as a task-centric area (Poysti et al., 2005; Seo and Torabi, 2004; Strayer and Drews, 2004). Cell phone distractions include the GES variables of talking, listening, or dialing a cell phone. The cognitive distraction category includes the GES codes for 'looked but did not see' and being 'lost in thought.' The in-vehicle category of driver distraction includes: distractions from moving objects in the vehicle, adjusting the in-vehicle controls, eating, drinking, smoking, and using other devices within the vehicle. A "no distraction" group was also included as a baseline and included crashes in which the driver was reportedly not distracted.

3. Data analysis

A multinomial logit model was used due to the discrete nature of the dependent variables. This model allows for multiple unordered categories of the dependent variable to be predicted based on the same combination of categorical predictor variables examined. The NASS applies a three-stage sampling design to collect the GES data. Therefore the estimation of the variance and significance of the estimated coefficients must account for the complex sampling procedure (see Selton (1991) for a description of the sampling design). SUDAAN 9.0 (using the MULTILOG procedure and the sample design specified as WR [with replacement]) is capable of correctly estimating the variance and significance of the regression coefficients and was used for this analysis. Outcomes of this model are used to predict the odds that the dependent variable (crash type) will be in one category as compared to another category. Thus, for this analysis, there are three category contrasts for each of the crash types: (1) angular collisions compared to collisions with fixed objects, (2) rear-end collisions compared to collisions with fixed objects, and (3) angular collisions compared to rear-end collisions. The output of a multinomial logit model typically reveals all but one of the relationship contrasts, and this is typically how the results of such analyses are reported. However, all three of the relationship contrasts are provided to offer the reader additional insights that may not have been easy to determine otherwise.

4. Results

There were 449,049 (weighted) crashes included in the analysis. Female drivers were involved in about 43% of the crashes and male drivers in about 57%. About 72% of collisions occurred during daylight conditions, and 75% of crashes occurred on clear roads. Over 45% of the crashes occurred in intersections and about 46% of crashes occurred in urban setting, whereas only 6% of crashes occurred on the interstate. Only about 27% of all of the crashes occurred when the teenage driver was speeding. Table 1 shows the number of crashes for teenage drivers by crash and distraction type.

The multinomial logit model reveals the contrasts between each crash type (Table 2). The model was adjusted for certain variables identified in the literature as having a significant impact on crashes. There were no significant differences in crash type observed based on the driver's gender or on interstate highways. In urban settings, teenage drivers were more likely to be involved in angular collisions (OR = 2.41) and rear-end collisions (OR = 2.22) when compared to collisions with fixed objects. Similar trends in likelihood of a particular crash were also observed during daylight conditions. In contrast, teenage drivers that were speeding were more likely to be involved in a fixed-object (OR = 8.33) and rear-end collision (OR = 6.66) when compared to an angular collision.[1] Drivers traveling on poor surface conditions were more likely to have collisions with fixed objects than collisions with other moving vehicles. The same outcome was observed when alcohol was involved in the crash.

The main goal of this study was to examine whether different driver distractions would influence the crash involvement type of teenage drivers. Once the model was adjusted for other behavioral and environmental factors, significant effects are observed based on the different distractions. Teenage drivers distracted by cell phones were more likely to be involved in rear-end colli-

[1] These odds ratios are calculated as the inverse of the odds ratios provided in Table 2.

Table 2
Likelihood of crash type based on driver distraction (parameter estimates and odds ratios from a multinomial logit model)

Variable	Angular collision vs. collision with a fixed object				Rear-end collision vs. collision with a fixed object				Angular collision vs. rear-end collision			
	Contrast estimate	S. E.	Odds ratio (95% CI)	*p*	Contrast estimate	S. E.	Odds ratio (95% CI)	*p*	Contrast estimate	S. E.	Odds ratio (95% CI)	*p*
Intercept	0.11	0.22		n.s.	−0.60	0.19		0.0002	0.71	0.20		0.0006
In an urban setting	0.88	0.21	2.41 (1.58, 3.69)	0.001	0.80	0.19	2.22 (1.72, 3.15)	<0.0001	0.08	0.16	1.09 (0.73, 1.49)	n.s.
Driving during daylight	0.85	0.15	2.33 (1.72, 3.15)	<0.0001	1.10	0.14	3.02 (2.30, 3.96)	<0.0001	−0.26	0.14	0.77 (0.59, 1.01)	n.s.
While speeding	−2.14	0.21	0.12 (0.08, 0.18)	<0.0001	−0.18	0.26	0.84 (0.50, 1.40)	n.s.	−1.96	0.23	0.17 (0.09, 1.01)	<0.0001
In an intersection	−1.36	0.35	0.26 (0.13, 0.52)	0.0002	−0.12	0.24	0.89 (0.55, 1.43)	n.s.	−1.24	0.32	0.29 (0.15, 0.55)	0.0003
Driving on poor surface conditions	−0.62	0.16	0.54 (0.42, 0.77)	0.0002	−0.57	0.15	0.57 (0.42, 0.77)	0.0004	−0.05	0.13	0.95 (0.73, 1.23)	n.s.
Alcohol involved	−1.80	0.41	0.17 (0.07, 0.38)	<0.0001	−1.68	0.37	0.19 (0.09, 0.39)	<0.0001	−0.12	0.40	0.89 (0.40, 2.00)	n.s.
Cell Phone distractions	1.23	1.00	3.43 (0.47, 25.25)	n.s.	2.45	0.90	11.56 (1.90, 70.19)	0.0087	−1.21	0.67	0.30 (0.08, 1.13)	n.s.
Cognitive distraction	0.48	0.32	1.61 (0.85, 3.03)	n.s.	1.03	0.23	2.81 (1.77, 4.44)	<0.0001	−0.56	0.23	0.57 (0.37, 0.90)	0.0163
Cognitive distraction at an intersection	1.96	0.37	6.88 (3.29, 14.39)	<0.0001	1.76	0.30	5.83 (3.17, 10.70)	<0.0001	0.17	0.19	1.18 (0.81, 1.71)	n.s.
Cognitve distractions in urban settings	−0.58	0.37	0.56 (0.26, 14.39)	n.s.	0.11	0.31	1.11 (0.60 2.06)	n.s.	−0.69	0.28	0.50 (0.29, 0.87)	0.0153
Passenger distractions at an intersection	3.21	0.62	24.85 (7.19, 85.95)	<0.0001	2.35	0.67	10.49 (2.75, 39.95)	0.0008	0.86	0.64	2.37 (0.66, 8.54)	n.s.
In-vehicle distractions	−3.11	0.67	0.04 (0.01, 0.17)	<0.0001	−0.45	0.30	0.64 (0.35, 1.16)	n.s.	−2.66	0.64	0.07 (0.02, 0.25)	0.0001
Number of observations (unweighted)	3619											
Number of observations (weighted)	449049											
−2 Log-likelihood at zero	7753											
−2 Log-likelihood at convergence	6481											

Note: n.s. indicates no significance found.

sions than fixed object collisions (OR = 11.56). However, when drivers' were distracted cognitively, they were more likely to be in a rear-end crash than in a collision with a fixed object (OR = 2.81) or an angular collision (OR = 1.75). If the driver was cognitively distracted at an intersection, they were more likely to be in a rear-end collision (OR = 5.83) or angular collision (OR = 6.88) than in a collision with fixed object. Additionally, in urban environments, cognitively distracted teenage drivers are two times more likely to be involved in a rear-end collision than an angular collision.

Passenger related distractions alone did not significantly influence the crash type that involved the teenage drivers. However, when teenage drivers were distracted by their passengers at an intersection, they were more likely to be in a rear-end or angular collision. Drivers that were distracted by in-vehicle items or devices were less likely to be involved in angular collisions when compared to both fixed objects (OR = 0.04) or rear-end (OR = 0.07) collisions.

5. Discussion

The different forms of task-centric distractions affected the types of crashes that teenage drivers were involved in. Because the three crash types studied include the majority of crashes by teenage drivers, some insights can be gained about their behavior. Teenage drivers who have consumed alcohol or were observed speeding were significantly more likely to be involved in collisions with fixed objects than in collisions with other vehicles (both angular collisions and rear-ends). There was no interaction effect with driver distraction and this may be the result of how these two variables and distraction is reported on the crash forms. Reporting the intoxication of a driver or the speeding behavior typically takes precedence over whether or not the driver was distracted.

Distractions clearly influenced the likelihood of each crash type for teenage drivers. Both cognitive distractions and passenger-related distractions increased the likelihood of rear-end collisions, even when accounting for these distractions at intersections. In-vehicle distractions appear to increase the likelihood of teenage driver involvement with fixed object collisions. Cell phone related distractions increase the likelihood of rear-end collisions when compared to fixed object collisions; a result that is consistent with other studies (Wilson et al., 2003).

Although the results appear quite intuitive, it is important to note that there were very few occurrences of cell phone distractions in the GES database (e.g. only 0.6% of all crashes was related to cell phone distractions) and thus, the results should be interpreted with caution. An alternative approach would have been to categorize cell phones with another distraction category (such as in-vehicle devices). However, there has been substantial research conducted on distractions related to cell phones (Strayer et al., 2003; Horrey and Wickens, 2006). Cell phones have also been associated with higher crash likelihood (Redelmeier and Tibshirani, 1997; Laberge-Nadeau et al., 2003). Therefore, it was important to identify this factor's contribution in the number of reported crashes as well as how complete the information appears to be.

The outcomes of the model are interesting in that the types of crashes that are predicted are associated with different features. Collisions with fixed objects do not have the same potential to cause injuries to the drivers and passengers of other vehicles. Rear-end collisions are related to drivers failing to brake effectively or following too closely, whereas angular collisions may occur when drivers have poor lane-keeping performance. Because cognitive, cell phones, and passenger-related distractions tend to result in a higher likelihood of rear-end collisions, they also have a higher potential for inflicting injuries on passengers and drivers of other vehicles.

Overall, driver distractions appear to be more likely in rear-end collisions. This is consistent with previous findings that driver inattention accounts for 66% of all police reported rear-end crashes (Knipling et al., 1993). The literature on driver inattention actually encompasses more than driver distraction, including driver fatigue (Stutts et al., 2005). Thus, results may have different magnitudes, but the relative findings are similar. In the US, driver distraction was included as a crash reporting variable in 1995. At that time, Wang et al. (1996) identified 10% of crashes related to "looked but did not see". The cognitive distraction variable in this study is based on data from a decade later, and included this descriptor as well as a separate category of being "lost in thought." Because cognitive distractions have such a broad definition, a large proportion of drivers were identified in this category. Driving an automobile can be come quite an automatic task and allows the driver to attend to many things other than driving (McGehee et al., 1994). This can then encourage the driver to be more complacent to the driving task leading to greater driver inattention concerns.

The higher likelihood of rear-end collisions observed for those drivers who were engaged in passenger and cell phone distractions provides strong support for greater education of these distractions in the graduated driver licensing programs and driver education. However, the results do need to be interpreted with caution because the sample sizes associated with some of the conditions are quite small. Nonetheless, they do offer some interesting findings that have not been discussed previously in the literature.

Driver distraction information in crash databases have typically been underreported for several reasons. The data on distraction is dependent on the personal perceptions and self-reported information of the drivers and the documenting police officer. If a crash includes a driver who has a more critical concern (e.g., under the influence of alcohol or is severely injured), then driver distraction becomes less critical. Further, the large proportion of crashes that are attributed to cognitive distractions is interrelated in this reporting scheme. For example, cell phone-related distractions can be further researched using phone records if not recorded on the crash forms. However, if a driver contributing factor is unknown; many drivers may identify themselves as being lost in thought or having their eyes on the road but not aware of their surroundings (the "lost in thought" or "looked but did not see" phenomena).

The analyses of this data provide important insight into the influence of driver distraction on crashes that has not been previously captured. The collection of driver distraction data should continue to advance so that these effects can be more appropriately represented. Suggested improvements range from better education of police officers for the need to accurately complete crash forms, to working with state department of transportation officials to create a more comprehensive section about distraction on crash forms with an expanded list of distraction related variables. Often times on state crash forms, distraction is listed under the heading of driver contributing circumstances which typically encompass several factors (including alcohol and speeding). However, distractions can occur in conjunction with these factors and should perhaps, have its own heading on the reporting forms.

These results may also provide support for different crash warning systems that adapt to a driver's changing conditions. Other studies has shown that future collision avoidance systems need to incorporate sensors that capture the attentional demands of the driver in addition to the vehicle dynamics (Brown et al., 2001; Lee et al., 2002). If we have a better understanding of the types of distractions that a driver is more likely to be engaged in during a specific crash type, we can design algorithms that account for the increase likelihood of a rear end, angular or fixed-object collision. Crash warning systems that can adapt to varying driver distractions based on either the roadway (e.g., lane deviations) or driver state (e.g., eye trackers or other workload sensors) can be effective countermeasures for teenage drivers who may not otherwise be aware of the demands placed on them by the different distracting tasks (Donmez et al., in press).

6. Conclusion

Driver distraction has been a widely researched topic in the development and acceptance of new in-vehicle devices and driver support systems (Olsen et al., 2005; Sheridan, 2004). As more initiatives are established to investigate crash avoidance and driver support systems, a greater understanding of how driver distraction impacts various crash types is needed, particularly as they pertain to teenagers. Teenage drivers already represent the highest crash risk age category for both frequency of crashes and for severity (Ferguson, 2003). Focusing on crashes in this population of drivers can thus have a significant impact on society. If we understand the influence of distraction on crash likelihood, policies can be developed around such distractions to reduce crash risks. Given the findings of this study, examining the influence of driver distraction on crash likelihood and injury severity for all driver age groups would be a logical next step to gain a better understanding of this growing problem. Current studies in driver distraction and driver psychophysiology illustrate that it is possible for in-vehicle driver support systems to capture when drivers are distracted (e.g. Siewiorek et al., 2002). Improvements in the data collection of driver distraction variables will help better quantify the differences among other driver distraction categories and improve our understanding of the relationship between distractions and crashes. In terms of education, it is important for teenage drivers to gain a better understanding of how distraction impacts their driving risk and how mitigating their distraction tasks can substantially impact their crash risks for the most common crash types. Understanding these influences can lead to better crash mitigation strategies, in-vehicle systems design, and polices to reduce the crash risks for teenage drivers.

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References

Bedard, M., Guyatt, G.H., Stones, M.J., Hirdes, J.P., 2002. The independent contributions of driver, crash, and vehicle characteristics to driver fatalities. Accident Anal. Prev. 34 (6), 717–727.

Brown, T.L., Lee, J.D., McGehee, D.V., 2001. Attention-based model of driver performance in rear-end collisions. Transport. Res. Rec. 1724, 14–20.

Chen, L.H., Baker, S.P., Braver, E.R., Li, G., 2000. Carrying passengers as a risk factor for crashes fatal to 16- and 17-year-old drivers. JAMA 283 (12), 1578–1582.

Cooper, D., Zheng, Y., Richard, C., Vavrik, J., Heinrichs, B., Siegmund, G., 2003. The impact of hands-free message reception/response on driving task performance. Accident Anal. Prev. 35, 23–35.

Donmez, B., Boyle, L.N., Lee, J.D., in press. The impact of driver distraction mitigation strategies on driving performance, Hum. Factors.

Ferguson, S., 2003. Other high-risk factors for young drivers—how graduated licensing does, doesn't, or could address them. J. Safety Res. 34, 71–77.

Horrey, W.J., Wickens, C.D., 2006. Examining the impact of cell phone conversations on driving using meta-analytic techniques. Hum. Factors 48 (1), 196–205.

Jonah, B.A., 1986. Accident risk and risk-taking behaviour among young drivers. Accident Anal. Prev. 18 (4), 255–271.

Knipling, R.R., Mironer, M., Hendricks, D.L., Tijerina, L., Everson, J., Allen, J.C., et al., 1993. Assessment of IVHS Countermeasures for Collision Avoidance: Rear-end Crashes (No. DOT HS 807 995). National Highway Traffic Safety Administration, Washington, DC.

Laapotti, S., Keskinen, E., Hatakka, M., Katila, A., 2001. Novice driver's accidents and violations—a failure on higher or lower hierarchical levels of driving behaviour. Accident Anal. Prev. 33 (6), 759–769.

Laberge-Nadeau, C., Maag, U., Ballavance, F., Lapierre, S., Desjardins, D., Messier, S., Saidi, A., 2003. Wireless telephones and the risk of road crashes. Accident Anal. Prev. 35 (5), 649–660.

Lam, L.T., 2002. Distractions and the risk of car crash injury: the effect of drivers' age. J. Safety Res. 33 (3), 411–419.

Lee, J.D., MeGehee, D.V., Brown, T.L., Reyes, M.L., 2002. Collision warning timing, driver distraction, and driver response to imminent rear-end collisions in a high-fidelity driving simulator. Hum. Factors 44 (2).

Mao, Y., Zhang, J., Robbins, G., Clarke, K., Lam, M., Pickett, W., 1997. Factors affecting the severity of motor vehicle traffic crashes involving young drivers in Ontario. Inj. Prev. 3 (3), 183–189.

Massie, D.L., Campbell, K.L., Williams, A.F., 1995. Traffic accident involvement rates by driver age and gender. Accident Anal. Prev. 27 (1), 73–87.

Matthews, M.L., Moran, A.R., 1986. Age differences in male drivers' perception of accident risk: the role of perceived driving ability. Accident Anal. Prev. 18 (4), 299–313.

McEvoy, S.P., Stevenson, M.R., McCartt, A.T., Woodward, M., Haworth, C., Palamara, P., 2005. Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study. Brit. Med. J., doi:10.1136/bmj.38537.397512.55.

McGehee, D.V., Dingus, T.A., Mollenhauer, M.A., 1994. A review of human factors studies and issues in automotive front-to-rear-end collision intervention systems. Frontier Engineering, DOT/NHTSA, Task I, Volume VI Report. Contract No. DTNH22-93-C-07326.

McGwin, G., Brown, D.B., 1999. Characteristics of traffic crashes among young, middle-aged, and older drivers. Accident Anal. Prev. 31 (181–198).

McKnight, J.A., McKnight, A.S., 2003. Young novice drivers: careless or clueless? Accident Anal. Prev. 35 (6), 921–925.

NHTSA, 2003a. General Estimates System (GES). Retrieved January, 2005, from http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/GES.html.

NHTSA., 2003b. Traffic Safety Facts 2003: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. Retrieved from http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSFAnn/2003HTMLTSF/TSF2003.htm.

Olsen, E., Lerner, N., Perel, M., Simons-Morton, B.G., 2005. In-car electronic device use among teen drivers. In: Paper Presented at the Transportation Research Board, Washington, DC.

Poysti, L., Rajalin, S., Summala, H., 2005. Factors influencing the use of cellular (mobile) phone during driving and hazards while using it. Accident Anal. Prev. 37, 47–51.

Ranney, T., Mazzae, E., Garrott, R., Goodman, M., 2000. NHTSA Driver Distraction Research: Past, Present, and Future. NHTSA.

Redelmeier, D.A., Tibshirani, R.J., 1997. Association between cellular-telephone calls and motor vehicle collisions. N. Engl. J. Med. 336 (7), 453–458.

Sarkar, S., Andreas, M., 2004. Acceptance of and engagement in risky driving behaviors by teenagers. Adolescence 39 (156), 687–700.

Selton, T., 1991. National accident sampling system general estimates system technical note. NHTSA Technical Report, NCSA Washington DC. DOT HS 807 796.

Seo, D.C., Torabi, M.R., 2004. Impact of in-vehicle cell-phone use on accidents or near-accidents among college students. J. Safety Res. 53 (3), 101–107.

Sheridan, T.B., 2004. Driver distraction from a control theory perspective. Hum. Factors 46 (4), 587–599.

Siewiorek, D., Smailagic, A., Hornyak, M., 2002. Multimodal contextual car-driver interface. In: Paper Presented at the Proceedings of the Fourth IEEE International Conference on Multimodal Interfaces (ICMI’02).

Strayer, D.L., Drews, F.A., Johnston, W.A., 2003. Cell phone-induced failures of visual attention during simulated driving. J. Exp. Psychol.: Appl. 9 (1), 23–32.

Strayer, D.L., Drews, F.A., 2004. Profiles in driver distraction: effects of cell phone conversations on young and older drivers. Hum. Factors 46 (4), 640–649.

Stutts, J., Knipling, R., Pfefer, R., Neuman, T., Slack, K., Hardy, K., 2005. Guidance for Implementation of the AASHTO Strategic Highway Safety Plan Volume 14: A Guide for Reducing Crashes Involving Drowsy and Distracted Drivers. NCHRP Report 500.

Tavris, D.R., Kuhn, E.M., Layde, P.M., 2001. Age and gender patterns in motor vehicle crash injuries: importance of crash and occupant role. Accident Anal. Prev. 33 (2), 167–172.

Wang, J., Knipling, R.R., Goodman, M.J., 1996. The role of driver inattention in crashes; new statistics from the 1995 Crashworthiness Data System. In: Proceedings of the 40th Annual Proceedings, Association for the advancement of Automotive Medicine, Vancouver, British Columbia, Canada.

Williams, A.F., 2001. Teenage Passengers in Motor Vehicle Crashes: A Summary of Current Research. Insurance Institute for Highway Safety, Arlington.

Williams, A.F., 2003. Teenage Drivers: Patterns of Risk. J. Safety Res. 34, 5–15.

Wilson, J., Fang, M., Wiggins, S., Cooper, P., 2003. Collision and violation involvement of drivers who use cellular telephones. Traffic Injury Prev. 4, 45–52.