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Review article

The Effect of Secondary Task Engagement on Adolescents' Driving Performance and Crash Risk

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A B S T R A C T

Purpose: The purpose of this review was to synthesize the evidence of the effects of secondary task engagement on novice adolescent's driving performance and crash risk.
Methods: Searches of multiple databases were conducted using search terms related to secondary task engagement and teenage drivers. Articles were selected for inclusion if they were: written in English, an empirical study assessing the impact of secondary task engagement on driving, and included study participants who were licensed drivers between the ages of 14 and 17 years (if research was conducted in the United States) or within 18 months licensure in other countries. Thirty-eight abstracts were reviewed.
Results: Fifteen studies met the inclusion criteria. Most studies examined the effects of electronic device use as the secondary task. Effects were assessed using crash databases, simulator, instrumented vehicle, and naturalistic driving studies. Texting resulted in increased lane deviations and eyes off road time in simulated driving, whereas talking on a cell phone had little effect. Naturalistic studies, which use vehicle instrumentation to measure actual driving, found secondary tasks that required drivers to look away from the forward roadway also increased the risk of crashes and near-crashes for young novice drivers, whereas tasks that did not require eyes to be off the forward roadway (e.g., talking on cell phone) had no effect on crash risk.
Conclusions: Methodological differences in the definition and measurement of driving performance make it difficult to directly compare findings, even among the limited number of studies conducted. Despite this, results suggest that secondary tasks degrade driving performance and increase risk only when they require drivers to look away from the forward roadway. Future research needs to focus more explicitly on the ways in which secondary task engagement influences drivers' behavior (e.g., interfering with information acquisition or manual control of the vehicle). This, along with the use of standard measures across studies, would build a more useful body of literature on this topic.

IMPLICATIONS AND CONTRIBUTION

Secondary tasks degrade novice driver performance and risk primarily when drivers look away from the forward roadway. Standard measures of driving performance and definitions would greatly improve the body of driver distraction literature.

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Motor vehicle crashes are the leading cause of death and disability among adolescents in the United States [1], and driving while being distracted is increasingly recognized as a threat to the safety of adolescents [2]. Driver distraction is defined as the "diversion of attention away from activities critical for safe driving toward a competing activity" [3]. This competing activity could include mental processes such as mind wandering, the presence of passengers, or engaging in secondary tasks such as using in-vehicle technology or eating. Specifically, secondary task engagement entails behaviors—such as eating, using a cell phone, inserting a compact disc (CD), and attending to irrelevant roadside objects—that may occur in conjunction with driving, but are not critical to the driving task per se. The goal of this review was to summarize the effects of secondary task engagement on driving performance and crash risk reported in studies that focus specifically on adolescents.

Although extensive research has been conducted on the effects of secondary task engagement by adult drivers, less attention has been devoted to adolescent drivers. Adolescent drivers differ from adults in several ways as a result of their youthfulness and lack of driving experience. These include rapidly developing vehicle handling and maneuvering skills, poorer hazard detection skills, a propensity to engage in risky driving, and susceptibility to peer influence—all of which can result in greater crash risk [4–7]. Novice drivers are also more likely to adopt and use new technologies in their daily lives, which lead to a greater likelihood of them using these technologies while driving [8]. Thus, the impact of secondary task engagement may be greater for these drivers and contribute to their higher crash and injury rates.

The prevalence of secondary task engagement among adolescent drivers varies according to the type of task. Studies analyzing self-reported behavior indicate most adolescents occasionally use an electronic device while driving. In one study, four fifths of high school age adolescents reported having ever talked on a phone while driving [9]; in another study, 72% reported having texted while driving in the previous 30 days [10]. However, the actual prevalence of secondary task engagement while driving is far less common than these might suggest. For example, Goodwin et al. [11] observed novice drivers engaging in some form of secondary task in approximately 15% of driving segments that were sampled in a naturalistic driving study. These included wireless device use (6.7%), adjusting controls (6.2%), personal hygiene (3.8%), and eating/drinking (2.8%) among other tasks. Klauer et al. [2] observed young drivers increasingly engaging in risky secondary tasks over the first 18 months of driving, ranging from 7% to 14% of all normal driving periods.

Naturalistic driving studies, or studies that record driver behavior in situ with drivers in their personal vehicles on normal daily commutes, have greatly improved objective measures of prevalence of many driving behaviors. Secondary task engagement is just one such driving behavior naturally captured in these studies because interactions with other objects and/or in-vehicle systems can be easily witnessed. Conversations can also be observed; however, the cognitive demand of a conversation as measured by the intensity of the conversation is difficult to capture unless audio is also collected.

Interestingly, naturalistic studies have found that secondary tasks that require the driver's eyes and hands (i.e., visual-manual tasks) to be at least partly disengaged from the driving task increase the risk more than secondary tasks that do not have visual and/or manual requirements. Tasks such as talking on a cell phone, which have been described as cognitive distraction in the literature, do not appear to increase risk [12]. This has been reported for novice drivers, experienced drivers, commercial vehicle drivers, and drivers who were recruited because they self-reported wireless device use while driving [13–15]. Although naturalistic driving studies have also shown performance decrements (reduced scanning, greater speed variance) while drivers are talking on a cell phone, these performance decrements have not been found to translate into increased crash or near-crash risk. Thus, although cognitive distractions may degrade driving performance, they do not appear to result in the same risk that accompanies visual-manual tasks.

Current approaches to limit secondary task engagement while driving—especially among teenage drivers—include laws that restrict cell phone use, promotion of devices that prevent incoming or outgoing communication, and educational campaigns to discourage secondary task engagement while driving. Legislation and the accompanying public education that defines the boundaries for acceptable road user behavior may also draw attention to general normative expectations. Although a few studies have examined the effectiveness of laws in reducing cell phone use and crashes among novice teenage drivers, little is known about the potential for these approaches to limit drivers' engagement in other secondary tasks.

The purpose of this review was to synthesize the literature assessing the effects of secondary task engagement on adolescent' driving performance and crash risk. Specifically, the following research questions will be addressed:

1. What is the effect of secondary task engagement on adolescent driving performance?
2. What are the crash characteristics and risks associated with secondary task engagement?

Methods

Search strategy and inclusion criteria

Transportation, engineering, and medical research databases were searched to identify reports of empirical research on adolescent driver secondary task engagement. These included Transport Research International Documentation (Transportation Research Board, Washington, D.C.), SafetyLit (SaftyLit Foundation, San Diego, CA), PsycINFO (American Psychological Association, Washington, D.C.), Compendex (Elsevier, Amsterdam, Netherlands), and Inspec (Institution of Engineering and Technology, Stevenage, UK). The search interfaces used to scan these databases were Engineering Village, PubMed, and Ebsco. Search terms were used to identify novice or young drivers and distraction (which was subsequently limited to secondary task engagement). The search term *novice* was expanded to include teen, teenager, adolescent, and young driver. The term *distraction* was expanded to include distracting, texting, cell phone, smart phone, reading handheld device, electronic device, music, and eating. Inclusion was limited to articles written in English, which were published either in peer-reviewed journals, conference proceedings, or as government technical reports. No restrictions were placed on the year of publication. We were only interested in empirical scholarly research; thus, critical reviews, letters to the editor, or general literature reviews were not included. The references from selected articles were also reviewed to identify relevant studies that the general search procedure may have missed (this resulted in the inclusion of two additional studies).

The search was conducted in March 2014 and yielded 86 unique publications. The titles and abstracts of these articles were reviewed by one of the authors. If the title indicated that young drivers were included in the study population, the abstract and method section (if necessary) was reviewed and articles selected if:

1. Study participants (or at least one group of participants) included drivers aged 14–17 years for studies conducted in the United States. For studies in other countries—where the licensing age is older than in the United States—articles were reviewed for the inclusion of novice drivers within 18 months of licensure and
2. The study included a measure of driving performance or crash risk as an outcome. Studies that examined only perceptions, beliefs, or self-reports of secondary task engagement were not included.

This process resulted in the identification of 15 research articles for review (Table 1).

Discussion

Eleven articles were from the United States, there were two from Canada and one from Belgium and Australia, respectively. Four of the studies used qualitative data with two of the studies examining crash data (General Estimates System [GES] [National Highway Traffic Safety Administration, Washington, D.C.] and National Motor Vehicle Crash Causation Study [National Highway Traffic Safety Administration]), one used crash reports coupled with driver interviews, and one used self-reported crash occurrence. The other 11 studies used quantitative data with six studies using a driving simulator as the primary means of evaluating driving performance, one using a test track, one using an instrumented vehicle, and three using naturalistic driving methods. Both instrumented vehicle and naturalistic driving studies measure actual driving, usually in real world settings. The main difference is that instrumented vehicle studies typically have an experimenter present; whereas, naturalistic driving studies do not.

The findings from the literature will be summarized for the two research questions as previously presented. A discussion of lessons learned from this review of the literature will conclude this article.

What are the effects of secondary task engagement on driving performance?

Cell phone use. Cell phone use was a common secondary task to be assessed in the literature. Cell phone use can be synthesized into specific tasks such as texting, dialing, talking, reaching for cell phone, holding cell phone, and so forth. Different studies measured driving performance during one or multiple of these specific cell phone tasks.

Data collected in a simulated driving setting suggested that when texting, novice drivers had more lane deviations [16,17], speed deviations [16], longer time headway [17], and longer eyes off road time [17]. In contrast, conversations on a cell phone resulted in fewer lane changes and more cars passing the driver during conversation [16]. Conversing or answering a cell phone did not affect the time needed for drivers to notice surprise events such as pedestrians or other vehicles entering the roadway; novice drivers had overall slower response times than experienced drivers for all these surprise events irrespective of distraction.

Drivers looked away from the roadway for longer durations during text messaging tasks in simulated driving studies. Hosking et al. [17] reported a 400% increase in time looking away from the simulated road during a text messaging task versus no task. Smahel et al. [18] found that time with eyes off the road when engaging in cell phone tasks while driving a simulated vehicle was shorter for novice drivers than that for experienced drivers, because novice drivers tended to use “speed dial” more often.

Stavrinos et al. [16] found that “collisions” in simulated driving were slightly more frequent when texting. However, Chisholm et al. [19] found no increase in collision occurrence during cell phone conversation. The authors remarked that this result is counterintuitive and that the participants were possibly “on alert” for potential surprise events when asked to engage in secondary tasks.

In a test track study, Pradhan et al. [20] assessed the impact of texting and talking on a cell phone with novice drivers' eye glances toward roadway hazards at licensure and after 12 months of driving experience. The results suggest that eye glances toward hazards improved slightly during texting tasks after 12 months of driving experience, but decreased during cell phone talking tasks over the same time period.

Ross et al. [21] conducted a simulator study and found evidence to support the hypothesis that teen drivers with higher working memory capacity would experience less driving performance degradation than those with less capacity in the presence of a secondary task. This may explain some of the individual variability observed with novice drivers and secondary task engagement and is an important complicating factor that should be considered in future research.

Compact disc changing task. Several simulator studies examined novice driving performance during CD changing tasks, where participants were asked to select a CD from a soft case and insert into the CD player located in the center console. The results indicated no increase in reaction time for a surprise vehicle turning into the lane of traffic for the novice drivers; however, novice drivers spent less time looking at rear view mirrors and more time looking either straight ahead at the roadway or into the vehicle [19]. This pattern of eye glance behavior, focused either straight ahead or on the secondary task, is comparable to findings from other studies assessing eye glance behavior during secondary task engagement for experienced drivers [12,22,23].

External distractions. Divekar et al. [24] conducted a simulator study to assess the impact of external distractions on novice drivers. External distractions in this study consisted of participants reading digital billboards while driving. Results indicated that eyes off road time did not differ significantly between novice and experienced drivers. Detection of a hazard while reading the digital billboards was significantly reduced for both experienced and novice drivers; however, more so for novice drivers.

Summary. Results of these studies suggest some increase in lane deviations and collisions when experimental participants

Table 1
Articles meeting inclusion criteria for systematic review.

Author	Year	Journal	Persons studied	Method	Metrics	Description
Braitman, et al. [30]	2008	*Journal of Safety Research*	893 nonfatal crashes by 16-year-old drivers	Interviews and crash reports in Connecticut (3/2005—2/2006)	Crash types and contributing factors were identified.	Runoff road, rear-end striking, and collided with another vehicle with the right of way. Most failures to detect also involved inappropriate scanning. Driver was distracted or inattentive 19% of the time.
Carney, et al. [32]	2014	*Federal Highway Report TPF*-5(207)	30 16-year-old drivers	Naturalistic driving study	Percentage of time engaging in many secondary tasks while driving.	Novice drivers are engaged in some form of secondary task in nearly half of the events observed. Wireless device use was observed in 10% of all events.
Chisholm, et al. [19]	2006	*Proceedings of the Human Factors and Ergonomics Society*	20 novice drivers (less than 6 months experience)	Driving simulator	Perception response time to hazards and eye movement measures during baseline, cell phone, or compact disc player task.	Results showed longer PRTs for novice compared with experienced drivers for lead vehicle brake, pedestrian, and pullout events. Compact disc task increased glances into the vehicle and decreased rear view mirror glances.
Curry, et al. [27]	2011	*Accident Analysis & Prevention*	795 crashes of 15- to 18-year-old drivers	National Motor Vehicle Crash Causation Study (7/2005—12/2007)	Driver errors, including internal distraction, external distraction, and inattention were evaluated	These types of distraction were contributing factors to 21.9% of all teen driver crashes investigated.
Divekar, et al. [24]	2012	*Transportation Research Record*	24 novice drivers (aged 16—18 years)	Simulator	Impact of external distractions on novice drivers. Billboard task and billboard task + hazard detection.	External distractions impact novice drivers' ability to maintain lane position and anticipation of hazards.
Goodwin, et al. [11]	2012	*AAA-FTS*	52 drivers (aged 16—18 years)	Naturalistic	Sample of 7,858 15-second clips were coded for secondary task engagement.	Teens were observing using an electronic device in 6.7% of all clips. Nearly twice as many were suspected of using versus those that were holding device to their ear. Some type of secondary task occurred during 15.1% of all clips. Secondary task engagement did not vary by day of week. Declined gradually by time of day. Drivers were nearly three times more likely to look away from the forward roadway when using an electronic device.
Hosking, et al. [17]	2007	*International Conference on Distractions While Driving*	20 drivers (Less than 6 months experience with probationary driver's license between the ages of 18 and 21 years)	Simulator	Evaluated driving performance in a pedestrian emerging from cars, traffic lights, car emerging in front, car following, and lane change task. Eye glance was also measured during text messaging tasks.	Results indicated that novice drivers do perform some compensatory behaviors because they realize they are distracted, they do not decrease speed. Drivers also looked away from the forward roadway 400% more time than that of during nondistracted activities.
Klauer, et al. [2]	2014	*New England Journal of Medicine*	42 novice drivers (aged 16—18 years)	Naturalistic driving study	Calculated odds ratios for a variety of secondary tasks including tasks with cell phones as well as eating, drinking, adjusting radio, and external distractions. Prevalence of engagement in high risk secondary tasks was also evaluated.	Increase in risks for novice drivers were identified for texting, dialing cell phone, reaching for cell phone, reaching for object, eating, and external distractions. Prevalence of engagement in high risk tasks increased as novice drivers gained driving experience.
Neyens and Boyle [26]	2007	*Accident Analysis & Prevention*	449,049 weighted crashes for 16- to 19-year-olds	2003 General Estimates System data	Frequency of cell phone, cognitive distraction, passenger presence, in-vehicle distraction coded as contributing factor to rear-end, angular, and fixed-object crashes.	Teenage drivers distracted by cell phones were more likely to be involved in rear-end collision than those by fixed object. Teen drivers distracted in-vehicle were more likely to be involved in angular collisions compared to either fixed object or rear-end.
Ohlhauser, et al. [25]	2011	*Proceedings of HFES*	16- to 17-year-olds (weeks of licensure)	Simulator study	Time to stop line during yellow phase.	Found that novice drivers were more likely to run yellow lights when using handheld device than drivers of other ages. Similar to

(*continued on next page*)

Table 1
Continued

Author	Year	Journal	Persons studied	Method	Metrics	Description
						With the exception of Ohlhauser et al, all of the papers in Table 1 are included in the reference section of this paper. I will add the Ohlhauser Boyle, etal citation in the reference section at the end of the paper. Will this be sufficient? Olsen et al. and Simons-Morton et al.
Pradkan, et al. [20]	2011	*Driving Assessment Conference*	42 teenage drivers (aged 16–18 years)	Test-track instrumented vehicle study	% of drivers who glanced at hazard, demonstrated indecision, and suspended secondary task.	Novice drivers drove an instrumented vehicle on a test track with various roadway scenarios of varying complexity and were asked to engaged in different types of secondary tasks.
Ross, et al. [21]	2014	*Accident Analysis and Prevention*	46 17- to 25-year-old drivers (with learners permit or less than 2 years experience)	Simulator	Working memory load test, visuospatial capacity, verbal working memory test in presence of lane change test.	Results suggested that novice drivers with higher working memory load capability were able to perform better using the verbal working memory when performing the lane change test.
Smahel, et al. [18]	2008	*Proceedings of the Human Factors Society 52nd Annual Meeting*	19 teenage drivers (must have received provisional license within past 6 months and aged less than 21 years)	Instrumented vehicle study	Missed proportion of hazards, response to green light, number and length of glances off road, speed, lane exceedances,	Novice drivers have shorter glances when dialing, answering, and terminating calls. Novice and experienced drivers are slower to detect hazards when talking on the cell phone.
Stavrinos, et al. [16]	2013	*Accident Analysis & Prevention*	30 novice drivers (aged 16–18 years)	Simulator	Measures include vehicle collisions, lane deviations, cars passed by participant, speed deviation, lane change frequency, and time to complete scenario.	Results suggest that there are no differences between novice and young adult drivers. Lane deviations increased during texting and no distraction conditions. Speed fluctuations increased during texting, less so during cell talking, compared to no distractions. Distraction tasks so appear to negatively impact traffic flow.
Westlake and Boyle [31]	2012	*Transportation Research Part F*	14- to 19-year-old drivers (N = 1,893 completed surveys)	Survey Likert scale	The following are the four sets of questions: frequency of engagement in distracting tasks; level of driving experience; demographic information; and crash/driving violation occurrence.	Three subgroups of teenage drivers were identified as follows: infrequent, moderate, and frequent engager in distracting activities. The frequent engagers were also most likely to be involved in a crash and also engaged in cell phone tasks, eating/drinking, doing homework, reading more frequently than the moderate or infrequent cluster of teenagers.

PRTs = perception-response times.

performed visual/manual tasks, such as texting or dialing a cell phone during simulated driving. No performance degradations were identified when participants were asked to talk on a cell phone. This is true for general driving performance measures and response to "surprise" events.

Results from studies evaluating eye glance behaviors were somewhat mixed. For some tasks, novice driving performance was either equal or better than experienced drivers in that novice drivers were looking forward a greater percentage of time than experienced drivers. Regardless, detection of hazards was typically not better for novice drivers; regardless of where they were looking. Many studies have found that glances to rear-view mirrors or scanning the road environment are significantly lower when drivers are engaging in a secondary task; whereas, glances either straight ahead or in the vehicle (at the secondary task) increase in frequency.

What are the crash characteristics and risks associated with secondary task engagement?

Crash type. Neyens and Boyle used the GES crash database to examine the association of driver secondary task engagement with crash type [26]. GES is a nationally representative sample of police-reported motor vehicle crashes of all severity levels. Although cell phone use was associated with an increased risk of rear-end collisions, cell phone distractions only represented .6% of the total crashes. In-vehicle distractions were identified in only 2.6% of the crashes in these analyses. These percentages are low compared with other more direct measures of secondary task engagement and suggest that secondary task engagement is underreported in crash databases.

Contributing factors. Curry et al. [27] used the National Motor Vehicle Crash Causation Study data looking at only crashes of 15- to 18-year-old drivers (N = 822). National Motor Vehicle Crash Causation Study involved intensive investigation of nearly 6,000 crashes in the United States, of varying severity, in 2005–2007. Particular attention was devoted to determining the reason underlying the critical event in the crash. This approach was employed as the involvement of secondary task engagement by drivers was more likely to have been detected than in other crash databases. The most common driver errors were inadequate surveillance (21.3%), driving too fast (20.7%), and being distracted either by internal or external sources (19.9%). This result is slightly higher than other crash database results (13%) but lower than results found in naturalistic studies (35%) [28,29].

Finally, a study conducted in Connecticut used combined police crash reports and driver interviews to determine characteristics and apparent contributing factors of crashes [30]. Using police crash reports and interviews from 260 16-year-old drivers, 68% of the crashes were deemed to be at-fault. Driver distraction was reported as a contributing factor in 12% of these at-fault crashes.

These results suggest that population-based crash databases such as GES or Fatality Accident Reporting System (FARS) (National Highway Traffic Safety Administration, Washington, D.C.) may not be a reliable source of secondary task engagement data. There are many potential reasons for this unreliability of GES and FARS which include the police accident reports are written by police officers minutes/hours after the collision; thus, driver behavior in the seconds leading up to the crash may not be accurate. The published analyses based on these databases are also several years older than other reported analyses, which can also account for differences. Regardless, when police accident reports in addition to an in-depth examination of crash causation are used, secondary tasks appear to be a contributing factor in between 12% and 20% of all crashes.

Crash risks. Westlake and Boyle [31] administered a survey to students aged 14–19 years from seven high schools in Iowa. Respondents ranked the frequency in which they engaged in a wide variety of secondary tasks while driving as well as reported crash occurrence, traffic violations/warnings, and driving exposure. Drivers were grouped into frequent, moderate, or infrequent secondary task engagers. These clusters were based on the reported frequency with which they performed 13 secondary tasks ranging from minimally distracting (adjusting climate controls, tuning radio) to highly distracting (texting, doing homework). The results indicated that 20% of drivers classified as frequent engagers in secondary tasks were 1.45 times more likely to have been involved in a crash than those were the 49% of participants classified as infrequent engagers (confidence interval [CI], 1.06–2.00). However, this study did not directly link secondary task engagement to the reported crashes. It simply used reported secondary engagement to classify drivers into groups, which were then determined to have different crash risks.

Carney et al. [32] conducted a feedback and monitoring study with 90 14- to 16-year-old drivers in Iowa, where half of the participants received feedback and the other half did not receive any feedback (control group) . The data acquisition system used for this study was a triggered system where video and driving performance data are only collected and saved when the driver exceeds a performance threshold (e.g., braking beyond −.5 g). Using results from the control group only, when novice drivers were involved in a high g force event, they were also six times more likely to be engaging in secondary tasks than paying attention to the driving task [32].

The Naturalistic Teenage Driving Study recruited 42 16- to 17-year-old drivers, for whom driving behavior and crashes and near-crashes were observed over a period of the first 18 months of independent driving. Both crashes and near-crashes were used as an outcome measure because near-crashes contain all the characteristics of a crash with the addition of a successful evasive maneuver [33]. In a case-control analysis of naturalistic driving data, Klauer et al. [2] reported that among novice drivers, a crash/near-crash was significantly more likely when dialing a cell phone (odds ratio [OR] = 7.9; CI = 2.7–23.1), reaching for a phone (OR = 4.7; CI = 1.9–11.7), reaching for other objects (OR = 7.7; CI = 3.5–16.8), texting (OR = 4.3; CI = 1.9–10.0), looking at a roadside object (OR = 3.8; CI = 1.7–8.5), or eating (OR = 3.3; CI = 1.5–7.2). Talking on a cell phone was not associated with crash/near-crash occurrence for novice drivers (OR = .61; CI = .24–1.57). Similar ORs calculated for experienced drivers found that only dialing a cell phone increased crash/near-crash occurrence (OR = 2.5, CI = 1.4–4.5) [2]. These results suggest that risks may be higher for novice drivers than experienced drivers for these secondary tasks. These results also suggest that visual-manual secondary tasks that require the driver to look away from the forward roadway increase crash/near-crash risk, whereas purely cognitive tasks such as talking do not increase crash/near-crash risk.

The results from these studies suggest that engaging in secondary tasks, those that involve visual or visual and manual distraction, increases crashes, near-crash risk, or high g-force event rates for young, relatively inexperienced drivers. One study also indicated that crash/near-crash risk is higher for novice drivers than that for experienced drivers when engaging in secondary tasks. Frequent involvement in any type of secondary task resulted in an increase in crash risk of at least 1.45 times than that of an alert driver. These findings suggest that novice drivers' higher crash rates may be partially because of secondary task engagement.

The analyses using crash databases have the benefit of consisting of data from severe crashes that result in fatalities, injuries, and/or property damage. The analyses using naturalistic data are primarily made up of some property damage crashes, minor collisions, and near-crashes. Results from these analyses should be interpreted with these differences in mind.

Discussion

Summary of findings

This review of the literature on the impact of secondary task engagement on adolescent driving performance has largely demonstrated the need for additional research on this topic. Of the 15 research articles reviewed here, 10 were published in the last 5 years, which suggests a positive trend toward more research in the future.

Experimental studies of simulated driving suggest sizeable decrements in driving performance when adolescent drivers engage in a variety of secondary tasks. However, these involve precise measures that are only possible in highly controlled settings. They clearly indicate that when drivers engage in secondary tasks, their driving is affected. However, it is not known whether, or how much, the measured effects (usually small changes in lane positioning or speed variance) might influence real crash risk during actual driving.

The crash data analysis studies focused on distraction more generally, so findings were not limited only to secondary task engagement. These suggest that distraction is present in approximately 12%–20% of teenage driver crashes. However, these should be considered crude estimates, as it is challenging for postcrash investigations to detect all driver behaviors that immediately preceded and may have led to a crash.

Naturalistic driving studies indicate that relatively inexperienced teenage drivers are more likely than experienced drivers to experience a crash, near-crash, or safety-relevant event when engaging in secondary tasks. This is especially true for those tasks that involve taking their eyes off the road or a hand off the steering wheel.

Summary of methodological issues

The literature on secondary task engagement and driving performance focuses almost exclusively on electronic device use, particularly wireless devices. Although the manipulation of wireless devices is a considerable source of secondary task engagement, there are a number of other nondriving behaviors, such as eating or attending to external objects, that also elevate crash risk. Additional research is needed to not only validate these findings but also to obtain a deeper understanding of the interaction of secondary task engagement and traffic and roadway demand, which may also impact crash risk.

It is particularly troubling that in the 13 experimental studies reviewed, there are a total of 13 different outcome measures. There is no standardization of driving performance metrics across driving studies, which makes comparisons across studies very difficult and seriously impedes the development of a coherent body of literature on the issue. Although there are some efforts underway to develop standardized metrics for human factors research studies within the Society for Automotive Engineers (SAE J2944-Proposed draft) and the International Standards Organization, these efforts are currently in the initial planning stages.

Along with the use of more standard measures, future research on effects of secondary task engagement would benefit from a more conceptual approach. One that focuses on identifying general classes of behavior, prevalence of these general classes of behavior and their corresponding risks, instead of specific activities. For example, the behaviors involved in dialing a phone have changed markedly in a few years, with the evolution of touch tone cell phones into smart phone technology.

Risk calculations in naturalistic driving studies, while far more precise given the recorded video and precise kinematic data, represent small numbers of participants, a few serious crashes or near-crashes, and one geographic location. Fortunately, future analyses of naturalistic data should be able to incorporate larger numbers of participants, geographic locations, and numbers of crashes.

Research priorities

Secondary task engagement among adolescent drivers increases crash risk, particularly for visual-manual tasks. The rapid evolution of nomadic technology, such as smart phones and wearable devices may increase the risks posed to young drivers, given what is currently understood about the effects visual-manual tasks while driving. This review did not find any research assessing the impact on driving performance or risk of additional cell phone tasks or smart phone tasks such as Internet browsing, video chatting, watching videos, and so forth, while driving, all of which may be new classifications of behaviors, which have not yet been evaluated.

Parallel with scientific efforts to understand the association between secondary task engagement and crash risk, an emerging body of literature is examining the effects of public policies that proscribe the use of wireless devices by teenage drivers. Findings from these studies have been mixed, and additional research is required to understand the role that policy can play to reduce wireless device use while driving [34]. This review did not identify studies of other approaches to crash mitigation for adolescents engaging in secondary tasks while driving. Some efforts are underway to assess collision avoidance warning systems for novice drivers, but there is very limited work in the area [35].

Driver distraction is a complex problem that will require a complex solution. Given the proliferation of wireless communication devices that can be brought into vehicles and the ever expanding capabilities of these devices, the potential for growth in crash rates because of distraction among adolescent drivers is worrisome. The findings of the limited literature on secondary task engagement and adolescent drivers reviewed here should help to provide direction for future research as well as evidence on which future policies and programs to counter this looming problem can be based.

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References

[1] Centers for Disease Control and Prevention. Web-based Injury Statistics Query and Reporting System (WISQARS)[Online]. Atlanta, GA: National Center for Injury Prevention and Control, Centers for Disease Control and Prevention (producer); 2012 [Cited 2015 February 2015].
[2] Klauer SG, Guo F, Simons-Morton B, et al. Distracted driving and risk of road crashes among novice and experienced drivers. N Engl J Med 2014; 370:54–9.
[3] Regan M, Lee JD, Young K. Defining Driver Distraction. In: Regan M, Lee JD, Young K, eds. Driver Distraction: Theory, Effects, and Mitigation. Boca Raton, FL: CRC Press, Taylor & Francis Group; 2009:31–40.
[4] Simons-Morton BG, Ouimet MC, Chen R, et al. Peer influence predicts speeding prevalence among teenage drivers. J Safety Res 2012;43: 397–403.
[5] Simons-Morton BG, Ouimet MC, Zhang Z, et al. The effect of passengers and risk-taking friends on risky driving and crashes/near crashes among novice teenagers. J Adolesc Health 2011;49:587–93.
[6] Carney C, McGehee D, Lee J, et al. Using an event-triggered video intervention system to expand the supervised learning of newly licensed adolescent drivers. Am J Public Health 2010;100:1101–6.
[7] McGehee D, Raby M, Carney C, et al. Extending parental monitoring using an event-triggered video intervention in rural teen drivers. J Safety Res 2007;38:215–27.
[8] Lee JD. Technology and teen drivers. J Safety Res 2007;38:203–13.
[9] O'Brien NP, Goodwin AH, Foss RD. Talking and texting among teenage drivers: A glass half empty or half full? Traffic Inj Prev 2014;11: 549–54.
[10] Ehsani J, Brooks-Russell A, Li K, et al. (2013). Novice teenage driver cell phone use prevalence. Proceedings of the Seventh International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design. Iowa City, IA.
[11] Goodwin AH, Foss RD, Harrell SS, O'Brien NP. Distracted driving among newly licensed teen drivers. Report to the Automobile Association of America -Foundation for Traffic Safety; 2012. Washington, DC. Publisher is the Automobile Association of America-Foundation for Traffic Safety.
[12] Harbluk JL, Noy YI, Trbovich PL, Eizenman M. An on-road assessment of cognitive distraction: Impacts on drivers' visual behavior and braking performance. Accid Anal Prev 2007;39:372–9.
[13] Klauer SG, Dingus TA, Neale VL, et al. The impact on driver inattention on near crash/crash risk: An analysis using the 100 car Naturalistic Driving Study data (Report No. DOT HS 810 594). Washington, DC: National Highway Traffic Safety Administration; 2006.
[14] Olsen RL, Hanowski RJ, Hickman JS, Bocanegra JL. Driver distraction in commercial vehicle operations (Report No. FMCSA-RRR-09–042). Washington, DC: Federal Motor Carrier Safety Administration; 2009.
[15] Fitch GM, Hanowski RJ, Guo F. The risk of a safety-critical event associated with mobile device use in specific driving contexts. Traffic Inj Prev 2014:1–34.
[16] Stavrinos D, Jones JL, Garner AA, et al. Impact of distracted driving on safety and traffic flow. Accid Anal Prev 2013;61:63–70.
[17] Hosking, SG, Young, KL, and Regan, MA. The effects of text messaging on young novice driver performance. Report No. 246. Melbourne, Australia. National Roads and Motorists' Association Motoring and Services and National Roads and Motorists' Association.
[18] Smahel T, Smiley A, Donderi D. The effects of cellular phone use on novice and experienced driver performance: An on-road study. Proc Hum Factors Ergon Soc Annu Meet 2008;52:1910–4.
[19] Chisholm, SL, Caird, JK, Lockhart, JA, et al. Novice and experienced driving performance with cell phones. In The Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting. Santa Monica, CA; 2006.
[20] Pradhan A, Simons-Morton B, Lee S, Klauer S. Hazard perception and distraction in novice drivers: Effects of 12 months driving experience. In The Proceedings of the Sixth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design. 2011. Iowa City, Iowa.
[21] Ross V, Jongen EM, Wang W, et al. Investigating the influence of working memory capacity when driving behavior is combined with cognitive load: An LCT study of young novice drivers. Accid Anal Prev 2014;62:377–87.
[22] Victor T, Harbluk JL, Engstrom JA. Sensitivity of eye-movement measures to in-vehicle task difficulty. Transportation Res Part F 2005;8:167–90.
[23] Victor TW and Johansson E. Gaze concentration in visual and cognitive tasks: Using eye movements to measure driving information loss. Thesis publication at Uppsala University.
[24] Divekar G, Pradhan AK, Pollatsek A, Fisher DL. Effect of external distractions: Behavior and vehicle control of novice and experienced drivers evaluated. Transportation Res Rec 2012;2321:15–22.
[25] Ohlhauser AD, Boyle LN, Marshall D, Ahmad O. Drivers' behavior through a yellow light: Effects of distraction and age. In the Proceedings of the Human Factors and Ergonomics Society. 2011. Santa Monica, CA.
[26] Neyens DM, Boyle LN. The effect of distractions on the crash types of teenage drivers. Accid Anal Prev 2007;39:206–12.
[27] Curry AE, Hafetz J, Kallan MJ, et al. Prevalence of teen driver errors leading to serious motor vehicle crashes. Accid Anal Prev 2011;43:1285–90.
[28] Wang JS, Knipling RR, Goodman MJ. The role of driver inattention in crashes: New statistics from the 1995 crashworthiness data system. In 40th Annual Proceedings of the Association for the Advancement of Automotive Medicine, Vancouver, British Columbia; 1996.
[29] Dingus TA, Klauer SG, Neale VL, et al. The 100-Car naturalistic driving Study: Phase II—Results of the 100-car field experiment (Interim Project Report for DTNH22-00-C-07007, Task Order 6; Report No. DOT HS 810 593). Washington, D.C: National Highway Traffic Safety Administration; 2006.
[30] Braitman KA, Kirley BB, McCartt AT, Chaudhary NK. Crashes of novice teenage drivers: Characteristics and contributing factors. J Safety Res 2008; 39:47–54.
[31] Westlake EJ, Boyle LN. Perceptions of driver distraction among teenage drivers. Transportation Res Part F 2012;15:644–53.
[32] Carney C, McGehee D, Reyes M. Prevalence and distribution of young driver distraction errors in naturalistic driving; 2014. Federal Highway Report TPF-5(207).
[33] Guo F, Klauer SG, Hankey JM, Dingus TA. Near-crashes as crash surrogate for naturalistic driving studies. Transportation Res Rec J Transportation Res Board 2010;2147:66–74.
[34] McCartt AT, Kidd DG, Teoh ER. Driver cellphone and texting bans in the United States: Evidence of effectiveness. Ann Adv Automot Med 2014;58: 99–114.
[35] Sayer J. Teens experience with crash avoidance technologies. Presentation to the Michigan Traffic Safety Summit, Lansing, MI; 2014.