Teen driver crashes potentially preventable by crash avoidance features and teen-driver-specific safety technologies

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Abstract

Introduction: Vehicle technologies have the potential to help address the disproportionate crash risk that teen drivers face. While crash avoidance features benefit the general population, several address crash scenarios for which teen drivers are particularly at risk, such as rear-end and lane-drift crashes. Other emerging technologies have been designed for teen drivers by addressing certain crash or injury risk factors associated with risky driving behavior, such as speeding or not wearing a seat belt.

Methods: Using nationwide U.S. crash data from 2016 to 2019, this study examined the maximum potential safety benefits of three currently available crash avoidance features (front crash prevention, lane departure prevention, and blind spot monitoring) and three teen-driver-specific technologies (speeding prevention, extended seatbelt reminders and interlocks, and nighttime curfew violation alerts).

Results: Teen-driver-specific features have the largest potential for reducing teen driver injuries and fatalities, followed by lane departure prevention, front crash prevention, and lastly blind spot monitoring; however, altogether these technologies have the potential to prevent 78% of teen driver fatalities, 47% of injured teen drivers, and 41% of crashes involving teen drivers.

Conclusions: Crash avoidance features and teen-driver-specific vehicle technologies appear to address different risk factors and crash scenarios, which emphasizes the importance of utilizing both types of safety features to reduce the crash risk of teen drivers.

Practical applications: Wider acceptance, accessibility, and use of these technologies are needed for their safety potential to be realized. More manufacturers should offer and advertise teen-driver-specific technology suites that integrate crash avoidance systems and safety features that address risky driving behavior. While this study shows the maximum potential safety benefits of these technologies, further research is needed to understand the behavioral implications as teens learn to drive with these features.

Keywords: Adolescent drivers; young drivers; novice drivers; inexperienced drivers; ADAS; crash avoidance technology; safety benefits.

Introduction

The vehicle environment is changing considerably to improve driver safety. Vehicle crashworthiness has improved over the years to reduce injury severity (Highway Loss Data Institute [HLDI], 2020b), and crash avoidance systems are gaining popularity with more being offered in new vehicles every year (HLDI, 2020c). The safety benefits of these systems are especially strong among those that intervene on behalf of the driver, such as front crash prevention features with automatic emergency braking (Cicchino, 2017). However, not all drivers have the same degree of risk of getting into a crash in the first place. Teenage drivers have the greatest crash risk compared with any other age demographic; their fatal crash risk per 100 million miles traveled is only comparable with drivers aged 80 years and older, and their risk of getting into a police-reported crash far exceeds that of any other age group (Insurance Institute for Highway Safety [IIHS], 2021b). Little is known about what safety benefits driver assistance systems have for these young novice drivers.

Teen drivers have a unique set of risk factors that predispose them to be involved in certain crash scenarios (Shope & Bingham, 2008). Speeding is a common contributing factor in crashes involving teen drivers (Braitman, Kirley, McCartt, & Chaudhary, 2008; Curry, Hafetz, Kallan, Winston, & Durbin, 2011; IIHS, 2021b; National Highway Traffic Safety Administration [NHTSA], 2020b). Seat belt use is also lower among teens than among vehicle occupants of other ages (Carpenter & Stehr, 2008; Enriquez, 2020; NHTSA, 2020b). With their crash risk being especially high at night (Ferguson, Teoh, & McCartt, 2007; McCartt & Teoh, 2015; Rice, Peek-Asa, & Kraus, 2003), the implementation of graduated driver licensing (GDL) programs has shown considerable reductions in nighttime crash rates in states that impose curfew restrictions on learner drivers (Williams, 2017); however, nighttime restrictions in GDL programs vary from state to state (IIHS, 2021b) and noncompliance remains an issue (Carpenter & Pressley, 2013).

In addition to a general propensity for higher risk-taking behavior, teen drivers are also at a disadvantage due to their inexperience with the driving task itself (McCartt, Mayhew, Braitman, Ferguson, & Simpson, 2009). These young novice drivers typically have poorer hazard recognition compared with older, more experienced drivers (Lee et al., 2008). Teen drivers also face greater difficulty when it comes to vehicle control and hazard avoidance behavior, as they tend to have more loss of control and run-off-road crashes (Braitman et al., 2008) as well as longer braking reaction time than other drivers (Loeb, Kandadi, McDonald, & Winston, 2015). They are more likely to be involved in single-vehicle crashes than vehicle-to-vehicle crashes, especially at night (Carney, McGehee, & Harland, 2015).

In their naturalistic study of teen driver crashes, Carney et al. (2015) noted that most vehicle-to-vehicle crashes were rear-end and angle crashes, which typically occurred during the day in higher traffic volume conditions. The authors found that inattention and inadequate surveillance were more common to vehicle-to-vehicle crashes whereas speeding or going too fast for conditions, loss of control, and inadequate or inappropriate vehicle control (e.g., overcorrection) were more common to single-vehicle crashes. Teens and young adults also tend to be more engaged in visual-manual distractions than other drivers (Guo et al., 2017), and distraction can lead to rear-end crashes (Carney, Harland, & McGehee, 2016) and unintentional lane drifts (Peng, Boyle, & Hallmark, 2013; Yekhshatyan & Lee, 2013). Moreover, novice drivers compensate less to adverse road conditions than more experienced drivers, such as by lowering speed to adjust for poorer visibility in fog (Mueller & Trick, 2012).

Although crash avoidance features are designed for drivers of all ages, certain systems address crash scenarios for which teen drivers are especially vulnerable, such as front crash prevention (which addresses rear-end crashes) and lane departure prevention (which addresses lane-drift crashes). There are, however, other technologies available in the market that are designed specifically for teen drivers to address some of their high-risk behaviors. Some of these teen-driver-specific technologies come in the form of in-vehicle technology suites, such as Ford’s MyKey and GM’s Teen Driver systems. Some of these technology suites offer features that always remain on, such as extended seat belt reminders, gearshift or stereo system interlocks that activate when the front occupants are unbelted, volume limits on the stereo system, and navigation system lockout while the vehicle is in gear. These teen driver suites may also have features that limit audio system volume control automatically based on vehicle speed, block cellphone use when connected to the vehicle's Bluetooth, and prevent the driver from disabling certain safety features (e.g., crash avoidance systems). Owners (i.e., the parents) can program a key fob for the teen driver that activates the system's features. Some features allow parents to set vehicle use restrictions or modifications for their teen drivers, such as limiting the top speed of the vehicle or having audible alerts when the vehicle reaches certain set speeds.

Parent involvement (Farah et al., 2013; Klauer, Sayer, Baynes, & Ankem, 2016) and access restrictions (e.g., curfew enforcement; McCartt, Shabanova, & Leaf, 2003) during a teenager's skill acquisition period tend to attenuate risky driving behavior and lower crash risk. In addition to the vehicle technology suites that offer physical restrictions on the teen driver's behavior, there are other teen-driver-specific tools available in the market that enable parents to monitor and coach their teens. These tools include subscription smartphone apps by automakers that connect through the vehicle's infotainment system, such as Hyundai's BlueLink system, as well as third party products that plug into the on-board diagnostics (OBD) port on the vehicle or operate through smartphone apps using GPS and/or accelerometers. These features can provide daily or weekly report cards about the teen driver's behavior or offer real-time alerts relating to, for example, curfew or speeding.

While crash avoidance features and teen-driver-specific technologies are designed to reduce crashes and/or crash severity by mitigating risk-taking behavior or alerting drivers to an imminent crash, it is unclear what their maximum potential safety benefits might be for this at-risk demographic. Using nationwide crash data from the United States, this study calculated the number of crashes involving teen drivers and the number of teen drivers injured and killed in crashes relevant to these features. The purpose of the analysis was to provide an estimate of their maximum potential safety benefit if all vehicles were outfitted with these technologies.

Method

Data

Two national crash databases from NHTSA were used: the Crash Report Sampling System (CRSS) and the Fatality Analysis Reporting System (FARS). The CRSS database is a nationally representative sample of police-reported crashes of all severities involving at least one motor vehicle that represents more than 6 million crashes across the United States every year. The FARS database is a yearly census of motor vehicle crashes that resulted in fatal injuries across the United States.

The analysis was restricted to crashes during 2016–2019 involving passenger vehicle (body types 1 to 49) drivers between the ages of 16 and 19 years old. Crashes were categorized according to their relevance to three crash avoidance features (lane departure warning/prevention, blind spot monitoring, and front crash prevention) and three teen-driver-specific features that are deployed as part of in-vehicle teen monitoring systems or smartphone apps (speeding prevention, nighttime curfew notification, and extended seat belt reminder and interlock features).

Counts and percentages of crashes, driver injuries, and driver deaths were summed per technology type (crash avoidance features vs. vehicle technologies specific to teens) and in total, without double counting, to quantify the maximum safety potential of teen drivers having these systems in their vehicles. The CRSS data were used to extract crashes involving teen drivers and nonfatally injured teen drivers, which was defined as drivers with suspected serious (A) or minor (B) injuries. Teen driver deaths were extracted from the FARS data. CRSS sampling weights were used in those data to generate national estimates. The weighting represented 3,994,056 crashes that involved teen drivers in total (on average, 998,514 per year) and 245,212 injured teen drivers (on average, 61,303 per year). Within the same year range in the FARS database, there were 4,352 teen driver deaths (on average, 1,088 per year).

Analysis

Crash avoidance features

Table 1 contains the variables and definitions of the crash scenarios used in the analysis for all technology types. The CRSS data set handles missing data for some variables by statistically imputing values, which were used when available. Scenarios relevant to crash avoidance features focused on single- and two-vehicle crashes because sequences of events are difficult to determine in crashes with more than two vehicles. Additionally, crashes precipitated by vehicle failures (i.e., blow out, stalled engine, disabling vehicle failure, and nondisabling vehicle problem) were not considered relevant to crash avoidance features, because it is difficult for any driver under those circumstances to perform the maneuvers necessary to avoid crashing.

Table 1. Definitions of crash scenarios.

System	Crash scenario	Scenario definition	CRSS/FARS code[a]
Lane departure prevention	Single-vehicle road departure	Single-vehicle drive off road; critical precrash event of traveling over the lane line or road edge; not passing, overtaking another vehicle, changing lanes, merging, or executing a successful avoidance maneuver to a previous critical event prior to crash; speed limit ≥ 35 mph.	ve_forms=1 and acc_type in (1,6) and p_crash2 in (10,11,12,13) and p_crash1 not in (6,15,16,17) and 35<=vspd_lim<98
	Sideswipe in the same direction	Two-vehicle sideswipe where neither vehicle intended to change lanes; critical precrash event of traveling over the lane line; not passing, overtaking another vehicle, changing lanes, merging, or executing a successful avoidance maneuver to a previous critical event prior to crash; speed limit ≥ 35 mph.	ve_forms=2 and acc_type in (44,45) and acc_type_p in (44,45) and p_crash2 in (10,11) and p_crash1 not in (6,15,16,17) and 35<=vspd_lim<98
	Head-on and opposite direction sideswipe	Two-vehicle head-on collision where the vehicle left the lane; critical precrash event did not involve loss of control due to blow out/flat tire, stalled engine, disabling vehicle failure, or nondisabling vehicle problem; not passing, overtaking another vehicle, changing lanes, merging, or executing a successful avoidance maneuver to a previous critical event prior to crash; speed limit ≥ 35 mph.	ve_forms=2 and acc_type in (50, 64) and p_crash2 not in (1,2,3,4) and p_crash1 not in (6,15,16,17) and 35<=vspd_lim<98

System	Crash scenario	Scenario definition	CRSS/FARS code[a]
Blind spot monitoring	Lane change	Two-vehicle sideswipe where the vehicle was passing, overtaking another vehicle, changing lanes, or merging prior to crash; critical precrash event did not involve loss of control due to blow out/flat tire, stalled engine, disabling vehicle failure, or nondisabling vehicle problem.	ve_forms=2 and acc_type in (46,47) and p_crash2 not in (1,2,3,4) and p_crash1 in (6,15,16)
Front crash prevention	Pedestrian	Single-vehicle crash involving a pedestrian with frontal point of impact; critical precrash event did not involve loss of control due to blow out/flat tire, stalled engine, disabling vehicle failure, or nondisabling vehicle problem.	ve_forms=1 and per_typ_c=5 and acc_type=13 and impact1 in (11,12,1) and p_crash2 not in (1,2,3,4)
	Rear end	Two-vehicle rear-end where teen's vehicle was the striking vehicle; critical precrash event did not involve loss of control due to blow out/flat tire, stalled engine, disabling vehicle failure, or nondisabling vehicle problem.	ve_forms=2 and ((acc_type in (20,24,28)) or (acc_type in (32,33) and impact1 in (11,12,1) and impact1_p in (5,6,7)) and p_crash2 not in (1,2,3,4)
Speeding prevention	Speeding was a factor	Driver was racing, exceeded speed limit, was traveling too fast for conditions, or speeding with specifics unknown as reported by law enforcement.	speedrel in (2,3,4,5)
Nighttime curfew notification	Occurred at night	Time of crash from 9:00 p.m. to 5:59 a.m.	$0 \leq hour \leq 5$ or $21 \leq hour \leq 23$
Extended seat belt reminders and interlocks	Driver was unbelted	Driver did not use restraint or use was not applicable.	(year=2016 and rest_use in (0,7)) or ($2017 \leq year \leq 2019$ and rest_use=20)

[a] Coded in terms of teen driver or teen's vehicle unless otherwise noted. "_p" signifies partner vehicle in crash; "_c" signifies a person of this type was involved in the crash.

Note: More information on crash type configurations for the acc_type variable can be found at in the *2019 FARS/CRSS Coding and Validation Manual* (National Center for Statistics and Analysis, 2020).

Crash avoidance-relevant scenarios were primarily defined using the crash type variable, which captures information on the vehicle level and considers the movement of both vehicles prior to the crash. Scenarios were further disambiguated using the variables for initial impact point, vehicle movement prior to the critical event of the crash, and critical precrash event.

Lane departure warning/prevention. Lane departure warning or prevention features, also known as lane keeping assistance, use cameras to detect the vehicle's position within the lane lines and help prevent the vehicle from inadvertently departing the lane. The warning-based systems send alerts to the driver to steer the vehicle back into the lane, and lane departure prevention features automatically steer or lightly brake to prevent the vehicle from leaving the lane or to bring it back into the lane if it crosses the line. These systems can potentially prevent single-vehicle road departure, sideswipe, and head-on collisions that result from the vehicle inadvertently drifting out of the lane. This technology typically operates at 35 mph and above, and therefore crash types in this category were restricted to those that occurred on roads with speed limits of a minimum of 35 mph. Relevant crashes further excluded those where the teen passed or overtook another vehicle, changed lanes, merged, or avoided another critical event prior to the crash.

Blind spot monitoring. Blind spot monitoring systems, also known as side-view assistance, alert the driver when another vehicle is detected in their blind spot with the goal of preventing crashes that result from intentional lane changes. This crash category included sideswipe crashes where the teen driver was passing, overtaking, changing lanes, or merging.

Front crash prevention. Front crash prevention, also known as forward collision warning, automatic emergency braking, or autobrake, detects when a collision with a vehicle in front is imminent and alerts the driver or automatically applies the brakes. Relevant crashes included rear-end crashes where the teen's vehicle was the striking vehicle. While most front crash prevention features are designed to detect other vehicles, some are also designed to detect pedestrians. Pedestrian crashes involving a single vehicle with a frontal impact point were also considered relevant to front crash prevention features. Given that pedestrian crash prevention features are primarily designed to prevent or reduce injury to the pedestrian, the analysis only considered pedestrian scenarios on the crash level, not on the teen driver level for injuries or fatalities.

Vehicle technologies designed for teen drivers

Speeding prevention features. Smartphone and vehicle infotainment system apps can alert teens (and parents) whenever the teen driver exceeds the speed limit, exceeds the speed limit by a specific amount set by the parent, or exceeds a speed set by the parent. Some apps also offer parental monitoring through real-time alerts or report cards about the teen's speeding behavior. A few automakers offer vehicle features that parents can program, such as speed limiters. Crashes relevant to these systems were those where the teen driver's speeding, racing, exceeding the speed limit, or going too fast for conditions contributed to the crash.

Nighttime curfew violation notification features. Some smartphone apps offer parental monitoring through location tracking with departure and arrival notifications that can alert the parent when the teen driver is operating the vehicle after curfew. As graduated driver licensing laws vary across states (IIHS, 2021b), crash outcomes were examined for different curfew starting times beginning at 9:00 p.m., 10:00 p.m., 11:00 p.m., or 12:00 a.m. and ending at 5:59 a.m. Most GDL laws in the U.S. are lifted by the time drivers reach 18 years of age (IIHS, 2021b), and therefore this analysis was restricted to 16- and 17-year-olds.

Extended seat belt reminder and interlock features. While seat belt reminder and interlock features cannot prevent crashes, they have the potential to reduce injury severity and death of vehicle occupants by encouraging seat belt use. Extended seat belt reminders deliver alerts for a certain duration if a front-seat occupant is unbelted while the ignition is on. Some features, such as Ford's Belt-Minder feature in their teen driver MyKey system, also use other strategies to enhance the salience of the alerts, such as lowering the stereo system volume or turning it off completely while the front occupants are unbelted. GM's Buckle to Drive system offers a gearshift interlock while the Teen Driver mode is active. If the driver turns on the ignition and remains unbuckled, the interlock will not allow the vehicle to be put into gear for a maximum of 20 seconds while the driver is unbelted. The purpose of this analysis was to highlight the percentages of teen drivers with nonfatal and fatal injuries who were unbelted.

Results

Crashes relevant to crash avoidance features

Single-vehicle road departure, sideswipe, and head-on collisions due to lane departures were combined to calculate the number of lane departure warning/prevention-relevant crashes. Although a small percent of these scenarios was represented among crashes involving teen drivers (6%), they were relevant to 17% and 34% of injured teen drivers and fatalities, respectively (Table 2). Crash scenarios relevant to blind spot monitoring features were represented in only a small percent of crashes. Approximately 3% of crashes involving teen drivers, 1% of injured teen drivers, and 0.4% of teen driver deaths were relevant to blind spot monitoring features.

Table 2. Average annual teen driver crash outcomes relevant to crash avoidance features, 2016–2019.

Crash avoidance feature	Crash scenario	Crashes involving a teen driver *n* per year	Teen drivers with serious or minor injuries (A or B) [a] *n* per year	Teen drivers with fatal injuries *n* per year
Lane departure prevention	Single vehicle road departure	47,349 (5%)	8,933 (15%)	243 (22%)
	Same direction sideswipe	4,041 (0.4%)	65 (0.1%)	2 (0.2%)
	Head-on/opposite direction sideswipe	6,048 (1%)	1,194 (2%)	125 (12%)
	Total potentially prevented by lane departure prevention	57,438 (6%)	10,191 (17%)	370 (34%)
Blind spot monitoring	Lane change	32,766 (3%)	604 (1%)	5 (0.4%)
Front crash prevention	Pedestrian	3,716 (0.4%)	N/A	N/A
	Rear end	221,034 (22%)	5,659 (9%)	17 (2%)
	Total potentially prevented by front crash prevention	224,750 (23%)	5,659 (9%)	17 (2%)

[a] Serious (A) or minor (B) injuries as defined in the Crash Report Sampling System (CRSS) data.

Twenty-three percent of crashes involving teen drivers, 9% of injured teen drivers, and 2% of teen driver deaths were relevant to front crash prevention (Table 2). We separated the data to identify pedestrian crashes with involving teen drivers and found that only 0.4% of crashes were relevant to pedestrian front crash prevention.

Crashes relevant to vehicle technologies designed for teen drivers

A teen driver speeding was a related factor in 11% of all crashes (Table 3). Nineteen percent of teen drivers injured in crashes and 39% of teen driver deaths involved speeding. Nighttime crashes represented 13% of crashes involving teen drivers (ages 16 and 17 years only), and 19% of injured teen drivers and 32% of teen driver deaths occurred at night between 9:00 p.m. and 5:59 a.m. The same pattern persisted for different curfew windows, but earlier curfew start times captured more crashes, injured teen drivers, and teen driver fatalities. We used the largest curfew window of 9:00 p.m. and 5:59 a.m. to calculate the total maximum potential safety benefits of the teen systems listed in Table 3. Failure of the driver to wear a seat belt was represented in a substantially greater percent of teen driver deaths (43%) than injured teen drivers (8%).

Table 3. Average annual teen driver crash outcomes relevant to technologies designed for teen drivers, 2016–2019.

Technologies specific to teen drivers	Crash scenarios	Crashes involving a teen driver	Teen drivers with serious or minor injuries (A or B) [a]	Teen drivers with fatal injuries
		n per year	*n* per year	*n* per year
Speeding prevention	Speeding was a factor	105,982 (11%)	11,376 (19%)	422 (39%)
Nighttime curfew violation notification (16- and 17-year-olds only)	Occurred at night between:			
	9:00 p.m. to 5:59 a.m.	50,955 (13%)	4,157 (19%)	116 (32%)
	10:00 p.m. to 5:59 a.m.	34,130 (9%)	2,812 (13%)	97 (27%)
	11:00 p.m. to 5:59 a.m.	21,092 (5%)	1,944 (9%)	78 (22%)
	12:00 a.m. to 5:59 a.m.	14,482 (4%)	1,310 (6%)	62 (17%)
Extended seat belt reminders and interlocks	Driver was unbelted	N/A	5,203 (8%)	468 (43%)

[a] Serious (A) or minor (B) injuries as defined in the Crash Report Sampling System (CRSS) data.

Total maximum potential safety benefit

Across all the crash avoidance features, 32% of crashes involving a teen driver, 27% of injured teen drivers, and 36% of teen driver deaths were relevant (see Table 4). Fifteen percent of crashes involving a teen driver, 29% of injured teen drivers, and 66% of teen driver deaths were relevant to technologies specific to the teen. In total, 41% of crashes involving a teen driver, 47% of injured teen drivers, and 78% of teen driver deaths were relevant to all of the technologies combined.

Table 4. Average annual teen driver crash outcomes relevant to crash avoidance features and technologies specific to teen drivers combined, 2016–2019.

	Crashes involving a teen driver	Teen drivers with serious or minor injuries (A or B) [a]	Teen drivers with fatal injuries
	n per year	*n* per year	*n* per year
All crash avoidance features	314,955 (32%)	16,455 (27%)	392 (36%)
All technologies specific to teen drivers	150,370 (15%)	17,741 (29%)	717 (66%)
Total vehicle technologies	408,041 (41%)	29,017 (47%)	846 (78%)

[a] Serious (A) or minor (B) injuries as defined in the Crash Report Sampling System (CRSS) data.

Discussion

Teen drivers are at risk for crashes involving risky behavior and errors in vehicle control. This study demonstrates that many of those crashes are relevant to current vehicle technologies that have the potential to prevent crashes and reduce crash severity. Front crash prevention, lane departure prevention, and blind spot monitoring features altogether could be relevant to approximately a quarter of injured teen drivers and a third of teen driver deaths. Vehicle features and smartphone apps that are designed specifically for teen drivers could be applicable to almost a third of injured teen drivers and up to two thirds of teen driver deaths. All of these technologies combined could potentially be relevant to up to half of injured teen drivers and three quarters of teen driver deaths, which represents opportunities to improve the safety outlook for these vulnerable drivers.

An important caveat to these findings is that the estimates represent the maximum potential benefits for teen drivers with the assumption that these technologies would work perfectly and prevent all relevant crashes, which current technologies do not. Actual effect estimates from the general population have been calculated for crash avoidance and other technologies (Cicchino, 2017, 2018a, 2018b; Farmer & Wells, 2010; Fildes et al., 2015; Isaksson-Hellman & Lindman, 2016; Sternlund, Strandroth, Rizzi, Lie, & Tingvall, 2017). For example, Cicchino (2017, 2018a, 2018b) demonstrated that lane departure warning and blind spot monitoring were associated with reductions in crash rates for relevant crash types of 11% and 14%, respectively, and automatic emergency braking reduced rear-end crash rates by 50%. If these effects were applied to the number of system-relevant crashes involving teen drivers, they would result in nearly 6,500 teen crashes prevented annually by lane departure warning, more than 4,500 prevented by blind spot monitoring, and over 110,000 prevented by automatic emergency braking. The safety effects of these technologies for teen drivers specifically are unknown, although front crash prevention and lane departure warning have shown the greatest benefits in lowering insurance claims (HLDI, 2020a, 2021a) and police-reported rear-end crashes (Spicer, et al., 2021) for drivers 24 years old and under compared with other age groups.

Another issue when assessing the potential safety benefits of these features is that they must be used in order to have an effect, yet teen drivers tend to drive older vehicles that do not have the latest crashworthiness and crash avoidance features (Eichelberger, Teoh, & McCartt, 2015; Metzger, Sartin, Foss, Joyce, & Curry, 2020). Although their parents are far more likely to own newer vehicles, which are more likely to be equipped with driver assistance features, many people do not realize that their vehicles might have technologies that are designed specifically to help teen drivers. In a survey of parents of teen drivers who own MyKey-equipped Ford vehicles, Weast (2018) found that just over half were aware that their vehicles were equipped with the technology suite, and only a third reported using it with their teen drivers. Many parents who knew about the MyKey system in their vehicles but did not use it reported that their teen driver did not drive the vehicle enough to justify using the system, they trusted their teen to drive safely without the system, they did not see the safety benefits of the system, or they did not know how or have the time to set up the system.

Parental attitudes about the technology will influence the likelihood of those features being used by teens at the beginning of their learning-to-drive phase when they are most likely driving their parents' vehicles. In a focus group study by Weast, Mueller, and Kolodge (2021), parents who owned vehicles equipped with crash avoidance features and had teenage drivers in their households often expressed concerns about the effects that these technologies might have on their teens' skill acquisition, despite unanimous acknowledgement of their potential safety benefits. Many parents worried about distraction from system notifications and the risk that their teens would develop incomplete driving skills by becoming overreliant on the features. Some parents were so concerned that they reported disabling certain features until they felt their teens were more experienced and ready for the driving assistance. These concerns highlight the need for more research to understand the behavioral effects of crash avoidance features among teen drivers. For example, Jermakian, Bao, Buonarosa, Sayer, and Farmer (2017) observed mixed effects of exposure to forward collision warning and lane departure warning among teenage drivers, with fewer lane departures and unsignaled lane changes but also shorter following distances over time.

As is the case for drivers of all ages (Jermakian, 2011), the potential safety benefit of lane departure prevention for teens is substantial with respect to reducing severe crashes. The data also revealed that over a fifth of crashes involving teen drivers were rear-end crashes, and front crash prevention appears to have a greater potential safety benefit for teen driver injury reduction than fatality reduction. However, it should be noted that 8% of fatal crashes involving teen drivers during the study period were relevant to front crash prevention with pedestrian detection (not reported in the Results), which highlights its benefits for nonmotorized road users. Only a small percent of crashes was relevant to blind spot monitoring, but that does not undermine the utility of the system as blind spot monitoring remains one of the most highly rated and widely used driver assistance features on the market (J.D. Power, 2017; Reagan, Cicchino, Kerfoot, & Weast, 2018).

Speeding is overrepresented in teen driver deaths and crashes relative to drivers of other age groups (IIHS, 2021b; NHTSA, 2020b). This study found that speeding contributed to almost 40% of teen driver deaths and approximately one fifth of injured teen drivers, underscoring the importance of speeding prevention technologies as some vehicle or smartphone app alerts have already been shown to have speed control benefits (Creaser, Morris, Edwards, Manser, Cooper, et al., 2015; Farmer, Kirley, & McCartt, 2010; Peer, Muermann, & Sallinger, 2020). A limitation is that our definition of speeding included crashes where the driver was coded as traveling “too fast for conditions,” which may not necessarily be captured by current speeding prevention technologies. We elected to keep these crashes as speeding-related because it was unclear how many of these crashes represented a lack of caution in adverse conditions as opposed to exceeding the speed limit or aggressive driving. However, that category highlights an important aspect that ought to be further developed for teen-driver-specific speeding prevention features beyond merely restricting driving speed to the speed limit. Ideally, speeding prevention should be sophisticated enough to encourage speed control adaptation in response to adverse road conditions, such as by encouraging drivers to slow down in inclement weather.

Crashes associated with noncompliance to traffic and GDL laws show the need for teen-driver-specific vehicle technologies. Over 40% of teen driver deaths occurred in crashes where the driver was not wearing a seat belt, whereas failure to wear a seat belt was associated with a much smaller percent of injured teen drivers. NHTSA (2020a) estimated that seat belts reduce fatal injuries to front-seat occupants by 45–60%. Using the equation proposed by Evans (1991), we estimate the lives of 97 to 166 teenage drivers could be saved every year if belt use increased from 88% (the observed rate among 16- to 24-year-old front-seat occupants in 2019; Enriquez, 2020) to 100%. The observed noncompliance with seat belt laws reinforces the importance of driver assistance features that encourage seat belt use, such as gearshift interlocks (Kidd, Singer, Huey, & Kerfoot, 2018) and extended and escalating seat belt reminder technologies (Kidd & Singer, 2019), both of which promote greater adherence for seat belt use than conventional reminders. The present analysis also shows that curfews with earlier starting hours would be most beneficial for 16- and 17-year-old drivers, as a fifth of injured 16- and 17-year-old drivers and a third of their deaths occurred between 9:00 p.m. and 5:59 a.m. These findings support the need to establish earlier curfew restrictions through GDL programs in every state, as each additional hour of nighttime driving restriction results in lower fatal crash rates for teens (McCartt, Teoh, Fields, Braitman, & Hellinga, 2010).

Seat belt, curfew, and speed compliance among teen drivers could be better enforced through parent involvement via vehicle and smartphone features (Curry, Peek-Asa, Hamann, & Mirman, 2015; Simons-Morton & Ouimet, 2006; Simons-Morton, Ouimet, & Catalano, 2008), but all teen-driver-specific technologies will have limited effect if parents do not reinforce traffic laws and GDL restrictions and actively address risk-taking behavior during the beginning of the learning-to-drive phase (Klauer et al., 2017). Parental involvement may not be feasible for older teens when they are no longer living in their parents' households, however. This underscores the importance of other vehicle technologies that encourage safer driving behavior for the general population through direct behavioral intervention, such as crash avoidance features, extended seat belt reminders, and intelligent speed assistance.

There are several limitations of this study. The analysis assumed optimal performance of the crash avoidance features in their relevant crash scenarios, but these systems currently perform better in some situations than in others in the real world; for example, front crash prevention with autobrake is adversely affected in inclement weather conditions, such as snow or rain (Cicchino & Zuby, 2019; Spicer et al., 2021). A commonplace vehicle technology that can also affect the performance of these systems is headlamps. Headlamps affect the effectiveness of camera-based systems under low light conditions, such as front crash prevention and lane departure prevention, and headlamp performance also varies between vehicle makes and models (IIHS, 2021a). The safety benefits of the crash avoidance features are likely to improve towards their maximum potential as vehicle design and system capability are refined.

Another limitation of this analysis is that it did not include an exhaustive list of currently available technologies that are relevant to teen driver safety. For example, teen drivers are particularly at risk for distraction (Curry, Hafetz, Kallan, Winston, & Durbin, 2011), such as from cell phone use (Wenners, Knodler, Kennedy, & Fitzpatrick, 2013). Although cell phone blockers have been shown to effectively reduce teen driver phone conversations and texting (Creaser, Morris, Edwards, Manser, & Donath, 2015), driver cell phone use at the time of the crash is difficult to reliably extract from crash data, thereby limiting the ability to calculate the maximum potential safety benefits of such technologies.

Conclusions

There are numerous tools on the market that have the potential to help improve the safety of teen drivers. The aim of this study was to identify the maximum potential safety benefits of vehicle technologies and smartphone apps that are designed for adolescent drivers as well as crash avoidance features that address the crash scenarios for which these drivers are particularly at risk. The data emphasize the importance of their use and acceptance among teen drivers and their parents in order for these safety benefits of crash and injury severity reduction to be realized.

Practical Applications

Lack of accessibility, acceptance, and use are barriers to reaching the maximum potential safety benefits of these technologies. As various technologies address different risk factors and crash types, more manufacturers ought to offer teen-driver-specific technology suites that integrate crash avoidance systems and other safety features, such as speeding prevention and extended seat belt reminders. Clear advertising and consumer education about these technologies are needed to reach wider audiences of parents and teens. In addition, more research on the behavioral implications of these technologies is required to understand whether they have any unintended consequences for young inexperienced drivers that might not emerge among the general population.

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References

Braitman, K., Kirley, B., McCartt, A., & Chaudhary, N. (2008). Crashes of novice teenage drivers: Characteristics and contributing factors. *Journal of Safety Research, 39*, 47–54. doi:10.1016/j.jsr.2007.12.002.

Carney, C., Hardland, K., & McGehee, D. (2016). Using event-triggered naturalistic data to examine the prevalence of teen driver distractions in rear-end crashes. *Journal of Safety Research, 57*, 46–52. doi:10.1016/j.jsr.2016.03.010

Carney, C., McGehee, D., & Harland, K. (2015). *Using naturalistic driving data to assess the prevalence of environmental factors and driver behaviors in teen driver crashes.* Washington, DC: AAA Foundation for Traffic Safety.

Carpenter, D., & Pressley, J. (2013). Graduated driver license nighttime compliance in U.S. teen drivers involved in fatal motor vehicle crashes. *Accident Analysis & Prevention, 56*, 110–117. doi:10.1016/j.aap.2011.12.014

Carpenter, C., & Stehr, M. (2008). The effects of mandatory seat belt laws on seat belt use, motor vehicle fatalities, and crash-related injuries among youths. *Journal of Health Economics, 27*, 642–662. doi:10.1016/j.jhealeco.2007.09.010

Cicchino, J. (2017). Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates. *Accident Analysis & Prevention, 99*(Part A), 142–152. doi:10.1016/j.aap.2016.11.009

Cicchino, J. (2018a). Effects of blind spot monitoring systems on police-reported lane-change crashes. *Traffic Injury Prevention, 19*, 615–622. doi:10.1080/15389588.2018.1476973

Cicchino, J. (2018b). Effects of lane departure warning on police-reported crash rates. *Journal of Safety Research, 66*, 61–70. doi:0.1016/j.jsr.2018.05.006

Cicchino, J., & Zuby, D. (2019). Characteristics of rear-end crashes involving passenger vehicles with automatic emergency braking. *Traffic Injury Prevention, 20,* S112–S118. doi:10.1080/15389588.2019.1576

Creaser, J., Morris, N., Edwards, C., Manser, M., Cooper, J., Swanson, B., & Donath, M. (2015). *Teen driver support system (TDSS) field operational test* (Report No. CTS 16-04). Minneapolis, MN: University of Minnesota Center for Transportation Studies.

Creaser, J., Morris, N., Edwards, C., Manser, M., & Donath, M. (2015). Are cellular phone blocking applications effective for novice teen drivers? *Journal of Safety Research,* 75.e29–78. doi:10.1016/j.jsr.2015.06.014

Curry, A., Hafetz, J., Kallan, M., Winston, F., & Durbin, D. (2011). Prevalence of teen errors leading to serious motor vehicle crashes. *Accident Analysis & Prevention, 43,* 1285–1290. doi:10.1016/j.aap.2010.10.019

Curry, A., Peek-Asa, C., Hamann, C., & Mirman, J. (2015). Effectiveness of parent-focused interventions to increase teen driver safety: A critical review. *Journal of Adolescent Health, 57*(1 Suppl), S6–S14. doi:10.1016/j.jadohealth.2015.01.003

Eichelberger, A., Teoh, E., & McCartt, A. (2015). Vehicle choices for teenage drivers: A national survey of U.S. parents. *Journal of Safety Research, 55*, 1–5. doi:10.1016/j.jsr.2015.07.006

Enriquez, J. (2020). *Occupant restraint use in 2019: Results from the NOPUS controlled intersection study* (Report No. DOT HS 812 992). Washington, DC: National Highway Traffic Safety Administration.

Evans, L. (1991). *Traffic safety and the driver*. New York: Van Nostrand Reinhold.

Farah, H., Musicant, O., Shimshoni, Y., Toledo, T., Grimberg, E., Omer, H., & Lotan, T. (2013). The first year of driving: Can an in-vehicle data recorder and parental involvement make it safer? *Transportation Research Record, 2327,* 26–33. doi:10.3141/2327-04

Farmer, C., Kirley, B., & McCartt, A. (2010). Effects of in-vehicle monitoring on the driving behavior of teenagers. *Journal of Safety Research, 41,* 39–45. doi:10.1016/j.jsr.2009.12.002

Farmer, C., & Wells, J. (2010). Effect of enhanced seat belt reminders on driver fatality risk. *Journal of Safety Research, 41*, 53–57. doi:10.1016/j.jsr.2009.11.001

Ferguson, S., Teoh, E., & McCartt, A. (2007). Progress in teenage crash risk during the last decade. *Journal of Safety Research, 38*, 137–145. doi:10.1016/j.jsr.2007.02.001

Fildes, B., Keall, M., Box, N., Lie, A., Page, Y., Pastor, C., Pennisi, L., Rizzi, M., Thomas, P., & Tingvall, C. (2015). Effectiveness of low speed autonomous emergency braking in real-world rear-end crashes. *Accident Analysis & Prevention, 81*, 24–29. doi:10.1016/j.aap.2015.03.029

Guo, F., Klauer, S., Fang, Y., Hankey, J., Antin, J., Perez, M., Lee, S., & Dingus, T. (2017). The effects of age on crash risk associated with driver distraction. *International Journal of Epidemiology, 46*, 258–265. doi:10.1093/ije/dyw234

Highway Loss Data Institute. (2020a). Compendium of HLDI collision avoidance research. *HLDI Bulletin, 37*(12), 1–29.

Highway Loss Data Institute. (2020b). IIHS crashworthiness evaluation programs and the U.S. vehicle fleet—a 2020 update. *HLDI Bulletin, 37*(10), 1–12.

Highway Loss Data Institute. (2020c). Predicted availability and prevalence of safety features on registered vehicles—a 2020 update. *HLDI Bulletin, 37*(11), 1–14.

Highway Loss Data Institute. (2021a). Impact of Honda Accord collision avoidance features on claim frequency by rated driver age. *Bulletin, 38*(13), 1–12.

Highway Loss Data Institute. (2021b). Impact of Kia Drive Wise collision avoidance features on insurance losses by rated driver age. *Bulletin, 38*(14), 1–9.

Insurance Institute for Highway Safety. (2021a). *About our tests: Headlight evaluation*. Retrieved on June 8, 2021, from https://www.iihs.org/ratings/about-our-tests#headlight-evaluation

Insurance Institute for Highway Safety. (2021b). *Teenagers: Graduated licensing*. Retrieved on April 29, 2021, from https://www.iihs.org/topics/teenagers

Isaksson-Hellman, I., & Lindman, M. (2016). Evaluation of the crash mitigation effect of low-speed automated emergency braking systems based on insurance claims data. *Traffic Injury Prevention, 17(Suppl 1)*, 42–47. doi:10.1080/15389588.2016.1186802

J.D. Power. (2017). *Non-premium vehicles provide same tech experience as premium vehicles, J.D. Power Finds* [Press Release]. Retrieved from https://www.jdpower.com/business/press-releases/2017-tech-experience-index-txi-study

Jermakian, J. (2011). Crash avoidance potential of four passenger vehicle technologies. *Accident Analysis & Prevention, 43*, 732–740. doi:10.1016/j.aap.2010.10.020

Jermakian, J., Bao, S., Buonarosa, M., Sayer, J., & Farmer, C. (2017). Effects of an integrated collision warning system on teenage driver behavior. *Journal of Safety Research, 61*, 65–75. doi:10.1016/j.jsr.2017.02.013

Kidd, D., & Singer, J. (2019). The effects of persistent audible seat belt reminders and a speed-limiting interlock on the seat belt use of drivers who do not always use a seat belt. *Journal of Safety Research, 71,* 13–24. doi:10.1016/j.jsr.2019.09.005

Kidd, D., Singer, J., Huey, R., & Kerfoot, L. (2018). The effect of a gearshift interlock on seat belt use by drivers who do not always use a belt and its acceptance among those who do. *Journal of Safety Research, 65*, 39–51. doi:10.1016/j.jsr.2018.03.005

Klauer, C., Ankem, G., Guo, F., Baynes, P., Fang, Y., Atkins, W., Baker, S., Duke, R., Hankey, J., & Dingus, T. (2017). *Driver coach study: Using real-time and post hoc feedback to improve teen driving habits*. Blacksburg, VA: Virginia Tech Transportation Institute.

Klauer, C., Sayer, T., Baynes, P., & Ankem, G. (2016). Using real-time and post hoc feedback to improve driving safety for novice drivers. *Proceedings of the Human Factors and Ergonomics Society, 60*(1)*,* 1936–1940. doi:10.1177/1541931213601441

Lee, S., Klauer, S., Olsen, E., Simons-Morton, B., Dingus, T., Ramsey, D., & Ouimet, M. (2008). Detection of road hazards by novice teen and experienced adult drivers. *Transportation Research Record, 2078*, 26–32. doi:10.3141/2078-04

Loeb, H., Kandadai, V., McDonald, C., & Winston, F. (2015). Emergency braking in adults versus novice teen drivers: Response to simulated sudden driving events. *Transportation Research Record, 2516*, 8–14. doi:10.3141/2516-02

McCartt, A., Mayhew, D., Braitman, K., Ferguson, S., & Simpson, H. (2009). Effects of age and experience on young driver crashes: Review of recent literature. *Traffic Injury Prevention, 10*, 209–2019. doi:10.1080/15389580802677807

McCartt, A., Shabanova, V., & Leaf, W. (2003). Driving experience, crashes and traffic citations of teenage beginning drivers. *Accident Analysis & Prevention, 35*, 311–320. doi:10.1016/s0001-4575(02)00006-4

McCartt, A., & Teoh, E. (2015). Tracking progress in teenage driver crash risk in the United States since the advent of graduated driver licensing programs. *Journal of Safety Research, 53*, 1–9. doi:10.1016/j.jsr.2015.01.001

McCartt, A., Teoh, E., Fields, M., Braitman, K., & Hellinga, L. (2010). Graduate licensing laws and fatal crashes of teenage drivers: A national study. *Traffic Injury Prevention, 11*, 240–248. doi:10.1080/15389580903578854

Metzger, K., Sartin, E., Foss, R., Joyce, N., & Curry, A. (2020). Vehicle safety characteristics in vulnerable driver populations. *Traffic Injury Prevention, 27*, 1–6. doi:10.1080/15389588.2020.1805445

Mueller, A. & Trick, L. (2012). Driving in fog: The effects of driving experience and visibility on speed compensation and hazard avoidance. *Accident Analysis & Prevention, 48*, 472–479. doi:10.1016/j.aap.2012.03.003

National Center for Statistics and Analysis. (2020). *2019 FARS/CRSS coding and validation manual* (Report No. DOT HS 813 010). Washington, DC: National Highway Traffic Safety Administration.

National Highway Traffic Safety Administration. (2020a). *Traffic safety facts: Occupant protection 2018 data*. Retrieved on April 29, 2021, from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812967

National Highway Traffic Safety Administration. (2020b). *Traffic safety facts: Young drivers 2018 data*. Retrieved on April 29, 2021, from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812968

Peer, S., Muermann, A., & Sallinger, K. (2020). App-based feedback on safety to novice drivers: Learning and monetary incentives. *Transportation Research Part F, 71*, 198–219. doi:10.1016/j.trf.2020.04.005

Peng, Y., Boyle, L., & Hallmark, S. (2013). Driver's lane keeping ability with eyes off road: Insights from a naturalistic study. *Accident Analysis & Prevention, 50*, 628–634. doi:10.1016/j.aap.2012.06.013

Reagan, I., Cicchino, J., Kerfoot, L., & Weast, R. (2018). Crash avoidance and driver assistance technologies—Are they used? *Transportation Research Part F, 52*, 176–190. doi:10.1016/j.trf.2017.11.015

Rice, T., Peek-Asa, C., & Kraus, F. (2003). Nighttime driving, passenger transport, and injury crash rates of young drivers. *Injury Prevention, 9*, 245–250. doi:10.1136/ip.9.3.245

Shope, J., & Bingham, R. (2008). Teen driving: Motor-vehicle crashes and factors that contribute. *American Journal of Preventative Medicine, 35*, S261–S271.

Simons-Morton, B., & Ouimet, M. (2006). Parent involvement in novice teen driving: A review of the literature. *Injury Prevention, 12*(Suppl 1), i30–i37. doi:10.1136/ip.2006.011569

Simons-Morton, B., Ouimet, M., Catalano, R. (2008). Parenting and the young driver problem. *American Journal of Preventative Medicine, 35(3 Suppl)*, S294–S303.

Spicer, R., Vahabaghaie, A., Murakhovsky, D., St. Lawrence, S., Drayer, B., & Bahouth, G. (2021). *Do driver characteristics and crash conditions modify the effectiveness of automatic emergency braking?* SAE Technical Paper 2021-01-0874). Warrendale, PA: SAE International.

Sternlund, S., Strandroth, J., Rizzi, M., Lie, A., & Tingvall, C. (2017). The effectiveness of lane departure warning systems-A reduction in real-world passenger car injury crashes. *Traffic Injury Prevention, 18*, 225–229. doi:10.1080/15389588.2016.1230672

Weast, R. (2018). *Parent awareness and use of Ford's MyKey system*. Arlington, VA: Insurance Institute for Highway Safety.

Weast, R., Mueller, A., & Kolodge, K. (2021). *Learning to drive: Parental attitudes toward introducing teen drivers to advanced driver assistance systems*. Arlington, VA: Insurance Institute for Highway Safety.

Wenners, K., Knodler, M., Kennedy, J., & Fitzpatrick, C. (2013). Large-scale observational study of drivers' cell phone use. *Transportation Research Record, 2365*, 49–57. doi:10.3141/2365-07

Williams, A. (2017). Graduated driver licensing (GDL) in the United States in 2016: A literature review and commentary. *Journal of Safety Research, 63*, 29–41. doi:10.1016/j.jsr.2017.08.010

Yekhshatyan, L., & Lee, J. (2013). Changes in the correlation between eye and steering movements indicate driver distraction. *IEEE Transactions on Intelligent Transportation Systems, 14*(1), 136–145. doi:10.1109/TITS.2012.2208223