NATIONAL DISTRACTED DRIVING COALITION

How Technology Can Help Reduce Driver Distraction

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NATIONAL DISTRACTED DRIVING COALITION (NDDC)

The National Distracted Driving Coalition (NDDC) was formed in March 2021 to address distracted driving which is a contributing factor to road deaths and injuries. This road safety issue is a priority concern shared by many organizations across many sectors. A diverse cross-section of entities, representing academia, non-profits, government, advocacy, and industry, including insurance, transportation, automotive and technology, have come together to create a National Action Plan to tackle this important issue.

Vision

To accelerate national efforts to implement effective interventions and encourage attentive driving by eliminating distractions.

Mission

To promote innovative and collaborative approaches to create a traffic safety culture of attentive drivers.

Disclaimer

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usnddc.org/wp-content/uploads/2022/05/NDDC-Steering-Committee-16.pdf

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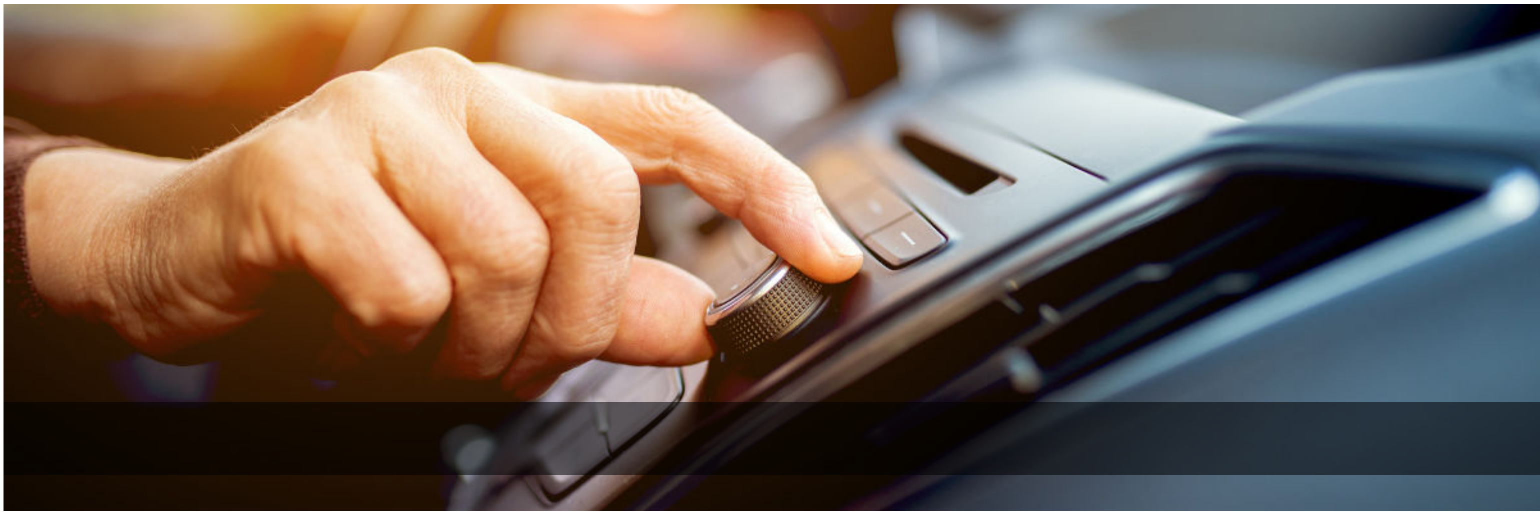
Introduction

Distracted driving, which is risky for all drivers, is a specific case of inattention when non-driving tasks capture the driver's attention such that the driver becomes oblivious to the road and traffic events (Gershon et al., 2019). From the latest National Highway Traffic Safety Administration (NHTSA) reports, we learn that in 2020 alone in the United States, over 300,000 people were injured and more than 3,000 were killed in crashes related to distracted driving (Stewart, 2022, NCSA, 2022). While these are the official numbers, the extent to which distracted driving contributes to the occurrences of crashes is likely underreported. Distracted driving and the resulting crash risk may vary depending on a wide range of factors related to the style of driving, the type of task, driver characteristics, driving environment, and the vehicle where driving automation features and active safety systems are assisting the driver and reducing workload (Gershon et al., 2017; Norman, 1990).

To prevent crashes, injuries, and deaths, distraction while driving should be minimized. Minimizing driver distraction is particularly relevant in light of the technological and digital transformations of infotainment and other in-vehicle systems. Following the key design principles of simplicity and familiarity can make infotainment systems and other non-driving-related activities less confusing to drivers, and less demanding (Strayer et al., 2019). Both NHTSA (2013) and the Alliance of Automobile Manufacturers (2006) specify limits on the visual demands of in-vehicle infotainment systems. Both use tuning a radio as a test criterion because of the prevalence of radio tuning in vehicles, because radio tuning was available in vehicles before the digital age, and because the distraction resulting from radio tuning was considered reasonable for a driver to experience while driving.



However, there are limitations to the application of these guidelines. First, the guidelines do not account for the visual demands of short tasks performed in sequence. Antecedent and dependent tasks linked together (Angell et al., 2013) can lead to extended total eyes off-road time durations. Second, the guidelines do not account for the visual demands of a short task performed in repetition. Third, they do not address drivers looking for the next best available option in a list of items (e.g., looking through previous items in a music playlist) when the list is truncated to meet the guideline criteria. For instance, a Google study found that users do not stop browsing Android Auto™ when they reach the end of a list, and instead look for the next best available option. Finally, placing restrictions on infotainment system design may lead drivers to use their smartphones instead to complete a task, which may come with a higher risk (Dingus et al., 2016, 2019). As such, a holistic approach to minimizing driver distraction is needed.

Recent and emerging technological advancements offer many new ways to mitigate driver distraction. The current report summarizes existing approaches and technologies that can mitigate driver distraction

Policies and regulations should be an integral part of the development of driving automation and be built from the ground up to foster innovation and guide implementation without restricting progression.

and provides a road map to guide future research and the development of new approaches needed to monitor, manage, and motivate drivers to effectively collaborate with the automation and avoid distracted driving. The opportunity to develop technology-based countermeasures for distracted driving as part of the development of driving automation calls for policies and regulations that will foster innovation and guide implementation without restricting progression. These approaches should be an integral part of the automation and be built from the ground up.

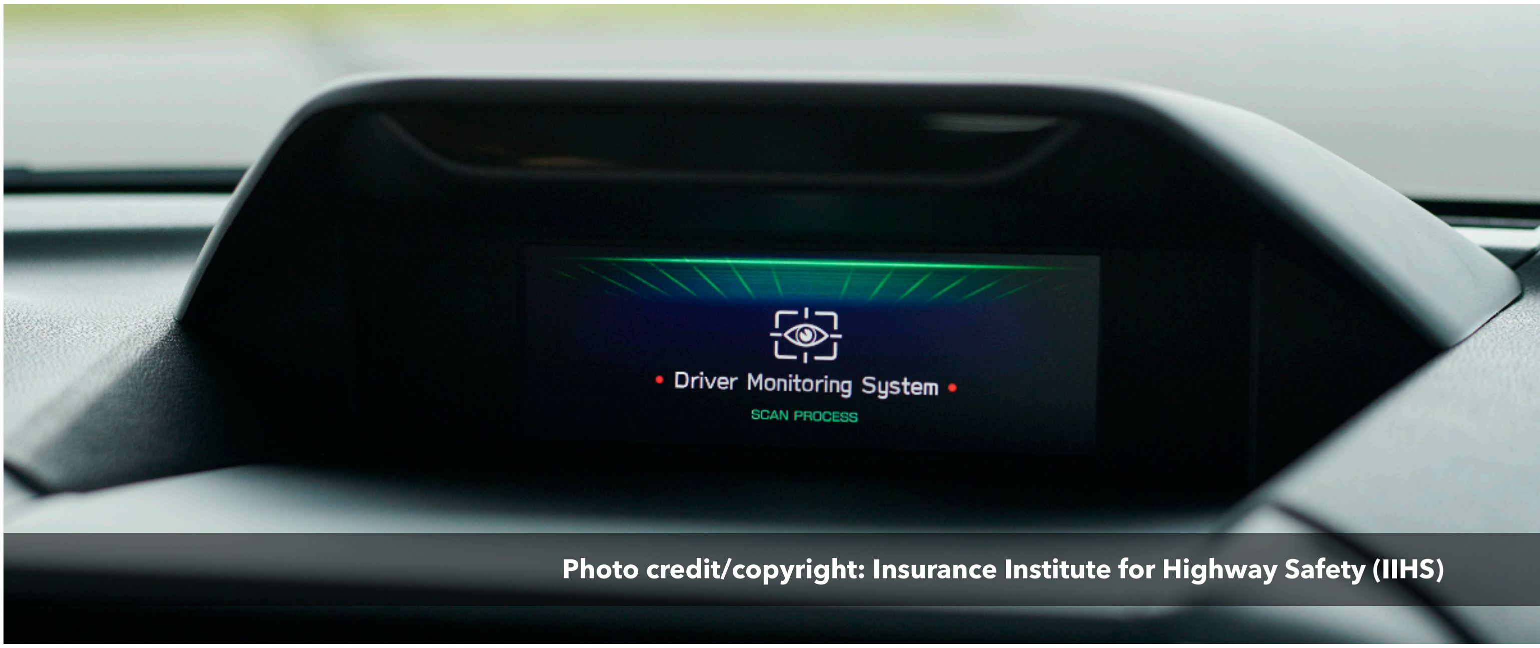
Technologies to mitigate distracted driving

Monitoring-based prevention

Driver-monitoring systems (DMS) typically use a camera mounted on the dashboard or steering column (i.e., a pillar or inside the rear view mirror) to track driver distraction and/or drowsiness. The systems alert the driver to look back at the road if the driver is detected to be looking away from the road for an extended period of time. DMS with indirect driver monitoring infer driver state using vehicle control measures (e.g., steering or throttle inputs), duration of driving, and other inputs. Direct driver monitoring relies on camera-based methods, which affords a greater level of specificity in identifying risky behaviors and driver states. Research on direct monitoring approaches has informed the development of European Commission regulations mandating this type of technology in future years (Hynd et al., 2015). These 'direct' measures of driver state are the focus of the upcoming European New Car Assessment Program (Euro NCAP) Occupant Status Monitoring (OSM) protocols (Fredriksson et al., 2021), and are discussed in a later section. More advanced approaches will use combinations of metrics including head pose and gaze direction to classify when a driver is disengaged from the driving task.

DMS technologies offer new opportunities to manage driver states including distraction in real-time and thus reduce fatal and serious injury. To achieve the desired crash reductions, it is important that a system not only detect and warn of an impaired driver state, such as distraction, but that the driver state is communicated to the other safety systems in the vehicle. This is best achieved by combining warning and intervention strategies such as, for example, increasing the sensitivity of driver assistance systems when a driver is classified as not attentive (Fredriksson et al., 2021).

The Euro NCAP continues to evolve its DMS protocols to recognize more advanced technologies such as driver monitoring as an integral part of upcoming rating protocols. Higher safety ratings will be linked to countermeasures that use direct measures of driver state rather than indirect measures, and for those solutions that pursue strategies that are centered on intervention and not warning only (Fredriksson et al., 2021). These protocols are likely to become effective for new vehicle models in Europe from 2023 and evolved for a 2025 update.



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DMS is expected to become a standard feature in new cars as a result of regulatory and rating agency requirements. For example, the European Union has mandated drowsiness and attention monitoring for inclusion in all new vehicle models starting in 2024 (see Commission Delegated Regulation (EU[1])), and the Euro NCAP will grant vehicle points toward a 5-star rating for including DMS from 2023 (see Euro NCAP[2] report). DMS as applied to drowsiness detection will be required in all new vehicles by 2024, while DMS as applied to distracted driver detection will be required by 2026.

Automakers in Europe are beginning to equip their vehicles with DMS in response to Euro NCAP promotion and regulatory directives such as the European Commission General Safety Regulations (GSR). In the United States, such systems typically are included as part of partial automation systems that, while automating steering, following distance and speed control, nevertheless require that drivers perform other aspects of the dynamic driving task (e.g., object event detection and response). Few automakers have offered in the U.S. market DMS solely to address distracted or fatigued driving.

The DMS and associated alerts or interventions described here are new features in the vehicle market. As such, there are few, if any, studies of real drivers in real cars in real traffic demonstrating their effectiveness at curbing real distraction-related crashes. Among the early evidence suggesting that they may be helpful is an analysis by the Highway Loss Data Institute (HLDI) of Subaru's DriverFocus, an optional feature on 2019–2021 Forester and 2020–2021 Legacy and Outback models. DriverFocus uses a driver-facing camera to monitor the driver's head pose and eye gaze to issue audible alerts when the driver is inattentive or drowsy. A recent preliminary analysis found that the presence of this feature was associated with a statistically significant lower claim frequency under collision and property damage liability coverage types and a nonsignificant lower claim frequency under bodily injury liability coverage compared with the same models not equipped with DriverFocus (HLDI, 2022). However, these reductions cannot yet be directly linked to the prevention of distracted- and drowsy-driving crashes. As more automakers offer similar features, it will be important to examine more closely their acceptability among drivers, whether such DMS influence driver behavior, and most importantly whether their use reduces crashes associated with driver distraction.

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As stated above, driver monitoring systems are focused on identifying when the driver is distracted so that an alert can be issued. Driver attention management, in contrast, is more about how drivers supply attention to the road over space and time (Kircher, Alström, & Kircher, 2009, Ahlstrom et al., 2021). Attention to the road is critical for building and maintaining a model of the driving situation. It's a key aspect of defensive driving, where drivers not only avoid crashing when in a conflict scenario but avoid conflict scenarios altogether by maintaining good situational awareness. While diverting attention away from the road lowers situation awareness, supplying attention to the road can rebuild it. Work by the MIT AHEAD consortium has modeled the driver's instantaneous understanding of the driving task demands and has shown that a sufficient sequence of glances to the road is critical for vehicle control and avoiding conflicts (Seppelt et al., 2017a, 2018; Seaman et al., 2017, 2021). Different driver attention management systems have been introduced based on this concept. For instance, Android Auto™ employs a temporary browsing restriction when the number of taps on the screen exceeds a set threshold over a period of time. The temporary lockout reminds drivers to look back at the road to rebuild their situation awareness before the system unlocks, presents a chime, and allows the task to continue.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R1341&from=EN
[2] https://cdn.euroncap.com/media/70315/euro-ncap-assessment-protocol-sa-safe-driving-v101.pdf

Driver monitoring systems that provide real-time alerts and event-based reports can also be used for driver coaching. These systems send alerts and/or recorded video clips to a parent/guardian/fleet safety manager to review. The reviewer can then elect to talk with the driver about the circumstances of the event, why it occurred, and what could have been done to avoid it. Such a review process serves as a coaching moment that has been shown to improve the safety of commercial fleets. For instance, Boyle et al. (2016) investigated the effectiveness of on-board monitoring systems using four operational fleets (two trucking fleets and two motorcoach fleets) that included 156 vehicles and 317 commercial drivers. They found that onboard monitoring helped to reduce safety-critical event rates. Although, the effectiveness of onboard monitoring was dependent on the carrier and the type of coaching received (Boyle et al., 2016).

Driver monitoring systems that provide event-based reports may also serve as a coaching tool for parents of novice teen drivers. Parental interest and willingness to use teen driver monitoring to reduce driver distraction was the topic of a parent-teen focus group study (Lerner et al., 2010). Two dozen parent-teen dyads were interviewed, but teens and parents were interviewed as separate groups. The parents in the study had a wide range of opinions on teen monitoring, raising concerns about privacy and the interpersonal trust established between parents and teens. Some parents indicated that the use of monitoring technology should only occur during the provisional Graduated Driver Licensing (GDL) phase due to these concerns and that having to install a monitoring system as part of GDL could address some of the privacy/trust issues. Another theme raised by parents was doubt that technology could replace the benefits of increased driving experience with parental supervision. Despite the mixture of reactions, parents favored monitoring applications for speeding and cellphone use over behaviors such as seatbelt use and impaired driving. Parents expressed concern that recorded data could be used against them or their teens in a disciplinary fashion. Lastly, some parents believed that real-time monitoring and feedback could have unintended consequences such as an auditory warning being a distraction and as such were more supportive of driver monitoring that used post hoc summary reports than other approaches. Overall, with sufficient parent-teen trust, parents agreed that monitoring technologies have promise as educational tools (Lerner et al., 2010) (see Weast et al., 2022 for a similar theme that arose about parental concern about the use of ADAS).

Furthermore, FHWA research shows that pairing driver monitoring with behavioral economics and vehicle telematics (i.e., driving kinematic data coming from the vehicle) can introduce behavioral changes that significantly reduced driver cellphone interaction (Delgado et al., 2022). In this study, participants were recruited from Progressive Insurance's population of drivers using the Snapshot program. Through a field study, drivers were randomly assigned to one of six treatments: a control group as a baseline, and five groups that received economic incentives to reduce cellphone distraction, social comparison feedback, or both incentive with feedback. Results showed that pairing feedback about peers' behavior combined with an economic incentive reduced distraction by 23%. A follow-on study found that gamification can be an additional way to motivate drivers to avoid cellphone distraction.

The next iteration of monitoring-based prevention systems is likely to include workload management capabilities (Green, 2004). The attention required to drive safely is a function of (i) the instantaneous driving task demands, (ii) the driver's capabilities, and (iii) the ADAS level of support. Due to the proliferation of in-vehicle, infrastructure, and mobile device connectivity, data to estimate the required attention are now becoming increasingly available. The driving task demands can be estimated using vehicle and infrastructure sensors (e.g., speed, map data of congestion/road design, camera/radar/lidar, user-generated content, weather data, and traffic signal phase and timing). Workload management systems can use data from the external environment to characterize the driving task difficulty. For example, when driving is deemed to be difficult, under conditions like lane change maneuvers, left/right turns, and passing through a work zone, the system could limit notifications and/or secondary task functionality (Piechulla et al., 2003).

Above, we described workload management systems that characterize driving scenarios and identify challenging driving conditions. We also described driver monitoring systems that assess if a driver is paying sufficient attention to the road. What is really promising is a system that effectively combines these two systems. We call this driver attention support and safeguards. They are about adjusting the in-vehicle user interface or restricting secondary task engagement based on both the required attention for the given driving conditions and the supplied attention by the driver at the moment. As models for estimating the instantaneous required and supplied attention become more feasible, there's an opportunity to make the HMI adaptable and provide active intervention. This could involve suppressing notifications when the driving task demands are high, presenting collision avoidance alerts earlier if a driver is deemed to be distracted, and holding off on presenting nuisance collision avoidance alerts if a driver is deemed to be attentive. However, when both the required and supplied attention are unknown, in-vehicle interfaces should be designed to meet the existing driver distraction guidelines. Research can help identify how to optimally combine driver monitoring with workload management systems. Other research gaps include how to make sure the systems do not annoy drivers, and integrate well with systems that perform parts of the driving task.

When implementing driver monitoring systems, state and local laws concerning consumer privacy may affect the accessing and handling of in-cabin video, particularly when accessed offboard the vehicle should be taken into consideration.

It should also be noted that state and local laws concerning consumer privacy may affect the accessing and handling of in-cabin video, particularly when accessed offboard of the vehicle. Such laws should be taken into consideration when implementing driver monitoring systems.

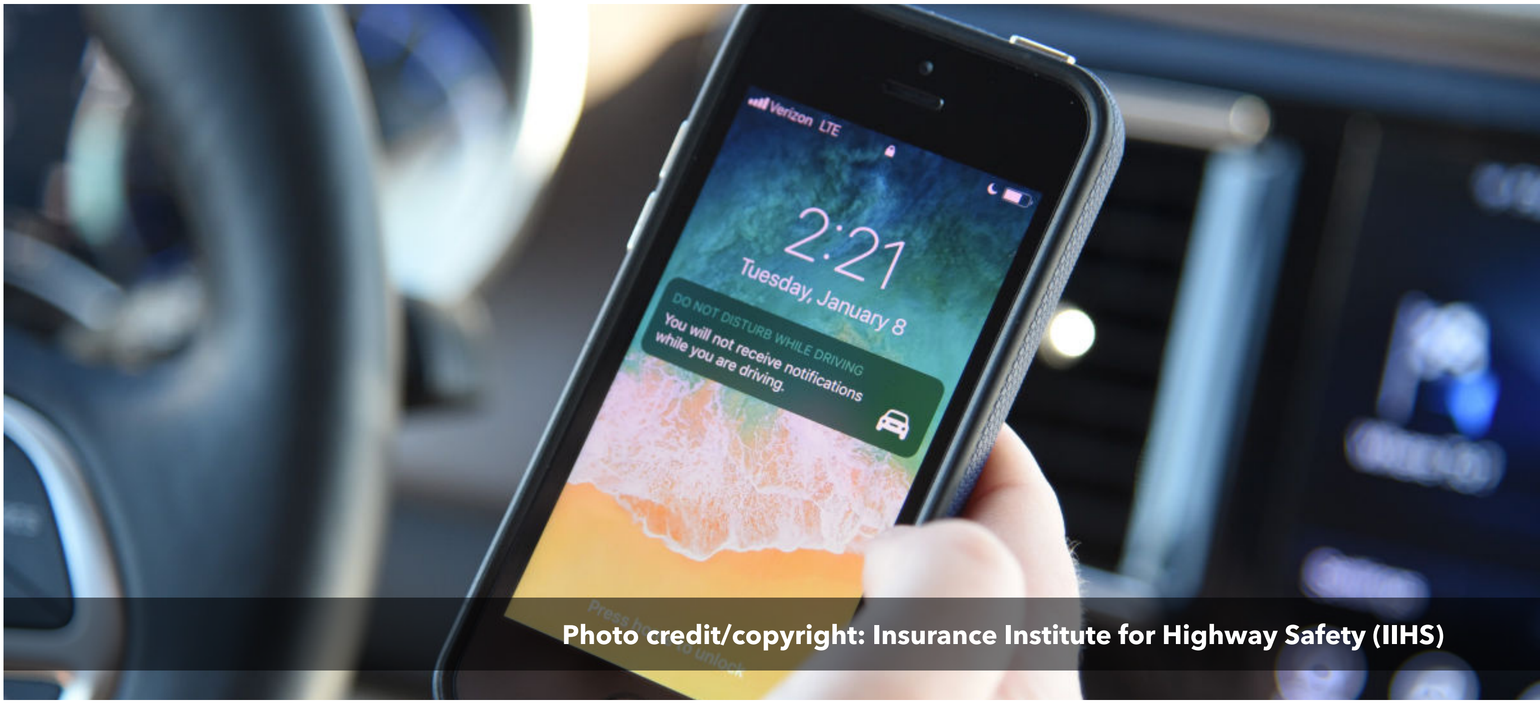
Restriction-based prevention

Drivers in general and high-risk driver populations, in particular, may benefit more from in-vehicle technology suites and smartphone apps that limit the driver's opportunity to engage in risky behaviors. Ford's MyKey is one example of an in-vehicle technology suite that includes features like speed control as well as a Do Not Disturb feature that blocks all incoming text messages and calls while the vehicle is in motion. The system does not block the hands-free use of smartphones. Another example of restrictions that utilize hardware in the vehicle to prevent distracted driving is Groove. Using the vehicle telematics data, the smartphone geolocation, and an algorithm that determines who is the driver, the Groove feature will stop incoming texts. After arriving at the destination, all texts and calls will then be received.

In general, smartphone-based blocking technology has been introduced to target the distracted driving problem by prohibiting calls and texts and, blocking audio features and specific apps. Smartphone-blocking technology can come as either a service or as an app. A few examples include the LifeSaver, TextLimit, and Drive Mode Apps.

Cellphone manufacturers are also offering a Do Not Disturb Driving Mode that can help drivers stay focused on the road by silencing or limiting notifications when driving is detected. The mode permits voice interaction, allows messages from select contacts to be automatically read out, and does not run if the driver is using Android Auto or Apple CarPlay.

The use of the Do Not Disturb (DND) mode while driving has been of interest, particularly as awareness of digital wellbeing has grown. A telephone survey of 800 adult drivers who own smartphones was conducted to estimate cell phone blocker use (Reagan & Cicchino, 2020). The focus of the survey was Apple's Do Not Disturb While Driving (DNDWD) application, which was installed when the devices were updated to a major software update issued in September 2017 (iOS version 11). DND is fully compatible with all iPhone 6 or newer iPhones. Apple used an "opt in" prompt with DND. The first time an owner used a compatible iPhone (e.g., new iPhone, or immediately after the iOS 11 update), they received the prompt "Do you want to try Do Not Disturb While Driving?" Response options included "Turn on while driving" or "Not now." When installed and running, DND silences incoming notifications and provides a visual reminder to discourage manual interaction if drivers handle their phones and look at the screen while the app is running. Reagan & Cicchino (2020) found that only 20.5% of respondents with DND-compatible iPhones had DND set to activate automatically when driving or when connected to a vehicle's Bluetooth. Among respondents with DND-incompatible phones, 18.7% of respondents reported having an alternative non-DND blocker, and only half of these reported turning it on while driving at least three-quarters of the time. 39% of drivers with DND-compatible iPhones who had DND set to turn on when manually activated trip-by-trip said they would not be frustrated if they received another prompt to use the application, and 26.7% reported they would be likely to try it if they received another prompt. Respondents classified as using blockers were less likely to report cell phone use, although results varied between those with DND and other blockers. It is unknown whether the difference in self-reported use is the result of using a blocker or reflects self-selection bias by those who opted to use blockers. The modest use of DND was disappointing given the widespread nature in which it was installed. Implementing a blocker in conjunction with an "opt-out" approach that automatically activates a blocker like DND whenever it determines the owner is driving may present an opportunity to increase the use of this countermeasure.



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Oviedo-Trespalacios and colleagues (2019a&b) conducted a pair of studies to categorize available cellphone-blocking apps by common features and to identify aspects of blockers that users find acceptable. In their content analysis of available blocking apps, the researchers categorized 29 apps based on whether the blocker is acting on an aspect of the human-machine interactions (driver, phone, or vehicle) or information that is provided to communicators or users outside of the vehicle cabin (Oviedo-Trespalacios et al., 2019a). Of the 29 apps reviewed, all but Apple's DNDWD worked for Android phones. The Android Auto app was the most prevalent blocker. DNDWD was the most common app for iOS phones; only 10 of the other apps worked on iPhones. AT&T's DriveMode was the most prevalent app that worked on both platforms. Most (26) apps permitted phone calls; 22 permitted navigation, and 10 permitted texting. The most common feature associated with those trying to communicate with a driver was to send auto-replies. The authors noted that while the apps do try to limit visual-manual distractions, some of the cellphone blocking apps allow social media apps to run that have texting functions (e.g., Facebook messenger). Another limitation of cellphone-blocking apps noted by the authors is that the most frequently used cellphone applications for driving are navigation and music streaming, and drivers may choose to override blockers or forego their use completely so they can access their maps and music. The authors conclude that these apps are a promising component of a system-based approach to addressing distraction.

Oviedo-Trespalacios et al.'s (2019b) survey of 700+ Australian drivers aged 18–90 years looked at use and factors that affect use of blocking apps and whether there are app features that would be preferred by different demographics. About 95% of the sample owned Android phones (48%) or iPhones (46%). The survey collected data on demographics, self-reported cellphone use, previous experience with blocking apps, willingness to install 12 hypothetical apps that blocked various functions, and preference using 15 different features that existing apps can deploy to limit cellphone use. 40% of the sample had heard of blocking apps. However, only 10% reported that they had used a blocker app, and only 3% were still using one at the time of the survey. Two-thirds of the sample indicated a willingness to install and activate an app that blocked cellphone functions with heavy visual-manual demand (texting, browsing, email) but permitted voice calls, but less than 50% of the sample indicated a willingness to download 10 of the 12 hypothetical blocking apps. Factors that increased the likelihood of installing an app included being female and having the ability of the app to disable visual-manual notifications or the ability to have hands-free conversations. Knowing the app prevented distraction and reporting more frequent cellphone use were associated with lower likelihood of installing an app. There were clear differences across young (18–24), adult (25–59) and senior (60+) driver preferences for various app features. Younger and middle-aged drivers most commonly wanted apps to provide access to maps and music functions, and senior adult drivers most commonly wanted automatic activation over other features.

A survey of teen drivers who drive themselves to school and admit to texting while driving gauged participants' willingness to stop using their cellphones while driving and perceived effectiveness of behavioral economics-based incentives and cellphone-blocking technologies to reduce cellphone use (Delgado et al., 2018). Respondents reported their willingness to stop using a cellphone for 12 specific phone functions (e.g., reading texts, sending texts, social media, navigation, music). Respondents provided thoughts on 10 social (e.g., peer expresses concern), technological (e.g., hypothetical cellphone blocking), and behavioral economic strategies (e.g., insurance discount, group-based rewards) to reduce phone use while driving. Large majorities of respondents indicated willingness to stop using social media (99%), sending texts (95%), and reading texts (90%); lower proportions indicated willingness to stop using GPS or music apps. Cellphone-blocking applications were perceived as less effective than financial incentives but more effective than having a peer or parent express worry about the teen's phone use while driving. Respondents perceived that cellphone-blocking apps would be most beneficial in reducing distraction and avoiding citations for distraction. Factors listed as limiting use of blockers included concern about parental monitoring and unfamiliarity with how the blockers work.

Research to understand the effectiveness of DNDWD apps in reducing crashes related to cellphone distraction would be valuable. The emergence of telematics as a data source seems to present an opportunity for such an effort. Evaluations of effectiveness must account for the likelihood that drivers who are willing to use DNDWD apps are those who rarely use their cellphones to begin with. Such studies would also be well-served to measure the potential for unexpected behavior change that might limit effectiveness (e.g., drivers substitute non-cellphone distraction (looking at a map) that is riskier than a cellphone app (auditory route guidance).

Research to understand the effectiveness of DNDWD apps in reducing crashes related to cellphone distraction would be valuable.

Other research gaps center on increasing driver awareness, acceptance, and use of DNDWD apps over the long term. While the literature review suggests an opportunity to improve use by improving messaging on the availability and functionality of DNDWD apps, the trend of rapidly evolving app functionality may also lead to increased use and acceptance. Thus, it will be useful to document how changes to an app's implementation are associated with use and acceptance. For example, a decision to shift from an opt-in to opt-out strategy may lead to a large increase in use initially, but drivers opposed to their use may reject the technology, whereas efforts to identify and remove barriers to use that improve acceptance may result with gradual increases in acceptance and use.

Using Crash Avoidance Features for Prevention

Crash avoidance features available on modern vehicles are one countermeasure against distracted driving. While not designed specifically to address this risk, they nevertheless can alert distracted drivers to risks of crashing or in many cases intervene with momentary braking or steering to avoid or mitigate crashes when drivers don't respond to system alerts. Front crash prevention and lane departure prevention systems, in particular, respectively address rear-end and lane drift crashes that are highly associated with visual distraction (Owens et al., 2018).

Front crash prevention (FCP) features include forward collision warning and automatic emergency braking. FCP features scan the road ahead using sensors like radars and cameras. When algorithms calculate that a crash is likely without intervention, drivers are alerted with audible, haptic, and/or visual cues. If the driver fails to respond to the warning, then some systems will apply brakes to avoid or mitigate the impending crash.

Passenger vehicles equipped with FCP features are involved in fewer front-to-rear crashes (Fildes, 2015; Isaksson-Hellman & Lindman, 2016; Cicchino, 2016). For example, Cicchino found a 27% reduction associated with forward collision warning (FCW) by itself and crashes were cut in half when FCW was combined with automatic braking. Somewhat larger reductions were observed among crashes with injury indicating that even when crashes are not avoided the speed reductions associated with automatic braking reduced the risk of injury, an effect predicted by Kraft et al. (2009).

Passenger vehicles equipped with FCP features are involved in fewer front-to-rear crashes.

FCP technology has also been associated with front-to-rear crash reductions among heavy trucks (Teoh, 2021). The analyses also showed that truck speeds were reduced by about half between the issuing of an FCW warning or the onset of automatic braking and those crashes that occurred among equipped trucks.

In the United States in 2020 there were 587 nonoccupants (pedestrians, pedalcyclists, and others) killed in distraction-affected crashes (NCSA, 2022). FCP with pedestrian detection technology also has been shown to be effective at reducing the number and severity of these crashes (Cicchino, 2022). Crash rates for pedestrian crashes of all severities were 27% lower for vehicles equipped with pedestrian AEB than for unequipped vehicles. Rates for crashes with injury were 30% lower. Similarly, Subaru vehicles equipped with the Eyesight system, which includes pedestrian detection and automatic braking, have a lower rate of pedestrian-related insurance claims than their counterparts without the system (Wakeman et al., 2019).

Research has shown that FCP could be improved. For example, IIHS research has previously identified crash factors that are over-represented in front-to-rear crashes involving an AEB-equipped striking vehicle (Cicchino & Zuby, 2019). Crash-involved vehicles with autobrake were more likely to be turning, to strike a vehicle that was turning or changing lanes, to strike a non-passenger vehicle or special-use vehicle (medium or heavy trucks or motorcycles, for example), crash on a snowy or icy road, or on a road with a 70 mph or higher speed limit than control-group vehicles. Follow-up investigation confirmed that these crash characteristics were rare in front-to-rear crashes, but those in which a motorcycle or large truck were struck accounted for about 40% of fatal rear-end crashes (Kidd, 2022). Also, nearly 80% of police-reported rear-end crashes occurred on roads with speed limits ranging 30–65 mph and subsequent research shows that the speed of the striking vehicle is more than 40 mph even on roads with a limit of 25 mph. Thus, enhancing the capabilities of FCP to more reliably respond to large trucks and motorcycles and to avoid crashes at higher speeds would be an improvement over the current state of the art. FCP with pedestrian detection could be improved if it worked better in low-light and dark conditions.

Lane departure prevention (LDP) features typically use cameras to track a vehicle's position within marked lanes. If the vehicle crosses or is about to cross the lane marker without the driver having signaled a lane change then these systems will alert the driver with audible or haptic warnings. Some systems may apply momentary steering or braking to direct the vehicle back to its original lane of travel.

Vehicles equipped with lane departure prevention systems are involved in fewer head-on, sideswipe and single-vehicle crashes than their counterparts without (Cicchino, 2018). Reductions for crashes with injury were greater than crashes of any severity. LDP also appears to confer greater benefits on wet or dry (not snow\ice covered) high-speed roads than on lane-drift crashes involving all road and weather conditions (Sternlund et al., 2017).

Lane departure warning\prevention systems are not used as often by drivers as other crash avoidance features (Reagan, 2018). Among vehicles that preserved the system's on\off status from one ignition cycle to the next, LDP was found 'on' for about 50% of observed vehicles compared with a use rate of 93% for FCP. Low use of these systems may be addressed through design efforts as their use seems to be influenced by system attributes (Reagan et al., 2019). Drivers of vehicles with systems that intervened with corrective steering\braking before the vehicle crossed the lane marker had higher use rates than drivers of vehicles that didn't respond until the vehicle had crossed the lane marker.

LDP effectiveness could be improved if these features were designed to address drivers suffering various forms of incapacitation. An examination of 631 lane-drift crashes in the National Motor Vehicle Crash Causation Survey showed that 34% of drivers who crashed because they drifted from their lanes were sleeping or otherwise incapacitated (Cicchino & Zuby, 2017). These sleeping or incapacitated drivers would be unlikely to regain full control of their vehicles if an active safety system only prevented their initial drift. An additional 13% of drivers in lane-drift crashes had a non-incapacitating medical issue, blood alcohol concentration (BAC) ≥ 0.08%, or other physical factor that could impair their ability to safely control a vehicle. Compared with crashes of any severity, crashes involving serious or fatal injuries had higher proportions of drivers with these afflictions––42% were sleeping or otherwise incapacitated and 14% had a non-incapacitating medical issue, BAC ≥ 0.08%, or other physical factor. Systems that could detect drivers unable to safely control their vehicles and utilize automated control capabilities to bring their vehicles to a safe stop, ideally at the side of the road, would address many of the crashes that current LDP cannot.

One of the impediments to vehicle crash avoidance features as a countermeasure for distracted driving is the long time between the initial availability of vehicle innovation and its significant penetration into the fleet of vehicles used on U.S. roads. New vehicle technology typically enters the market as optional features with extra cost on new vehicles. As such, their uptake by consumers varies. Despite being available on 76% of 2018 vehicle models, only 10% of registered vehicles in the same year were estimated to be equipped with FCP and 95% of the fleet is not expected to be equipped until 2043 (HLDI, 2019). This estimate reflects the commitment made by 20 automakers to make FCP standard equipment in the 2023 model year (IIHS, 2016). Lane departure warning was available on 72% of new 2020 vehicles series but only 8% of registered vehicles with an expected 95% penetration of the registered fleet in 2044.

Research suggests that after-market systems could help increase the prevalence of crash avoidance technologies in the vehicle fleet (Reagan, 2018) and that the benefits from the systems may be related to the direct effects of imminent crash alerts and to effects associated with behavioral change related to the motivation to reduce the frequency of alerts. A 14-week field operational test assessed 21 drivers who had an aftermarket system installed in their own vehicle. The system provided a suite of warnings (forward collision, lane departure, time headway warning, pedestrian detection, and urban forward collision warning). Fifteen drivers who also had a telematics device installed showed 30% to 70% reductions in warning rates when the systems were activated at 5 weeks post-installation relative to weeks 1-4 when they were in silent mode.

As noted above, there are clear opportunities to improve upon the known effectiveness of crash avoidance features to prevent crashes. Their effectiveness as a tool to curtail distracted driving crashes could use further substantiation by studies examining whether their interventions are associated with driving distractions. Studies examining whether drivers use these features to facilitate engaging in secondary tasks are inconclusive and merit further study.

Automated enforcement-based prevention

Automated enforcement of traffic laws, including those proscribing certain distracting behaviors, is another possible technology that could be deployed against distracted driving. Typically, sensors of various types are used to detect violations, then cameras record evidence of the violation as well as the license number of the offending vehicle. Traffic stops are not required as the automatically generated citations are usually sent to the vehicle owner, although law-enforcement officers may be involved in any of several steps of the process.

There is no firm link between distracted driving and red-light running or speeding in the record of real crashes, but surveys and driving simulator studies suggest that inattention may lead to these behaviors. A meta-analysis of studies examining the effects of texting on driving (Caird et al., 2014) found that reading and sending texts while driving the simulator adversely affected subjects' detection of hazards. Although some individual studies did not find that texting affected reactions to visual stimuli (e.g., Irwin, Monement & Desbrow (2015)). The difference in results may be due to differences in experimental protocols. Nevertheless, engaging in visual-manual tasks is associated with increased crash risk (Klauer et al., 2006).

Automated enforcement has been used to reduce red light running in the United States. Sensors in the road detect whether vehicles enter an intersection after the red-light phase begins. During 2020, approximately 348 communities operated red light camera programs (IIHS). Radar and laser sensors used in conjunction with traffic cameras were used to enforce speed limits in 155 U.S. communities in 2020 (IIHSb). More recently, the Australian states of New South Wales and Queensland began using cameras mounted over traffic lanes to detect violations of laws prohibiting the use of handheld electronic devices (Acusensus). Image recognition and machine learning techniques are used to process the images in real-time and separate cameras record vehicle registration plates of vehicles with offending drivers.

Automated enforcement of traffic law deters drivers from engaging in the targeted behavior by helping drivers understand that they are likely to be sanctioned for their transgressions even when law enforcement officers cannot possibly observe all offenses. As with high-visibility enforcement campaigns, it is recommended that implementing automated enforcement programs include publicizing both the harm associated with the targeted infractions and that automated enforcement is being used to enforce the rules (IIHSc). Drivers must attend to their driving to avoid committing infractions like red light running or speeding, so more rigorous enforcement of traffic laws may lead to less distracted driving.

Focus groups exploring the reasons behind speeding behavior conducted for the U.S. Department of Transportation found the speeding was often claimed to be due to inattention (Richard et al., 2013). Some studies involving driving simulators have found that subjects engaged in conversation committed more speeding violations than undistracted drivers (Kass, Cole & Stanny, 2007) and that emotional conversations led to more speeding (Dula et al., 2011). Other studies have not found an effect of conversation on speeding behavior (Stein, Parseghian & Allen, 1987) and that reading\typing texts was associated with driving at slower speeds (Caird et al., 2014) compared with just driving. While the direct effect of talking\reading\typing on speeding behavior is somewhat ambiguous, people who report using a mobile device while driving tend to exhibit other risky driving behavior. In an on-road study, drivers who reported frequent cellphone use drove faster, changed lanes more often and made more hard braking maneuvers than drivers who said they rarely used cellphones while driving (Zhao et al., 2013).

Automated enforcement programs have been shown to be effective at reducing infractions, crashes, and injuries. Red light violations, for example, were reduced by about 40% after the introduction of red-light camera programs in two U.S. cities (Retting et al., 1999a, 1999b). The effect was found also to carry over to nearby intersections without cameras. Moreover, violations that occurred later after the signal turned red were reduced by more than those involving earlier incursions into the intersection (McCartt & Hu, 2014). The Cochrane Collaboration, an international public health organization, found an estimated 13%–29% reduction in all types of injury crashes and a 24% reduction in right-angle injury crashes in its review of the most rigorous before-after studies of red light camera effectiveness (Aeron-Thomas & Hess, 2005). Most importantly, automated enforcement of red-light rules has been shown to save lives (Hu & Cicchino, 2017). Cities with red-light camera programs had a 21% lower red-light running fatality rate than similar cities without.

Speed cameras, likewise, have been shown effective countermeasures against speeding behavior and its consequences. Studies in the U.S. showed that the proportion of drivers driving 10 mph or more over the limit were reduced by 62-82% after camera programs were introduced (Retting et al., 2008a; Retting, Kyrychenko & McCartt, 2008b; Retting & Farmer, 2003; Hu & McCartt, 2016). A review of studies from various countries by the Cochrane Collaboration found that camera-enforcement of speed limits was associated with 1–15% reduction in average speeds and 14% - 65% reduction in the proportion of vehicles traveling above the speed limits at camera sites. Speed camera enforcement was also associated with an 8%reduction in the likelihood that a crash on a camera-eligible road was speeding-related and a 19% reduction in the likelihood that a crash involved an incapacitating or fatal injury (Hu & McCartt, 2016). These reductions were increased by 30% with a corridor approach, in which cameras were periodically moved along the length of a roadway segment. The Cochrane Collaboration also found reductions of 8%–49% for all crashes, 8%–50% for injury crashes and 11%–44% for crashes involving fatalities and serious injuries, in the vicinity of camera sites (Wilson et al., 2010).

The effectiveness of automated enforcement for speeding and red light running suggests that it also could be effective at reducing prohibited driving distractions (e.g. texting) and associated crashes. As mentioned above, a system of overhead cameras watching for manipulation of electronic devices has been deployed in two Australian states. The program in New South Wales detected 30,000 drivers using phones in the 3 months of deployment. However, the effectiveness of utilizing automated enforcement to directly enforce distracted driving laws is one of the open questions about technologies that can be employed to curb distracted driving.

The effectiveness of automated enforcement to curb red-light running, speeding and the associated crashes is reasonably well established. As mentioned above, a case can be made that distracted driving is associated with red-light running but its relation to speeding is less well understood. Thus, counting automated enforcement of speed limits as a tool to combat distracted driving hinges on the ability to better understand the relationship between distracted driving and the increased probability to observe automatically detected risky behaviors.

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Relevant policy & regulation

Public policy has attempted to address driver distraction through different mechanisms and through various authorities, from the local municipality level up through the various branches of the federal government. While there have also been efforts to address distraction internationally, the focus of this section is limited to policy considerations within the United States. The National Highway Traffic Safety Administration (NHTSA), which holds authority over the construction and performance of motor vehicles, has attempted to address distracted driving through a series of guidance documents concerning the electronic equipment in the vehicle, as well as portable aftermarket devices brought into the vehicle. NHTSA's Driver Distraction Guidelines were planned to be issued in three phases: Phase 1, published in April 2013, concerned in-vehicle electronic devices and was further clarified by NHTSA in September 2014; Phase 2, which was only ever proposed but never finalized, was issued in December 2016 and attempted to address portable electronic devices brought into the vehicle; and, a Phase 3 was planned to expand the guidelines to address auditory-vocal human-machine interfaces, however such guidelines were never proposed.

It is important to note that NHTSA's driver distraction guidelines were issued as voluntary and the Agency did not hold any enforcement authority to require manufacturers or electronic equipment suppliers or manufacturers to comply. With the advent of driver monitoring technology capable of assessing driver distraction, as previously discussed, there has been renewed interest in regulating in this space. The Bipartisan Infrastructure Law (BIL) has a provision (§24209) to require the Secretary of Transportation to research the use of driver monitoring to, in part, minimize or eliminate driver distraction, and if deemed necessary, to issue a rulemaking to require such systems.

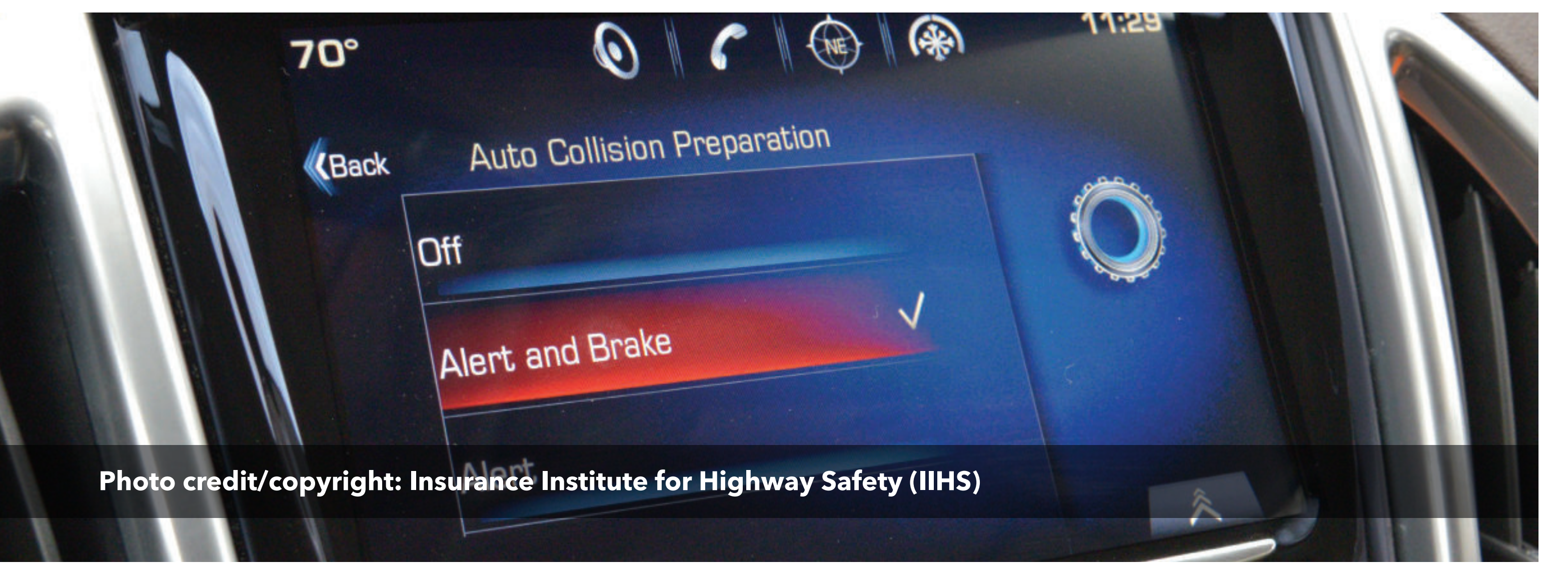
As the federal government regulates the performance of the vehicle, state and local municipalities have authority over the use of the vehicle and of driver behaviors, including distraction. The Governors Highway Safety Association (GHSA) notes that 30 states have handheld cellphone laws with primary enforcement, meaning that drivers can be cited without any other traffic offense taking place. GHSA also notes that nearly all states have prohibitions against text messaging while driving.

Outside of governmental policy, the automotive industry had previously developed consensus guidelines regarding the design and construction of in-vehicle electronic devices. In 2006, the Alliance of Automobile Manufacturers (AAM) developed their *Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems*. Amended in 2021, the guidelines, now under the stewardship of the Alliance for Automotive Innovation, were amended to account for new technologies that have the ability to assess driver attention and engagement.

The outstanding research gaps that remain include cultural, societal, and regulatory differences across various states and how these differences may impact the implementation of driver monitoring technology (e.g., privacy, third-party information sharing, local vs. server-side processing, etc.). In addition, the development of strategies to motivate the use of driver distraction mitigation technology, especially targeting high-risk populations (i.e., teens; possibly based on behavioral economics) should also be studied.

Driving automation & distracted driving

Automating the driving task has been a quest for nearly a century, and nowadays, there is a growing number of systems that automate multiple aspects of the driving task, including braking, steering, monitoring, and issuing warnings. The Society of Automotive Engineers (SAE) defines a taxonomy of six automation levels, ranging from manual driving (i.e., SAE Level 0 - no driving automation) to fully self-driving vehicle under all conditions (i.e., SAE Level 5 - full automation) (SAE International, 2021). Consumer vehicles equipped with partial automation (SAE Level 2) can simultaneously control the longitudinal (e.g., adaptive cruise control) and lateral (e.g., lane centering) vehicle kinematics on a sustained basis. The driver still remains responsible for doing the monitoring, object/event detection, response selection, and execution. Partial-automation systems are considered to be comfort systems, with the purpose of assisting and reducing the driver's workload (Gershon et al., 2021). Research suggests that, after a relatively short period of time, drivers are getting comfortable with using these systems and allowing the vehicle to brake and accelerate without even placing their hands on the steering wheel (Morando et al., 2021). As the driver role pivots toward monitoring and the driving demands are low, it is actually very difficult to devote all the attention to the driving task and we start to see evidence of an increase in undesired driver behaviors related to distracted driving when using driving automation systems. Drivers often use the "freed-up" resources to do other things than driving and this tendency is amplified even more by the increased availability of portable electronic devices and in-vehicle technologies in the form of entertainment, navigation, information, and communication systems (Reagan et al., 2021). For example, a recent naturalistic driving study of Tesla owners showed that the use of Autopilot was associated with an increase in the proportion of long off-road glances (two seconds or longer) to the Down and the Center-Stack locations, increased from 4% in manual driving to 22% when driving with Autopilot. At the same time, hands-free driving increased from 1% to 46% soon after drivers turned on Autopilot and throughout Autopilot use. Taken together, when using Autopilot, drivers had higher visual inattention (longer and more frequent off-road glances), and a reduction of direct vehicle control (more frequent hands-free driving) compared to when driving manually (Morando et al., 2020). These findings may be a consequence of drivers' engagement in non-driving related tasks more often and for a longer time when Autopilot was active. These behavioral changes may capture a misunderstanding of the proper use of Autopilot or false expectations that are reinforced when automation performs relatively well (Abraham et al., 2017; Lin et al., 2018; Teoh, 2020; Victor et al., 2018).



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While all partial-automation systems provide similar driving functionalities, differences in the underlining design philosophy can explain the variations we find in the extent to which automation is used, disused, misused, and abused. DMSs are one mechanism designed to mitigate lapses in driver engagement by providing feedback to the driver or adapting automation functionality in real time (Donmez et al., 2008). Currently available DMSs use steering wheel torque-based sensors and/or driver-facing cameras to track gaze and/or head position to infer driver state and intervene when a threshold for apparent inattention is exceeded. The concerns regarding failures to take back control from the automation in time-critical situations due to driver inattention are underpinned by the recent high-profile crashes of vehicles equipped with partial automation that were investigated by the National Transportation Safety Board (NTSB), and by the National Highway Traffic Safety Administration (NHTSA) standing general order (issued on June 2021) that require manufacturers to report on crashes involving the use of partial-automation up to 30 seconds before the crash (NHTSA, 2021).

The limited data on the safety benefits of partial automation systems with their encapsulated DMSs and the apparent synergetic relationship between automation and driver distraction calls for further research to assess different DMS approaches and evaluate how they can effectively monitor and manage driver attention under a wide and dynamic array of driving conditions.

Summary

In 2020, over 3,000 people in the United States were killed and over 300,000 were injured in crashes involving a distracted driver (NCSA, 2022). The crash risk of driver distraction is a highly nuanced topic and is impacted by who's driving, where they are driving, the type of vehicle being driven, and the level of driving support the vehicle provides. This report summarized existing approaches and technologies to prevent drivers from being distracted and to reduce the negative consequences of driver distraction. This report also identified gaps in current technology and outlined where future work can contribute to prevention. The areas covered by this report were technologies to mitigate distracted driving, policy- and regulations-based prevention, and the relationship between driving automation and distracted driving.

So far, the technologies available to mitigate distracted driving are monitoring and attention management systems, smartphone-blocking technologies, crash avoidance vehicle technologies, and automated enforcement. Monitoring systems in vehicles can detect driver inattention to the road and alert the driver; driver attention management systems can prevent distracting interaction with infotainment systems. The next step, called driver attention support and safeguards, is the combination of these two systems such that potential distractions can be reduced to match both the requirements imposed by the driving environment and the driver's attention allocation. The Insurance Institute for Highway Safety (IIHS) and Consumer Reports (CR), both provide information to vehicle consumers in the U.S., recently highlighted the benefits of direct DMS as a means to monitor and engage the driver when using partial automation features. In January 2022, IIHS shared a safeguard ratings program for partial automation systems that include driver monitoring for both the driver's gaze and hand position. In January 2023, CR announced ratings for 12 systems that also promote direct DMS. Smartphone-blocking technology that prevents smartphone use while driving can be incorporated either into vehicles or smartphones. More research is needed on their effectiveness in preventing crashes and it remains to be seen how developments and changes in technology will affect adoption and use. Crash avoidance features, such as front crash prevention and lane departure prevention, have been found to reduce crashes in multiple studies, and they might prevent distracted driving crashes. There is room for improvement in the function of these technologies in specific situations, such as high speeds and low-light conditions. Additionally, new in-vehicle technologies take a long time to permeate the market, so after-market systems are also a potentially important intervention. Automated enforcement,

having been used successfully for the prevention of red light running and speeding and associated crashes, is also relevant to distracted driving in two ways. Automated enforcement could prevent distracted driving because of the connections between distracted driving and red light running and speeding, and automated enforcement can be used to identify and penalize use of handheld devices.

From a regulatory perspective, there are currently no requirements in the U.S. mandating any specific technology intended to mitigate or eliminate distraction. However, there are currently a number of industry- and government-developed guidelines on the construction and performance of in-vehicle electronic systems that seek to minimize distraction to the driver. In addition, Congress has recently passed the Bipartisan Infrastructure Law, which in part holds NHTSA to research possible driver monitoring technologies specifically as a countermeasure to driver distraction. The law states that should NHTSA decide technology can reduce or stop distracted driving, then it should begin a formal rulemaking process. Last year several U.S. Senators wrote NHTSA in support of this and other vehicle safety provisions included in the new law. Because distraction largely falls to state and local governments, as these entities are responsible for regulating driver behavior, there are ubiquitous cell phone laws in nearly every state. The use of on-board images and video captured by in-vehicle monitoring systems is currently also being discussed at the state level from a privacy perspective. Any new vehicle designs should account for legislation and regulation at each of the local, state, and federal levels.

Throughout this report, the importance of understanding how humans interact with technology in both positive and negative ways was highlighted. For example, smartphone-blocking technology could prevent texting while driving but also the use of auditory route guidance that is safer during driving than looking at a map. Similarly, in-vehicle technology to automate driving may make driving less taxing, but they may also make drivers feel like they can safely engage in non-driving tasks while operating a vehicle. Future research will be needed on automation and driver distraction and how driver attention can be managed in a variety of contexts.

Innovative technological solutions for vehicles, electronic devices, and enforcement could help prevent driver distraction and related crashes and deaths. The building blocks for many of these solutions already exist; future work will require both technology development and enhanced understanding of how humans interact with technology.

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