RESEARCH BRIEF

Effectiveness of Distracted Driving Countermeasures:

An Expanded and Updated Review of the Scientific and Gray Literatures

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According to the National Highway Traffic Safety Administration, 3,142 people were killed in 2019 in motor vehicle crashes in the United States in which one or more drivers was reported as distracted (National Center for Statistics and Analysis, 2021). On a recent nationally-representative survey, 37% of respondents reported talking on a handheld cellphone while driving in the past 30 days, while 34% reported reading texts or emails and 23% reported typing texts or emails while driving (AAA Foundation for Traffic Safety, 2021). While it is generally acknowledged that distracted driving is underreported in crash data, it is well established that distracted driving interferes with safe driving and increases crash risk, though estimates of risk vary by specific behavior and context. Given the limited resources available for improving traffic safety, it is important to understand the effectiveness of various countermeasures against distracted driving that may be considered for implementation.

In 2019, the AAA Foundation for Traffic Safety conducted a review of the then-current scientific literature concerning the effectiveness of existing and emerging countermeasures against distracted driving (Arnold et al., 2019). In general, this review found that some studies have shown promising results; however, across the different types of countermeasures, there are many instances of nuanced or mixed outcomes, questionable generalizability to other populations or regions and, in other cases, insufficient evidence to draw firm conclusions. The 2019 review focused only on those studies that included safety or behavioral measures, such as the occurrence of crashes, observed or self-reported behaviors, or objective measures of driving performance.

Based on this review and an expert workshop that was convened in September 2019, there was a need to continue to examine distraction countermeasures, adopting more inclusive criterion and going beyond the peer-reviewed scientific literature. The specific objectives of this follow-up work are as follows:

- To review and update the relevant scientific literature published since the 2019 review with new studies looking at the efficacy of existing and/or novel countermeasures on safety-based measures.
- To consider the current state of knowledge regarding studies that have included non-safety based measures in evaluating the efficacy of countermeasures.
- To document and characterize available smart-phone based apps, products, or services aimed at mitigating driver distraction.

Method

Literature Search

A search for scientific literature published since May 2019 was conducted in April 2021 using the same databases and search terms as in the previous review of sources published between 2010 and April 2019. The inclusion criteria from the previous review were expanded to include sources that were previously excluded.

Databases	■ PubMed ■ Transport Research International Documentation (TRID) ■ PsycARTICLES ■ PsycINFO ■ PsycEXTRA
Search terms	Combinations of key words related to (i) transportation modes (i.e., driving, walking, bicycling, motorcycling) and (ii) distraction (both generally and including specific distracting behaviors)
Inclusion criteria	■ Addresses the effectiveness of one or more countermeasures specifically targeting distracted driving, as measured using crash data, observed behavior and/or behavior change, self-reported behavior and/or behavior change, behavioral intentions, risk perceptions, driving performance, eye glance behavior, awareness, and/or knowledge, expert opinion, cost-effectiveness, and/or technical performance ■ Sourced from peer-reviewed journal articles, conference abstracts and proceedings, white papers, dissertations, or reports from organizations such as the National Highway Traffic Safety Administration and the Insurance Institute for Highway Safety ■ Written in English

As in the previous review, we excluded summary reports corresponding to full reports returned in our searches, and review articles were scanned for relevant references to add to our results.

The initial search yielded more than 5,000 references. All titles and abstracts were reviewed for inclusion by two independent reviewers. In addition, we reviewed the titles and abstracts of references that were deemed relevant to the topic of distracted driving but excluded from the 2019 review in light of the newly added inclusion criteria.

For the final set of articles, key information was distilled and summarized in tabular form using the abstract and/or full article as necessary. The information entered into the tables included the countermeasure type(s); a description of the countermeasure; target behavior(s); study sample; study design, main outcome measure(s); results; notes, if applicable; and reference (source). Entering this information and consulting full texts further identified studies that were excluded due to not addressing countermeasure effectiveness, or being a review or summary. A total of 72 articles were entered into Summary Tables (see associated file: Distracted Driving Countermeasure Effectiveness Summary Tables), with one table for references reflecting the original inclusion criteria (see sheet: Summary table-Safety outcomes) and a second for references reflecting the added inclusion criteria (see sheet: Summary table-Other outcomes).

App/Product Search

Internet searches, along with searches of the Apple App and Google Play stores, were carried out in March and April 2021 in order to identify apps or commercial products aimed at mitigating distracted driving. Search terms included various combinations of (a) drive, driver, driving, and (b) distract, distracting, distraction, cell, phone. Additional searches added other related terms: (c) safety, prevention, blocking. Relevant apps were identified by a manual review of the search results. The final set of apps or products was catalogued according to a variety of features, including system platform, type of mechanism (e.g., driver monitoring, cell blocking), and timing of feedback, among others. This information was gleaned, as much as possible, from the app store pages as well as the developer's websites.

Results

Educational and/or Behavioral Countermeasures

Findings of the 2019 Review (Arnold et al., 2019)

Studies assessing the effectiveness of countermeasures that educate and/or train drivers in order to reduce distracted driving have utilized a wide variety of approaches and metrics and have yielded varying results. For example, evaluations of distracted driving awareness campaigns have had mixed results. Multi-faceted campaigns have been credited with short- and longer-term reductions in observed distracted driving among employees in hospitals (Joseph, Zangbar, et al., 2016; Rana et al., 2018); short-term reductions in the same behavior at colleges and universities (Fournier et al., 2016; Joseph, Haider, et al., 2016); and reductions in self-reported and observed distracted driving (Unni et al., 2017) as well as collisions (Layba et al., 2017) in hospital-school programs. Assessments of education on distracted driving delivered through a single event have shown limited success, with some finding positive increases in awareness and behavioral intentions. Studies of demonstration countermeasures utilizing computers or simulators have found positive improvements in awareness, attitudes, behavioral intentions, and attention to the forward roadway in the short term but have not addressed impacts in the longer term, nor on actual driving behavior (e.g., Downs et al., 2018; Jashami et al., 2017; Pradhan et al., 2011).

Updated Findings: Safety and Behavioral Outcomes

The majority of the evaluations published since the previous review assessed the effects of intervention and/or training programs for teen and/or novice drivers. A simulator evaluation of a social norms intervention delivered to teens through in-vehicle feedback resulted in reduced engagement in distraction and improved driving performance (Donmez et al., 2019). Another simulator study of a web-based intervention to reduce inattention among teen drivers did not show significant effects; however, the effects were positive and sample size may have been a limitation (McDonald et al., 2021). In another study, a majority of teens who completed a classroom and closed-road advanced driving program reported changing their behaviors specifically by reducing distractions while driving (Mims et al., 2020). Teenage students who participated in the one-day Prevent Alcohol and Risk Related Trauma in Youth (P.A.R.T.Y.) injury prevention program reported decreased likelihood of engaging in risky behavior, including cellphone use while driving, following the program (Brockamp et al., 2019). An assessment of the impacts of app-based feedback with or without monetary incentives for novice drivers, nearly three quarters of which were teens, showed moderate improvements in driving skills relevant to safety; improvements were more prominent with the incentives and among drivers who elected for higher intensity feedback, indicating self-selection as well as attrition biases (Peer et al., 2020). An evaluation of the efficacy of mindfulness-based neurofeedback training demonstrated benefits in attentional performance and reduced aggressive driving behaviors; however, the measures did not specifically address distracted driving behaviors (Balconi et al., 2019).

Two recently published studies evaluated the effectiveness of a campaign or specific messaging. An evaluation of the impact of different framing of printed texting-while-driving messaging showed that social loss messaging promoted greater intentions to reduce unsafe behavior than mortality messaging (Martin & Kamins, 2019). Somewhat more recently, Stewart et al. (2021) evaluated the impacts of a multi-pronged campaign based on epidemiology, personal stories, and consequences; there was a significant decline in distracted driving citations after the campaign; 80% of self-reports indicated that the campaign made them "think twice" about future cellphone use while driving.

Other Outcome Measures

As was the case above, the majority of evaluations with previously excluded outcome measures focused on teen drivers. In a survey of willingness to reduce cellphone use and perceptions of various countermeasures, teens demonstrated differences in willingness to give up certain phone-based tasks, and rated different financial incentives (gain-framed, loss-framed, and group-based) likely to be "very effective" (Delgado et al., 2018). In another study of adolescents who played a driving game, either with a peer (or not) and with (or without) a reward for safe choices, rewards positively impacted risky decision making, particularly among drivers that reported risky

driving styles (Hinnant & Stavrinos, 2020). Among high school students that participated in a distracted driving curriculum that integrated statistics on distraction and interactive learning stations, a majority learned new information and would recommend the program. After the program, participants were more likely to report that they would speak up as a passenger with a drowsy or distracted driver (Linden et al., 2019). In an evaluation of the FOrward Concentration and Attention Learning (FOCAL) driver training program among young drivers using a driving simulator, drivers trained with FOCAL were more attentive to the forward roadway and reported better awareness of how they distributed their attention than placebo-trained drivers (Unverricht et al., 2020). A similar curriculum, the Sleepiness and Fatigued Driving Evaluation and Training Program (SAFE-T), showed benefits in terms of hazard anticipation and mitigation, and attention maintenance among young drivers (Knodler et al., 2015).

Other research has evaluated programs for populations other than teens or young drivers. A large-scale evaluation of an employee-based intervention, 'Just Drive,' aimed at reducing distracted driving showed that a majority of participants reported increased awareness and motivation to change behaviors, and in a 3-month follow up, reported positive changes in distracted driving behavior (Hill et al., 2020).

Other studies have assessed the impacts of distracted driving messaging or campaigns. In a study in which participants viewed three fear-based public service announcement of increasing severity, those with higher emotional intelligence scored higher on self-efficacy and response efficacy (Peyton, 2021). In another evaluation of non-traditional safety messages for use on dynamic message signs, messages employing humor, or word play and rhymes, and messages concerning distracted driving were scored high in terms of perceived effectiveness to change behavior, recall, and increased attention (Shealy et al., 2020). Tamul et al. (2021) demonstrated that news coverage of texting while driving fatalities can denormalize and stigmatize the behavior. Frietze & Cohn (2018) found that utilizing mortality salience in messaging amplified negative attitudes about phone use while driving and reduced intentions to do so among young adults. Hayashi et al. (2019) found similar impacts of threat appeals on intentions to text while driving among undergraduate students, as well as a decrease in the degree of impulsive decision-making regarding texting while driving. An assessment of the quality and accuracy of information on websites about distracted driving and related outcomes found that they largely focus on distraction involving mobile phones while neglecting other forms of distractions (Poon et al., 2019). Further, death was often discussed but injuries were overlooked despite being much more likely. Wu & Weseley (2013) found that students in driver education who were shown statistical messages that referenced a general population stated lower intentions of cellphone use while driving than students who were shown messages referencing a specific population with smaller numbers.

Legislative and Policy Countermeasures

Findings of the 2019 Review (Arnold et al., 2019)

Legislative efforts to curb distracted driving tend to fall into three types: all-driver handheld cellphone bans, all-driver texting bans, or complete cellphone bans that apply to a subset of drivers. Evaluations of all-driver handheld cellphone bans have found reductions in self-reported or observed phone use while driving and, in some cases, fatal and injury crashes. However, these outcomes are not universal. Studies of these bans have sometimes failed to document reductions in call rates, freeway crashes, or collision claims. Moreover, increases in handheld cellphone crashes and self-reported, hands-free phone use have also been documented in studies of handheld bans. All said, the majority of evaluations of all-driver handheld cellphone bans have indicated favorable reductions in handheld phone use. Evaluations looking at fatal or injury crashes are less conclusive.

Updated Findings: Safety and Behavioral Outcomes

As in the prior review, most recent studies on legislative countermeasures evaluated one or more of the three types of distracted driving bans.Wickens et al. (2020) evaluated the impact of increased penalties for texting while driving accompanied by enhanced enforcement and public education using an ongoing cross-sectional survey, which indicated that the proportion of drivers reporting texting while driving in the previous 30 days decreased by 36% after the law was implemented, with the most marked reductions among those who engaged

in the behavior more frequently. Liu et al. (2019) analyzed impacts of California's all-driver handheld cellphone ban, finding that it was effective in reducing the frequency and proportion of crashes caused by cellphone usage. They also demonstrated that such crashes produce more severe outcomes, and crashes caused by hands-free cellphone usage did not differ in severity from handheld cellphone crashes. One study utilizing fatal crash data from states with various types and strengths of distracted driving laws found that texting bans and handheld bans for all drivers were associated with reduced rates of motor vehicle crash fatalities in all age groups, and primary texting bans were associated with lower fatality rates involving drivers ages 16–19 (Flaherty et al., 2020). A similar analysis of crash fatality rates in relation to cellphone-use-while-driving laws suggested that, aside from handheld bans, distracted driving bans have no effect (Zhu et al., 2021); handheld bans, the authors asserted, reduce driver fatalities but paradoxically not non-driver fatalities or total fatalities. Studies that have considered cellphone use bans in the context of graduated driver licensing systems have shown positive indications in terms of reduced crash rates (Senserrick et al., 2021) and reduced fatalities per 16- to 17-year-old licensed female driver (Gilpin, 2019).

Unlike the 2019 review, this review identified a relevant study examining impacts of (non-legislative) policy, specifically fleet safety management practices and policies including mobile phone policies. Based on data from a large number of companies, Vivoda et al. (2019) found several practices were related to collision and injury rates, including checking mobile phone records. Another study that utilized naturalistic data from a large number of truck and bus fleets found that drivers with fleet cellphone policies had odds 0.83 times less than those without a policy, there was no significant impact of state law, and drivers were more likely to comply with a fleet policy than a state law (Hickman et al., 2011). The authors proffer that state cellphone laws should be enforced similarly to fleet policies.

Other Outcome Measures

Several studies have used surveys to assess perceptions of and engagement in distracted driving, as well as potential impacts of legislation limiting mobile phone use while driving. Bradish et al. (2019) found that the strongest predictor of cellphone use in Georgia after implementation of a hands-free law was pre-law cellphone use, suggesting that the law might not be effective at breaking strong habits. In a survey of drivers in Australia, Kaviani et al. (2020) explored perceptions of formal and informal deterrents to illegal smartphone use while driving, showing that while those who engage in the behavior perceive deterrents differently than law-abiding drivers, but the prospect of self-injury was most impactful for both groups. Drivers also tended to underestimate consequences of smartphone use while driving but overestimate the certitude of being apprehended. A survey of drivers in the U.S., Canada, and Europe demonstrated that young drivers showed higher engagement in and acceptance of distracted driving than drivers of other ages, and were also the least likely to support zero tolerance distracted driving policies (Lyon et al., 2020). Another survey showed that knowledge of laws regarding cellphone use while driving varied among drivers: those who were employed, highly educated, and lived in urban areas were better informed (Sagberg & Sundfør, 2016). In the same survey, female drivers were more likely to support distraction countermeasures (Sagberg & Sundfør, 2016), as was also the case for a survey of adolescents with respect to a text/email ban (Pope et al., 2019).

In an economic analysis of a law banning driver cellphone use in Alberta, Canada, taking into account potential health gains and related costs, Sperber et al. (2010) concluded that the law was likely to be cost effective.

Enforcement Countermeasures

Findings of the 2019 Review (Arnold et al., 2019)

The few studies that assessed the effectiveness of high-visibility enforcement (HVE) of handheld cellphone and texting bans have found decreases in observed handheld phone use but no significant effects on crashes or collision claims. Enforcement of distracted driving laws is necessary but can be quite challenging (Coben & Zhu, 2013), particularly those that apply to only a subset of drivers (Buckley et al., 2014) or only certain types of phone manipulation (Delgado et al., 2016; McCartt et al., 2014).

Updated Findings: Safety and Behavioral Outcomes

One additional evaluation of an enforcement countermeasure was identified in the current review. A survey of Japanese drivers regarding various forms of visible roadside policing found intentions to abstain from distracting activities were greater for policing than other types of countermeasures, and when an officer rather than a police car was visible, leading the study authors to suggest increasing officer conspicuity may be beneficial (Nakano et al., 2019).

Other Outcome Measures

Two studies addressed enforcement with respect to outcomes excluded in the previous review. Rudisill & Zhu's (2016) analysis of several years' worth of citations for cellphone use while driving in 14 states and the District of Columbia provides insight into potential reasons why state distracted driving laws may not always be highly effective. Their results showed that such citations were relatively infrequent and accounted for only 1% of all traffic violations where complete citation data was available. Citations for handheld phone use were much more common than those for texting or young driver bans (Rudisill & Zhu, 2016). Truelove et al. (2020) assessed perceptions of enforcement of moving violations including two forms of distracted driving, finding fluctuations over time, particularly in terms of certainty of apprehension, which the authors assert suggests persistent enforcement efforts are needed.

Technological Countermeasures

Findings of the 2019 Review

Arnold et al. (2019) found that evaluations of technology countermeasures that aim to reduce distracted driving have demonstrated potential success. While there have been issues with the reliability of and compliance with cellphone blocking technology (e.g., Funkhouser & Sayer, 2013; Reagan & Cicchino, 2018), reductions in actual and self-reported phone use have been noted (e.g., (Creaser et al., 2015; Reagan & Cicchino, 2018). Mixed results were found regarding the efficacy of technology that monitors and provides feedback on driver behavior.

Updated Findings: Safety and Behavioral Outcomes

The majority of new publications identified in the current study regarding the effectiveness of technological countermeasures were evaluations of smartphone applications that block notifications and/or provide warnings. Oviedo-Trespalacios, Truelove, et al. (2020) provide additional evidence of reductions in self-reported mental workload and phone use, including visual-manual, cognitive-auditory, and manipulations to control music among adult drivers using smartphone blocking technology for one week; the authors noted that the technology would benefit from improved functionality and automatic activation. A trial of a 2-month smartphone blocking application intervention involving employees of eight organizations in Israel showed significant reduction in smartphone interactions that persisted, albeit to a lesser degree, in a month of post-intervention monitoring (Rispler & Luria, 2020); male employees and those with high safety climate perceptions were more likely to remain in the intervention. Davis et al. (2019) conducted a 3-month implementation of a smartphone application that monitors and coaches driving behavior in real-time in addition to blocking notifications, and which was originally designed for novice drivers; while the study did not include outcomes directly related to distraction, it demonstrated high user acceptance and efficacy in improving driving performance among a small sample of older drivers. An evaluation of an alerting smartphone application to reduce pedestrian distraction at intersections showed promise but suffered from technological limitations, and participants intentionally tested the app rather than using caution to cross like usual (Schwebel et al., 2021).

Other Outcome Measures

Studies have addressed user preferences, perceptions, acceptance, and/or performance with respect to various technologies. With respect to smartphone applications to reduce or prevent distracted driving, Oviedo-Trespalacios, Vaezipour, et al. (2020) found that drivers perceived potential benefits in terms of reduction in smartphone use while driving and increased safety; however, they also feel pressure to respond while driving. Oviedo-Trespalacios et al. (2019) further explored drivers' willingness to install and use a smartphone application to prevent distracted driving, and identified several important functions, including the ability to disable visual-manual tasks and

notifications, to employ hands-free conversations and automatic responses, and to use applications that support driving as well music-playing functions. A handful of recent driving simulator studies offer guidance of varying specificity. Shupsky et al. (2020), for example, offer guidelines for improving the design and implementation of mobile computer terminals in police vehicles, while others have investigated acceptance and impacts of adaptive in-vehicle technology systems (Reinmueller & Steinhauser, 2019; Weber et al., 2020) and partial and full lockout of in-vehicle information systems (Jung et al., 2019). While not technology per se, a case study by Azam et al. (2018) demonstrates how an analytical framework and data visualization can be used by state DOTs for problem identification and allocation of law enforcement efforts and funding.

While development and testing of driver monitoring systems are out of scope for this review, some research has explored augmenting such systems with driver feedback, often delivered in real time. For example, a simulator study by Gaspar et al. (2018) demonstrated that real-time attentional maintenance alerts improved situational awareness and takeover performance, while driver state-contingent takeover messages did not improve performance. Another study conducted on a test track found that context-sensitive distraction warnings from a smartphone application increased drivers' glance time on road and garnered trust and acceptance (Kujala et al., 2016). An evaluation of similar warnings for distracted pedestrians crossing a road using connected vehicle technology in a virtual simulation showed benefits in terms gap selection accompanied by reduced attention to the roadway (Kearney et al., 2016).

App Review

The internet and app store searches yielded many hits; however, manual examination revealed that the majority of the results were false positives. As such, searches were discontinued when no more true positives were identified on consecutive results pages (searches typically did not exceed 10 pages of results). Twenty-eight apps or products were identified in the search. Nearly all of the products were smartphone-based apps (26 out of 28); the others utilized equipment that was added into the vehicle cab. The majority were intended primarily for personal use (23 out of 28) vs. commercial operations and about 20% were tied to insurance discount programs (6 out of 28). In terms of the mechanism, seven were apps intended to block the use of cellphones (or certain cell features) while the vehicle is in motion and 18 involved some form of passive monitoring of driver behavior (most often using the phone sensors to determine when the phone was being manipulated). These latter apps sometimes employed gamification approaches to promote user engagement through competition via safe behaviors or safety scores. Of the remaining apps, two were display enhancements to facilitate the use of a smartphone (via head-up display) and one was an app that provided alerts to distracted drivers when they approached critical areas of the road, such as rail crossings, school zones, and traffic lights. These touted safety by allowing drivers to keep their eyes fixated in a location closer to the road or helping them reorient their attention to the roadway. Thus, they did not represent countermeasures to curb distracting behaviors (and could even exacerbate such behavior).

For apps that monitored driver phone-use behavior, these typically monitored driving as well: acceleration and hard braking as well as speed and other control dynamics. Typically (16 out of 18), feedback on all aspects was provided at the end of a trip (e.g., a trip summary with scores on the sub-dimensions and an overall score). In a few cases, this information was provided to a third party, such as a parent or employer for their review and action. Only one app provided real-time alerts about distracting behavior.

Importantly, of all of the products included in the current review, only one had any substantive evidence of evaluation (and even this was not specific to distraction alone; it included several risky driving behaviors). Another small handful presented some cursory information about the efficacy of the product in curbing distracted driving behaviors; however, there was insufficient information about how these claims were reached. The remaining products made no mention of efficacy or evaluation in their support material. It follows that this space, although replete with many different products and offerings, is a largely unknown commodity in terms of efficacy in reducing distraction and/or enhancing safety.

Discussion

Educational and/or Behavioral Countermeasures

Research on educational and/or behavioral countermeasures continued in large part to focus on teen drivers, adopting a wide variety of approaches for educational or training programs as well as campaign messaging. Many recent studies have shown some favorable outcomes along a number of safety, performance, or behavioral indices. The provision of incentives or rewards has resulted in benefits in terms of perceived effectiveness among teens, and when coupled with app-based feedback or a driving game. Several studies evaluated the impacts of specific content in messaging or campaigns, including fear, threats, and fatalities, with generally positive but occasionally conflicting results. Beyond safety and behavioral measures, studies published in the past few years have shown improvements in the target group's understanding of risks associated with distraction and higher motivation to change behaviors, among other measures. There remains some uncertainty regarding the long-term effects as well as the translation to actual on-road behaviors.

Legislative and Policy Countermeasures

In the original review, evaluations of all-driver handheld cellphone bans in many cases had documented reductions in self-reported or observed phone use while driving; however, the outcomes concerning the resulting fatal and injury crashes were less conclusive. More recent work has renewed efforts to document the effect of texting and cellphone bans on crashes or emergency room visits. These studies have contributed important data, showing significant reduction in crashes and emergency visits, while considering an array of other factors (e.g., age of driver, type of ban: primary vs. secondary, etc.). Others have shown that increased penalties for texting while driving can lead to marked decreased in self-reported texting behavior. Studies have also documented other outcomes associated with legislative or policy countermeasures, including the interaction between bans and pre-law behaviors. These studies help shed insight into how effective laws will be on different drivers. All told, the updated and expanded results of the review help reinforce that legislation is an important and necessary countermeasure in combatting distracted driving.

Enforcement Countermeasures

From the previous review, studies of enforcement countermeasures were few in number and the updated review did not expand this significantly. Collectively, these studies suggest that visible enforcement and in some cases, higher conspicuity of roadside police, can reduce distracting behavior or self-reported intentions to perform distracting activities in drivers. One study that examined perceptions of enforcement found they vary over time, implicating the duration or continuity of any enforcement activity or campaign. Overall, this class of countermeasures still suffers from a paucity of research (though it is strongly linked to legislative countermeasures).

Technological Countermeasures

The original review found some positive support for technology-based countermeasures, though noting that there were many different approaches, yielding a knowledge base that was not very deep for a particular solution. New research uncovered in this review was largely focused on smartphone-based apps that either blocked distracting activities or provided warnings to drivers. These works again provided some positive outcomes in terms of behaviors and performance, even for extended trials (2–3+ months), although in some studies the effects were stronger for different groups of drivers.

Using the expanded criteria for study outcomes, many studies examined driver perceptions and acceptance of the technology, which are important considerations for any countermeasure that requires the user to opt in or continue its use over time. As before, more work is needed to reinforce and replicate some of the knowledge gleaned in these studies, along with more deliberate efforts to translate the effects to real world driving behaviors and safety.

The app review yielded a modest number of relevant apps, most of which either monitor driver behavior or block use of the phone partially or entirely. Most monitoring apps provide post-drive feedback, while a few share feedback with a third party. For most of the apps, no information was provided about efficacy, and most for which claims were made lacked supporting evidence. It is also important to note that some apps are marketed as safety tools that ease the demands associated with distracting tasks (e.g., placing visual information closer to the forward

roadway or alerting drivers to upcoming obstacles). These approaches should not be construed as countermeasures aimed at mitigating distracting driving.

This review of literature regarding the effectiveness of distracted driving countermeasures augments the findings of our prior review (Arnold et al., 2019) with the most recent publications concerning safety-based outcome measures, the current state of knowledge regarding non-safety based outcome measures, and a review of commercially available relevant apps. The overall picture remains largely the same, with the effectiveness of many countermeasures unclear due to limited or conflicting research.

References

AAA Foundation for Traffic Safety. (2021). *2020 Traffic Safety Culture Index*. AAA Foundation for Traffic Safety. https://aaafoundation.org/wp-content/uploads/2021/09/2020-Traffic-Safety-Culture-Index-October-2021.pdf

Arnold, L. S., Benson, A. J., Tefft, B. C., Barragan, D., Jin, L., Kolek, S., Horrey, W. J., & AAA Foundation for Traffic Safety. (2019). *Effectiveness of Distracted Driving Countermeasures: A Review of the Literature* (Research Brief). AAA Foundation for Traffic Safety. https://aaafoundation.org/wp-content/uploads/2019/11/19-0553_AAAFTS-DD-Countermeasures-Brief_FINAL.pdf

Azam, M. S., Burke, P. W., & Manepalli, U. R. R. (2018). *Using Analytics and Data Visualization to Help Reduce Distracted Driving: A Montana Case Study* (No. 18–03598). Article 18–03598. Transportation Research Board 97th Annual Meeting.

Balconi, M., Crivelli, D., & Angioletti, L. (2019). Efficacy of a Neurofeedback Training on Attention and Driving Performance: Physiological and Behavioral Measures. *Frontiers in Neuroscience*, 13, 996.

Bradish, T., Wilson, J. H., & Locker, L. (2019). Hands-free law in Georgia: Predictors of post-law cellphone use among college drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, 66, pp-226-233.

Brockamp, T., Koenen, P., Caspers, M., Bouillon, B., Köhler, M., & Schmucker, U. (2019). The influence of an injury prevention program on young road users: A German experience. *European Journal of Trauma and Emergency Surgery: Official Publication of the European Trauma Society*, 45(3), 423–429.

Buckley, L., Chapman, R. L., & Sheehan, M. (2014). Young Driver Distraction: State of the Evidence and Directions for Behavior Change Programs. *Journal of Adolescent Health*, 54(5), S16–S21.

Coben, J. H., & Zhu, M. (2013). Keeping an Eye on Distracted Driving. *JAMA*, 309(9), 877–878.

Creaser, J. I., Edwards, C. J., Morris, N. L., & Donath, M. (2015). Are cellular phone blocking applications effective for novice teen drivers? *Journal of Safety Research*, 54, 75–78.

Davis, B. (2019). T*een Driver Support System Technology Transfer* (01714239; CTS 19-24; p. 33p). Roadway Safety Institute. https://www.cts.umn.edu/publications/report/teen-driver-support-system-technology-transfer

Delgado, M. K., McDonald, C. C., Winston, F. K., Halpern, S. D., Buttenheim, A. M., Setubal, C., Huang, Y., Saulsgiver, K. A., & Lee, Y.-C. (2018). Attitudes on Technological, Social, and Behavioral Economic Strategies to Reduce Cellphone Use While Driving in Teens. *Traffic Injury Prevention*, 19(6), 569–576.

Delgado, M. K., Wanner, K. J., & McDonald, C. (2016). Adolescent Cellphone Use While Driving: An Overview of the Literature and Promising Future Directions for Prevention. *Media and Communication*, 4(3), 79–89.

Donmez, B., Merrikhpour, M., & Nooshabadi, M. H. (2019). Mitigating Teen Driver Distraction: In-Vehicle Feedback Based on Peer Social Norms. *Human Factors*, 18720819891285.

Downs, E., Limperos, A., Strange, S., Schultz, W., Engberg, A., Oyaas, T., Gala, D., Bloom, N. R., Bloom, K., Harpster, K., Liu, X., & Petters, N. (2018). Fair Game: Using Simulators to Change Likelihood of Distracted Driving at the Minnesota State Fair. *Communication Research Reports*, 35(2), 121–130.

Flaherty, M. R., Kim, A. M., Salt, M. D., & Lee, L. K. (2020). Distracted Driving Laws and Motor Vehicle Crash Fatalities. *Pediatrics*, 145(6).

Fournier, A. K., Berry, T. D., & Frisch, S. (2016). It can W8: A community intervention to decrease distracted driving. *Journal of Prevention & Intervention in the Community*, 44(3), 186–198.

Frietze, G., & Cohn, L. D. (2018). Texting and tombstones: Impact of mortality salience on risky driving intentions. Transportation Research Part F: *Traffic Psychology and Behaviour*, 59, 1–11.

Funkhouser, D., & Sayer, J. R. (2013). *Cell Phone Filter/ Blocker Technology Field Test* (Technical Report DOT HS 811 863; p. 90). National Highway Traffic Safety Administration. http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2013/Cell_Phone_Filter_Blocker_Technology_Field_Test_811863.pdf

Gaspar, J. G., Schwarz, C., Kashef, O., Schmitt, R., & Shull, E. (2018). *Using Driver State Detection in Automated Vehicles* (p. 28). SaferSim University Transportation Center. http://safersim.nads-sc.uiowa.edu/final_reports/UI%201%20Y1%20report.pdf

Gilpin, G. (2019). Teen driver licensure provisions, licensing, and vehicular fatalities. *Journal of Health Economics*, 66, 54–70.

Hayashi, Y., Foreman, A. M., Friedel, J. E., & Wirth, O. (2019). Threat appeals reduce impulsive decision making associated with texting while driving: A behavioral economic approach. *PloS One*, 14(3), e0213453.

Hickman, J. S., Hanowski, R. J., Camden, M., & Alvarez, A. (2011). *Comparison of a state cell phone law versus a fleet cell phone policy using naturalistic data*. 2nd International conference on driver distraction and inattention.

Hill, L., Rybar, J., Jahns, J., Lozano, T., & Baird, S. (2020). "Just Drive": An Employee-Based Intervention to Reduce Distracted Driving. *Journal of Community Health*, 45(2), 370–376.

Hinnant, J. B., & Stavrinos, D. (2020). Rewards decrease risky decisions for adolescent drivers: Implications for crash prevention. *Transportation Research Part F: Traffic Psychology and Behaviour*, 74, pp-272-279.

Jashami, H., Hurwitz, D. S., Abdel-Rahim, A., Bham, G. H., & Boyle, L. N. (2017). Educating Young Drivers in the Pacific Northwest on Driver Distraction. *TRB 96th Annual Meeting Compendium of Papers*, 19.

Joseph, B., Haider, A., Hassan, A., Kulvatunyou, N., Bains, S., Tang, A., Zangbar, B., O'Keeffe, T., Vercruysse, G., Gries, L., & Rhee, P. (2016). Injury prevention programs against distracted driving among students. *The Journal of Trauma and Acute Care Surgery*, 81(1), 144–148.

Joseph, B., Zangbar, B., Bains, S., Kulvatunyou, N., Khalil, M., Mahmoud, D., Friese, R. S., O'Keeffe, T., Pandit, V., & Rhee, P. (2016). Injury prevention programs against distracted driving: Are they effective? *Traffic Injury Prevention*, 17(5), 460–464.

Jung, T., Kaß, C., Zapf, D., & Hecht, H. (2019). Effectiveness and user acceptance of infotainment-lockouts: A driving simulator study. *Transportation Research Part F: Traffic Psychology and Behaviour*, 60, 643–656.

Kaviani, F., Young, K. L., Robards, B., & Koppel, S. (2020). Understanding the deterrent impact formal and informal sanctions have on illegal smartphone use while driving. *Accident; Analysis and Prevention*, 145, 105706.

Kearney, J. K., Plumert, J. M., Safety Research Using Simulation University Transportation Center (SaferSim), & Department of Transportation. (2016). *Using Connected Vehicle Technology to Deliver Timely Warnings to Pedestrians* (01616923; p. 30p). http://safersim.nads-sc.uiowa.edu/final_reports/UI-2-Y1_Report.pdf

Knodler, M. A., Fisher, D., Romoser, M., New England University Transportation Center, & Research and Innovative Technology Administration. (2015). *Evaluating the Effects of Integrated Training on Minimizing Driver Distraction* (01590448; p. 3p). http://utc.mit.edu/uploads/UMAR24-22-FP.pdf

Kujala, T., Karvonen, H., & Mäkelä, J. (2016). Context-sensitive distraction warnings: Effects on drivers' visual behavior and acceptance. *International Journal of Human-Computer Studies*, 90, 39–52.

Layba, C., Griffin, L. W., Jupiter, D., Mathers, C., & Mileski, W. (2017). Adolescent motor vehicle crash prevention through a trauma center-based intervention program. *The Journal of Trauma and Acute Care Surgery*, 83(5), 850–853.

Linden, P. L., Endee, L. M., Flynn, E., Johnson, L. M., Miller, C.-A., Rozensky, R., Smith, S. G., & Verderosa, C. (2019). High School Student Driving Perceptions Following Participation in a Distracted Driving Curriculum. *Health Promotion Practice*, 1524839918824322.

Liu, C., Lu, C., Wang, S., Sharma, A., & Shaw, J. (2019). A longitudinal analysis of the effectiveness of California's ban on cellphone use while driving. *Transportation Research Part A: Policy and Practice*, 124, pp-456-467.

Lyon, C., Mayhew, D., Granié, M.-A., Robertson, R., Vanlaar, W., Woods-Fry, H., Thevenet, C., Furian, G., & Soteropoulos, A. (2020). Age and road safety performance: Focusing on elderly and young drivers. *IATSS Research*, 44(3), pp-212-219.

Martin, I. M., & Kamins, M. A. (2019). Effectively using death in health messages: Social loss versus physical mortality salience. *Journal of Consumer Behaviour*, 18(3), 205–218.

McCartt, A. T., Kidd, D. G., & Teoh, E. R. (2014). Driver Cellphone and Texting Bans in the United States: Evidence of Effectiveness. *Annals of Advances in Automotive Medicine*, 58, 99–114.

McDonald, C. C., Fargo, J. D., Swope, J., Metzger, K. B., & Sommers, M. S. (2021). Initial Testing of a Web-Based Intervention to Reduce Adolescent Driver Inattention: A Randomized Controlled Trial. *Journal of Emergency Nursing*, 47(1), 88-100.e3.

Mims, L., Brooks, J. O., Jenkins, C., Schwambach, B., & Gubitosa, D. (2020). Teenage drivers' views of a classroom and closed-road post-license advanced driving program, Guard Your Life. *Safety*, 6(4), Article-ID 44.

Nakano, Y., Okamura, K., Kosuge, R., Kihira, M., & Fujita, G. (2019). Effect of visible presence of policing activities on drivers' vigilance and intention to refrain from non-driving activities: A scenario-based survey of general Japanese drivers. *Accident; Analysis and Prevention*, 133, 105293.

National Center for Statistics and Analysis. (2021). Distracted Driving 2019 (Research Note DOT HS 813 111; Traffic Safety Facts, p. 7). *National Highway Traffic Safety Administration*. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813111

Oviedo-Trespalacios, O., Truelove, V., & King, M. (2020). "It is frustrating to not have control even though I know it's not legal!": A mixed-methods investigation on applications to prevent mobile phone use while driving. *Accident; Analysis and Prevention*, 137, 105412.

Oviedo-Trespalacios, O., Vaezipour, A., Truelove, V., Kaye, S.-A., & King, M. (2020). "They would call me, and I would need to know because it is like life and death": A qualitative examination of the acceptability of smartphone applications designed to reduce mobile phone use while driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, 73, pp-499-513.

Oviedo-Trespalacios, O., Williamson, A., & King, M. (2019). User preferences and design recommendations for voluntary smartphone applications to prevent distracted driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, 64, pp-47-57.

Peer, S., Muermann, A., & Sallinger, K. (2020). App-based feedback on safety to novice drivers: Learning and monetary incentives. *Transportation Research Part F: Traffic Psychology and Behaviour*, 71, pp-198-219.

Peyton, D. F. (2021). *An evaluation of fear appeals response using cognition value through emotional intelligence and texting and driving public service announcements*. ProQuest Information & Learning.

Poon, J., Gjorgjievski, M., Moga, I., & Ristevski, B. (2019). Quality and Accuracy of Information Available on Websites for Distracted Driving: Qualitative Analysis. *Interactive Journal of Medical Research*, 8(4), e16154.

Pope, C. N., Mirman, J. H., & Stavrinos, D. (2019). Adolescents' perspectives on distracted driving legislation. *Journal of Safety Research*, 68, 173–179.

Pradhan, A. K., Divekar, G., Masserang, K., Romoser, M., Zafian, T., Blomberg, R. D., Thomas, F. D., Reagan, I., Knodler, M., Pollatsek, A., & Fisher, D. L. (2011). The effects of focused attention training on the duration of novice drivers' glances inside the vehicle. *Ergonomics*, 54(10), 917–931.

Rana, N., Ross, M., LaRock, L., Mele, J., Cumbo, N., Colom, L., Trecartin, A., Granet, J., & Behm, R. (2018). An awareness campaign decreases distracted driving among hospital employees at a rural trauma center. *Traffic Injury Prevention*, 19(sup2), S165–S167.

Reagan, I. J., & Cicchino, J. B. (2018). *Do Not Disturb While Driving – use of cellphone blockers among adult drivers* (p. 24). Insurance Institute for Highway Safety. https://www.iihs.org/api/datastoredocument/bibliography/2179

Reinmueller, K., & Steinhauser, M. (2019). Adaptive forward collision warnings: The impact of imperfect technology on behavioral adaptation, warning effectiveness and acceptance. *Accident; Analysis and Prevention*, 128, 217–229.

Rispler, C., & Luria, G. (2020). Employee perseverance in a "no phone use while driving" organizational road-safety intervention. *Accident; Analysis and Prevention*, 144, 105689.

Rudisill, T. M., & Zhu, M. (2016). Who actually receives cell phone use while driving citations and how much are these laws enforced among states? A descriptive, cross-sectional study. *BMJ Open*, 6(6), e011381.

Sagberg, F., & Sundfør, H. B. (2016). *Inattention at the wheel: Prevalence, consequences and countermeasures* (01634720). Institute of Transport Economics (TØI). https://www.toi.no/getfile.php/Publikasjoner/T%C3%98I%20rapporter/2016/1481-2016/1481-2016-elektronisk.pdf

Schwebel, D. C., Hasan, R., Griffin, R., Hasan, R., Hoque, M. A., Karim, M. Y., Luo, K., & Johnston, A. (2021). Reducing distracted pedestrian behavior using Bluetooth beacon technology: A crossover trial. *Accident; Analysis and Prevention*, 159, 106253.

Senserrick, T., Boufous, S., Olivier, J., & Hatfield, J. (2021). At what stages of licensing do graduated driver licensing systems reduce crashes? Example from Queensland, Australia. *Accident; Analysis and Prevention*, 152, 105989.

Shealy, T., Kryschtal, P., Franczek, K., Katz, B. J., Virginia Transportation Research, C., Virginia Department of, T., & Federal Highway, A. (2020). *Driver Response to Dynamic Message Sign Safety Campaign Messages* (01741727; p. 65p). http://www.virginiadot.org/vtrc/main/online_reports/pdf/20-R16.pdf

Shupsky, T., Lyman, A., He, J., & Zahabi, M. (2020). Effects of Mobile Computer Terminal Configuration and Level of Driving Control on Police Officers' Performance and Workload. *Human Factors*, 18720820908362.

Sperber, D., Shiell, A., & Fyie, K. (2010). The cost-effectiveness of a law banning the use of cellular phones by drivers. *Health Economics*, 19(10), 1212–1225.

Stewart, T. C., Edwards, J., Penney, A., Gilliland, J., Clark, A., Haidar, T., Batey, B., Pfeffer, A., Fraser, D. D., Merritt, N. H., & Parry, N. G. (2021). Evaluation of a population health strategy to reduce distracted driving: Examining all "Es" of injury prevention. *The Journal of Trauma and Acute Care Surgery*, 90(3), 535–543.

Tamul, D., Einstein, C., Hotter, J., Lanier, M., Purcell, L., & Wolf, J. (2021). Narrative persuasion and stigma: Using news accounts to denormalize texting while driving. Accident; *Analysis and Prevention*, 151, 105876.

Truelove, V., Freeman, J., Watson, B., Kaye, S.-A., & Davey, J. (2020). Are perceptions of penalties stable across time? The problem of causal ordering in deterrence applied to road safety. *Accident; Analysis and Prevention*, 146, 105746.

Unni, P., Estrada, C. M., Chung, D. H., Riley, E. B., Worsley-Hynd, L., & Stinson, N. (2017). A multiyear assessment of a hospital-school program to promote teen motor vehicle safety. *The Journal of Trauma and Acute Care Surgery*, 83(2), 289–295.

Unverricht, J., Yamani, Y., Chen, J., & Horrey, W. J. (2020). Minding the Gap: Effects of an Attention Maintenance Training Program on Driver Calibration. *Human Factors*, 18720820965293.

Vivoda, J. M., Pratt, S. G., & Gillies, S. J. (2019). The Relationships Among Roadway Safety Management Practices, Collision Rates, and Injury Rates Within Company Fleets. *Safety Science*, 120, pp-589-602.

Weber, B., Dangelmaier, M., Diederichs, F., & Spath, D. (2020). User rating and acceptance of attention-adaptive driver safety systems. *European Transport Research Review*, 12(1), 26.

Wickens, C. M., Ialomiteanu, A. R., Cook, S., Hamilton, H., Haya, M., Ma, T., Mann, R. E., Manson, H., & McDonald, A. (2020). Assessing the impact of the 2015 introduction of increased penalties and enhanced public awareness and enforcement activities on texting while driving among adults in Ontario, Canada. *Traffic Injury Prevention*, 21(4), 241–246.

Wu, A., & Weseley, A. J. (2013). The effects of statistical format and population specificity on adolescent perceptions of cell phone use while driving. *Current Psychology: A Journal for Diverse Perspectives on Diverse Psychological Issues*, 32(1), 32–43.

Zhu, M., Shen, S., Redelmeier, D. A., Li, L., Wei, L., & Foss, R. (2021). Bans on Cellphone Use While Driving and Traffic Fatalities in the United States. *Epidemiology*, 32(5), 731–739.

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