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State-of-Knowledge on Distracted Driving Due to Portable Electronic Device Use: 2008 – 2022 Update

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16. Abstract

This report updates what is known about behavioral aspects of driver distraction due to portable electronic device (PED) use since publication of a 2008 NHTSA state-of-knowledge (SOK) report. This update is a reference for highway safety stakeholders by benchmarking the state of driver PED-use problems from 2008 through September 2022 as defined by four primary focus areas, with each focus area covered in a separate chapter. Two introductory chapters cover the background and purpose of the SOK, key terminology, and research methodologies illuminating each defined problem area. Chapter 3 focuses on driver PED use, estimates of distracted driving prevalence, related characteristics, and driver motivations for driving distracted. Chapter 4 centers on effects of distraction on driver behavior and performance, focusing on driver attention and aspects of performance such as lane position, headway, speed, and reaction time. Chapter 5 involves distracted driving's effects on safety, describing crash prevalence, characteristics, and risk. Chapter 6 describes behavioral countermeasures for reducing driver distraction.

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List of Abbreviations and Acronyms

AAAFTS	AAA Foundation for Traffic Safety
ADAS	advanced driver assistance systems
CNC	crash and near-crash
CRSS	Crash Report Sampling System
FARS	Fatality Analysis Reporting System
GES	General Estimates System
GHSA	Governor’s Highway Safety Association
HF	hands-free
HH	handheld
HVE	high-visibility enforcement
KRD	kinematic risky driving
MCI	mild cognitive impairment
NASS	National Automotive Sampling System
NCSA	National Center for Statistics and Analysis
NDS	naturalistic driving study
NEST	Naturalistic Engagement in Secondary Task
NMVCCS	National Motor Vehicle Crash Causation Survey
NOPUS	National Occupant Protection Use Survey
NSDDAB	National Survey on Distracted Driving Attitudes and Behaviors
OR	odds ratio
PCR	police crash report
PDA	personal digital assistant
PDO	property damage only, property-damage-only crash
PED	portable electronic device
PI	principal investigator
RT	reaction time
SHRP2	Second Strategic Highway Research Program
SCE	safety-critical event
SDLP	standard deviation of lane position
SHSO	State Highway Safety Office
SOK	state-of-knowledge
TAM	Technology Acceptance Model
TPB	theory of planned behavior
TSCI	Traffic Safety Culture Index
UMass	University of Massachusetts
UTAUT	unified theory of acceptance and use of technology
VM	visual-manual
YRBSS	Youth Risk Behavior Surveillance System

Executive Summary

The National Highway Traffic Safety Administration recognizes that safe driving requires driver attention be fully on the driving task. This report summarizes what is known about the behavioral aspects of driver distraction due to portable electronic device use since the publication of the last NHTSA state-of-knowledge report in 2008 with the current SOK covering literature from 2008 through September 2022. The 2008 driver distraction SOK had a broader scope, focusing on driver distraction more generally than the current SOK. PED use involves any device easily carried into and out of a vehicle that a driver can interact with while driving, whether the interaction is directly with the device or through a vehicle interface. This report is a reference for highway safety stakeholders, benchmarking the state of PED use behind the wheel as defined by four primary focus areas, with each focus area covered in a separate chapter. Two introductory chapters cover the background and purpose of the SOK, key terminology, and research methodologies that illuminate the problem in each defined area. Each chapter stands alone or can be read in conjunction with the whole report. Therefore, abbreviations and acronyms will be defined the first time they are used in each chapter.

Chapter 1 – Introduction

Chapter 1 describes the distracted driving problem including the most recent statistics emphasizing distraction's impact on the driving task as a significant safety problem and societal cost. The chapter addresses the breadth of distraction sources (external or inside vehicle), the range of activities in each source, and the variation in sources and activities that translate to forms of distraction such as cognitive, visual, and manual.

The chapter then states the report objectives, identifying what is known about driver distraction due to PED use, delimitation of scope of the review, stating the report focuses exclusively on distracted driving behavior related to PED use. Chapter 1 also describes the intended audience, the time period of reviewed research, and the search and literature review methodology.

Chapter 2 – Key Terminology and Research Methodologies

Chapter 2 operationally defines various key terms including

- Driver inattention,
- Distracted driving, and
- PED.

It also describes and synthesizes the types and characteristics of distraction studies as well as how distraction is measured, specifically summarizing the benefits and limitations of the methods below.

- Observational studies
- Self-report studies
- Naturalistic driving studies
- Experimental approaches (i.e., on-road, closed course, simulator)
- Retrospective analyses
- Prospective analyses

Chapter 3 – Driver Use of Portable Electronic Devices

The third chapter reviews studies examining driver PED use, which include observational studies, NDSs, and self-report study methodologies. Having measured prevalence of driver PED use and the characteristics of this use in different ways, researchers show a range of estimates for this prevalence. For example, the most recent data from NOPUS suggests 0.4% to 3.1% of U.S. drivers during an average daylight moment are using a PED (NCSA, 2024). Estimates are higher based on NDS and self-report data. Analyses of NDS data collected from 2010 to 2013 suggest that PED use comprised as much as 6.4% of total driving time (Dingus et al., 2016). Self-report estimates show that 42% to 48% of respondents reported they answer phones while driving (Schroeder et al., 2018), and that 22.7% of drivers reported sending and 33.9% reported reading a text or e-mail in the last 30 days (AAAFTS, 2021).

Chapter 3 also reviews studies that examine key characteristics related to PED use. Researchers found that higher levels of PED use tend to be associated with being younger; driving vehicles other than personal passenger cars (pickup trucks, SUVs, or taxis); using lane keeping assist, adaptive cruise control, or associated ADAS warning systems; experiencing less difficult driving conditions (e.g., when it is not dark outside or fair weather); and weekday driving (Huemer et al., 2018; Hungund et al., 2021; Li et al., 2018; NCSA, 2021; Pope et al., 2017; Risteska et al., 2018; Schroeder et al., 2018; Tison et al., 2011). Regarding motivational factors, increased PED use tends to be associated with the belief that PED use while driving is less risky, having a significant other who one perceives to use PEDs while driving, overconfidence in one's driving abilities, previous PED use while driving, and engagement in other risky driving behaviors (Beck & Watters, 2016, 2017; Engelberg et al., 2015; Hill et al., 2015; Jashami & Abadi, 2017; Li et al., 2018; Nemme & White, 2010; Olsen et al., 2013; Schlehofer et al., 2010; Shevlin & Goodwin, 2019; Tian & Robinson, 2017; Trivedi & Beck, 2018; Trivedi et al., 2017; Watters & Beck, 2016). Personality factors that may influence PED use include greater impulsivity and potential psychological dependence or attachment to one's cellphone (Briskin et al., 2018; Hayashi et al., 2015, 2017, 2018; Lantz & Loeb, 2013; Liese et al., 2019; Meldrum et al., 2019; Mirman et al., 2017; Pearson et al., 2013; Reed et al., 2016; Sanbonmatsu et al., 2013; Struckman-Johnson et al., 2015; Weller et al., 2012).

Chapter 4 – Effects on Driver Behavior and Performance

Chapter 4 reviews studies examining how attention and driving are affected by using a PED. Simulator, closed-course, and controlled and naturalistic in-traffic studies comprise this chapter. Experimental studies in the simulator or on the road as well as NDSs provide extensive information on how PED use affects driver behavior and performance. In general, these studies have shown that PED use, particularly use requiring drivers to take their eyes away from the forward roadway or their hands off the steering wheel, affects the ability to steer, maintain lane position, and react to events (Caird et al., 2014, 2018; Ranney et al., 2011; Reimer et al., 2014; Simmons et al., 2017; Young et al., 2014). Some PED use tends to be associated with more off-road glances, such as with reading or typing for text messages, as well as destination entry for navigation (Caird et al., 2014; Knapper et al., 2015). Hazard detection -- taking more time to detect targets or events -- tends to be associated with dialing cellphones, and both handheld (HH) and hands-free (HF) cellphone conversations (Caird et al., 2018). Hazard detection accuracy tends to decrease with both HH and HF cellphone conversations and with voice-based versions of visual-manual tasks. Some drivers, at least in experimental studies, appear to compensate by increasing their headway or reducing speed, but the extent the compensation is effective in restoring a sufficient safety level is unknown (Caird et al., 2014, 2018; Simmons et al., 2017).

Chapter 5 – Effects on Safety

Chapter 5 reviews studies examining how safety is affected by driver use of a PED. NDSs and studies based on police crash reports (PCRs) are the primary methodologies in this chapter.

It is difficult to measure distraction effects due to PED use on crash occurrence. Direct measure or observation of device use immediately prior to a crash are rare and subject to error. Self-reported use may be biased and understates the problem because drivers and passengers are reluctant to admit their contribution to crash causation. As a result, it is difficult to estimate the increased risk due to PED use. Nevertheless, the weight of evidence from analyses of crashes and NDSs strongly suggests use of PEDs compromises safety. Researchers estimate about 12% of injury crashes, 11% of property-damage-only (PDO) crashes, and 8% of fatal crashes are distraction-affected crashes (NCSA, 2024). Of the distraction-affected crashes, approximately 12 to 14% of fatal crashes, 6 to 9% of injury crashes, and 5 to 10% of PDO crashes are cellphone-involved (NCSA, 2016, 2017, 2018, 2022, 2023, 2024). However, a report published in February 2023 by Blincoe et al. estimates the percentage of all motor vehicle crashes attributable to distraction to be 29% for 2019. The Blincoe et al. report also attributes 6.1% of crashes to cellphone distraction for 2019. Crash data from certain States show rear-end crashes are the most frequent type of distraction-affected or cellphone-involved crash type (Savolainen et al., 2011; Sun & Rahman, 2018). Distraction-affected crashes, including those involving PED use or cellphones, specifically, tend to involve younger drivers (Brown, 2009; Carlotto et al., 2015; Savolainen et al., 2011; Singh, 2010; White et al., 2018). Both distraction-affected and cellphone-involved crashes tend to occur more on high-speed roadways and rural roadways (Savolainen et al., 2011; Singh, 2010; Sun & Rahman, 2018; Wilson & Stimpson, 2010). When analyzing crash risk, NDSs show safety-critical events occur more for PED use that involve more time with eyes off the road such as dialing, locating/answering a cellphone, and text messaging/browsing (Hammond et al., 2019; Klauer et al., 2010; Simmons et al., 2016; Simons-Morton et al., 2014).

Chapter 6 – Reducing Driver Distraction

The sixth chapter discusses possible methods to reduce driver distraction from PEDs or alleviate the consequences associated with use. Relatively little literature on large-scale activities to prevent distracted driving from the use of PEDs or lessen its consequences was found. Engineering, education, and enforcement approaches have been suggested, and some have been developed, deployed, and evaluated. The small number of tests and their limited scale preclude arriving at data-driven conclusions on the relative effectiveness of the various approaches. While some approaches appear promising based on the limited available information, the lack of compelling findings and the limitations inherent in the few studies conducted preclude identification of preferred approaches. Cellphone blocking technology may be a promising approach, as some (mostly non-U.S.-based) studies show drivers may think they are beneficial and promote safer driving (Funkhouser and Sayer, 2013; Oviedo-Trespalacios, Truelove, & King, 2020). Some research indicates decreased self-reported phone use among participants when using cellphone blocking technology (Arnold et al., 2019, 2022). Education involving driver attention maintenance strategies have not shown a reduction in cellphone use (Horrey et al., 2009; McDonald et al., 2021). Some programs focused on increasing awareness of driver PED use and its consequences have shown short-term changes in participants' reported attitudes and intent not to engage in distracted driving, with a few longer-term programs showing reductions in self-reported or observed distracted driving behavior (Arnold et al., 2019; Arnold & Horrey, 2022; Hill et al., 2020; Joseph et al., 2016; Rana et al., 2018). Driver cellphone use laws have not been widely associated with reductions in use for young drivers; however, there is some evidence that bans affecting all drivers, rather than those focusing on young drivers, may be more effective (Ehsani et al., 2016; Li et al., 2020; Rudisill & Zhu, 2015). Some research suggests that HH laws tend to be associated with reductions in HH use and fatal and injury crashes (Arnold et al., 2019; Arnold & Horrey, 2022). A few high-visibility enforcement (HVE) evaluation studies have shown a reduction in driver HH use, but there is some evidence of similar reductions in HH use in control sites (Chaudhary et al., 2014, 2015; Retting et al., 2017). Given the limited literature available evaluating these countermeasures, caution should be used in making conclusions.

Chapter 1 – Introduction

Ranney (2008) conducted the last comprehensive NHTSA state-of-knowledge report of distracted driving in 2008. The intervening years have seen a marked growth in quantity and types of distraction sources and activities that affects drivers. The increase is a consequence of several factors including advances in PED technology, the numerous ways drivers interact with them, advances in measuring these interactions, and the ways PEDs can affect driver behavior and, hence, safety. Even with the presence of laws in many States that regulate PED use by drivers and implementing countermeasures to prevent distracted driving from PED use, or at least blunt its consequences, distracted driving continues to be a significant problem. The latest data from NHTSA's National Center for Statistics and Analysis (NCSA) showed that, in 2021, 8% of all drivers involved in fatal crashes were reported as distracted at the time of their crashes (Stewart, 2023). The latest cost estimate of societal harm caused by distraction-involved crashes was $395 billion yearly (Blincoe et al., 2023). This same report estimates the percentage of all motor vehicle crashes that are attributable to distraction to be 29% and the percentage of crashes involving cellphone distraction to be 6.1% for 2019.

One challenge of addressing the distraction problem is the breadth of distraction sources and activities available to a driver and the varied task demands of each activity. Strayer et al. (2011) characterized these task demands by the extent they divert visual, cognitive, or manual resources away from the driving task, with visual distractions as those that require drivers to take their eyes off the road, manual distractions as those that require drivers to take their hands off the wheel, and cognitive distractions as those that require drivers to take their minds off the road. Note that these are not mutually exclusive. For example, some tasks require both a high level of visual and manual resources. Any task that requires visual or manual resources is assumed to require at least some level of cognitive resources as well (Strayer et al., 2011). It is also important to note not all tasks in a category are equal. For instance, talking on a handheld phone may allow drivers to control the stability of their vehicle better than sending text messages—a finding making the activity more like cognitive tasks than manual ones (see findings in Chapter 4).

PEDs are arguably the most complex source of distraction with an array of activities and distraction forms available, all at a driver's fingertips. For example, a cellphone may audibly convey navigation directions, resulting in cognitive distraction, or may involve sending a text message, resulting in visual-manual-cognitive distraction. This complexity and the efforts to regulate driver use of these devices through legislative efforts makes the state of the driver PED use problem of particular interest.

Objective and Scope

The objective of this report is to identify what is known about the behavioral aspects of driver distraction due to PED use after what was identified in the 2008 SOK report, to September 2022. Driver distraction guidelines regarding in-vehicle electronic devices and portable and aftermarket devices were published in different notices (Visual-Manual NHTSA Driver Distraction Guidelines for In-vehicle Electronic Devices, 2013) during the timeframe of the current SOK; however, given that the SOK includes only peer-reviewed research documents, technical reports, theses, and dissertations, the guidelines were outside the scope of review for the SOK. This report is a reference for highway safety stakeholders that gives them a benchmark of the state of the PED use problem as defined by four primary focus areas, with each focus area covered in a separate chapter:

- Driver Use of PEDs (Chapter 3),
- Effects on Driver Behavior and Performance (Chapter 4),
- Effects on Safety (Chapter 5), and
- Reducing Driver Distraction (Chapter 6).

The SOK opens with this introductory chapter covering the background and purpose of the SOK. The next chapter (Chapter 2) defines key terminology and research methodologies central to illuminating the problem in each of the defined areas. As each chapter is intended to be used singularly, or in conjunction with the whole report, abbreviations and acronyms are defined the first time they are used for each chapter.

Methods

To accomplish the project objectives, researchers used comprehensive, systematic search, retrieval, screening, and review strategies. The adopted approach was consistent with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) (see Moher et al., 2009) as shown by the following sections.

Sources

Researchers examined numerous databases and other sources of documents for peer-reviewed research documents, such as journal articles and conference proceedings, as well as State and Federal technical reports, and university theses and dissertations. Table 1-1 lists the primary databases and associated disciplines the project team consulted for the current review.

Table 1-1. Databases Consulted

Database	**Discipline**
PsycINFO	Psychology
PubMed	Biomedicine
Web of Science	Multi-disciplinary
TRID	Transportation
National Transportation Library (searching within NHTSA's Behavioral Safety Research collection)	Transportation

The project team also considered reviews and meta-analyses of original investigations of driver distraction due to PED use, and, if deemed of sufficient quality, incorporated these reviews and meta-analyses into the SOK as is or updated for the time periods that were not covered by the review or meta-analysis.

Search

For each of these databases, the project team used the key words and search strategy shown in Figure 1-1 to identify relevant literature. Specifically, the search strategy involved conducting four searches related to the four specific chapter topics of this SOK in each of the databases in Table 1-1. Each box in this figure represents an "OR string." That is, the keywords in each respective box were connected via an OR Boolean operator (e.g., demographics OR incidence OR prevalence OR motivation). Each chapter-specific searches used the general terms in the black boxes. The left of the two black boxes contains keywords describing PEDs. The right black box contains keywords describing driving or distraction. The two general term OR strings were connected by an AND Boolean operator. Each of the four chapter-specific searches used three Boolean OR strings connected by an AND Boolean operator.

To ensure a comprehensive study pool, all references in documents included in the review were used to generate a superset "web of references" to identify any possible relevant studies that may have been missed by the search terms.

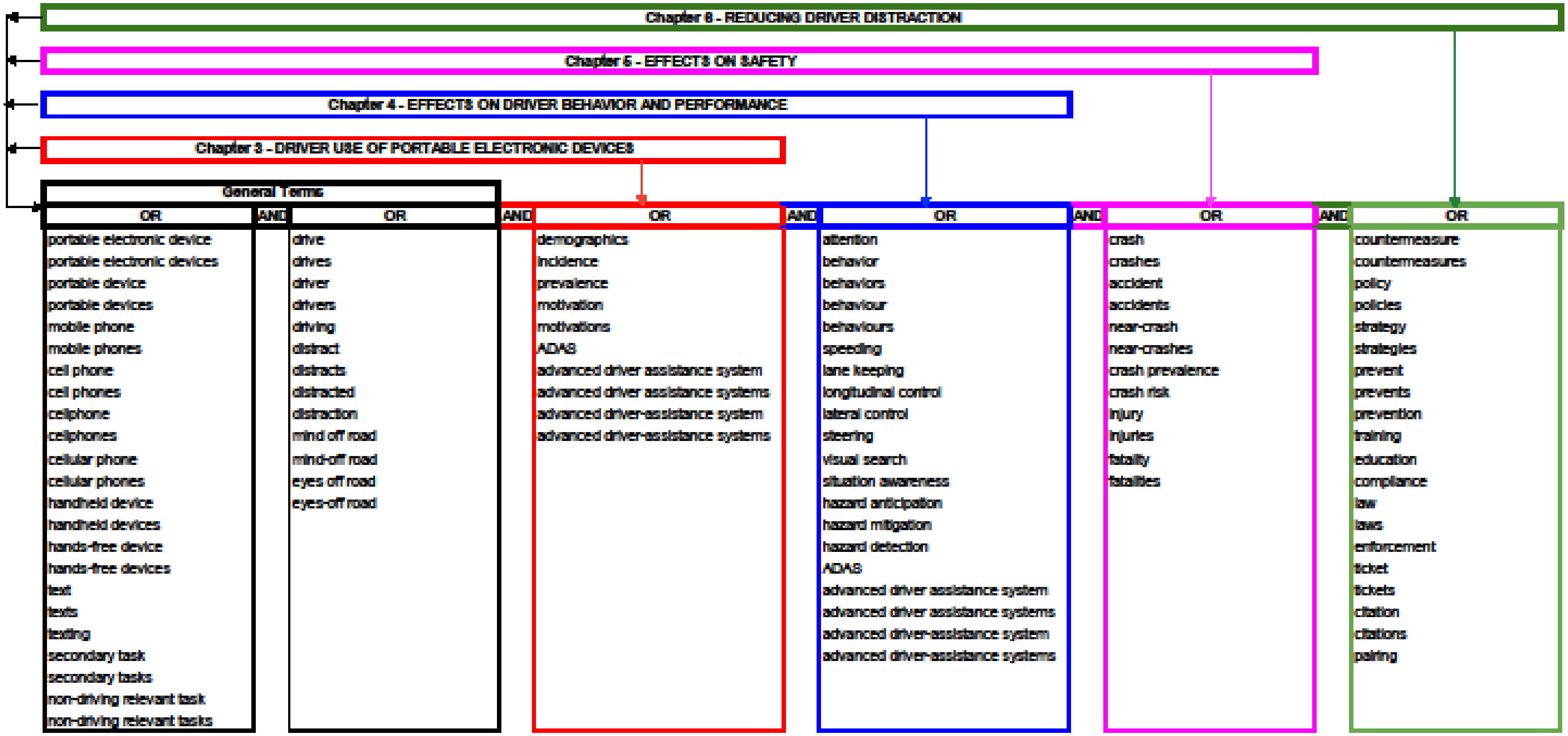

Figure 1-1. Search terms and strategy

Screening

After an exhaustive list of documents on the topic of driver distraction due to PED use was identified through the sources and search terms described above and other sources, such as referrals by colleagues in the field (*n* = 16,707 through databases and *n* = 38 from other sources), the researchers next determined which documents warranted further review. First, researchers screened the list of documents for duplicate entries, and duplicates were deleted. The titles and abstracts of the remaining entries (*n* = 7,474) were used to conduct the initial relevance screening. In this process, researchers examined the abstract of each document to make a first absolute judgment concerning whether it was possibly relevant to the objectives of this SOK. For studies whose abstracts passed this initial relevance screening (*n* = 1,817), the researchers collected and assessed full-text publications for eligibility. The assessment used the form shown in the appendix to apply the following inclusion criteria.

- On the topic of driver distraction due to PED use
- An original empirical investigation or review/meta-analysis of original investigations
- Published after January 1, 2008, and before searching was stopped on September 7, 2022
- Published in English
- Methodologically appropriate
- From a sample of a relevant population (e.g., a U.S. or other population deemed to be sufficiently representative of a U.S. population)

Whether an article was appropriate with respect to methodology or contained a sample relevant to the U.S. population depended in part on the research question it addressed. Thus, each chapter contained differing eligibility criteria pertaining to study methodology and sample characteristics. Table 1-2 presents these chapter-specific criteria. The review also included a more rigorous assessment of study quality using the critical review criteria discussed below. After the application of the eligibility criteria and the quality assessment (see below "Critical Review Criteria"), 285 records remained for synthesis.

Table 1-2. Chapter-Specific Eligibility Criteria

Chapter	**Appropriate Study Methodology**	**Sample Relevance to U.S. Population**
Chapter 3: Driver Use of Portable Electronic Devices	Roadside observation; Naturalistic driving; Self-report	U.S. samples or a non-U.S. based sample with a novel finding/approach
Chapter 4: Effects on Driver Behavior and Performance	Naturalistic driving; Experimental (Closed track, Live roadway, Simulator)	All populations relevant
Chapter 5: Effects on Safety	Naturalistic driving; Crash-based	U.S. samples or a non-U.S. based sample with a novel finding/approach
Chapter 6: Reducing Driver Distraction	No chapter-specific criteria	All populations relevant

Figure 1-2 presents a summary of the steps in the screening process and their effect on the sample size of documents available for the subsequent step. As can be seen in the figure, the process decreased the sample of over 16,000 documents to the 285 discussed in the balance of this SOK.

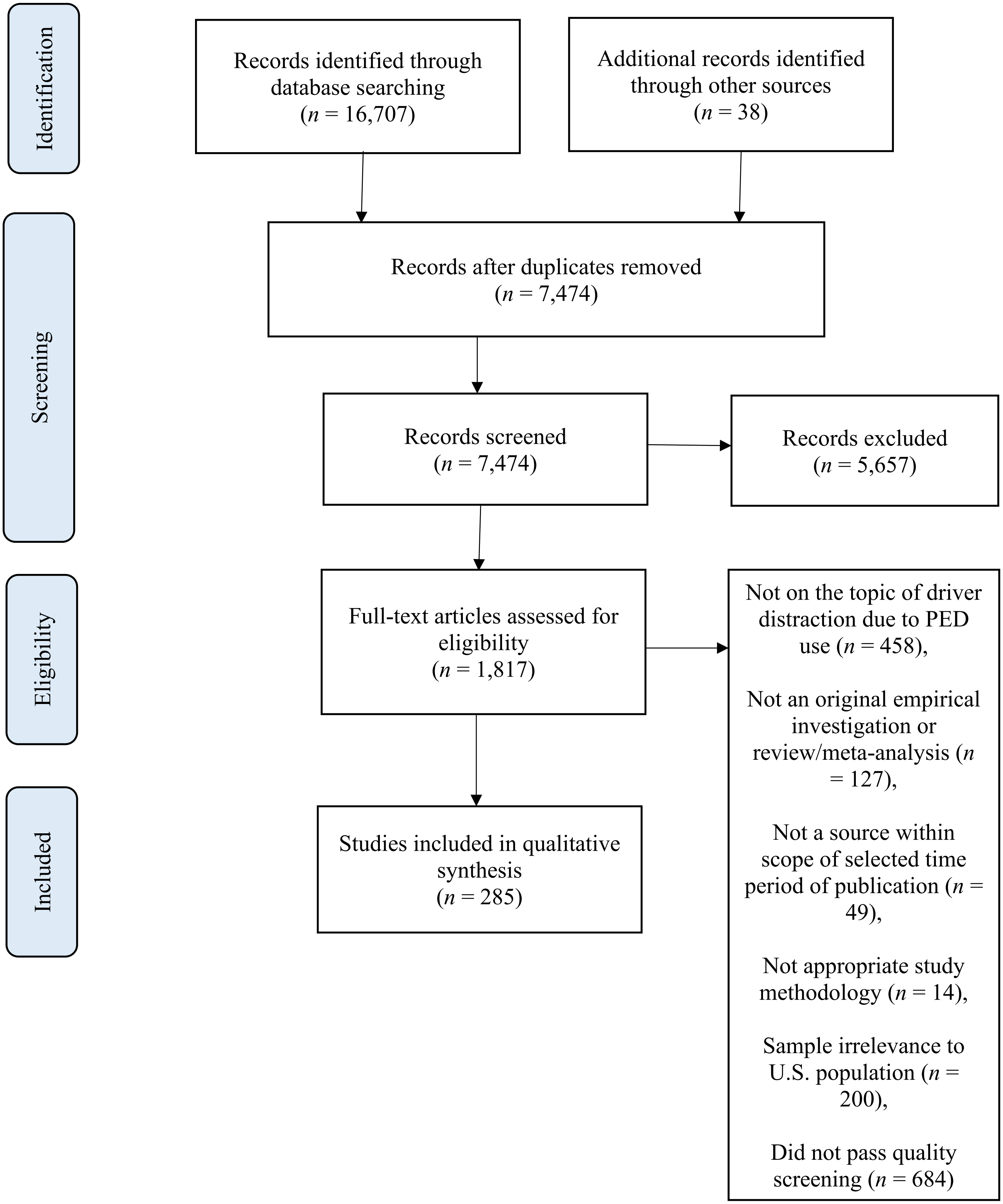

Figure 1-2. Summary of results of search and screening process

Retrieval, Organization, and Filing Methods

Most of the sources searched employed linking technology that enabled cross-database access that let researchers using one resource to connect seamlessly to the full-text resources in another. For example, if one source contained only the abstract but provided linking, it was easy for the researcher to access the full-text publication from another source. In addition, as part of the research team, the University of Massachusetts used its library to supplement resources through established interlibrary loan agreements. Thus, a document not available through either the UMass or other study resources could be easily borrowed from another library. If necessary, the research staff contacted the author of a study to retrieve their report when it could not be obtained from any of the other available sources. Once a document was retrieved, it was organized by the topics it fit best. For example, all documents pertaining to countermeasures were grouped together and assessed with the same criteria while documents covering crash risk of distracted driving were grouped and assessed separately.

The project used Mendeley, a computer- and web-based reference management program, to manage and organize documents. The program permits a user to import information about an article directly from many databases and contains features that facilitated the organization and coordination of documents and references between Dunlap and UMass.

Critical Review Criteria

All studies deemed eligible for the review received a full-text evaluation recorded using a custom computer program that presented citations and abstracts; prompted with questions; and managed the collection, storage, and retrieval of responses. The appendix lists the questions presented by this computer program. They included a variety of question types in a total of nine items. Four of the questions pertained to internal validity (adapted from Gyorkos et al., 1994), another pertained to construct validity, still another to statistical validity, two more to external validity, and the remaining question concerned conflicts of interest, an important threat to validity. The sufficiency of information available for each document could also be assessed by the number of items that could not be coded due to missing information. Each question also included a comment field, so relevant detailed information for the synthesis could be collected.

Reviewers considered their responses to each of the nine questions to assist their assessment of the extent to which each study was discussed in the review. In general, if the review suggested a study was weak because a researcher coded unavailable or insufficient information for any of the nine questions, inclusion of that study was limited to at most an example citation that illustrated common weaknesses in the category of studies to which it belonged. Exceptions were made for studies that covered unique or important topics and for which no higher quality similar studies existed. Finally, reviewers assessed whether the abstract accurately reflected each study's content.

Critical Review Procedures

Two teams of researchers reviewed the documents. One team was composed of two research associates, who assessed the bulk of the documents. The principal investigators (PIs) from Dunlap and UMass constituted the second team. Before researchers began the coding, they were given training to establish inter-rater reliability and consistency and ensure that all used the same definitions, criteria, and procedures. All staff independently reviewed a subset of six studies included in each of the four literature review chapters. The studies used to assess inter-rater reliability varied in conceptualization, execution, and writing quality. The staff had very high agreement (kappa = 0.91) on the overall quality assessment of the total 24 documents coded. The coding itself involved the following procedures.

- The two research associates initially reviewed all accessed studies. They independently reviewed and rated each study based on a review of their full text using the questions in Appendix A.
- If a research associate was not confident in their rating, they consulted with one of the PIs to reach a final decision.
- If a PI was uncertain about a rating, the other PI was consulted.

Synthesis

Researchers reduced the number of documents that contributed to the information in this final synthesis if they determined that a document was not relevant to the objectives and scope established for this synthesis. The final chapter topics were determined by grouping similar studies. The synthesis then qualitatively compared and contrasted findings of studies within each topic. This provided both a summary of research for each topic and conclusions based on the preponderance of evidence available from the studies.

The goal for each chapter or subtopic was to create a coherent narrative that flowed well and read easily so that understanding by the intended audience was maximized. As needed, researchers augmented the information for unique or important studies and those that best represented a particular topic. The synthesis for each chapter concluded with a summary of what is and is not currently known (as of September 2022) about the topic to provide the reader with an understanding of the prevailing SOK on each topic and how it can be applied for both programmatic and research purposes.

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Chapter 2 – Key Terminology and Research Methodologies

This chapter introduces the key terms and types of distraction study approaches discussed in the balance of this state-of-knowledge (SOK) report.

Terminology

Before delving into the SOK on the topic of distracted driving due to portable electronic device (PED) use in the balance of this report, it is important for the reader to understand the definitions of the key terms used throughout the report's chapters. These are presented in Table 2-1. Although the terms themselves may appear to be common parlance, it is important to understand them in the specific context of this SOK report.

Table 2-1. SOK Definitions of Key Terms

Key Term	Definition
Driver inattention	"Insufficient or no attention to activities critical for safe driving" (Regan et al., 2011, p. 1780)
Distracted driving	"The diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving" (Regan et al., 2011, p. 1776)
Portable electronic device (PED)	Any device capable of being easily carried in and out of a vehicle with which a driver can interact while driving whether or not the interaction is directly with the device or through the vehicle interface

The literature contains several definitions for the first two terms in Table 2-1, *driver inattention* and *distracted driving*. Regan et al. (2011) reviewed the various alternatives and assembled comprehensive definitions and a framework to characterize distracted driving's relationship with other forms of driver inattention. Like driver inattention, distracted driving involves "insufficient or no attention to activities critical for safe driving" (Regan et al., 2011, p. 1776). However, unlike other forms of inattention, distracted driving involves a "diversion of attention away from" these activities "toward a competing activity" (Regan et al., 2011, p. 1776). As discussed earlier in Chapter 1 and in Regan et al. (2011), the competing activities can be: inside or outside of the vehicle; driving-related or non-driving-related; visual, manual, cognitive, or a combination thereof in nature; and involve either unintentional or intentional shifts of attention. For purposes of this SOK, the focus is on the diversion of a driver's attention, whether unintentional or intentional, that is a consequence of any activity—regardless of form, driving-related or not—due to interaction with a PED inside the vehicle. This basic concept is common to aviation (e.g., Chase and Hiltunen, 2014), healthcare (e.g., Khan et al., 2015), and highway safety domains (e.g., Young & Zhang, 2015).

Despite this widespread use across disciplines, no universal, detailed definition of PED is available from the literature. Table 2-1 provides a definition of PED for use in this SOK that is consistent with the one for electronic devices used by the National Center for Statistics and Analysis' (NCSA) National Occupant Protection Use Surveys (NOPUS; NCSA, 2019) and includes devices such as simple cellphones, smart phones, video gaming devices, tablets, portable music players, portable GPS units, and laptop computers. In the context of this study, the definition of PED use does not include the use of original equipment subsystems, such as built-in navigation or built-in entertainment systems, but does include the use of in-car systems that couple with PEDs, such as Apple's CarPlay, even if they use a common vehicle-based user interface with excluded functions.

The wide range of PEDs available to a driver highlight the breadth of potential distraction sources that can result in cognitive, visual, or manual distractions. The specific distraction form depends on the characteristics and demands of the activity itself and not the type of PED.

Distraction Research Study Methodologies

This section describes and synthesizes the types, characteristics, and limitations of research approaches used to study distraction. It also covers the ways distraction is measured. Table 2-2 at the end of this section summarizes this information. Each approach, when relevant to a specific topic or study, is also addressed in this SOK report.

Observational Studies

In the context of distracted driving research, observational studies typically involve roadside data collectors or cameras recording driver engagement in distracting activities at preselected locations, often intersections where traffic moves slowly or is stopped. The relatively simple, direct, and unobtrusive nature of this approach facilitates the collection of the type of large, representative samples that have been instrumental in the studies that define the SOK of driver use of PEDs presented in Chapter 3. The nature of the observational approach typically results in measurements of distraction based on a single encounter, often when the driver is stopped. Observational studies cannot generally measure the phenomenon at times and places when a driver is in sustained motion. Distraction activities are, however, habitual (see, for example, Kita & Luria, 2018) and likely more detrimental to safety when a vehicle is in motion than when the vehicle is stopped.

Although observers can be tasked with recording behaviors, such as hands-free (HF) device use, and characteristics, such as driver age and race, the validity and reliability of the resulting data may be questionable unless the observers are placed in environments that are extremely conducive for taking data, are suitably trained, and get to practice until criterion validity is deemed appropriate (see, for example, Huemer et al., 2018 for discussion of limitations of this approach). In addition, there are other possibly relevant factors internal to a driver, such as knowledge level, attitudes, and motivations, that are essentially impossible to measure or even estimate using observational methods (see, for example, NCSA, 2021).

Self-Report Studies

Self-report survey data go beyond the information only available through direct observation at the roadside, and therefore have also been instrumental in defining the SOK of driver use of PEDs presented in Chapter 3. Through this approach, more detailed information on the habitual use of PEDs by drivers, including the reported incidence of activities, such as HF use, that are difficult to observe, can be estimated. Self-report studies also support delving into internal factors related to the willingness and frequency of drivers' engagement in distracting activities. As with roadside observations, the ease of the approach permits efficient collection of large samples from diverse populations. Unlike roadside observations, though, the ability to measure potential respondent characteristics as well as factors such as their specific knowledge, beliefs, and attitudes makes it possible to study PED use among very specific samples of interest. Self-report survey information, however, has its own limitations. It relies on recall by the respondents, which may not be accurate. Truthfulness of responses can also be an issue, particularly when dealing with sensitive topics, such as illegal driving behavior, where drivers may be hesitant to implicate themselves or when respondents want to conform with social norms and, therefore, provide the responses they believe to be most acceptable to society (see Elvik, 2011, for further discussion of limitations).

Naturalistic Driving Studies

As its name implies, the naturalistic driving study (NDS) approach can yield extensive high-fidelity, continuous, objective measures of driver behaviors and performance, vehicle response, and even direct measurement of safety-relevant events under real traffic conditions (see, for example, Hankey et al., 2013). Information from NDSs can add significant, detailed information on virtually every major topic relevant to this SOK. The data from this approach is rich, but the approach does have limitations. For example, the need to instrument vehicles with extensive equipment such as sensors, radars, and cameras makes the approach expensive and limits the number of test participants that can be used. This, in turn, limits the collection of a sufficient sample of relatively rare crash events that are of primary interest. Also, retrieving the data from the test vehicles requires either costly cellular data transfer or repeated interactions between the participants and the research staff. In addition, the requirement to install data collection equipment in vehicles and the basic need for all participants to have essentially exclusive access to a vehicle typically limits the representativeness of samples that have been used with this approach. Finally, as with any approach that involves monitoring specific human behaviors among participants who know that they are being observed, the act of monitoring can affect the very behaviors of interest.

Experimental Approaches

It is possible to use experiments to gain insights on the effects of PED use on driving performance and the ways use might interfere with safety critical behaviors. Experimental data can be collected in a laboratory setting using driving simulators ranging from simple portable computers to sophisticated, moving-base units (see, for example, Fisher et al., 2011). Experiments can also be conducted on public roadways or on closed courses that appear to be in-use roadways but are closed to all traffic other than that under the control of the experiment. While the extent of realism of NDSs and observational studies is not possible using experimental approaches, they allow careful control of the characteristics of PED use to help establish causal relationships between this use and driver behaviors or driver performance. Experiments, especially in simulators, also allow testing conditions that would be unsafe to produce in actual traffic, such as distractions resulting in long periods of time the driver’s eyes are off-road. The results of experimental studies have contributed much to the SOK of the effects of PED use on driver behavior and performance discussed in Chapter 4.

On-Road

On-road experiments are conducted in actual traffic, and, thus, have a high degree of realism. In exchange for the increased realism, experimenters lose significant control over the conditions under which data collection takes place. Also, realism can be lost in on-road experiments if participants are aware they are being measured and therefore change their normal driving behavior. Realism also suffers when safety monitors (e.g., a certified driving instructor in a dual-brake vehicle) must be placed in the vehicle because participants may act differently in the presence of others than they would while driving alone (Thomas et al., 2011).

Closed Course

A step-down in fidelity but offering more control than that of on-road experiments, the closed course approach is a good one for research questions that are not heavily reliant on a driver's interaction with other traffic or with a wide variety of road conditions. A closed course is usually a real roadway closed to traffic not controlled by the study (e.g., a newly built stretch of road that has yet to be opened), a stretch of "real" road built just for experimental use ("test road"), or a closed road-like facility (e.g., a proving ground test track, airport runway) adapted for use in a study. Closed-course approaches are a good option when addressing the research question with an on-road approach would put the driver and/or other traffic at unacceptable risk but the fidelity of driving a real vehicle on real roads is desired.

Driving Simulator

Simulation is a broad term that reflects the use of some type of virtual environment. While fidelity with this experimental approach varies considerably from basic desktop simulators to full motion-based ones, overall simulation is at the lower end of fidelity among experimental approaches but offers the highest level of control. With this approach, data can be collected in a wide variety of conditions of interest, including simulation of future technology or conditions unsafe in actual driving, such as having the vehicle malfunction.

Retrospective Analyses

Analyses of archival data, such as crashes, can provide information on the ultimate measure of distracted driving's impact on safety and, thus, is particularly relevant to Chapter 5. This approach is compatible with comprehensive examinations, as it is feasible to work with large datasets, often even population data (e.g., Fatality Analysis Reporting System; FARS). The analysis of two or more years of information can support the examination of trends that coincide with historical events. By definition, though these are data that have already been collected, so researchers have no control over how variables were defined or how the information was assembled. Thus, the quality of the inputs can vary, and the researcher may have little or no insight into quality changes over time (see, for example, NCSA, 2022).

Prospective Analyses

Prospective analyses involve collecting data about particular people or groups of interest over time and analyzing the data in the context of person or group-level changes. This approach is compatible with analyzing the effect of an intervention and, thus, is germane to Chapter 6. For example, State crash data files or FARS could be analyzed as the data matures to see if crash rates change as a function of time differentially in States that recently outlawed handheld (HH) PED use. An example of a study reporting on prospective analyses is NHTSA's evaluation of distracted driving high-visibility enforcement (HVE) campaigns. In this study, Chaudhary et al. (2015) collected enforcement, roadside observation, and crash data from before and after campaigns in California and Delaware to see if the campaigns had effects on reducing incidence of distracted driving behaviors.

Table 2-2. Characteristics of Types of Distraction Studies

Method	Description	Benefits	Limitations
Observation	Roadside data collectors or instruments record driver engagement in distracting activities at predetermined location(s).	• Directly measures incidence of distraction at that location/time • Allows efficient collection of large samples • Unobtrusive. Drivers likely unaware they are observed, so natural behavior is usually undisturbed	• Spatially and temporally limited, measure of a re-occurring, complex behavior • Difficult to observe some characteristics and behaviors because they are not apparent from outside the vehicle • No measure of internal factors such as decision-making • Observer accuracy and consistency is critical and sometimes difficult to achieve
Self-Report	Survey data on driver distraction knowledge, attitudes, motivations, and behaviors	• Allows measurement/estimation of internal factors or behavior • Allows efficient collection from large, diverse samples under a variety of conditions • Supports examining hypotheticals	• Depends on respondent correctly interpreting prompts/questions • Inclusion of sensitive topics may bias results through non-responses and/or untruthful answers • Validity can be questionable
NDS	Data on driver and vehicle behavior, performance, and safety during "normal" driving in real traffic	• Provides continuous, objective measures • Measures can be obtained with high fidelity	• Study participation and/or instrumentation may affect behavior • Difficult to recruit fully representative samples • May provide limited data on conditions or events of interest if they rarely occur
On-Road Experiment	Experimental data on distracted driver behaviors and performance in traffic when drivers are assigned specific conditions to fulfill	• Can provide continuous measures of driver behaviors and performance • Data obtained under realistic conditions thereby minimizing experimental biases	• Inability to control some traffic, environmental, and personal conditions (e.g., fatigue) that could affect results • Difficult to collect data in some possible conditions of interest
Closed-Course Experiment	Experimental data on distracted driver behaviors and performance in a real roadway environment that is closed to all traffic not controlled by the experiment	• Can provide continuous measures of driver behaviors and performance • Highly realistic measures • More experimental control than with in-traffic studies	• Less experimental control than in simulation studies • Difficult to collect data in some possible conditions of interest • Participants know there is no "real" traffic threat

Method	Description	Benefits	Limitations
Driving Simulator Experiment	Experimental data on distracted driver behaviors and performance in virtual environment(s)	• Can produce measures equivalent to those from an actual vehicle plus others not easily obtained in live traffic and actual vehicles • Very high level of control of experimental variables • Permits collection of data in wide variety of conditions of interest, including simulation of future technology or conditions unsafe on a roadway in a real vehicle	• Realism can be low • Fidelity of different aspects of the traffic environment can vary widely • Participants know they are safe • Participants may be subject to simulator sickness • Sophisticated simulators can require significant capital investment
Retrospective Analysis	Historical data on distracted driver violations or safety events	• Can provide information for ultimate measure of safety (crashes) • Population data is feasible if already collected (e.g., FARS) • Supports analyses of trends that coincide with historical events • Potentially low-cost if data are readily available	• No control over past data definition and collection processes • Quality of inputs may be variable • All data of interest for measure formation may not be available (e.g., driver exposure)
Prospective Analysis	Plan for future data on distracted driver violations or safety events	• Can provide information for ultimate measure of safety (crashes) • Compatible with a priori experimental treatment (participants can be assigned to groups before outcomes are known) • Possibly more control over data definition and collection processes	• Data definitions can change over time and likely are not under study control • All data of interest for measure formation may not be collectable (e.g., driver exposure)

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Chapter 3 – Driver Use of Portable Electronic Devices

Introduction

With the increasing ownership of portable electronic devices (PEDs) and their widespread use in everyday life, it is critical to understand the extent to which this use intersects with the driving task. The potential for PED use to be a distraction, and the documented driving safety problems caused by distraction, in general, give rise to safety concerns if PEDs are being used by drivers while driving. Interest in the prevalence of PED use while driving has prompted several prior literature reviews and individual research studies that are discussed in this chapter.

Previous Reviews

NHTSA's previous state-of-knowledge (SOK) report reviewed studies examining engagement in secondary tasks by drivers, including the use of in-vehicle systems and PEDs (Ranney, 2008). Since 2008, the number and types of secondary tasks available to the driver, particularly when using a PED, have increased. Moreover, the availability of naturalistic driving data, most notably from the Second Strategic Highway Research Program (SHRP2) Naturalistic Driving Study (NDS), has provided new insights on the prevalence of PED use during everyday driving.

Several other reviews of the prevalence of driver distraction have been published since the Ranney (2008) SOK report. While some of these reviews included consideration of studies that examined individual sources of distraction, such as in-vehicle systems (e.g., route guidance systems, radio/CD players), none were found that specifically enumerated the prevalence of driver PED use (e.g., Governors Highway Safety Association, 2011). Other reviews restricted their scopes by either looking at limited sources of distraction (e.g., mobile phones only: Collet et al., 2010; World Health Organization, 2011) or a particular population of drivers (e.g., young drivers: Cazzulino et al., 2014; Delgado et al., 2016). Therefore, it was not possible to assess the characteristics of the general use of PEDs for the overall population from them.

Huemer et al. (2018) did, however, conduct a review with similar objectives to this SOK. Since the Huemer et al. (2018) review was recent, comprehensive, and judged to be of high quality, researchers synthesized its results with the findings of relevant single studies (not included within the Huemer et al., 2018, article) in this chapter.

Current Review

The current review considers the range of PED types; overall extent of use of these devices; driver, vehicle, and roadway/environment characteristics associated with this use; and the motivations and attitudes of drivers who use PEDs. The extent of literature produced since the Ranney (2008) review suggests a benefit from an updated examination of this topic to provide a better understanding of the problem as it has evolved. The current review begins by describing the methodology and measures used in past studies before discussing the results documented by the various approaches used in the more recent studies reviewed here.

Review Approach

For purposes of this chapter's specific review of the prevalence of PED use, 239 papers (reviews and original investigations) were identified as relevant based on the adopted eligibility criteria. The quality of the study reported was then assessed for these 239 documents using the criteria discussed in Chapter 1. The findings from those documents that used a nationally representative or diverse sample of drivers were given more weight in the review than those documents that only included data from a single State or a more restricted range of drivers. The quality assessment reduced the 239 papers to the subset of 97 works cited in this chapter.

Prevalence of PED Use

This section describes the best available estimates of the proportion of drivers using PEDs at a given point in time, i.e., prevalence of driver PED use. The methods used to estimate the prevalence of driver PED use, even within a specific study approach such as roadside observations, vary widely with respect to factors such as sample selection and measurement technique used, so an integration of results across collection approaches and methods was not attempted as it would be mixing very different types of information with uncertain results (Huemer et al., 2018). Therefore, the synthesis of prevalence estimates focuses primarily on combining studies in which the same specific measurement approach and methods were used. The section begins with a discussion of the various approaches and resulting measures used to estimate prevalence and how they affect the resulting use estimates. It then reviews the estimates produced by the various studies.

Types of Study Approaches

The three main study approaches applicable to this SOK were introduced previously in Chapter 2: self-report surveys, roadside observational studies, and NDSs. These same three approaches are further discussed here in the specific context of their applicability to the derivation of prevalence estimates. There are key differences among the methodologies that affect the estimates of PED use by drivers.

Self-Report Surveys

Surveys are one collection method that allows researchers to gather self-reported information from a large population. Surveys also potentially permit the examination of multiple distinct subgroups of PED types that would be difficult to observe or recruit. Survey data can include measures of individual motivations, perceptions, and attitudes as well as self-reports of behaviors over an extended time period. Surveys can collect information, albeit subject to self-report biases, on habitual behaviors that are difficult and can be expensive to observe. The validity of the resulting survey data can be limited to the extent a participant is aware of the information or willing to admit lack of familiarity, can remember it, and is willing to report it honestly and accurately or at all (e.g., Andrews et al., 2015). Willingness can be a particular issue when studying illegal or societally unacceptable behaviors such as drinking and driving or, in this instance, handheld (HH) cellphone conversation or texting. Surveys can be administered in a variety of ways including in person, by telephone, by mail, and on the internet. The choice of sampling method may bias results and therefore needs to be considered when assessing the results of a survey study (see, for example, Beck et al., 2009).

Roadside Observational Studies

Roadside observational studies typically use human data collectors, cameras, computers and/or radios to record driver engagement in distracting activities based on a single encounter at preselected locations, often intersections where traffic moves slowly or is stopped (see, for example, Brennan et al., 2019; Ponte & Wundersitz, 2019). The potential for a relatively simple, direct, and unobtrusive implementation of this approach can result in the collection of large and potentially interesting samples.

Observational studies cannot easily measure the phenomenon of interest at times and places when a driver is in sustained motion because the time available for viewing is very brief. As discussed in Chapter 2, observational studies have limitations related to the environments for collecting data, observational training, and unobservable aspects of driver distraction, e.g., attitudes and motivations.

NDSs

As its name implies, the NDS approach can yield extensive, high-fidelity, continuous, objective measures of driver behaviors and performance, vehicle response, and even direct measurement of safety-relevant events under real traffic conditions (see, for example, Hankey et al., 2013). With respect to the study of PED use, the NDS approach can be augmented by obtaining cellphone records for the participants to provide more detailed measures of a driver's distracting behaviors (see, for example, Atwood et al., 2018). The data from NDSs can be rich, but, as discussed in Chapter 2, the approach does have limitations. With specific reference to estimating prevalence, the non-representativeness of most NDS samples and the possible effect of the participant knowing they are being observed may be the most debilitating.

Prevalence Measure Considerations

The differences in the three study approaches can generate variations in the quality and nature of any resulting prevalence measures. It is therefore of interest to acknowledge some of the strengths and weaknesses of each data collection approach to assist in interpreting the various study results reported in the balance of this SOK. For example, while roadside observational studies provide a good, simple, direct, and unobtrusive measure of driver behavior, including PED use, the approach cannot obtain information on habitual PED activities because they are impossible to observe from a single observation at a distance. Also, roadside observation estimates are obviously limited both by the extent human observers can see the activity of interest and by the place and moment in time selected for the observation. This means the approach is ideal for obtaining general measures of the existence and extent of driver PED use, like visibly manipulating a device or holding a phone to one's ear and tracking them over time at the same location(s), but not for collecting more specific measures such as which cellphone activity (e.g., cellphone conversation, texting, navigation) is being engaged in or for developing an accurate estimate of overall prevalence.

As suggested by one non-U.S. (Australia) roadside observational study, a significant portion of mobile phone use (8 out of 23 drivers) is performed with the device on the driver's lap (Ponte et al., 2021). While only a single study based on an analysis of a non-U.S.-based sample's behavior, this highlights a further limitation of observational studies, and implies that well-placed instrumentation, particularly with NDSs, may reveal more details on a driver's activities and a higher incidence of PED use than a human observer can detect.

NDS data analysis, especially when combined with driver cellphone record data or self-report surveys, involves methods likely to obtain more specific information about driver PED activities. As discussed above, though, these methods are subject to limitations due to the more obtrusive nature of the measures. Surveys, on the other hand, provide the ability to uncover specific motivations for driver habitual PED use.

Given these considerations, an SOK must examine all three study types, and it is essential to consider the study type and the appropriateness of the measures it used when assessing its findings. Also, as stated earlier, it is not appropriate to combine results across study types or even within types to arrive at a more global, quantitative estimate of prevalence. The various prevalence estimates, taken together, should simply be used to help support a decision regarding whether the problem of PED use while driving is sufficient to warrant concern and action.

Prevalence Findings

Most studies of the prevalence of PED use report their findings by the specific activity or type of PED use (e.g., HH versus HF) measured. Most studies of PED use address the more granular ways a driver can use a PED while a few focus solely or primarily on the general use of the device. The combinations of measurement/study type and the specific activities the various researchers chose to measure within each study type are manifold and defy a coherent organization. Therefore, the discussion below describes the prevalence of PED use by a combination of seminal studies, measurement types, and the specific activities measured in each reported study, such as cellphone conversations (HH and HF), dialing, texting/emailing, browsing the internet/apps, and navigating. The subheadings below are a mixture of study name, study method, and activity type as a very general guide to the reader of the contents of the subsection. The headings themselves and their order of presentation are not intended to imply relative importance, quality, or the existence in the literature of an accepted or even widely used organization. A full understanding of the SOK with respect to prevalence of driver PED use must consider the full breadth and limitations of these disparate findings. The next sections review prevalence data from the National Occupant Protection Use Survey (NOPUS) and NDSs—two approaches that typically provide more general measures of driver PED use as these approaches have limitations in the form of not being able to observe details of specific driver activities (such as which apps are accessed during PED use while driving, which can be described in self-report data).

NOPUS Roadside Observational Studies

The NOPUS provides the only national estimate found during the literature search of driver PED use based on roadside observational data. NOPUS has been conducted annually for decades by NHTSA's National Center for Statistics and Analysis (NCSA) for the primary purpose of measuring a nationally representative sample of seat belt use. Trained data collectors observe seat belt use by drivers and front seat passengers while a vehicle is stopped at sampled intersections from 7 a.m. to 6 p.m. As part of the NOPUS data collection beginning in 2005, the trained data collectors also observed driver PED use in three categories (NCSA, 2009):

- Holding phone to ears (HH cellphone use),
- Speaking with a visible headset on (visible headset cellphone use),
- Visibly manipulating an HH device (but see below for a difference in observation in 2021).

Figure 3-1 presents the results of the NOPUS PED use observations for the years 2012 to 2022. The NOPUS measures are one estimate of the percentage of U.S. drivers using PEDs during an average daylight moment (NCSA, 2021), but the estimate is only for stopped drivers at a nationwide sample of intersections. Drivers may be more likely to use PEDs when stopped on the assumption that PED use is safer when stopped than when in motion. Although the timeframe for the research covered in the current report is through September 2022, the NOPUS PED shown in Figure 3-1 includes the years 2021 and 2022 (NCSA, 2024).

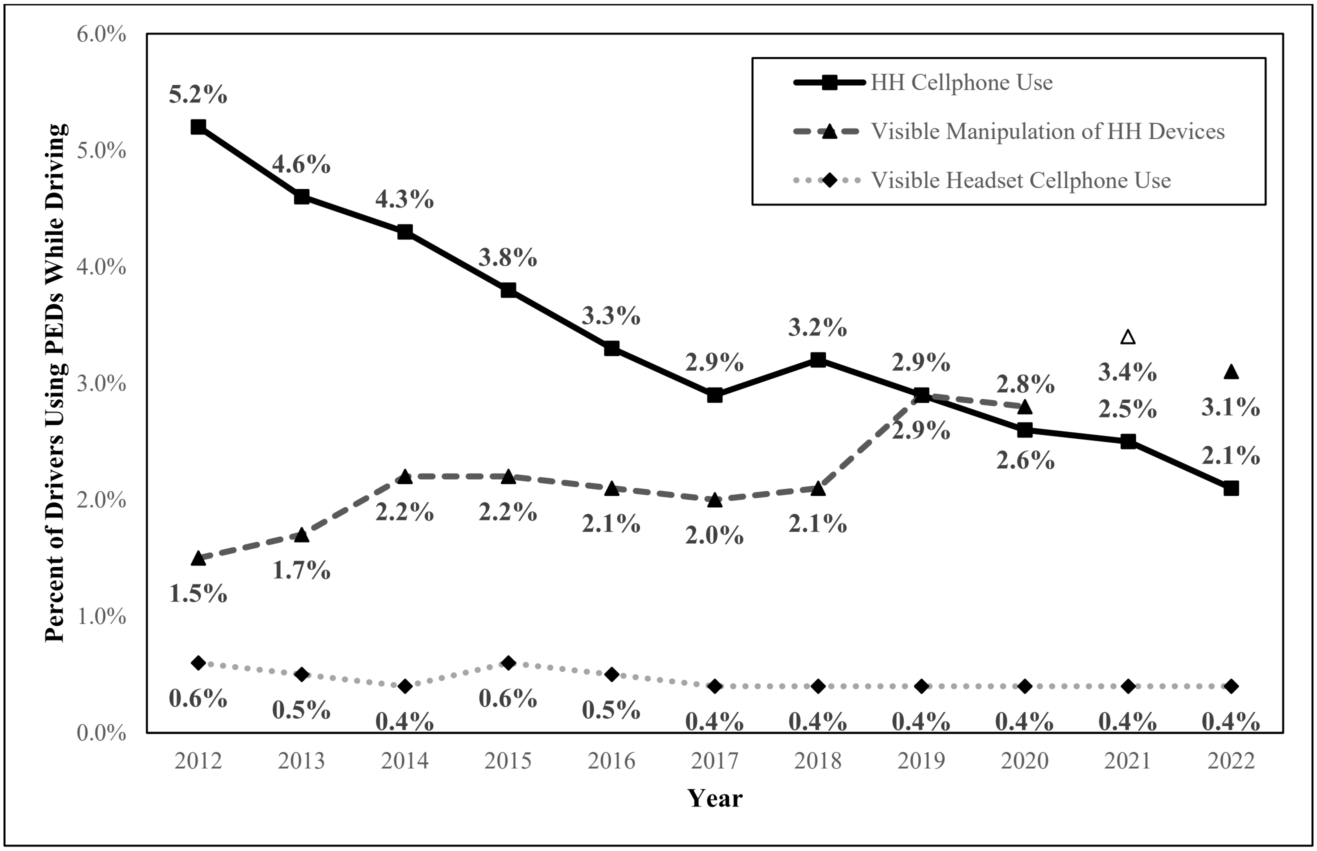

Figure 3-1. Driver use of PEDs. Adapted From NCSA (2024)

Note: Visible manipulation of handheld devices in the 2021 data collection erroneously included manipulation of infotainment systems.

As evident from the figure, driver HH cellphone use, which includes activities such as cellphone conversation, listening to messages, or conducting voice-activated dialing all while holding a phone to the ear, has decreased over the last decade. In 2012 some 5.2% of U.S. drivers measured by NOPUS engaged in HH cellphone use during an average daylight moment compared to 2.1% of drivers in 2022. Visible manipulation of HH devices, on the other hand, which includes activities such as dialing, texting, browsing the internet, interacting with smartphone apps, e-mailing, and navigating, increased in the NOPUS samples over the last decade. In 2012 there were 1.5% of U.S. drivers sampled who were visibly manipulating HH devices during an average daylight moment compared to 3.1% in 2022. Data collected in 2022 returned to the original methodology and did not include manipulation of infotainment systems. Therefore, the two data points for 2021 and 2022 are separate from the trend line for visible manipulation of handheld devices. Visible headset cellphone use, which includes activities such as cellphone conversation or voice-activated dialing with a wireless or wired headset, remained low and essentially stable from 2012 (0.6%) to 2022 (0.4%) (NCSA, 2024).

It must be noted that the NOPUS results are likely underestimates based on the findings of Sagberg et al. (2019), who combined observations like the type made by NOPUS with roadside interviews of Norwegian drivers near the observation site. Sagberg's group found that driver mobile phone use was 12.7% based on self-reports in roadside interviews but only 7.3% based on roadside observations. Drivers can be expected to underreport negative behavior such as cellphone use while driving when responding to a survey (e.g., Lajunen & Summala, 2003). Since the observation estimates by Sagberg et al. were even lower than their survey findings, it is a reasonable assumption that observation estimates, including those from NOPUS, also represent an underestimate of the prevalence of driver PED use. However, when taken periodically using equivalent methodology, e.g., if observations were taken annually (as with NOPUS) and used similar observational methodology as that used in NOPUS, they are a good identifier of trends. For example, for the NOPUS there were significant decreases in HH use from 2012 to 2013, 2015 to 2016, and 2016 to 2017 across the 2012 to 2022 timeframe, indicating a trend involving decreases in HH use. The actual nationwide magnitude of the decline in HH use of drivers, however, is uncertain. Additionally, NOPUS is a point-in-time observation, whereas interviews are based on entire trips, which may also affect prevalence estimates given that a driver may not be using a cellphone at the moment they are observed but may have used it at another time within the trip. This information can be accessed in an interview, but not with one observation.

NDSs

SHRP2 is the largest NDS of passenger vehicles to date. This NDS included data from a sample of over 3,000 volunteer drivers 16 to 90+ years old collected in six States (Florida, Indiana, New York, North Carolina, Pennsylvania, and Washington) from October 2010 to December 2013. The reader is cautioned, however, that, as a convenience sample, SHRP2 data cannot be used to calculate any national estimates. Also, while a rich source of the existence and context of many driver behaviors, this approach is also often limited in its ability to detail many of the specific driver activities, decisions, knowledge, and attitudes available from self-report data.

Based on an analysis of SHRP2 data, driver PED use amounted to approximately 6.4% of total driving time (Dingus et al., 2016). Further exacerbating the distracting effects of PED use, Risteska et al. (2018) showed that a significant number of SHRP2 drivers who used PEDs while driving also engaged in another distracting activity in close temporal proximity to the PED use.

SHRP2 used specially developed and built instrumentation installed in each study vehicle. Recently, smartphone-based apps have been developed for collecting similar data on PED use as part of an NDS and can lead to a more in-depth understanding of this behavior. In an NDS, McDonald et al. (2019) used a smartphone system to collect data on cellphone use while driving among newly licensed drivers. Data were collected over a 2-week period. Results showed that over the course of 5,624 miles in 705 trips, the 16 newly licensed drivers unlocked, via handheld manipulation, their phones 964 times, with an average of about 24 unlocks every 100 miles or 1.2 unlocks/trip (McDonald et al., 2019). It is unclear the extent to which this use would differ from more experienced drivers, considering the restricted sample from this single study. These data do, however, further highlight both the likely existence of a driver PED use problem and the utility of smartphone-based apps in quantifying it.

HH and HF Cellphone Conversation.

Self-report surveys are a method to obtain more specific information about driver PED activities among a large sample of drivers. The National Survey on Distracted Driving Attitudes and

Behaviors (NSDDAB), a series of telephone surveys conducted among a nationally representative sample of drivers in 2010, 2012, and 2015, examined the prevalence of reported cellphone conversation while driving (Schroeder et al., 2015; 2018; Tison et al., 2011). The results showed that 42% to 48% of the respondents reported that they answer phones while driving, and more than half of those (56% to 58%) admitted they will complete the conversation while driving (other drivers responded that they would engage in different actions, such as telling the caller that they would call them back, pulling over to a safe location to continue the conversation, etc.; Schroeder et al., 2015; 2018). The most recent NSDDAB considered HH versus HF usage and found that among respondents who engaged in cellphone conversation: 33% used the speakerphone capability of the PED; 31% used a built-in car system; 20% used an HF earpiece; and 29% engaged in HH conversation (Schroeder et al., 2018). Similarly, the 2020 AAA Foundation for Traffic Safety (AAAFTS) Traffic Safety Culture Index (TSCI), an annual national survey, found 37.2% of respondents report holding and talking on the phone while driving within the past 30 days, and 56% reported using HF technology which includes talking on the phone among other HF activities during the same time period (AAAFTS, 2021).

NDSs also provide information on the prevalence of cellphone conversations. The Naturalistic Engagement in Secondary Task (NEST) database was created from a subsample of 236 SHRP2 distraction-related, safety-critical events (SCEs) that involved secondary task engagement and four randomly selected periods of driving without an SCE from each driver of these SCEs (944 driving periods) (Owens et al., 2015). The analysis of the NEST database revealed that about 5% of all 944 driving periods involved cellphone conversation (Domeyer et al., 2016). Again, though, the reader is cautioned that as a convenience sample, SHRP2 and, particularly, the NEST subsample alone cannot be used to calculate a national estimate as that would require nationwide driver prevalence weights.

Similarly, another NDS that involved 108 drivers who varied in age examined 1,382 cellphone conversations and found that these conversations represented 6.7% of all driving time (Funkhouser & Sayer, 2012). Furthermore, based on this same NDS, driver's conversations lasted on average 2.6 minutes. Rates of conversation per hour were similar between this NDS and an analysis of a subset of SHRP2 that combined NDS data with driver cellphone records. Drivers engaged in 1.2 to 1.5 conversations per hour of driving (Atwood et al., 2018; Funkhouser & Sayer, 2012). An NDS of 106 German drivers over the course of 3 months found that drivers were engaged in HF conversation 11% of the driving time (Metz et al., 2015). Finally, another NDS of U.S. drivers found that HF calls tended to be longer in duration than HH calls (Soccolich et al., 2014).

Dialing Phone

Dialing the phone while driving was another activity examined in the NSDDAB survey (Schroeder et al., 2015; 2018; Tison et al., 2011). The most recent NSDDAB showed (with multiple answers permitted) that when drivers dial, 44.9% of drivers report using speed dial or stored favorite phone numbers, 28.8% report manual dialing, 32.9% report scrolling through numbers and selecting, 51.3% report voice-dialing, while 20.6% say it varies (Schroeder et al., 2018). The analysis of the SHRP2 NEST database discussed above revealed that less than 1% of all 944 driving periods involved dialing on a cellphone (Domeyer et al., 2016).

Texting and Emailing

Texting while driving was also examined by the NSDDAB (Schroeder et al., 2015; 2018; Tison et al., 2011). The most recent 2015 NSDDAB showed that 9% of respondents reported sending text messages or emails at least sometimes, with 80% reporting that they never do so. Twelve percent of respondents reported reading texts or emails at least sometimes. Of the drivers who send texts, 20% use a voice-to-text feature (Schroeder et al., 2018). Two other national surveys, the TSCI (AAAFTS, 2021) and the Distracted Driving Survey (Gliklich et al., 2016), show even higher estimates, perhaps due to differing methods of survey administration (online for the AAAFTS and phone administration for the Distracted Driving Survey). In the 2020 TSCI survey, 22.7% of drivers reported sending and 33.9% reported reading text or email in the last 30 days (AAAFTS, 2021). In the Distracted Driving Survey, 48% of drivers reported reading texts, and 33% of drivers reported writing texts (Gliklich et al., 2016). While findings are based on small samples restricted in age, young drivers appear more likely to reply to texts than initiate them (Atchley et al., 2011).

The extent of the texting and driving problem is further exemplified by the results of two of the previously mentioned studies. The analysis of the NEST database revealed that about 9% of all 944 driving periods involved texting (Domeyer et al., 2016). An analysis of SHRP2 and cellphone record data found drivers averaged 1.2 texts per hour of driving (Atwood et al., 2018).

Browsing the Internet/Apps

The availability of an array of apps on PEDS, such as on smartphones, gives drivers an increasing number of potential distractions while driving. The 2015 NSDDAB had a nationally representative sample of drivers report the frequency they engaged in the use of various smartphone apps while driving (Schroeder et al., 2018). Music apps were the most prevalent applications with over 40% of respondents indicating they use these apps at least rarely. Social media applications and web browsers were the next most frequent activity. The results of another survey of 550 drivers suggested that approximately 13% of these drivers indicated performing email or social network activity on at least half of their trips (Gerte et al., 2018). Similarly, a survey of young drivers in California and Utah found that approximately 17% of surveyed drivers report accessing the web at least a few times a month while driving (Cook & Jones, 2011). However, given that the previous article was published in 2011, and more recent surveys have been conducted, the results should be viewed with caution.

Navigating

Another common PED activity is the use of dedicated navigation devices and navigation apps on smartphones. The most recent NSDDAB showed that a little over 50% of drivers use navigation systems for driving directions at least rarely (Schroeder et al., 2018). The current SOK search revealed three other studies that examined the prevalence of visual navigation activities specifically – one included a nationally representative sample and found that 43% of drivers reported viewing maps on PEDs in the last 30 days (Gliklich et al., 2016). A survey of younger drivers (average age of 19.08 years; Ehsani et al., 2015) and a small-scale survey of older drivers (at least 65 years old, average age of 73.4 years; Vernon et al., 2015) also revealed similar findings. The analysis of 1,243 younger respondents in the Ehsani et al. study showed that slightly more than 50% of younger drivers reported looking at directions or maps on PEDs at least once over the last 30 days while driving. Results of the small-scale survey of older drivers showed that 39 of 100 older drivers (39%) surveyed reported using GPS of some type (not further defined) while driving (Vernon et al., 2015). Most of the use while driving consisted of looking at the GPS to navigate with 46.2% to 74.4% of older drivers reporting sometimes doing so depending on time of day and traffic conditions.

Characteristics

The sizeable prevalence of driver PED use suggests that it could represent a significant problem. This section disaggregates the use by key characteristics of interest including those related to the driver, vehicle, roadway, and the environment. Knowing more detail on who uses PEDs and where they are used provides a better understanding of prevalence and enables countermeasures to be more precisely targeted and evaluated.

Driver

This section examines driver characteristics such as age, sex, race/ethnicity, and driving behaviors that are associated with higher PED use.

Age

Huemer et al. (2018) synthesized roadside observational studies that compared the prevalence of cellphone use across various age groups. The authors found that in all the U.S. studies they examined, younger drivers either had higher prevalence than other age groups, or older drivers had lower prevalence than the other age groups (Huemer et al., 2018). Similarly, the latest prevalence estimates from NOPUS show that drivers observers perceived to be ages 16 to 24 and 25 to 69 have higher HH cellphone use and visual manipulation of HH devices than drivers 70 and older (NCSA, 2021). NDS (Risteska et al., 2018) and survey data (Li et al., 2018; Pope et al., 2017; Schroeder et al., 2015; 2018; Tison et al., 2011) are consistent with these observational study results.

Gender/Sex

Huemer et al. (2018) also synthesized roadside observational studies comparing the prevalence of cellphone use across observed gender.[1] In all U.S. studies synthesized, female drivers had a higher prevalence of PED use than male drivers (Huemer et al., 2018). The latest prevalence estimates from NOPUS show that female drivers continue to have a higher prevalence than male drivers; however, the difference is minimal and not statistically significant (NCSA, 2021). This sex difference is also evident from NDS data (Goodwin et al., 2012), but not always in survey data. Some smaller surveys find higher incidence among female drivers (Jashami et al., 2017; Wilkinson et al., 2013), but national surveys show that gender differences depend on the precise PED activity examined (Schroeder et al., 2015; 2018; Tison et al., 2011). For example, the most recent NSDDAB found that male and female drivers were equally likely to report making calls at least sometimes while driving, but male drivers were more likely than female drivers to report using apps or reading texts (Schroeder et al., 2018).

Race/Ethnicity

Huemer et al. (2018) estimated prevalence by race/ethnicity from observational studies. The reviewed studies covered the period from 2000 to 2016. Fifteen out of 16 studies found that drivers perceived to be White or Caucasian had higher PED use than other races/ethnicities

[1] For gender and sex, the term used by the relevant author is used in this analysis.

examined (Huemer et al., 2018). More recently, NOPUS results from 2019 and 2020 suggest that drivers perceived to be Black had higher incidence of HH device use and visible PED manipulation than drivers observed to be White or "Other" races (NCSA, 2021). There is no ready explanation for these opposing findings, but they could simply be an artifact of different timings of the studies examined or different collection methodologies. Additionally, prior research indicates that observed race does not always correspond to self-reported race (e.g., Saperstein, 2006). By contrast, the most recent NSDDAB survey found minimal differences of distraction behaviors across self-reported racial and ethnic groups (Schroeder et al., 2018).

Vehicle

PED use by vehicle characteristics, including type, moving versus stationary, and automation level, is of potential interest in understanding prevalence estimates. In the Huemer et al. (2018) review of roadside observational studies, the authors examined the extent of association between vehicle type and increased driver PED use and whether moving versus stationary vehicles were associated with higher use. In 28 of 34 studies that assessed vehicle type, differences emerged. Generally, vehicles other than personal passenger cars (e.g., pickup trucks, SUVs, taxis) had the highest PED use. Moreover, three out of four studies that assessed differences in prevalence between moving versus stationary vehicles found higher prevalence in stationary vehicles (the prevalence findings of the fourth study were not mentioned in this source) (Huemer et al., 2018). Results of a survey of drivers from 31 States also found that PED use while moving was less frequent than use while stationary (Kinney et al., 2019).

Theoretically, vehicle automation level can play a role in a driver's perceived risk of using a PED while driving, with drivers potentially feeling more freedom to use a PED while driving when automation is assisting with the driving task. Hungund et al. (2021) synthesized 29 papers and examined the association between the use of advanced driver assistance systems (ADAS) and increased distracted driving behaviors. The authors focused on the relationship between secondary task engagement and lane keeping assist or adaptive cruise control, as well as associated warning systems, or some combination of those ADAS. Results of the review suggest that drivers engaged in more distracted driving behaviors, including PED use, while these forms of ADAS were engaged (Hungund et al., 2021).

Roadway, Temporal, and Environment

Situational factors including roadway type, day of the week, time of day, presence of passengers, and weather conditions can potentially influence whether or not a driver engages in distraction behaviors (e.g., the willingness to use a PED). In the Huemer et al. (2018) review of observational studies, the authors synthesized studies that considered contextual factors such as road type and weather conditions. The authors found driver distracting behaviors were generally lower in more difficult driving conditions (e.g., darkness, degraded weather). Distracting activities involving a PED were also lower when at least one passenger was present. Observational studies after the Huemer group, including the most recent NOPUS, and analyses of NDS data are largely consistent with the results of the Huemer et al. review (Ahlstrom et al., 2020; NCSA, 2021; Ponte et al., 2021; Risteska et al., 2021; Tivesten & Dozza, 2015). For example, high-speed roads appear associated with reduced driver PED use (Ponte et al., 2021; Risteska et al., 2021).

According to research conducted by Tivesten and Dozza (2015), it appears that when drivers are aware of the risks a roadway or environment presents, they may adjust secondary task timing (when to pick up the phone, change a song, look at GPS, etc.) until after the difficult driving maneuver (making sharp turns, lane change, yielding) is completed. Further, an NDS study suggested that road and environmental conditions differentially affect cellphone conversation versus visual-manual (VM) tasks, with drivers reducing VM tasks, but not cellphone conversations, in high traffic conditions (Xiong et al., 2014).

Huemer et al. (2018) also examined whether time of day or day of the week were associated with increased driver distraction from PED use. Almost all the studies they examined found increased PED use on weekdays versus the weekend, but the relationship between time of day and driver PED use was not clear. While a subsequent small study in New Jersey found increased use during rush hours (Brennan et al., 2019), the latest NOPUS found minimal differences between rush hour and non-rush hour traffic (NCSA, 2021).

Motivations

Even though drivers are largely aware that PED use is risky, they still report using PEDs while driving (Lantz & Loeb, 2013; Mikoski et al., 2019; Nelson et al., 2009; Schroeder et al., 2018; Terry & Terry, 2016; Tison et al., 2011). The theory of planned behavior (TPB) was originally posited by Ajzen (1991) and broadly described the relationship between beliefs and behavior. According to this theory, a person's behavioral intentions are shaped by their attitudes, beliefs that important people will support their behavior, and the perceived ease or difficulty of engaging in the behavior. This theory has been widely used in the domain of distracted driving to explain, at least in part, driver decisions to use PEDs (Bazargan-Hejazi et al., 2017; Chen et al., 2016; McBride et al., 2020; Nemme & White, 2010; Shevlin & Goodwin, 2019; Tian & Robinson, 2017). This section addresses each of the factors underlying TPB, including attitudes, social influences, and overconfidence in driving abilities (i.e., high perceived behavioral control), as well as other factors such as driver personality, that are potential internal factors for PED activities.

Attitudes

As discussed, attitudes can be a factor in drivers' intentions to engage in PED use. Beliefs that driver PED use is less risky than it is in reality are associated with higher reported use while driving (Hill et al., 2015; Tian & Robinson, 2017; Watters & Beck, 2016). Still, surveys of drivers find that the majority would feel unsafe as a passenger in a vehicle with a driver using a PED (Kim et al., 2019; Tison et al., 2011), with a national survey of drivers showing as high as 90% of drivers reporting they would feel unsafe in this situation (Tison et al., 2011).

Attitudes about distracted driving vary by age, with older drivers viewing distracted driving behaviors as more dangerous than younger drivers (Tison et al., 2011; Trisko & Ferraro, 2014). Drivers in both older and younger age groups report that their positive attitudes towards benefits of using a PED while driving, such as promptly fulfilling a work obligation, are related to their willingness to engage in PED use, despite the belief that the behavior is risky (Engelberg et al., 2015; Gerte et al., 2018; Hill et al., 2018). This is consistent with studies of young drivers suggesting that perceived importance of communication motivates drivers to use their cellphones while driving (Nelson et al., 2009; Wise et al., 2018).

Social Influences

One of the top predictors of reported or observed distracted driving behavior, generally, and among young drivers, specifically, involves observing others engage in distracted driving behaviors (Bingham et al., 2015; Carter et al., 2014; Gershon et al., 2017; Hill et al., 2015; Jashami & Abadi, 2017; Watters & Beck, 2016; Woods-Fry et al., 2018). People with whom the young driver shares an important or meaningful relationship (e.g., significant other) are more likely to influence driver reported PED use than other friends or casual acquaintances, with drivers more likely to engage in PED use if they perceive their significant others as also doing so (Beck & Watters, 2016; 2017; Trivedi & Beck, 2018). A national survey of adult drivers revealed that social distance is an important factor in determining driver conscious decisions to use a PED. Teen drivers reported they were more likely to talk with parents on the phone while they drive, and adults reported that they were more likely to talk with spouses or partners than those more socially distant from them (LaVoie et al., 2016). Interviews of young drivers revealed that fear of judgement prevents them from intervening when those in their social circle engage in distracted driving behaviors (Watters & Beck, 2016); however, over half of adult U.S. drivers aged 18 and older surveyed indicated they would be more likely to intervene if the driver engaged in the behavior was close to them versus if they did not know them as well (Otto et al., 2016).

Not only the perception of how often other drivers engage in PED use, but also the perceived correctness of doing so are important factors that predict the engagement of young drivers in PED use behavior (Briskin et al., 2018; Nemme & White, 2010; Shevlin & Goodwin, 2019; Wilbur, 2019). While these moral norms appear to influence young driver behavior, they appear less influential on older age groups based on surveys of non-U.S.-based samples (Chen & Donmez, 2016; Chen et al., 2016).

Overconfidence in Driving Abilities

Self-belief in driving abilities is another critical factor that influences decisions to use PEDs while driving, with drivers high in self-efficacy (e.g., those with greater confidence or perceived capability in their own ability to engage in distracting activities and drive) more likely to use PEDs while driving (Engelberg et al., 2015; Hill et al., 2015; Schlehofer et al., 2010; Shevlin & Goodwin, 2019). This overconfidence is particularly evident from the findings of a national survey that shows that drivers believe that PED use has no effect on their driving performance but does influence the driving performance of others (Schroeder et al., 2018; Tison et al., 2011). In a large-scale survey of young drivers, nearly half (46%) of drivers surveyed believe that they were capable or very capable of driving while distracted but felt less than 10% of other drivers were similarly capable (Hill et al., 2015).

Past/Other Risky Driving Behaviors

In addition to the factors in the TPB, a driver's past risky behavior may be a good predictor of current or intended future risky behavior. For example, those young drivers who report using PEDs while driving are more likely to report having used PEDs while driving in the past (Nemme & White, 2010; Shevlin & Goodwin, 2019; Tian & Robinson, 2017; Trivedi et al., 2017). Young drivers (high school and university students, as well as people in these age ranges) who report using PEDs while driving are also more likely to report not wearing seatbelts (Li et al., 2018; Olsen et al., 2013), speeding (Jashami & Abadi, 2017), riding with a driver who had been drinking alcohol (Olsen et al., 2013), drinking alcohol and driving themselves (Li et al., 2018; Olsen et al., 2013), being in a crash (Hill et al., 2015; Jashami & Abadi, 2017; Westlake & Boyle, 2012), and binge drinking generally (Marcotte et al., 2012). Note though that the NEXT Generation Health Study showed no relationship between secondary task engagement in general and driving while alcohol/drug impaired (Simons-Morton et al., 2016). In the NEXT study, however, secondary task engagement was broadly defined, whereas the Olsen et al. (2013) study looked specifically at the riskier behavior of texting and how this behavior was associated with the other risky driving behaviors above. Also, consistent with the association of PED use with other risky behaviors, a survey of Canadian drivers found that drivers who report more driver errors, lapses, or violations are more likely to report engaging in distracting activities (Chen et al., 2016).

Personality

While not part of the TPB, researchers have examined personality traits and behaviors indicative of traits commonly associated with attention, awareness, and control to see if these same traits and behaviors are associated with PED use. For example, based on college student driver self-reports, higher PED use appears to be associated with acting impulsively and impulsive traits generally (Briskin et al., 2018; Hayashi et al., 2015; 2017; 2018; Lantz & Loeb, 2013; Meldrum et al., 2019; Pearson et al., 2013; Sanbonmatsu et al., 2013) and lower levels of mindfulness (Feldman et al., 2011; Moore & Brown, 2019). Similarly, an Australian sample of drivers in diverse age ranges also showed a relationship between lower levels of mindfulness and increased self-reported engagement in PED use (Young et al., 2018). Rumination, another personality trait related to attention and control, predicted self-reported risky driving behaviors such as aggressive driving among college student drivers, but it was not associated with PED use (Suhr & Dula, 2017).

As PED use while driving is a form of risky behavior, it is intuitive that drivers with riskier or sensation-seeking traits may be more likely to engage in PED use. Non-U.S.-based and U.S. studies found a relationship between higher sensation-seeking and higher reported driver PED use (Chen & Donmez, 2016; Merat & Coleman, 2013; Sanbonmatsu et al., 2013), but one of the non-U.S.-based studies found inconsistent results when comparing reported use to observed use in the simulator (Merat & Coleman, 2013). Inconsistency between reported use and observed use is expected as one is a subjective view of personal behavior (surveys and interviews), whereas the other is more objective (observations).

The use of PEDs (specifically, cellphones) has also been studied as a form of psychological dependence (Liese et al., 2019; Mirman et al., 2017; Reed et al., 2016) or attachment to the device itself (Struckman-Johnson et al., 2015; Weller et al., 2012) with increased dependence and device attachment associated with higher reported use while driving and undesirable outcomes such as reported motor vehicle crashes and reported moving violations. A study of young Israeli adult drivers included objective measures of smartphone use while driving (e.g., screen touches) and found that those drivers who scored higher on a “smartphone addiction” scale used smartphones more frequently while driving (Kita & Luria, 2018). A NHTSA literature review examining electronic device use and addictive behaviors had not been published during the timeframe of the research, but is currently available (Hoekstra-Atwood et al., 2023).

Driver-level demographic factors, such as gender and age, appear to influence the personality factors that predict PED use. Among young Australian male drivers, boredom proneness and social connectedness predicted reported phone use, but these same traits did not predict young female drivers' use (Oxtoby et al., 2019). Among young drivers, conscientiousness and openness to experience were associated with more reported distracted driving behaviors while agreeableness was associated with fewer behaviors (Parr et al., 2016). For older drivers (65 to 85 years old), extraversion was the only personality factor associated with distracted driving behaviors (Parr et al., 2016). A survey of young adults suggests that extraversion may predict engagement in distracted driving activities for this age group as well (Braitman & Braitman, 2017).

Summary

Researchers have measured the prevalence of driver use of PEDs and the characteristics of this use in a variety of ways, with each approach having its inherent strengths and weaknesses. This examination across the range of these approaches revealed much about the extent and nature of the problem. For example, the most recent data from NOPUS suggests 0.4% to 3.1% of U.S. drivers during an average daylight moment are engaging in some activity on PEDs (NCSA, 2024). Estimates are higher based on NDS and self-report data. Analyses of NDS data collected from 2010 to 2013 suggest that PED use comprised as much as 6.4% of total driving time (Dingus et al., 2016). Self-report estimates show that 42% to 48% of the respondents reported that they answer phones while driving (Schroeder et al., 2018) and that 22.7% of drivers reported sending and 33.9% reported reading a text or email in the last 30 days (AAAFTS, 2021). There is still, however, much that remains unknown about both the true prevalence of PED use by drivers and the determinants of that use. Despite the prevailing uncertainties, the preponderance of evidence from existing studies suggests the problem is significant. Better knowledge of both the extent of PED use as well as its characteristics and motivations for it, although difficult to measure, would be helpful in defining future prevention efforts.

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Chapter 4 – Effects on Driver Behavior and Performance

Introduction

The previous chapter highlights what is known about the extent portable electronic device (PED) use occurs while driving. Another area of relevance to the SOK is the extent to which driver use of PEDs affects driver behavior and performance of the driving task. Although not the ultimate measure—safety—numerous studies have shown certain undesirable driver behaviors or performance decrements associated with PED use, such as looking away from the forward roadway for an extended period, to be related to crash risk (see, for example, Klauer et al., 2010). Thus, several studies, literature reviews, and meta-analyses on the driver behavior and performance effects of PED use by drivers have been published.

Previous Reviews

The last comprehensive NHTSA SOK of the effects of distraction on driver behavior and performance was conducted by Ranney (2008). The intervening years have seen a marked change in PED technology, the ways drivers interact with these devices, and advances in measuring these interactions and their effects on driver behavior. For example, traditional cellphones have been largely replaced by smartphones and other more “intelligent” PEDs that present an even greater distraction potential. This technological transition produced a shift in the way drivers interact with these devices. For example, tactile manual keypad interactions required for the use of early generation cellphones have largely been replaced by touch screen interfaces that increase information availability and complicate interactions to control these devices. Also, advances in data collection methodologies and public funding of relevant studies have resulted in large datasets of naturalistic driving study (NDS) data, such as those from the Second Strategic Highway Research Program (SHRP2), that cover more diverse populations than many experimental studies conducted in a laboratory and have been designed specifically to understand driver behavior and performance in typical driving situations.

In response to these changes, there has been continued scientific focus on PED-caused driver distraction since the previous SOK report, including several reviews specifically focused on understanding distracted driving’s impact on driver behavior and performance. Most of the reviews were limited in scope and either focused primarily on characteristics of the distraction activity, such as handheld (HH) versus hands-free (HF) use of phones (Ishigami & Klein, 2009); on the nature of the driving task, such as driver distraction in the context of advanced driver assistance systems (ADAS) (Hungund et al., 2021); or on the population of drivers considered, such as young drivers (Klauer et al., 2015). Other reviews synthesized driver performance outcomes together with crash measures (e.g., Ferdinand & Menachemi, 2014).

Conducting meta-analyses on this topic has been facilitated by the increasing standardization of the dependent measures and experimental approaches used by researchers to examine driver behaviors and driver distraction, such as measures of driver visual glance or vehicle handling metrics. An important series of meta-analyses by Caird and colleagues (2008; 2014; 2018) and Simmons et al. (2017) quantified performance decrements by the characteristics of the distraction activity or how the performance decrements were measured. As the objectives of these high-quality meta-analyses overlap with those of the current review, their results will be synthesized together with results of subsequent independent studies in later sections of this chapter.

Current Review

A review of the literature published since the Ranney (2008) SOK through September 2022 showed it could support an augmented examination of PED use effects on driver behavior and performance. Because driver behaviors can translate to driving performance and therefore safety (see Chapter 5), it is essential to examine if and how distraction caused by PED use affects driver behavior. The ability to analyze this issue is complicated, however, by the sheer variety of distracting behaviors a driver can engage in and the potentially different impacts they can have on driver performance.

The current review approaches the issue of driver performance with separate examinations of behaviors associated with attention (mainly eye movements/visual attention) and those associated with vehicle management (e.g., driving speed). Initially, the focus below will be on studies that measure driver's shifting of attention away from the driving task due to PED use. Most of the relevant studies address the extent visual attention, as measured by eye glance metrics, is shifted away from the forward roadway. The second section will review studies that examined specific vehicle handling and speed control measures as well as the adequacy of responses to stimuli (e.g., reaction time [RT]). Where possible, results are contrasted by strength of research approach and characteristics of the driver, vehicle, roadway, and environment in addition to the type of distraction.

Review Approach

An extensive set of documents examining driver PED use effects on driver behavior and performance was identified and screened with the process detailed in Chapter 1. Researchers screened documents to identify the study methodology employed—on-road, closed course, simulator, or NDS. Documents based on non-U.S.-based experiments were included in this chapter as geographic or cultural differences are not expected to meaningfully impact driver behavior or performance.

A total of 436 papers (reviews and original investigations) were identified as relevant to this chapter. Researchers assessed these 436 documents for study quality using the quality dimensions discussed in Chapter 1. Documents for this chapter were also assessed for the realism of simulated driving or surrogate PED tasks and the extent to which proper baselines or controls were included. Findings from those documents that included more ecologically valid tasks and stronger experimental paradigms were given more weight in the review. The application of the quality criteria reduced the 436 to the set of 65 works cited in this chapter.

Effects on Driver Attention

This section reviews studies that measure attention shifts by a driver away from the driving task due to PED use. For the most part, these attention shifts were measured by eye glance metrics. Measuring a driver's eye movements to understand their visual glance patterns is a widely used and presumed valid approach to examining the influence of a secondary task on a driver's attention to the forward roadway. This is because there is a strong link between eye movements and attention, with overt attention being contingent on eye fixations towards a specific region (Posner, 1980).

Off-Road Glances

Since driving is a predominantly visual task (Sivak, 1996), the importance of drivers keeping their eyes on the forward roadway has been well recognized (see, for example, Samuel & Fisher, 2015). Frequent and prolonged glances away from the forward roadway have been associated with increased crash risk (see Chapter 5). Defining what constitutes a "prolonged glance" has been a longstanding debate that predates the literature synthesized in this SOK. There is general agreement, however, that any glance longer than 2 seconds away from the forward roadway is excessive, increases risk, and is therefore undesirable (e.g., Klauer et al., 2006; Pradhan et al., 2011).

Regardless of the definition of a prolonged or excessive glance employed, relevant studies typically examine the characteristics of a driver's activities with a PED that are most likely to lead to the increased frequency or duration of off-road glances (Caird et al., 2014). Caird et al. meta-analyzed data from 977 drivers in 28 experimental studies to examine the extent texting activities while driving affected driver behavior and performance. Ten studies, involving 383 drivers, examined eye movement outcome measures, including the frequency or duration of off-road glances. Table 4-1 presents the effect sizes from the Caird et al. (2014) meta-analysis representing the visual demands of reading or typing texts or a combination of both (typing/reading) versus a baseline or control condition typically involving no distracting activity. Effect sizes, r_c, can range from -1.00 to 1.00, with larger, positive effect sizes indicating the activity is associated with the eyes spending more prolonged or frequent glances away from the forward roadway.

Table 4-1. Visual Distraction Effect Size by Texting Activity. Adapted From Caird et al. (2014)

Texting Activity	**r_c (95% CI)**
Reading Texts vs. Baseline (***n*** = 5 Studies)	0.60 (0.35 – 0.86)
Typing Texts vs. Baseline (***n*** = 4 Studies)	0.88 (0.84 – 0.92)
Typing/Reading Texts vs. Baseline (***n*** = 4 Studies)	0.74 (0.41 – 1.00)

From Table 4-1, all driver texting activities (reading, typing, and both typing and reading simultaneously—"typing/reading") have relatively large effect sizes suggesting that these activities are visually distracting to drivers. Typing and typing/reading had somewhat larger effect sizes than reading alone, suggesting typing texts is particularly visually demanding. In fact, typing and typing/reading were the two largest effect sizes in the entire Caird et al. (2014) meta-analysis, which also included other driver behavior and performance outcomes discussed later in this chapter. The significant visual distraction that is often associated with the manual inputs on a PED required for texting is consistent with the findings of a second meta-analysis by Caird et al. (2018) that focused on the activity of dialing a cellphone. Dialing in this meta-analysis was defined broadly to involve activities such as manual entry of a phone number to scrolling to find a saved number. This meta-analysis synthesized two experimental studies involving a total 61 drivers and found that drivers had a high tendency to make off-road glances while dialing (r_c = .92).

A study also looked at the effect of general PED experience, i.e., the study participants were those who were experienced at using navigation systems and cellphones while driving, and included prior PED experience while driving or while not driving, on the extent a driver's PED activities result in off-road glances (Knapper et al., 2015). The Knapper et al. study focused on experienced PED users and found texting and destination entry when using a dedicated navigation device or function in a PED resulted in drivers looking off the road for a substantial amount of time. While only a single study that did not include an inexperienced PED user group as a comparison, the results of the Knapper et al. study suggest that general PED experience does not negate the visual distracting effects of PED activities.

While distraction activities that require the driver to read or manually input information are associated with the driver looking away from the forward roadway for an excessive amount of time, the magnitude of visual distraction also appears to depend to some extent on distraction source and the method of completing the distracting activities. For example, Brookhuis and Dicke (2009) found drivers in a simulator spent more time looking away from the forward roadway when navigation directions were presented via a series of texts on a cellphone compared to a single message displaying equivalent information on a personal digital assistant (PDA) screen. Traditional interfaces with discrete keys, such as those on flip phones, also have been shown to require fewer off-road glances for drivers than touchscreens during manual tasks, such as dialing, in a simulator (Reimer et al., 2014). This effect may be dependent on the complexity of the manual inputs required, as a simulator study involving short text message responses found no difference in the amount of time drivers looked at the forward roadway when comparing touchscreens versus a traditional interface with discrete keys (Young et al., 2014).

Considering the extent of visual distraction associated with activities such as texting, dialing, and destination entry, smartphone and automobile manufacturers have developed voice-based or other assistance technology that attempt to reduce the visual-manual (VM) demands of these activities. For example, experimental studies examining the extent that these technologies reduce visual distraction generally show that speech-based technology reduces the time driver's eyes are off-road compared to manual entry methods (Ibrahim, 2019; Neurater et al., 2012; Owens et al., 2010; Reimer et al., 2016; Reimer et al., 2021), but the time eyes are off-road was still greater than for a baseline condition with no distracting activity (Ibrahim, 2019; Reimer et al., 2016). Also, the extent that voice-based technology reduces visual demands compared to manual entry methods appears to depend on the design of the technology itself (Reimer et al., 2021). For example, vehicle-based systems that pair with phones and include standardized, context-sensitive text message responses for drivers (e.g., "I'm stuck in traffic") also have been shown to result in less frequent and shorter glances off the forward roadway compared to typical manual entry texting (Owens et al., 2011).

The Caird et al. (2018) meta-analysis also examined the effects of HH and HF cellphone conversations on a driver's attention maintenance, including off-road glances. The authors synthesized two experimental studies consisting of 40 drivers that compared the visual distraction associated with HH conversations to a baseline or control condition involving no secondary task. They also synthesized two experimental studies with 33 drivers that made similar comparisons of the effects of HF conversations. Small effect sizes with cellphone conversation were observed in both cases (r_c = -.27 for HF; r_c = .17 for HH), suggesting that neither mode of cellphone conversation generates particularly high visual demands when compared with VM activities such as texting, dialing, and destination entry discussed above.

Interestingly, the HF and HH effects associated with off-road glances were in opposite directions in the Caird et al. (2018) meta-analysis, with HH conversation associated with greater visual demands and HF conversation associated with reduced visual demands. This may be due to the inherent differences between the demands required of HH (with manual component) and HF (purely cognitive) conversation. Studies identified through this current SOK search that were done after the Caird et al. meta-analysis, though, also show that HH conversation has reduced visual demands compared to no secondary tasks in certain driving demands or environments (Fitch et al., 2015; Knapper et al., 2015). This finding is consistent with a simulator study that showed a similar decrease in percentage of time the driver's eyes were off road while conversing on a HH cellphone compared to baseline or a control condition that involves no secondary task while driving at higher speeds (Knapper et al., 2015). Similarly, a study that involved on-road data collection found that HH phone conversation decreased the percentage of time that a driver's eyes were off the road compared to conditions that involved no secondary task (Fitch et al., 2015). In sum, as suggested by Fitch et al. (2015) and Knapper et al. (2015), cellphone conversation may not always reduce a driver's attention to the forward roadway and may increase their visual attention to the road ahead either by reducing visual sampling of irrelevant driving locations or minimizing the ability/willingness to perform other more visually demanding secondary tasks (e.g., consuming food and drink) at the same time.

As discussed in Chapter 3, ADAS, such as lane keeping assist (LKA) and Adaptive Cruise Control (ACC), are functions designed to support drivers and reduce their driving task load. When using these forms of ADAS, drivers show a tendency to increase their use of PEDs (Hungund et al., 2021). This increased PED use may result in decreased attention to the forward roadway. Hungund et al. (2021) systematically reviewed 10 research documents and found that all reported decreased attention to the forward roadway when ADAS was active, and a PED was used for a potentially distracting task. The findings of this review suggest a potential counterproductive effect of the LKA and AAC ADAS features.

Hazard Anticipation and Detection

Another measure of a driver's attention behavior can be based on their hazard anticipation and detection performance. These driving behaviors are generally measured by a driver's specific glances towards regions of interest (target zones) that suggest the detection of a hazard or via more general anticipatory glance behaviors (e.g., Samuel et al., 2014) or visual scanning gaze dispersal (e.g., Desmet & Diependaele, 2019). The cognitive demands of secondary task engagement when driving could have a particular consequence on hazard anticipation and detection given that these behaviors are "higher order" cognitive skills (Crundall & Kroll, 2018).

Anticipation

Caird et al. (2018) synthesized five experiments with 183 drivers and found that drivers engaged in HF cellphone conversations performed a narrower scan of the horizontal field of view than when engaged in no secondary task. In contrast, Desmet and Diependaele (2019) report a wider horizontal scan pattern of drivers engaged in HF phone conversations as compared to a no-phone condition. These conflicting findings may be explained in part by the acknowledgment of Desmet and Diependaele concerning the inherent accuracy limitations of the head-mounted eye tracking devices used to study visual scan. The authors also note that the wider fixation patterns with HF should not necessarily imply improved information processing, and speculate that during HF conversations, a driver's eyes may "wander" more and fixate less on traffic-relevant areas. Consistent with cognitive distractions restricting a driver's scanning and anticipation abilities, Biondi et al. (2015) found that as cognitive tasks become more demanding (e.g., interacting with a voice-based email/text system versus listening to an audiobook), drivers make fewer anticipatory glances at potential hazard locations. Drivers engaging in VM tasks, such as texting, also appear to display a limited ability to make appropriate glances towards hazard locations (Samuel et al., 2014). Although only based on the results of a single study, the effect of VM tasks on anticipatory glances would seem to be independent of cellphone design or a driver's texting experience.

Detection

The Caird et al. (2018) meta-analysis examined the extent driver cellphone use (dialing and HH or HF conversation) affected the time drivers needed to detect visual targets or events. Table 4-2 presents the effect sizes from the Caird et al. meta-analysis for dialing or HH/HF cellphone conversation versus a baseline or control condition typically involving no distracting activity, and HH and HF conversation versus each other. Larger, positive effect sizes (r_c) show that the activity is associated with taking more time to detect targets or events.

Table 4-2. Dialing and HH/HF Conversation Effects on Driver Detection RT. Adapted From Caird et al. (2018)

Cellphone Activity	**Detection RT** r_c **(95% CI)**
Dialing vs. Baseline (***n*** = 4 Studies)	0.80 (0.68 – 0.93)
HH conversation vs. Baseline (***n*** = 5 Studies)	0.61 (0.49 – 0.73)
HF conversation vs. Baseline (***n*** = 19 Studies)	0.49 (0.35 – 0.64)
HH conversation vs. HF conversation (***n*** = 3 Studies)	0.13 (-0.09 – 0.35)

As evident from Table 4-2, dialing on a cellphone and cellphone conversation (both HH and HF) had moderate to large effect sizes, with dialing on a cellphone having by far the largest. HH and HF effects on detection time were similar. Caird et al. (2018) conducted moderator analyses examining how the effects on HF conversation changed across research environment and conversation type. The authors found that the slowing effects on detection time of HF conversation were greater as the research setting moved from simulator to on-road. More typical HF conversation impaired detection time to a similar magnitude as artificial HF tasks (e.g., adding two numbers together) (r_c = .48 vs. r_c. = .57). In sum, dialing on a cellphone and phone conversation, regardless of mode, increase the time needed for drivers to detect targets, with VM tasks, in this case dialing, having the greatest impact.

In addition to examining cellphone use effects on detection time, Caird et al. (2018) also examined the extent cellphone conversation (HH and HF) affected driver's accuracy in detecting targets. Simmons et al. (2017) did the same for speech-to-text or voice-recognition technology that affords the driver HF or voice-based methods of completing VM tasks, such as dialing a phone number or sending a text by speaking to a cellphone application that completes the action. Simmons et al. compared voice-based methods versus baseline or a control condition involving no secondary task and the voice-based methods versus traditional VM methods of completing similar tasks. Table 4-3 presents the effect sizes from the Caird et al. and Simmons et al. meta-analyses. Larger effect sizes (r_c) show that the activity has a stronger relationship with detection accuracy with positive effects indicating the activity is associated with better accuracy and negative effects indicating worse accuracy.

Table 4-3. Dialing and HH/HF Conversation Effects on Driver Detection Accuracy. Adapted From Caird et al. (2018) and Simmons et al. (2017)

PED Activity	**Detection Accuracy** r_c **(95% CI)**
HH conversation vs. Baseline (***n*** = 5 Studies)*	-0.40 (-0.64 – -0.17)
HF conversation vs. Baseline (***n*** = 13 Studies)*	-0.52 (-0.71 – -0.33)
HH conversation vs. HF conversation (***n*** = 4 Studies)*	-0.05 (-0.21 – 0.12)
Voice-based VM tasks vs. Baseline (***n*** = 19 Studies) †	-0.41 (-0.50 – -0.32)
Voice-based VM task vs. traditional VM tasks (***n*** = 5 Studies) †	0.21 (-0.06 – 0.48)

*Effects from Caird et al. (2018).
†Effects from Simmons et al. (2017).

The pattern in Table 4-3 is like the detection time effects in Table 4-2. HH and HF conversation both have moderate, negative effect sizes on detection accuracy, and there is no meaningful difference between HH and HF modes (Caird et al., 2018). Also, voice-based methods of completing VM tasks ("voice-based VM tasks" in the tables) have a similar effect size to HH/HF cellphone conversation with respect to detection accuracy. The comparison of voice-based methods of completing VM tasks versus traditional VM methods of completing similar tasks, such as using touchscreens, however, reveals that drivers display nominally better target detection performance with voice-based systems, although the difference is not significant (Simmons et al., 2017). This suggests that cellphone conversation and voice-based methods of completing VM tasks reduce a driver's ability to detect targets or events accurately but may be less impairing than PED VM activities such as dialing, texting, navigation, and music selection.

Effects on Driving Performance

As discussed, engaging in PED use while driving takes a driver's visual and cognitive attentional allocation away from the primary task of driving. In addition, it is logical that PED use may affect a driver's manual task resources. In turn, a shortfall in a driver's resources can theoretically limit their ability to undertake the basic tasks of vehicle handling, either because of their hands being occupied or due to added cognitive efforts and reallocation of visual attention that may limit the ability to maintain vehicle trajectories and/or speed or to predict and respond appropriately to critical stimuli and events. These driver performance issues are explored in this section with a synthesis of the included studies to examine the effect of PED use on vehicle handling and lane position, vehicle speed, headway distance, and RT.

Vehicle Handling and Lane Position

Indicators of vehicle handling and lane position include measures of lane keeping, lane adherence, and steering control. Variability or standard deviation of lane position (SDLP) is a widely used measure to gauge the stability of a driver's lane keeping (e.g., Vester & Roth, 2011). Meta-analyses have quantified the extent that VM tasks require drivers to look away from the forward roadway or move their hands away from the steering wheel, such as with texting and dialing, and how VM tasks affect vehicle handling and lane position relative to cognitive tasks that do not require these visual or manual resources, including no secondary task at all (Caird et al., 2014; 2018; Simmons et al., 2017). Table 4-4 presents the effect sizes from the meta-analyses that examine the influence of VM and cognitive tasks on driver's lateral positioning (e.g., SDLP). Larger effect sizes (r_c) show that the activity has a stronger association with SDLP. Positive effects mean the activity is associated with greater SDLP (more lateral position instability) whereas negative effects mean the activity is associated with lesser SDLP (more lateral position stability).

Table 4-4. VM and Cognitive Task Effects on Lateral Positioning. Adapted From Caird et al. (2014; 2018) and Simmons et al. (2017)

PED Activity	**Lateral Positioning – Standard Deviation of Lane Position (SDLP)** r_c **(95% CI)**
Reading Texts vs. Baseline (***n*** = 7 Studies)*	0.32 (0.18 – 0.52)
Typing/Reading Texts vs. Baseline (***n*** = 11 Studies)*	0.37 (0.25 – 0.50)
Typing Texts vs. Baseline (***n*** = 10 Studies)*	0.50 (0.39 – 0.62)
Dialing vs. Baseline (***n*** = 5 Studies) †	0.57 (0.44 – 0.70)
Voice-based VM tasks vs. Baseline (***n*** = 13 Studies) ^	0.20 (0.05 – 0.35)
Voice-based VM task vs. traditional VM tasks (***n*** = 17 Studies) ^	-0.39 (-0.48 – -0.30)
HF conversation vs. Baseline (***n*** = 27 Studies) †	0.04 (-0.07 – 0.16)
HH conversation vs. Baseline (***n*** = 8 Studies) †	-0.10 (-0.31 – 0.11)
HH conversation vs. HF conversation (***n*** = 3 Studies) †	0.00 (-0.17 – 0.16)

*Effects from Caird et al. (2014). In this meta-analysis, SDLP measures were combined with lane excursions and other lateral positioning measures.
† Effects from Caird et al. (2018).
^Effects from Simmons et al. (2017).

The pattern of effect sizes in Table 4-4 is like that discussed earlier in the "Off-Road Glances" section. VM tasks (e.g., texting, dialing) had the largest effects sizes. Voice-based methods of completing VM tasks or HF/HH conversation had small to almost no effect on the stability of lateral positioning. The similarity between lateral positioning and off-road glance effect sizes is consistent with simulator studies showing that a driver's extended off-road glances likely account for the relationship between lane position variability and engagement in a VM task (e.g., texting) (Kingery et al., 2015; Young et al., 2018). This is also consistent with a systematic review of ADAS and driver distraction showing that ADAS both decreases driver's attention to the forward roadway and increases lane position variability (Hungund et al., 2021). The decreased steering control performance associated with VM tasks is estimated to persist over 3 seconds after completion of the VM task (Thapa et al., 2015). The degraded steering control performance is more severe when using touch screen devices than when using more basic phones (Ranney et al., 2011; Reimer et al., 2014; Young et al., 2014) or when inputting directly to a phone versus using an in-vehicle system to send texts (Owens et al., 2011). The effects of VM tasks are also more pronounced for older drivers than younger age groups as indicated by lane position variability (Bao et al., 2015; Ortiz et al., 2018) and the frequency of lane departures (Rumschlag et al., 2015).

Researchers have also examined the extent a driver's experience—both texting experience in and out of the vehicle and their general driving experience—mitigates VM tasks' impact on steering control. These studies found VM tasks' impact on steering control and older drivers' increased susceptibility to these effects appear to be largely unaffected by either general texting experience (Knapper et al., 2015; Ortiz et al., 2018; Rumschlag et al., 2015) or total driving experience (Choudhary & Velaga, 2019), although with the latter, professional drivers showed smaller variations in lane positioning while texting than young drivers. Professional drivers were described as those drivers who were 25 years old or older, drove annually 15,000 or more km, and had more than 5 years of professional driving experience, whereas young drivers were described as drivers who were younger than 25 years old and had less than 4 years of driving experience involving recreational trips.

Finally, other researchers have examined the extent a driver's subjective response to the PED task relates to the extent the task affects lateral control. These researchers found that high reported enjoyment or lower perceived difficulty of the PED task can make these lateral control impairments less noticeable to the driver (Horrey et al., 2009; Irwin et al., 2015).

Headway, Speed, and Reaction Time

Longitudinal vehicle control can be characterized by measures of how far a vehicle is (both in terms of time and distance) from a lead vehicle (forward headway) and measures of acceleration and deceleration. Longitudinal control provides insight into driving style, ride comfort, and safety (e.g., Bellem et al., 2016; Murphey et al., 2009; Qi et al., 2015). Level of safety can be at least partially assessed by the closeness of following and tailgating given the potential consequences of these behaviors (e.g., Vogel, 2003). Studying longitudinal control also can provide an indication of driver compensatory behaviors when using a PED. Increased headways and/or reduced speeds for improving RT and offsetting a diminution in visual attention towards the driving task are possible indicators of compensation.

Headway

Meta-analyses have quantified the extent to which typing/reading texts, HH/HF phone conversation, and voice-based methods of completing VM tasks affect how far a driver's vehicle is from a lead vehicle (Caird et al., 2014; 2018; Simmons et al., 2017). Table 4-5 presents the effect sizes from these meta-analyses. Larger effect sizes (r_c) show that the activity has a stronger association with headway. Positive effects mean the activity is associated with greater headway whereas negative effects mean the activity is associated with lesser headway.

Table 4-5. VM and Cognitive Task Effects on Headway. Adapted From Caird et al. (2014; 2018) and Simmons et al. (2017)

PED Activity	Headway r_c (95% CI)
Typing/Reading Texts vs. Baseline (***n*** = 5 Studies)*	0.53 (0.36 – 0.70)
Voice-based VM tasks vs. Baseline (***n*** = 8 Studies) ^	0.16 (0.06 – 0.25)
Voice-based VM task vs. traditional VM tasks (***n*** = 3 Studies) ^	-0.18 (-0.36 – -0.01)
HF conversation vs. Baseline (***n*** = 15 Studies) †	0.06 (-0.02 – 0.15)
HH conversation vs. Baseline (***n*** = 5 Studies) †	0.21 (0.05 – 0.37)
HH conversation vs. HF conversation (***n*** = 4 Studies) †	0.01 (-0.14 – 0.15)

*Effects from Caird et al. (2014).
† Effects from Caird et al. (2018).
^Effects from Simmons et al. (2017).

As evident from Table 4-5, VM tasks, such as typing/reading texts, have a large effect on driver headway whereas cognitive tasks (voice-based VM task or HF/HH conversation) have small to no effect on driver headway. These results suggest that drivers may be compensating for the concurrent performance of VM tasks and driving by providing more distance between their vehicle and the vehicle ahead. These increased headways associated with distraction persist even after practice and experience (Cooper & Strayer, 2008). Also, consistent with a compensatory hypothesis, analyses of NDS data and simulator data show that members of older driver age groups, who are typically more risk-averse, maintain larger headways from a leading vehicle when engaged in secondary tasks than do younger age groups (Dozza et al., 2015; Farrah et al., 2016).

As discussed above, cognitive distractions such as HH and HF conversation have a small to negligible effect on headway distance (Caird et al., 2018). Results of simulator studies, though, suggest that the increased headway observed with HH and HF conversations and PED use in general may be greater in high traffic (Brookhuis & Dicke, 2009) or in urban rather than rural environments (Benedetto et al., 2012). These findings suggest that drivers may be more likely to compensate for their PED use in driving situations with greater complexity.

Speed

The driving speed chosen by drivers is an indicator of both safety performance and risk acceptance (e.g., Qi et al., 2015). As with headway, increased cognitive or other workload could impact performance, either directly or as a compensation for reduced attentional resources. Meta-analyses, as shown in Table 4-6, have quantified the extent typing/reading texts, dialing, HH/HF phone conversation, and voice-based VM tasks are associated with driving speed (Caird et al., 2014; 2018; Simmons et al., 2017). Larger effect sizes (r_c) show that the activity has a stronger association with speed. Positive effects mean the activity is associated with higher speed whereas negative effects mean the activity is associated with lower speed.

Table 4-6. VM and Cognitive Task Effects on Speed. Adapted From Caird et al. (2014; 2018) and Simmons et al. (2017)

PED Activity	Speed r_c (95% CI)
Typing/Reading Texts vs. Baseline (***n*** = 12 Studies)*	-0.32 (-0.22 – -0.47)
Dialing vs. Baseline (***n*** = 2 Studies) †	-0.66 (-0.78 – -0.54)
Voice-based VM tasks vs. Baseline (***n*** = 18 Studies) ^	-0.13 (-0.20 – -0.06)
Voice-based VM task vs. traditional VM tasks (***n*** = 12 Studies) ^	0.09 (0.01 – 0.17)
HF conversation vs. Baseline (***n*** = 30 Studies) †	-0.06 (-0.20 – 0.07)
HH conversation vs. Baseline (***n*** = 10 Studies) †	-0.07 (-0.21 – 0.07)
HH conversation vs. HF conversation (***n*** = 6 Studies) †	-0.16 (-0.28 – -0.03)

*Effects from Caird et al. (2014). In this meta-analysis the authors coded effects so that positive values show greater speed reductions. For 0, the direction was reverse-coded so that positive values indicate speed increases and negative values indicate speed reductions for consistency across all meta-analyses.
† Effects from Caird et al. (2018).
^Effects from Simmons et al. (2017).

As evident from Table 4-6, VM tasks, such as typing/reading texts and dialing, have a moderate to large effect on driver speed and are associated with a speed reduction. Cognitive tasks have small to no effect on speed. Simulator studies suggest that both increased demands of the driving task and increased demands of the cognitive task (e.g., speaking versus listening only) are associated with greater speed reductions (Iqbal et al., 2010); however, smartphone type does not have an impact on speed (Strayer et al., 2017).

Driving experience seems to affect the extent PED use results in speed reductions, with professional drivers showing larger speed reductions during phone use than young drivers (Choudhary & Velaga, 2019). General experience using a PED or specific experience using a PED while driving does not affect measures such as speed reductions or speed control (Knapper et al., 2015; Cooper & Strayer, 2008). Concerning special populations, Beratis et al. (2017) examined drivers with mild cognitive impairment (MCI) and found that these drivers exhibited lower speeds during secondary task engagement, even more so than cognitively intact drivers, and attributed that speed reduction to possible compensatory strategies for their attenuated cognitive resources.

Reaction Time

Theoretically, RT to driving events should be susceptible to compromise from visual, manual, and cognitive PED tasks. The previously mentioned meta-analyses have quantified the extent to which VM tasks, such as texting and dialing, that require looking away from the forward roadway or removing hands from the steering wheel, affect RT relative to cognitive tasks that do not require these visual or manual resources or to no secondary task at all (Caird et al., 2014; 2018; Simmons et al., 2017). Table 4-7 summarizes the effects on RT found in these meta-analyses. Larger effect sizes (r_c) mean a stronger relationship between the PED activity and the time interval between the onset of a stimulus and the driver's behavioral response to the stimulus. Positive effects mean the activity is associated with longer RT (worse performance) whereas negative effects mean the activity is associated with shorter RT (better performance).

Table 4-7. VM and Cognitive Task Effects on RT. Adapted From Caird et al. (2014; 2018) and Simmons et al. (2017)

PED Activity	Reaction Time (RT) r_c (95% CI)
Reading Texts vs. Baseline (***n*** = 7 Studies) *	0.47 (0.29 – 0.60)
Typing/Reading Texts vs. Baseline (***n*** = 8 Studies) *	0.59 (0.42 – 0.76)
Typing Texts vs. Baseline (***n*** = 6 Studies) *	0.57 (0.43 – 0.71)
Voice-based VM tasks vs. Baseline (***n*** = 29 Studies) [^]	0.55 (0.48 – 0.62)
Voice-based VM task vs. traditional VM tasks (***n*** = 18 Studies) [^]	-0.29 (-0.38 – -0.20)
HF conversation vs. Baseline (***n*** = 35 Studies) [†]	0.25 (0.16 – 0.33)
HH conversation vs. Baseline (***n*** = 13 Studies) [†]	0.27 (0.16 – 0.39)
HH conversation vs. HF conversation (***n*** = 8 Studies) [†]	-0.01 (-0.12 – 0.11)

*Effects from Caird et al. (2014).
[†] Effects from Caird et al. (2018).
[^]Effects from Simmons et al. (2017).

As evident from Table 4-7, VM tasks and more complex cognitive tasks (i.e., voice-based versions of these tasks) have the largest effect on RT to driving events (Caird et al., 2014; Simmons et al., 2017). Drivers do, however, have faster RT with voice-based methods of completing VM tasks than traditional VM methods of completing similar tasks (Simmons et al., 2017). HF and HH conversation do not differ notably in their effect on driver RT, with both having small, increasing effects (Caird et al., 2018). NDS data are consistent with these findings and show distraction duration as the primary factor leading to an increase in RT (Gao & Davis, 2017). Consistent with the compensatory behaviors discussed above, when RT is broken into the subcomponents of time when accelerator is released and time brake pedal is pressed, findings of a simulator study suggest that, although overall RT is slowed, distracted drivers anticipate slowing, as indicated by the release of the accelerator, and execute quicker movements from the accelerator to the brake pedal (Bellinger et al., 2009). This single study suggests succumbing to known distractions can be associated with some compensatory behavior, but it is unclear if this compensation is sufficient or effective.

Another factor related to the extent a secondary task affects driver RT to driving events is the type of HF mode. A simulator experiment showed HH and earphone operated conversation resulted in slower RTs than loudspeaker-oriented conversation (the participants interacted with the researchers through a mounted external speaker on some conditions) (Ferlazzo et al., 2008). Again, a driver's subjective response to the PED task is critical as well, as high reported enjoyment or lower perceived difficulty can make these RT impairments less noticeable to the driver (Horrey et al., 2009; Irwin et al., 2015). With respect to voice-based texting, the nature of the computer voice used by the system (e.g., synthetic vs natural) when listening to text messages does not seem to impact driver RT (Coleman et al., 2016).

Driver characteristics also impact the extent RT is affected by PED tasks. Across both simulator and NDSs, older drivers have worse RT associated with phone conversations (Papantoniou et al., 2015) or VM tasks (Higgins et al., 2017) than younger age groups. Similarly, a simulator study found that drivers with MCI have worse RT when conversing on a cellphone than cognitively intact people (Beratis et al., 2017). As with other behavior and performance outcomes, practice and real-world general experience using a cellphone do not appear to impact the extent using one while driving affects RT (Cooper & Strayer, 2008). Note that because the above findings are based on single studies, they should be accepted with caution.

Environmental and situational factors appear to be critical to the extent driver PED use affects RT. For example, a simulator study found that drivers conversing on an HF or HH phone were not any slower compared to baseline at detecting a traffic event within their central vision, but these distracting activities delayed RTs to a peripheral event by 50% (Haque & Washington, 2013). Moreover, a simulator experiment of young drivers showed that while texting delayed RT on both urban and rural roads, the delay was greater on rural ones (Yannis et al., 2014). The lower traffic on rural roads may be the underlying factor (Yannis et al., 2014). Finally, a systematic review of ADAS (LKA, ACC, associated warning systems, or some combination of the ADAS features) and distraction found that a driver's PED use with ADAS active increased brake RT to a braking lead vehicle or the amount of time needed for the driver to resume manual control when the system reached a situation it could not handle (Hungund et al., 2021).

Summary

Experimental studies in the simulator or on the road as well as NDSs provide extensive information on how PED use affects driver behavior and performance. In general, these studies have shown that PED use, particularly use requiring drivers to take their eyes away from the forward roadway or their hands off the steering wheel, impact the ability to steer the vehicle, maintain lane position, and react to events. Some drivers, at least in experimental studies, appear to compensate for these performance decrements by increasing their headway, or reducing their speed, but the extent to which the compensation is effective in restoring a sufficient safety level is unknown.

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Chapter 5 – Effects on Safety

Introduction

The previous chapters of this state-of-knowledge report highlight what is known about the extent portable electronic device use occurs while driving (Chapter 3) and the degree this use affects performance of the driving task (Chapter 4). One of the primary areas of interest is the extent of use of PEDs by crash-involved drivers and the possible safety-related performance decrements associated with this use. This has prompted several literature reviews and meta-analyses focused on the safety impacts of PED use by drivers.

Previous Reviews

The Ranney (2008) SOK report reviewed studies examining distracted driving's impact on safety. In the ensuing decade plus, this field of research has advanced considerably, including more standardization in crash reporting, increased precision in sampling techniques to derive national prevalence estimates, and the availability of naturalistic driving data, most notably from the Second Strategic Highway Research Program (SHRP2), that included extensive examinations of safety event risk (see Hankey et al., 2013).

Several reviews on the safety effects of driver distraction in general have been published since the previous SOK report. Some of these reviews (e.g., Governors Highway Safety Association, 2011; Hanowski, 2011) focused on studies that examined sources of distraction other than PEDs, such as in-vehicle systems (e.g., route guidance systems, radio/CD players), that are beyond the scope of this report. Other reviews limited their scopes by source of distraction (e.g., mobile phones only: Ige et al., 2016; Lipovac et al., 2017); severity of safety events (e.g., injury and fatality only: Zatezalo et al., 2018); or population of drivers considered (e.g., young drivers: Cassarino & Murphy, 2018).

A meta-analysis examining the effects of mobile phone use on crash risk suggested studies based primarily on drivers' self-reports of crash events cannot be relied upon to produce accurate estimates of associated driving risk due to imprecision in the information requested and the inability of respondents to recall accurate details of past events (Elvik, 2011). Thus, the previous reviews and meta-analyses that based their findings in whole or part on self-report methodologies (e.g., Lipovac et al., 2017; Llerena et al., 2015; Stavrinos et al., 2018) should therefore not be combined with studies that directly measured safety outcomes of PED use (e.g., National Center for Statistics and Analysis; NCSA, 2021). Also, findings from simulator studies that examined driver performance were largely incompatible with similarly focused epidemiological studies, suggesting that these methodologies should not be synthesized together (Elvik, 2011).

Simmons and colleagues (2016) meta-analyzed seven sets of data from six naturalistic driving studies (NDSs) to determine drivers' safety critical event (SCE) risk associated with a number of different cellphone activities. As the objectives of this high-quality meta-analysis overlap with those of the current review, the results of this meta-analysis will be synthesized with the results of subsequent independent studies in the risk subsection of this chapter.

Current Review

A review of the literature published since the Ranney (2008) SOK through September 2022 indicated it could support an augmented examination of PED use effects on safety. The current review considers a variety of PED types and activities, varying severity of safety events, and a range of driver populations. While the literature affords an updated look at the topic, it is not sufficient to enable an in-depth examination leading to a comprehensive, up-to-date, picture of the entire PED safety problem. In particular, the literature varies considerably in focus and quality by factors such as study locale, study timing, and severity of crash events examined. Perhaps most significantly, the available studies contain little specificity of PED distraction types and use patterns, largely because pre-crash behavior is rarely known with precision from standard police crash reports (PCRs). The level of confidence in reported results of national estimates varies because of the difficulty in defining and collecting national samples. Nevertheless, information from a limited sample, such as a single State, can be informative of the existence of a problem even if its precise magnitude nationwide cannot be determined.

This chapter reviews those studies that examine how safety can be affected by driver use of PEDs. It begins by describing the extent of the safety problem (i.e., number of crashes) and characterizes this problem by crash, driver, vehicle, roadway, and environment characteristics. Retrospective studies based on PCRs are the primary available resource to determine prevalence and problem characteristics. Risk estimates are then presented and are primarily derived from studies using an NDS methodology. These address the odds a driver using a PED will be involved in a safety event along with those factors that increase or decrease these odds.

Review Approach

An extensive set of documents examining driver distraction due to PED use was identified and screened with the process detailed in Chapter 1. Researchers specifically screened documents to identify those that used retrospective crash-based designs or NDS methodologies. Documents were only included if the samples were from the U.S. or involved a novel finding/approach based on a non-U.S. based sample.

For purposes of this chapter's specific review, 118 papers (reviews and original investigations) were identified as relevant based on the defined eligibility criteria. These 118 documents were assessed for study quality using the study-derived quality dimensions discussed in Chapter 1. Documents for this chapter were also assessed by the extent to which the safety results were generalizable to the entire U.S. population. This resulted in the 64 works cited in this chapter. Among those, findings from those documents that used a nationally representative or at least a diverse sample of U.S. crashes were given more weight in the review than those documents that were more limited in scope such as only including data from a single State, a non-U.S. based source, or a limited range of crash types. In general, if a study was not included in the synthesis, it was not mentioned or cited in this chapter unless it was used to illustrate the reason for excluding a pool of similar studies. Overall, despite the apparently large number of references, no seminal studies on which definitive conclusions could be based were identified.

Crash Prevalence

When examining a potential human factors problem, such as crashes resulting from driver distraction, it is of interest to understand its prevalence or incidence. That is, the proportion of people in a given population who have the problem or characteristic at a given point in time. This section examines the prevalence of distraction in crash events associated with cellphones and other PEDs in the context of all distraction-affected crashes. NHTSA's NCSA defines a distraction-affected crash as "any crash in which a driver was identified as distracted at the time of the crash" (NCSA, 2018). Distraction-affected crashes can include several forms of inattention, such as daydreaming and eating or drinking, as well as PED use.

Measurement

Before reviewing studies that estimate the prevalence of distraction in crash events, it is critical to understand the context in which these estimates were derived. It is a widespread conclusion in the literature that prevalence of distraction in crash events is not regularly or reliably measured (e.g., Griswold & Grembek, 2014). Few, if any, standards exist in the design and preparation of the PCR, the primary source of crash information, for the capture of the information necessary for a valid distraction prevalence estimate (see, for example, NCSA, 2021). After a crash occurs, if the circumstances of the crash suggest distraction may have been a factor, the investigating officer will often try to determine whether distraction was, in fact, involved. The typical inputs available to the officer to make that determination include statements from one or more drivers, passengers, or other road users and bystanders involved in or witness to the crash. In a single-vehicle crash, the only source of information may be the driver's self-report. Unfortunately, driver, passenger, and witness reports are not always available. Even when available, the information is subject to several biases and inaccuracies. For example, drivers may underreport their own undesirable behaviors to investigating officers, and passengers, particularly when they are family members or friends, may tend to give untruthful or incomplete answers to protect a driver. Even if accurate information is provided, it may not be correctly or completely recorded by the investigating officer. In most jurisdictions PCRs do not have extensive pre-coded input fields related to distraction. The officer must therefore put any findings concerning distraction in the narrative about the crash. This is more work for the investigator, makes standardization difficult or unlikely, and makes the information more difficult to retrieve for a researcher. Taken together, these factors suggest that distraction, and PEDs as a specific distraction source, are likely underestimated in retrospective studies based on PCRs.

As implied above, differences in information recording practices at the jurisdiction level appear to be one factor that determines the availability and quality of distraction-related information on PCRs (see, for example, NCSA, 2021). The availability and characteristics of relevant input fields and local policies on what should be included in the crash narrative also affect the availability of details regarding the specific role and sources of distraction and distraction activities. Therefore, prevalence estimates can differ across jurisdictions because of variability in reporting methods. For example, in one case study comparing State and national databases containing the same fatal crashes, agreement regarding cellphone involvement in the crashes was found only 10% of the time (Griswold & Grembek, 2014). Given the absence of definitive nationwide studies examining distraction prevalence at any level, a mixture of studies at the national, State, and local level are presented herein. To minimize any possible influence of inconsistent reporting methods, the applicable jurisdiction level for each finding is clearly noted.

Because of the limited available, reliable information as well as the variability in data categories across State and local jurisdiction levels, the national estimates of distraction prevalence in crash events presented are typically characterized either as generally distraction-affected or specifically cellphone-involved. As mentioned, the information from a PCR is often insufficient to determine the distraction source or activity. For example, in the most recently published national fatal crash data by activity (looking at specific, distraction activities beyond the distraction-affected category and the cellphone-involved category) (Fatality Analysis Reporting System; FARS, 2011), nearly half of distracted drivers' sources or activities were listed as "unknown" (NCSA, 2013). The extent of missing information on distraction and its sources is likely even higher in non-fatal injury and property damage only (PDO) crashes because they tend to be less thoroughly investigated than fatal crashes. In 2012 NCSA changed the attributes of its database variables included in the distraction-affected crash definition to reflect more accurately the coding on PCRs and, in turn, more precisely report the behavior of the driver (see Table A-1 in NCSA, 2014). Unfortunately, no information was found in examined studies on how this change affected the extent of missing information about distraction-affected crashes in NCSA databases.

As mentioned above, crashes involving driver distraction are generally not well-documented. Crash investigators are faced with missing, incomplete, and unreliable information, and there is little consistency in how these crashes are reported. This chapter will therefore use the simple hierarchy presented in Figure 5-1 to help describe the prevalence of distraction in crash events. The first focus will be primarily on synthesizing most prevalence studies that investigate crashes in which distraction, regardless of its source, was cited as a factor (the outer ring in Figure 5-1). Unless otherwise noted in the discussion, the NCSA definition of distraction-affected crashes was used to classify crashes in this category. Within the group of distraction-affected crashes, some studies specifically examined the use of PEDs; typically, without differentiating the type of device (the middle ring in Figure 5-1). This subset will be discussed separately whenever sufficient studies were available to differentiate PED-involved crashes from all distraction-affected crashes. Several studies focused specifically on cellphones as a type of PED. These will be addressed as an additional subgroup termed cellphone-involved crashes that includes both crashes attributed to the driver using the cellphone or crashes characterized by other behaviors related to the presence of the device, such as reaching for it in the vehicle (the inner ring in Figure 5-1).

It should be noted that when a study's authors did not specifically reference PEDs or cellphones as the studied source of distraction, their findings were considered in the distraction-affected crash category. Also, when a specific source of distraction is not mentioned in a review section below, it is because no study addressed that source within the context of the section's topic. Finally, if a study used a database such as FARS that contains distinctions among distraction types but its authors did not use the more granular information, it was considered in the broad, distraction-affected category.

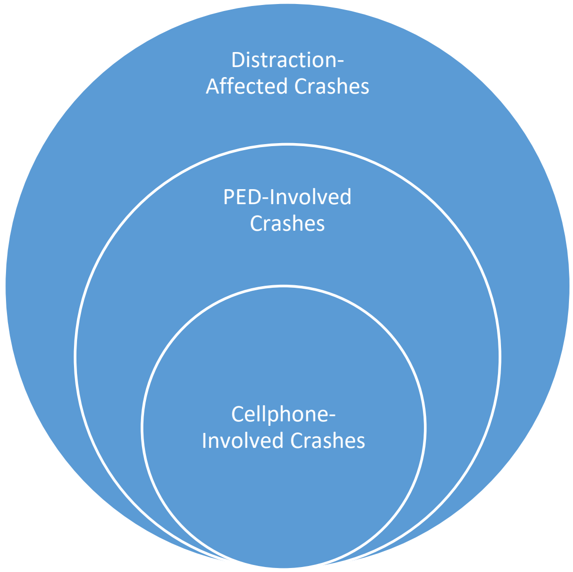

Figure 5-1. Crash prevalence examination hierarchy

The presentations that follow contain a mixture of results from all severities of crashes depending on available research. In addition to added information from the more comprehensive investigations typical in fatal crashes, the general characteristics of a crash, such as the crash type (e.g., single vehicle, rear-end), can differ by crash severity (see, for example, NCSA, 2020). The reader is therefore cautioned to note the severity of the crash data included in each study when considering the findings.

In summary, the incidence of distraction in crash events is difficult to measure, making accurate prevalence estimates hard to calculate. Most studies on distraction prevalence in crashes, therefore, have some limitations arising from their chosen measurement techniques. The reader is cautioned to include consideration of crash data sources when assessing a study and comparing it with other apparently similar studies even if their findings appear consistent.

Sources of U.S. National Data

Studies that present national prevalence estimates of distraction-affected or cellphone-involved crashes generally derive these estimates from one or more of the NCSA-maintained crash databases that were designed and are managed to portray as accurate a picture as possible of the national crash incidence. Prior to 2016, in addition to FARS, these sources were the National Automotive Sampling System General Estimates System (NASS GES) and the National Motor Vehicle Crash Causation Survey (NMVCCS). In 2016 NASS GES was replaced with the Crash Report Sampling System (CRSS). Each of these databases is described in detail below. Summary reports on a variety of topics, some weighted to provide an estimate of the crash types they contain for the United States as a whole, are prepared and presented annually in NCSA's *Traffic Safety Facts* (e.g., NCSA, 2021).

FARS

FARS data are collected annually through cooperative agreements between NHTSA and each of the 50 States, the District of Columbia, and Puerto Rico. The resulting data set is a census of police-reported traffic crashes in which an involved person died within 30 days of the crash.

Analysts in each State enter numerous crash (e.g., time, location), person (e.g., driver age, driver actions), and vehicle (e.g., make, model year) data into the system, guided by a standard template. The FARS analysts gather these data from sources including:

- PCRs,
- State vehicle registration files,
- State driver licensing files,
- State highway department data,
- Vital statistics,
- Death certificates,
- Coroner/medical examiner reports, and
- EMS reports.

NHTSA's FARS team then conducts quality control checks and makes imputations for some missing variables (e.g., driver blood alcohol concentration). The result is a standardized database that can be analyzed to examine fatal crashes nationwide. FARS uses the distraction-affected crash definition discussed in the previous section.

At the time of this writing, FARS data were available through calendar year 2020. However, the information has been updated to include through 2022.

NASS GES

GES is a nationally representative probability sample of police reported crashes ranging from minor property damage to fatalities that covers the period 1988 to 2015. The dataset is composed of PCRs selected from 60 areas of the country chosen to reflect the geography, roadway mileage, population, and traffic density of the United States. GES data collectors annually gathered PCRs from 400 police jurisdictions within the selected areas. Approximately 50,000 reports were randomly sampled each year. Common data elements were extracted from the reports and coded in a standardized format. GES used the same distraction-affected crash definition as FARS. GES was replaced by CRSS in 2016.

CRSS

CRSS is the replacement for GES but uses a different national probability-based crash sampling system. The CRSS sampling strategy was designed to make the sample more representative of crashes across the country. The database includes crashes of all severities—fatal, injury, and PDO crashes. Crash reports are selected from 60 designated areas across the United States that reflect the geography, population, miles driven, and crash distribution in the country. CRSS uses the same distraction-affected crash definition as FARS and GES.

NMVCCS

NMVCCS is distinct from the other national databases that can be used to estimate distraction prevalence as its data were derived from researchers' on-scene analysis of crashes during a 3-year period (January 2005 to December 2007). Each of the studied crashes had to involve a light passenger vehicle in the initial crash event; occur between 6 a.m. and midnight; and meet a specific event severity threshold. One goal of the NMVCCS program was to collect information as soon after the crash as possible. Therefore, at least one crash-involved vehicle and investigating police were required to be available at the scene of the crash for an event to be included in NMVCCS. Interviews were conducted with crash-involved drivers and witnesses as available. A total of 6,949 crashes were investigated, but not all crash investigations were completed. National crash prevalence estimates were derived by assigning weights to 5,470 of the 6,949 investigated crashes. While the data collection approach of NMVCCS minimizes some of the limitations of other retrospective studies by capturing more contemporaneous data, its sample construction precludes direct comparisons with the other nationally representative samples of crashes (Singh, 2010).

The NMVCCS definition of distraction is distinct from the distraction-affected crash definition typically used by the other NCSA databases. This also prevents direct comparison of NMVCCS distraction data with other national sources. In NMVCCS distraction is defined as "a specific type of inattention that occurs when a driver's attention is diverted from the driving task to focus on another activity" (Singh, 2010). These activities involve those from sources in the vehicle, such as cellphones, passengers, food and drink, and the vehicle radio/CD player, or from non-driving cognitive activities that involve distraction absent a physical source within the vehicle, such as drivers daydreaming or ruminating about personal problems (Singh, 2010). As NMVCCS clearly distinguishes between the internal sources of distraction that are a result of driver behavior and others with no clear behavioral cause, findings based on this data source will only focus on the former and refer to these as "behavioral distraction crashes."

In summary, a variety of national databases exist that permit examination of distraction and cellphone prevalence in crashes and the characteristics of these events. In consideration of the differences in sampling designs and distraction definitions across these databases, the specific source of any findings reported will be presented throughout the balance of this chapter. The reader should interpret results from each data source independently and only compare results obtained from the same source. That is, synthesis can occur across the same sources (e.g., FARS).

Total Crashes

Before examining the prevalence of distraction in crash events, it is critical to contextualize the prevalence estimates within the entire U.S. highway safety crash problem. The number of total U.S. crashes is available from FARS, NASS GES, and CRSS. Table 5-1 presents these totals from 2012 to 2022 by crash severity (although the timeframe for the current review concluded in September 2022, Table 5-1 includes crashes for 2022). The fatality data are from FARS and the injury and PDO crash information were derived from NASS GES/CRSS for non-fatal injury and PDO crashes. Because of the change from GES to CRSS, estimates across the transition in systems may not be comparable, but the general increase in crashes over the years appears rational. Over the last decade, PDO and injury events have been consistently more frequent than fatal ones. Moreover, crashes have increased across all severities, with non-fatal injury and PDO crashes showing larger increases than fatal crashes (NCSA, 2016; 2017; 2022; 2024).

Table 5-1. Total U.S. Crashes by Severity 2012-2022. Adapted from NCSA (2016; 2017;2018 2022; 2024)

Year	Fatal (FARS)	Injury (NASS GES/CRSS)*	PDO (NASS GES/CRSS)*
2012	31,006	1,634,000	3,950,000
2013	30,202	1,591,000	4,066,000
2014	30,056	1,648,000	4,387,000
2015	32,539	1,715,000	4,548,000
2016	34,748	2,116,308	4,670,073
2017	34,560	1,888,525	4,529,513
2018	33,919	1,893,704	4,807,058
2019	33,487	1,916,344	4,806,253
2020	35,935	1,593,390	3,621,681
2021	39,785	1,727,608	4,335,820
2022	39,221	1,664,598	4,226,677

* Because of the change from NASS GES to CRSS, estimates across the transition in systems that occurred in 2016 may not be comparable.

Distraction-Affected Crashes

Prevalence estimates of distraction-affected crashes are available with a common definition from the same sources as the total crash information presented in Table 5-1. These estimates are useful in understanding the extent of the overall safety problem due to distraction before focusing on the specific contribution to it by cellphones and other PEDs. Figure 5-2 presents the percentage of total U.S. crashes from 2012 through 2022 by crash severity that were classified as distraction-affected. Distraction involvement generally appears to have remained a factor in a relatively stable percentage of these crashes, with distraction-affected crashes representing a higher proportion of non-fatal injury and PDO events than in fatal crashes (NCSA, 2016; 2017; 2018; 2022; 2024). Although the timeframe for the current review concluded in September 2022, Figure 5-2 includes distraction-affected crashes for 2022 (NCSA, 2024).

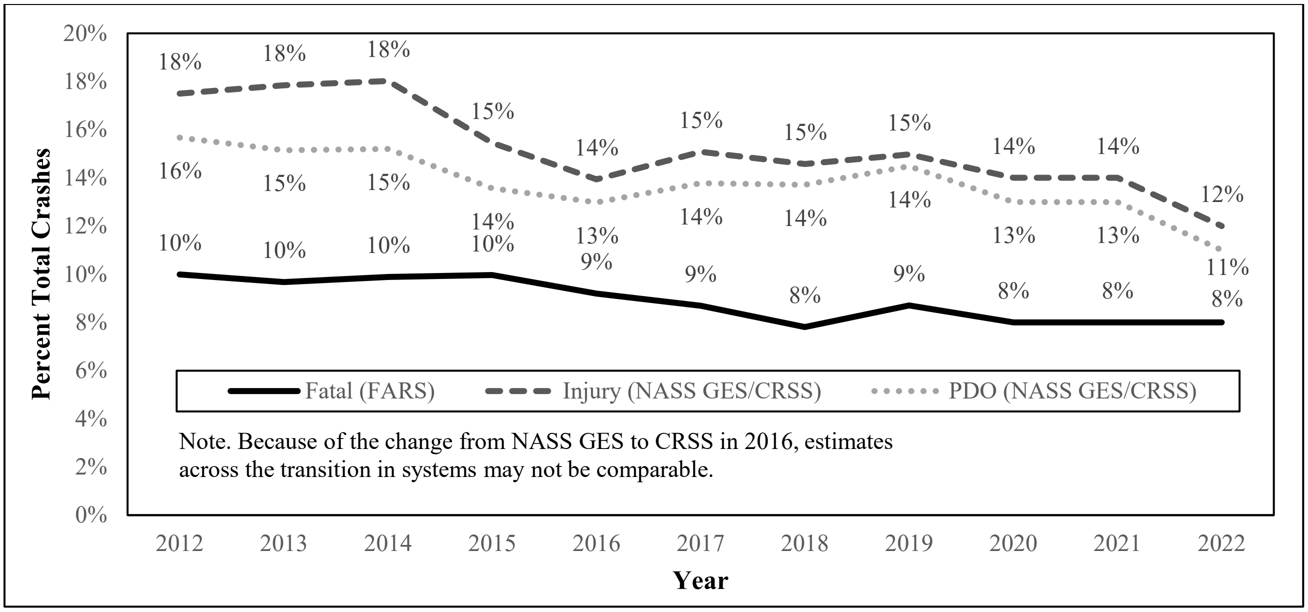

Figure 5-2. Percentage of total U.S. crashes by severity that are distraction-affected 2012-2022. Adapted from NCSA (2016; 2017; 2018; 2022; 2024)

Disaggregating distraction-affected crashes by the specific distraction sources and resulting distracting behaviors is important to better understand which sources and behaviors are contributing to the consistent distraction safety problem highlighted above. Unfortunately, none of the studies of distraction-affected crashes by the full variety of sources and behaviors that were reviewed for this SOK provides a definitive answer. For example, FARS was the only source of data used for analyses from studies identified in the literature review that disaggregates the sources and behaviors of distracted drivers, and these analyses were only available for 2010-2011 (NCSA, 2012; 2013). Moreover, cellphones were the only specific type of PED for which data were disaggregated. Table 5-2 presents the sources and behaviors of distracted drivers involved in fatal distraction-affected crashes from 2010-2011 FARS. The cells in Table 5-2 do not add up to the total number of distracted drivers in these crashes for the respective years as distracted drivers could be involved in several distraction-causing activities prior to a crash.

Table 5-2. Frequencies of Activities of Distracted Drivers Involved in Distraction-Affected Fatal Crashes 2010-2011. Adapted From NCSA (2012; 2013)

Distraction Source/Behavior	**2010 Distracted Drivers* (FARS)**	**2011 Distracted Drivers* (FARS)**
Cellphone-Involved (i.e., talking/listening, dialing, other)	373	371
Non-PED (i.e., in-vehicle, external, inattentive)	1,411	1,389
Details unknown	1,274	1,398

* Cells do not add up to the total number of distracted drivers in these crashes for the respective years as distracted drivers could be involved in several activities prior to a crash.

As evident in Table 5-2, the vast majority of distracted drivers involved in a fatal distraction-affected crash were engaged in an unknown activity or one not involving a cellphone. Nevertheless, cellphones were still identified as a source of distraction for a meaningful portion of drivers in these fatal events (NCSA, 2012; 2013).

Cellphone-Involved Crashes

Cellphones are the only PEDs that are reported separately in FARS (NCSA, 2021). This is likely because of the widespread use of cellphones and the ability of police completing a PCR to determine (or, at least, develop a reasonable hypothesis) that a cellphone was present and possibly involved in the crash causation. Estimates of cellphone involvement likely represent an incomplete picture of the overall PED safety problem because other types of devices may be in use. As the largest class of PEDs (see Schroeder et al., 2018), however, cellphone estimates serve as a reasonable surrogate for all PED use. Prevalence estimates of cellphone-involved crashes are available from the same sources as the distraction-affected crash prevalence estimates presented in Figure 5-3 (FARS, NASS GES, and CRSS). Figure 5-3 presents the percentage of distraction-affected crashes from 2012 to 2022 by crash severity that were classified as cellphone-involved. Although the timeframe for the current review concluded in September 2022, Figure 5-3 includes distraction-affected crashes that were classified as cellphone-involved for 2022 (NCSA, 2024).

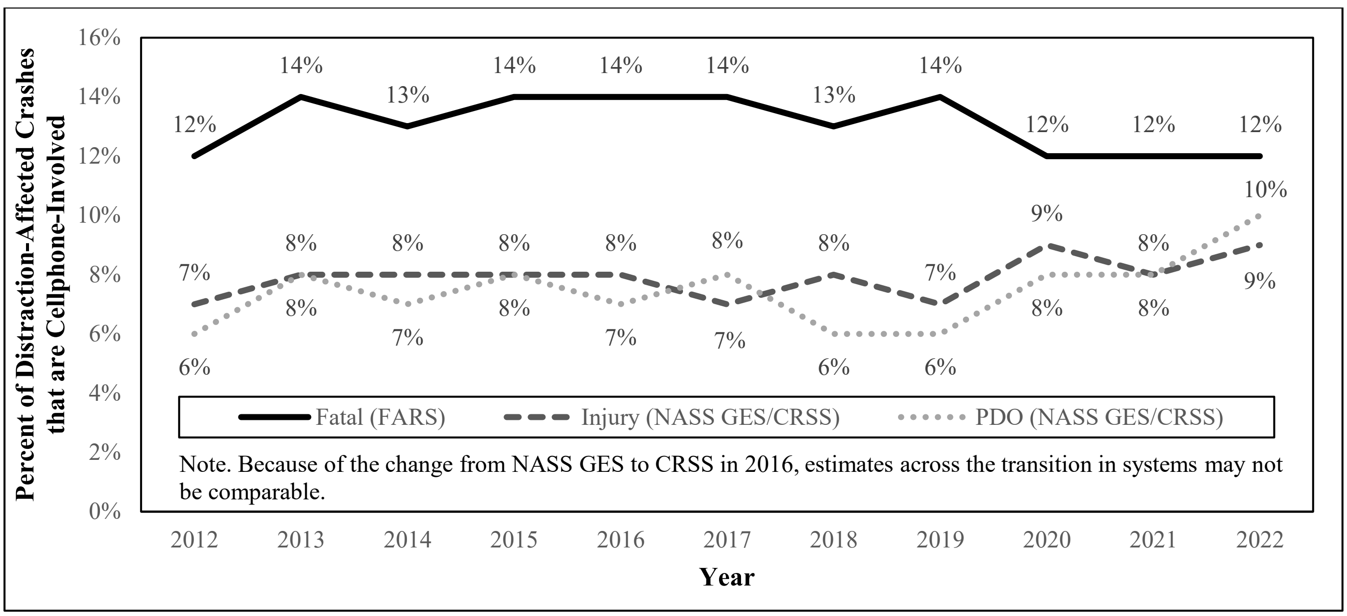

Figure 5-3. Percentage of distraction-affected crashes by severity that are cellphone-involved 2012-2022. Adapted From NCSA (2016; 2017; 2018; 2022; 2024)

From 2012-2022, the percentage of distraction-affected crashes that involved cellphone use has largely been stable. Cellphone use appears to be implicated more often in fatal distraction-affected crashes (12% to 14%) than in injury (7% to 9%) or PDO (6% to 10%; NCSA, 2016; 2017; 2018; 2022; 2024) events. The higher rate of cellphone use in fatal crashes compared to non-fatal crashes is consistent with previous analyses of NASS GES data that found cellphone use to be associated with more severe injury crashes compared to other distraction sources, such as in-vehicle systems and passengers. These findings also appear to be true both among teen drivers (Neyens & Boyle, 2008) and drivers generally (Razi-Ardakani et al., 2019). In an analysis of NMVCCS data from 2005 to 2007, Singh (2010) examined the fatal and non-fatal crashes where cellphone use was implicated. This analysis of NMVCCS data, which was more detailed than the simple tally of FARS data presented in Table 5-2, showed that cellphone use was the second most common behavioral distraction behind only conversing with passengers (Singh, 2010).

Although the current report was conducted with research published from January 1, 2008, to September 7, 2022, a report published in February 2023 by Blincoe et al. estimates the percentage of crashes that are attributable to distraction to be 29% for 2019. The Blincoe et al. report also attributes 6.1% of crashes to cellphone distraction for 2019 (2023). NCSA acknowledges the likelihood of underreporting of distraction-affected crashes (2023).

When cellphone use is cited in PCRs and the databases that are based on them, detail on the specific cellphone activity (e.g., texting, calling) is typically not included (NCSA, 2012; 2013). The availability of this information might shed light on whether drivers are self-regulating and refraining from engaging in those activities with a higher visual-manual (VM) demand in riskier situations or when these activities noticeably impair performance on tasks generally considered safety-critical. The limited available data suggest that estimates of prevalence of the involvement of different types of cellphone activity in crashes approximate drivers' observed use of these devices as described in Chapter 3. In the few available references, the investigating officer more often reports the driver to have been talking or listening on a cellphone than dialing or texting on it (Donmez & Liu, 2015; NCSA, 2012; 2013; Singh, 2010). For example, analyses of NMVCCS data from 2005 to 2007 show that an estimated 3.0% of behavioral distraction crashes involve the driver conversing on the phone, 0.4% involve dialing/hanging up the phone, and less than 0.1% involve text messaging before the crash (Singh, 2010)—a pattern consistent with the use of cellphones by drivers as presented in Chapter 3. In addition, an analysis of NASS GES data from 2003 to 2008 that controlled for other factors likely to contribute to a crash (e.g., speeding, weather) revealed that when VM distractions are involved in a crash, these activities were generally associated with more severe injuries (Donmez & Liu, 2015). A further suggestion of the relationship of VM distractions to severe crash injury was revealed by Wilson and Stimpson (2010). The authors examined gross monthly texting volume data (not just during driving) together with the frequency of distracted driving fatalities overall in the same geographic area within the same time period, and their analyses suggested that distracted driving fatalities would increase by more than 75% for every one million texts sent per month (Wilson & Stimpson, 2010).

The prevalence of drivers' cellphone use in crashes also varies by how the driver engages in the activity. As discussed in Chapter 3, handheld (HH) use is generally more common than hands-free (HF) use, and more consistently impairs driving behavior and performance (see Chapter 4). Analyses of crash data by HF versus HH-involvement are not available at the national level; however, an analysis of California non-fatal and fatal crash data from 2003 to 2011 shows that HH cellphone-involved crashes (2 to 17%) were more common than HF (0 to 3%; Limrick et al., 2014). With only one study, more work is necessary to fully understand the current prevalence of cellphone activities by use modality and their influence on crash injury severity.

In sum, cellphone use comprises a noteworthy portion of the distraction safety problem. Use of cellphones is one of the most frequently cited sources of distraction from PEDs contributing to crash causation and has been shown to be associated with increased crash injury severity. Also, while VM cellphone activities such as texting are not as prevalent as cognitive activities, such as talking or listening on a cellphone, cellphone use for texting and other tasks with a high VM demand still likely represent a significant problem because of the suggestion that these activities may be associated with increased injury severity crashes.

Other PED-Involved Crashes

Compared to cellphones, relatively little is known about the use of other types of PEDs during driving (see Chapter 3). As discussed in Chapter 4, however, other PEDs, especially those requiring significant VM activities, can impair driving behavior and performance. No studies with analyses of data on crashes at the national level in which other PEDs were implicated could be located for this review. An analysis of Missouri distraction-affected crashes from 2001 to 2006, however, showed slightly less than one percent (163 out of 20,176) of crashes were related to other PEDs (e.g., computers, GPS, games; Ghazizadeh & Boyle, 2009). More research is needed to understand the prevalence of other PEDs in distraction-affected crashes and any possible influence they may have on crash severity. The sparse available published research does at least suggest that other types of PEDs may comprise a less significant portion of the distraction safety problem than do cellphones. Whether this is due to a lower incidence of use or inherently lower safety risk of the task demands when using other electronics cannot be determined from the available literature.

Crash Characteristics

The sizeable prevalence of distraction-affected crashes, in general, and cellphone-involved crashes, suggests that they represent a significant safety problem. This section disaggregates the problem by key characteristics of interest including those related to the crash (e.g., time of day, day of week, dynamics), driver (e.g., age, sex, physical state), vehicle (e.g., type, condition), roadway (e.g., number of lanes, speed limit, curvature), and environment (e.g., weather, lighting). Knowing more detail on the crashes of interest enables countermeasures to be more precisely targeted and evaluated.

When examining if the circumstances of a crash vary as a function of whether distraction was a causal factor, it is important to recognize that crashes are not homogeneous events. Crashes are often characterized by the most severe crash outcome—fatal, injury, or PDO. This is appropriate when examining factors such as the cost to society or the extent of suffering associated with the various crash severities. It must be noted, however, that the different severities are associated with very different crash types. For example, although collisions between motor vehicles account for less than half of motor vehicle fatalities, they are the crash type for fully 79% of crash injuries (National Safety Council, 2020). Also, single-vehicle crashes (e.g., fixed object, pedestrian) and non-collisions (e.g., ran off roadway) are significantly more frequent in crashes resulting in a fatality than they are in less serious crashes (National Safety Council, 2020).

The focus of this report is on crashes where distraction was a causal element and, particularly, whether that distraction was caused by a driver's interaction with PEDs. This is not to imply that distraction was the sole or even the main cause of the crash. The other factors related to the crash, driver, vehicle, roadway, and environment described below could have co-occurred with the distraction and caused the crash, promoted the distraction, or simply been a non-causal coincidence. The level of investigation possible after most crashes does not typically permit a confident determination of the relative causal roles of the various factors.

Crash Descriptors

Distraction may lead to crashes or make crash outcomes more serious; therefore, it is important to identify which specific crash circumstances or types of crashes (e.g., rear-end, single-vehicle) are most often associated with distraction. Unfortunately, no relevant studies examining characteristics across the full spectrum of injury severities could be located. Most of what was uncovered relates to fatal crashes and is based on FARS. Given the differences among crash characteristics across the various crash severities discussed above, it is important not to assume that findings based on fatalities are generalizable to all crashes.

The most recent analysis of FARS data that includes an indication of crash circumstances for crashes where distraction was a factor was conducted over a decade ago and does not separate cellphone involvement specifically from all distraction-affected crashes (Wilson & Stimpson, 2010). The totality of the results presented suggests that single vehicle crashes are commonly distraction-affected and tend to be higher speed events (Wilson & Stimpson, 2010).

In addition to the Wilson and Stimpson (2010) nationally focused study based on FARS, analyses of crash data for single States were found that covered the full range of crash severities. These studies can provide important insights regarding recurring crash types and the behavioral errors of drivers that lead to crash events. Analyses of these State crash data suggest that, across all crash severities, rear-end crashes are the most frequent type of both general distraction-affected crashes and those crashes involving cellphone use. A Louisiana study covering 2007 to 2016 examined distraction-affected crashes in that State. It found 61% of all distraction-affected crashes were rear-end types (Sun & Rahman, 2018). A Michigan study covering 2007 to 2009 looked at cellphone use in crashes rather than all sources of distraction. It found that 41.5% of specifically cellphone-involved crashes were rear-end crashes, which was by far the largest percentage among the six crash types examined (Savolainen et al., 2011).

In both the Louisiana and Michigan analyses, single-vehicle crash types were another of the most common distraction-affected crash types—representing 19% of distraction-affected crashes in Louisiana (Sun & Rahman, 2018) and 20% of cellphone-involved crashes in Michigan (Savolainen et al., 2011). There is no compelling reason to believe that the Louisiana and Michigan results are unusual. If the Louisiana and Michigan results hold true for the rest of the United States, it appears that rear-end and single vehicle crashes may represent two of the most frequent types of crashes associated with distraction in general and cellphone use. However, given that only two studies supporting these results were located, extension of the findings to the United States in general should be made with caution.

Analyses of data from NDS studies suggest a link between the frequency of rear-end crashes and the specific nature of cellphone activities by the driver. Anything that increases visual demands and requires a driver's eyes to move away from the forward roadway for extended periods appears more likely to contribute differentially to a rear-end crash rather than other crash types (Carney et al., 2018; Engstrom et al., 2013). Further, in about half the rear-end crashes when a driver was visually distracted by a cellphone, the driver did not attempt an evasive maneuver, suggesting the extent of the distraction caused by cellphone use (Carney et al., 2016).

Overall, the limited studies examining crash type and distraction suggest that distracted drivers are vulnerable to rear-end crashes and single vehicle collision and non-collision events such as hitting a fixed object or running off the road and overturning, respectively. Since the rear-end crashes tend to be low-speed events, they most often result in injury or property damage. Single-vehicle crashes, on the other hand, tend to result in a greater proportion of fatalities because they often happen at higher speeds.

Driver Descriptors

This section examines driver characteristics in crashes classified as involving distraction generally or specifically resulting from PED or cellphone usage. Knowing factors such as age, sex, race/ethnicity, and driving behaviors in these distraction-affected events can permit more effective targeting of countermeasures. While knowing other driver factors such as health (mental and physical), would also permit more effective targeting of countermeasures, no studies were found that examined these and other driver descriptors.

Age

As discussed in Chapter 3, the prevalence of drivers' PED use varies across age with the youngest age groups of drivers generally more likely to use PEDs while driving, particularly for VM activities such as texting. This leads to the assumption that younger drivers are also using a PED more frequently prior to a crash. Analyses of NMVCCS data and more recent State crash data covering the full range of crash severities show that younger age groups tend to be more prone to distraction as drivers. The overrepresentation of young drivers was shown when distraction was coded as a crash causation factor (Carlotto et al., 2015), in crashes involving PED use in general (Brown, 2009), and in crashes involving cellphone use specifically (Savolainen et al., 2011; Singh, 2010; White et al., 2018). These studies tend to confirm that the high involvement in distraction-affected crashes by younger drivers is consistent with their observed use patterns.

Focusing specifically on the age distribution of distracted drivers involved in fatal crashes can shed light on whether younger drivers are over-involved in the most severe events as well. FARS data from 2020 show an overrepresentation of distraction (from all types) in drivers under 35 years old (NCSA, 2022). The same data also show a high involvement of coded cellphone use for the same age groups (NCSA, 2022). These findings illustrate that younger drivers are not only involved in the most distraction-affected and cellphone-involved crashes overall, but also the most severe ones.

Gender/Sex

As discussed in Chapter 3, sex differences in distraction activities while driving generally are minimal, but differences between the sexes, nevertheless, are observed depending on the distraction source and activity, with females sometimes using HH cellphones and conversing on the phone more than males. Similarly, national and State data also show minimal to no difference between male and female drivers when defining distraction before a crash more generally, but sex differences, although still minimal, appear to be more pronounced as crashes or drivers are disaggregated by distraction source and activity (Brown, 2009; Carlotto et al., 2015; Singh, 2010). For example, analyses of NMVCCS data estimate that about an equal share (17%) of male and female drivers involved in a crash exhibited some form of behavioral distraction, but this driver behavior was more often cellphone use for female drivers (12.4% of female distracted drivers) than male drivers (10.5% of male distracted drivers) (Singh, 2010).

Race/Ethnicity

Knowledge of any driver demographic patterns in distraction-affected crashes can also be useful in developing effective countermeasures. As with the other crash characteristics, driver demographics appear not to have been studied across all crash severities at the national level. The previously discussed analysis of FARS data by Wilson and Stimpson (2010), however, revealed important demographic information about drivers in fatal distraction-affected crashes. Specifically, drivers in these fatal crashes were typically male, White, and non-Hispanic. Given the age of the Wilson and Stimpson study and its focus on all distraction sources together, as well as that it is the findings of only a single study, care should be exercised when attempting to extend their results to the present situation or to specific distraction causes (e.g., PEDs).

Driving Behaviors

The literature provides some insights about the propensity to engage in protective behaviors by drivers on trips that resulted in distraction-affected and cellphone-involved crashes. As discussed in Chapter 3, driving with passengers may moderate a driver's distraction behavior, and using a seat belt may be predictive of less distracted driving. If these assumptions are valid, it might be expected that these behaviors would be less common among drivers who are distracted prior to crashes. FARS data from 1999 to 2008 show 60% to 66% of distracted-driver fatalities involved someone driving alone (Wilson & Stimpson, 2010). Note though that any possible protective effect of passengers may be dependent on the characteristics of the driver and passengers, at least based on analyses at the State level. Teens paired with other teens, particularly when both the driver and the passengers are male, and adults paired with children, particularly when the adult driver is female, may more often be involved in a distraction-affected crash (Carlotto et al., 2015).

With respect to seat belt usage in cellphone-involved crashes, a single State-level analysis was identified in the literature (Savolainen et al., 2011). No other relevant studies were found. The Savolainen et al. (2011) study shows that drivers using cellphones in the studied crashes were more than twice as likely to be unbelted at the time of the crash as drivers in crashes that did not involve cellphones (2.5% vs. 1.2% unbelted drivers).

Overall, it would appear that distraction is a risky driving behavior that some drivers engage in immediately preceding a crash. The research suggests that younger drivers and those willing to take other risks, such as not wearing seat belts, are more prone to distraction. The extent to which distraction was the primary or even a significant cause of the crashes in which it was identified cannot be determined. Nevertheless, the available literature implies that safety would be well served if PED use and its resulting distraction could be reduced, particularly among the driver subgroups identified as most susceptible to taking the risk. Overall, considering the paucity of literature, the SOK on this topic must be characterized as suggestive but inconclusive.

Vehicle Descriptors

This section examines distraction-affected crashes and cellphone use in crash events by vehicle type. No studies were found on the relationship between PED use in general and vehicle type or on the relationship of distraction of any kind with other relevant vehicle factors such as vehicle age and vehicle condition. Differences in crash prevalence by vehicle type could show an interaction between PED use and vehicle characteristics such as size or simply be an interaction of the device use of typical users and the type of vehicle they prefer.

National prevalence information related to distraction-affected and cellphone-involved crashes by vehicle type was last published using 2011 FARS data (NCSA, 2013). The analysis showed that the distribution of vehicle types used by distracted drivers overall, and cellphone users in particular, in fatal crashes was similar to the distribution of vehicles among all drivers involved in fatal crashes. Passenger cars (about 40%) and light trucks (approximately 38%) comprise the vast majority of the involved vehicle types (NCSA, 2013). Although the available study was methodologically sound, the limited number of studies adds uncertainty to this conclusion.

Roadway and Environment Descriptors

Situational factors, including speed limit, land use, weather conditions, and time of day can potentially play a role in crash causation either by making a distracted driver more likely to crash or influencing whether a driver engages in distraction behaviors (e.g., prompting the need to use a device). This section examines these roadway and environment factors in crashes classified as involving distraction generally or specifically resulting from cellphone usage. No studies were found on the relationship between the more general PED use and these descriptors.

Roadway

National information related to roadway descriptors and crashes coded with distraction as a factor are available from the Singh (2010) study involving the analyses of NMVCCS data and the Wilson and Stimpson (2010) study involving the analysis of FARS. While limited and outdated, the national analyses are consistent with analyses of State level data that together suggest a large portion of studied crashes, regardless of severity, attributed to distraction or cellphone use are on high-speed (Savolainen et al., 2011; Singh, 2010; Sun & Rahman, 2018) or rural roadways (Sun & Rahman, 2018; Wilson & Stimpson, 2010). While these roadway descriptors characterize a large portion of the overall problem, event severity appears to moderate the extent this characterization is fully relevant. Analyses of State data from Michigan suggest the portion of cellphone-involved crashes on high-speed roadways is smaller than expected when considering speed's contribution to crashes generally (Savolainen et al., 2011). Moreover, the analysis of FARS by Wilson and Stimpson (2010) shows that 60% to 67% of U.S. fatalities from distraction-affected crashes occur in rural areas—an incidence reported by the authors to be higher than expected based on the rate (unspecified by the authors) of fatalities in rural areas for crashes not coded as involving distraction.

Weather Conditions

Weather may theoretically affect a drivers' decision to engage in a secondary task or make the secondary task more likely to result in a safety critical consequence. Overall, there is only one study examining the weather conditions associated with crashes attributed to general distraction or specifically to cellphone use. Relevant information was only found from the Singh (2010) study involving the analyses of NMVCCS data. These analyses of national data suggested that poor weather conditions may increase the likelihood that general distraction or, specifically cellphone use, results in a safety consequence. Phone use was the most frequent source of distraction for the crash-involved distracted drivers in poor weather conditions (Singh, 2010). The fact that only a single study was located on this topic warrants caution in drawing strong conclusions.

Time of Day

As discussed in Chapter 3, drivers often choose to use PEDs in afternoon peak traffic periods, so it is reasonable to expect they may also have more crashes while using PEDs in these periods as well. No study was found that presented national information by time of day, but examinations of State distraction-affected and cellphone-involved crashes show increases in these crashes during the afternoon peak traffic periods (Savolainen et al., 2011; Sun & Rahman, 2018), particularly on weekdays (Limrick et al., 2014). In fact, comparisons of cellphone-involved crashes and those that do not involve cellphone use show that cellphone-involved crashes are overrepresented in these afternoon peak traffic periods (Savolainen et al., 2011). Thus, the available literature provides at least the suggestion that high driver usage of cellphones during afternoon peak traffic periods may be leading to increased crashes during these same periods.

Crash Risk

The previous sections examined what is known about the size and characteristics of the distraction safety problem. It is also of interest to understand the increased crash risk, if any, associated with distraction and PED use. While crash risk is the likelihood of being involved in a crash, it is often expressed in the literature in terms of odds ratios (OR), which is a function of two odds calculations instead of standard probabilities. Odds are the chances of an event happening compared to the chances of it not happening, and an odds ratio is a comparison of these chances across two different conditions (like case versus control). For example, if in a case-control study it is found that the odds ratio for crashes is 2.0, it can be said that the odds of cases being involved in crashes is twice as high as the odds of controls being in crashes. An odds ratio of 1.0 would show equivalent odds for cases and controls, and an odds ratio less than one would show lower odds of crashing for cases versus controls. The task of estimating crash risk is very complex and requires good data on both the prevalence of the use of these devices during driving in general and the prevalence of use while being involved in a distraction-affected or PED-involved crash event. As evident from Chapter 3, no studies were found that take a definitive look at the prevalence of distraction in general. Also, as described in the above sections of this chapter, no studies were found that take a definitive look at the prevalence of distraction prior to a crash event. Reasonable surrogates for crash events are kinematic risky driving (KRD) and the combination of crash and near-crash (CNC) events (see Simons-Morton et al., 2015). KRD includes measures such as extreme accelerations and jerk (the first derivative of acceleration). Since crashes are rare events, combining CNC events provides a larger base of events to examine in determining the overall safety consequences. NDSs, particularly the larger ones such as SHRP2, generally are good at measuring the prevalence of these surrogates. This section discusses the SOK of crash risk associated with distraction based on studies using PCRs and data from NDSs. The effects from distraction generally, cellphones, and other PEDs are discussed separately. The effect of driver and situational characteristics (roadway and environment) on this risk are examined in the subsequent sections.

Effect of PED Use

This section examines the effect of PED use on crash risk. Estimates derived from studies using data from PCRs and those derived from studies using data from NDSs are presented separately.

Estimates of Crash Risk from PCRs

Retrospective crash-based studies typically lack the data on driver use of PEDs during non-crash-involved driving needed to serve as the denominator in risk estimates. For example, no estimate of miles traveled while using a PED or even overall time of PED use are available from PCR data. No U.S. studies, and only a limited number of non-U.S.-based studies, have attempted to derive information needed for risk estimates. The limited studies use crash time and location from the PCR to define case boundaries and, with these boundaries, they examine population-level PED activity pre/post the crash near the event location (Gariazzo et al., 2018; Muehlegger & Shoag, 2014). These studies have advantages over those of NDSs as their inputs include the ultimate measure of safety (i.e., crash events) and can more readily include larger and more representative samples of drivers and events. A study of nearly 8,000 injury or fatality crashes in Italy by Garrizazo et al. (2018) is the most comprehensive of this type. The authors used the above approach and controlled for factors such as average traffic volumes and weather conditions pre/post the crash within the same locations as the events. Results of the Garrizazo et al. (2018) study showed that the frequency of calls, texts, and actual connections to the internet (not necessarily related to driving during the crash but at crash locations) were all significantly positively related to increased risk of a road crash, with internet connections associated with the highest risk.

Estimates of Crash Risk from NDSs

Unlike retrospective crash-based studies, NDSs can more easily measure person-level driver exposure information. NDSs are not bound by strict experimental designs, and not only can provide the incidence of drivers' behaviors, such as PED use (see Chapter 3), but also acquire this same information during measured SCEs. As mentioned previously, the rarity of crashes necessitates that less severe events also be considered in NDS-based risk calculations. These additional markers are either examined separately from crashes or combined with crashes to derive CNC rates (see, for example, Simons-Morton et al., 2015).

As discussed in Chapter 3, SHRP2 is the largest reported NDS of passenger vehicles. Due to the large scope of SHRP2, analyses of these data have been a critical source of information pertaining to the contribution of PED use by drivers on the risk of an SCE. While SHRP2 addresses some of the limitations of other, smaller NDSs with respect to the geographical and demographic diversity and size of its driver sample, it nevertheless used a convenience sample rather than a nationally representative sample of drivers. Moreover, NDSs and SHRP2 tend to measure a large number of low-severity SCEs such as tires striking curbs. A consequence of the overrepresentation of these low-severity events is that any resulting estimation of risk may be biased high in terms of frequency and low with respect to severity (Dingus, 2014; Kidd & McCartt, 2015).

Simmons et al. (2016) meta-analyzed six NDSs, including SHRP2, to examine factors such as the possible effect of varying definitions of an SCE, sample makeup, and type of cellphone use. No variability in crash risk estimates across studies was accounted for by differences in SCE types. Also, a non-significant amount of variability (only about 7%) was accounted for by differences in driver sample characteristics (e.g., novice, experienced, or commercial drivers). More than 50% of the variability in the risk estimates across studies could be explained by cellphone activity type. Table 5-3 presents the SCE risk by cellphone activity from the Simmons et al. (2016) study.

Table 5-3. SCE Risk by Cellphone Activity. Adapted From Simmons et al. (2016)

Cellphone Activity	**OR (95% CI)**
Dial (*n*= 5 Studies)	4.04 (2.65 – 6.16)
Locate/Answer (*n*= 5 Studies)	3.57 (2.52 – 5.02
Talking (*n*= 6 Studies)	0.89 (0.76 – 1.05)
Text Message/Browse (*n*= 5 Studies)	10.30 (2.38 – 44.67)
OVERALL (*n*= 6 Studies)	**2.72 (1.78 – 4.17)**

From Table 5-3, it appears that the risk of an SCE associated with cellphone use increases as the completion of a specific activity requires more time eyes off-road. This is consistent with analyses of data from other NDSs that show SCE risk increases as total time eyes off-road increases (Hammond et al., 2019; Klauer et al., 2010; Simons-Morton et al., 2014). Also, an NDS of novice drivers showed that time eyes off-road accounts for over 40% of the risk associated with performing a manual cellphone task (Gershon et al., 2019), and an NDS of commercial drivers showed that, on average, these drivers spent approximately 4.5 seconds looking away from the road when using their phones (Harland et al., 2016). Finally, glances closest in time to the SCE appear to be most critical for determining risk, likely because they decrease the situational awareness needed to avoid a crash (Hickman et al., 2015; Seaman et al., 2017).

The ORs calculated through the Simmons et al. (2016) meta-analysis are also consistent with subsequent analyses of SHRP2 and other data from NDSs that show cognitive distractions from cellphone tasks (e.g., HH conversations) that do not interfere with the control or visual demands of the driving task do not affect crash risk (Owen et al., 2018). In fact, HF conversation has been associated with the lowest risk of an SCE (OR = 0.25 to 0.58 depending on reference condition and crash severity) of all cognitive tasks and cellphone tasks examined (Dingus et al., 2019; Hickman & Hanowski, 2012; Olson et al., 2009).

Cellphones, although the most widely used PED, are not the only devices of interest. Risk associated with other PED activities, such as use of electronic navigation systems, however, is even more difficult to calculate due to the rarity of these behaviors prior to NDS safety events. The low frequency of events associated with other PEDs suggests that their use may not be a major safety issue (Dingus, 2014).

Rather than focus on the risk of a crash given cellphone use while driving, some studies have focused on whether the frequency of cellphone use overall (not just during driving) is associated with increased risk of a safety event. These studies found that this broad measure of cellphone use overall is not predictive of SCE risk (Farmer et al., 2015; Atwood et al., 2018). To disaggregate cellphone use by activity on the cellphone, Atwood and colleagues (2018) used SHRP2 drivers' cellphone records. The authors found that overall crash risk increased not only for those drivers who texted more per hour while driving, but also for those drivers who sent more texts overall as measured by the number of texts sent per day whether driving or not (Atwood et al., 2018). The latter finding suggests that compulsivity, such as extremely high texting frequencies, or other personality factors that are associated with risky behaviors may be predictive of increased crash risk.

Analyses examining risk often consider only the periods when the driver performs a single secondary task (e.g., Dingus et al., 2019) in an attempt to isolate the influence of that task on crash risk (see Young, 2017). Still, distracted drivers do not always perform these secondary task activities in isolation and are more likely to engage in multiple types of secondary tasks during periods when an SCE occurs than during safe epochs (Bálint et al., 2020; Risteska et al., 2018). In fact, SHRP2 analyses show in over 50% of PDO crashes that involve drivers holding cellphones, drivers were using them for texting—two distinct coded categories in the dataset (Bálint et al., 2020). Bálint et al. (2020) compared the risk of an SCE occurring when a driver was performing a single secondary task compared to two or more tasks. The results showed that the risk of an SCE increases significantly with two or more tasks and particularly for the risk of a rear-end collision: OR = 2.30 for single task, OR = 8.48 for at least two tasks, and OR = 16.53 for three or more tasks (Bálint et al., 2020). The duration of these secondary tasks is also a critical factor in determining risk. Tasks over 6 seconds increased the odds of a crash or near-crash five-fold in a sample of work zone events (Bharadwaj et al., 2019).

Effect of Driver Characteristics

As noted above, the meta-analysis by Simmons and colleagues (2016) examined the effect of driver characteristics, such as driver experience and professional driver status, on risk by including driver type as a factor to account for variation in risk estimates across studies (driver type referred to commercial drivers [bus and truck] and private, light vehicle drivers [either novice or experienced drivers]). The meta-analysis found that, though about 7% of the variability in effect size estimates was explained by this factor, driver type's effect on risk was not statistically significant. Nevertheless, the importance of driver characteristics in deriving crash prevalence estimates suggests it may be worthy of further examination beyond the aggregate examination from this meta-analysis.

A number of analyses of data from NDSs suggest driver experience and age are critical factors in predicting the risk associated with using a cellphone. With respect to experience, Klauer et al. (2014) found that newly licensed minor drivers (16.3 to 17.0 years old) risk of an SCE when using a cellphone for tasks other than conversing was three to five times greater than experienced drivers. With respect to age, analyses of SHRP2 data, including only the more severe events, show that, regardless of licensure timing, crash risk associated with secondary tasks is highest for young (16 to 29 years old) and older drivers (65+), but VM tasks among these secondary tasks, including those on cellphones, present increased risk for all ages (Guo et al., 2017).

Effect of Roadway and Environment

In general, it is difficult to determine how environmental characteristics and demands of the driving task impact crash risk associated with using PEDs in general and a cellphone in particular. Drivers appear to limit their use of cellphones when the task demands of driving increase (see Chapter 3). Also, the characteristics of the cellphone task itself appear to play a greater role in determining risk than do environmental characteristics (Fitch et al., 2015). The few studies that examine environmental characteristics find risk is greatest in free-flow traffic conditions (Ashley et al., 2019; Fitch et al., 2015; Owens et al., 2018). Also, the risk associated with engaging in VM tasks, such as dialing, locating/answering, and texting, appears to be greatest at non-intersection locations (OR = 3.40) compared to controlled (OR = 2.9) or uncontrolled intersections (OR = 2.7; Ashley et al., 2019). Given the paucity of data on the effects of the roadway and environment, however, these findings should only be viewed as suggestive.

Summary

It is difficult to measure the effects of distraction due to PED use on crash occurrence. Direct measures or observations of device use immediately prior to a crash are rare and subject to error. Self-reported use is biased and almost certainly understates the problem because drivers and their passengers may be reluctant to admit their contribution to crash causation. As a result, a credible estimate of the increased risk due to PED use cannot be confidently made. Nevertheless, the preponderance of evidence from studies based on retrospective analyses of crashes and NDSs strongly suggests that the use of PEDs compromises safety. Aspects of PEDs that require significant time with eyes off the road, such as texting when not using voice-text features, appear to increase the danger of driving while using PEDs. Moreover, anything related to a driver's ability, the vehicle, or the roadway and environment that exacerbates the effect of time eyes off-road, such as inexperience or high driving task demands, can further compromise safety.

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Chapter 6 – Reducing Driver Distraction

Introduction

The previous chapters of this state-of-knowledge report highlighted the extent drivers use portable electronic devices (PEDs) (Chapter 3) and the effects this use likely has on driving task performance (Chapter 4) and safety (Chapter 5). The extent of documented and likely performance and safety problems resulting from PED use emphasizes the important need for strategies that reduce drivers' PED use or negate the performance or safety consequences associated with it. Several literature reviews and individual studies have focused specifically on these strategies.

Previous Reviews

The Ranney (2008) SOK report reviewed relevant studies that examined behavioral strategies, such as enforcement and education, to reduce driver distraction. In the ensuing span of more than a decade, the legislative and technological landscape has changed considerably, including the number and types of cellphones in use; the growth of vehicle and traffic laws in many States that regulate PED use by drivers; the expansion of the range of products and services available to drivers through smartphones and other PEDs; and the initiation of a variety of countermeasures to prevent distraction from PEDs or, at least, blunt their consequences. Also, the Ranney (2008) report considered a wider range of distraction causes, including in-vehicle systems (e.g., entertainment functions) that prompted a broader focus on strategies, including vehicular and environmental changes, to address the distraction problem.

Since the Ranney (2008) SOK, several broad reviews on strategies to reduce driver distraction in general have been published. Some of these reviews (e.g., Governors Highway Safety Association, 2011; Hanowski, 2011; Vegega et al., 2013) reported primarily on studies that examined sources of distraction other than PEDs, such as in-vehicle systems (e.g., route guidance systems, radio/CD players), which are beyond the scope of this report. Other reviews limited their scopes to a single or limited number of strategy modalities, such as legislation (e.g., Ehsani et al., 2016); a single distraction-related outcome, such as crashes (e.g., McCartt et al., 2014); or a limited population of drivers, such as teens/novices (e.g., Classen et al., 2019).

Arnold et al. (2019) conducted the most recent, comprehensive review of strategies to reduce driver distraction. This review was recently expanded and updated with broader inclusion criteria that allowed for literature previously excluded (Arnold et al., 2022). As the objectives of these high-quality reviews overlap with those of this SOK, the results of these Arnold et al. (2019; 2022) reviews will be synthesized with results of relevant single studies within this chapter.

NHTSA's Countermeasures That Work

Strategies to reduce distracted driving range from the purely theoretical to those that have shown potential or actual effectiveness by analysis or test. Approximately every two years, NHTSA produces a guide, *Countermeasures That Work*, to assist State Highway Safety Offices (SHSOs) in selecting effective, evidence-based countermeasures for traffic safety problem areas. This guide contains strategies and countermeasures that are relevant to State authorities, summarizes countermeasure use, effectiveness, costs, and implementation time, and provides references to relevant research. Prior to the 10th edition of *Countermeasures That Work* (Venkatraman et al., 2021), distracted and drowsy driving countermeasures were presented in the same chapter (for example, Chapter 4 of Goodwin et al., 2015). The 10th edition devoted separate chapters to these two traffic safety problem areas (see Chapter 4 and Chapter 10 of Venkatraman et al., 2021) due to the growing body of literature under each respective topic and the differing driver behaviors that underlie each problem area.

While some of the strategies to reduce distracted driving that are discussed below in this chapter overlap with those highlighted in the *Countermeasures That Work* series, the scope of this chapter is less restrictive with respect to the extent of evidence that supports the distracted driving strategies discussed. Rather than being limited only to strategies that have analytic or empirical evidence, this chapter presents a wide range of strategies described in the literature, ranging from ideas assessed by analysis (such as focus groups) to those subjected to empirical evaluations. The present review of the literature published since the Ranney (2008) SOK through September 2022 indicated it could support an examination of this broader range of strategy maturity.

Current Review

This review reports on a wide range of strategy maturities and types including engineering, education, enforcement, and combined approaches. To the extent they exist, strategies targeting specific populations (e.g., teen drivers) are integrated throughout the four subtopics of this chapter. The discussion for each approach will include consideration of what is known about the extent and nature of outcomes from the application of the countermeasure. This can include changes in driver knowledge, attitudes, and/or opinions, driver PED use, driver performance, and safety. As in previous chapters, the organization of this chapter is by the research methodology used by the study being discussed.

- Observational studies
- Self-report studies
- Naturalistic driving studies
- Experimental approaches
    - On-road
    - Closed-course
    - Simulator
- Retrospective analyses.

In addition to these approaches, prospective studies that involve collecting data about particular people or groups of interest over time and analyzing the data in the context of person or group-level changes are also relevant to the current chapter. These studies would be of particular interest if they covered the period before and after the implementation of a distraction countermeasure program.

Review Approach

Reviewers assembled and screened a comprehensive set of documents examining driver distraction using the process detailed in Chapter 1. Researchers specifically identified those reviews and studies that included an examination of strategies to reduce driver distraction from PED use or alleviate the consequences associated with this use.

For purposes of this chapter's specific review, 226 papers (reviews and original investigations) were identified as relevant based on the defined eligibility criteria. These 226 documents were assessed for study quality using the study-derived quality dimensions. In the review, extra consideration was given to whether a study appropriately used pre/post designs or control groups and the extent to which the results were generalizable to the entire U.S. population. This resulted in the 69 works cited within this chapter. In general, if a study was not included in the synthesis, it was not mentioned or cited in this chapter unless it was used to illustrate the reason for excluding a pool of similar studies.

Engineering

This SOK's consideration of engineering approaches was focused on those dealing with the design and operational characteristics of PED devices themselves as opposed, for example, to changes in the vehicle being driven or the roadway on which it was being operated. When studies focused on multiple engineering areas including the design of the PED, pertinent comments related to them may be included. The limitation only to the design of the PED should not be interpreted as suggesting that engineering as broadly applied is not a potential countermeasure area.

Cellphone Blocking

The idea behind cellphone blocking technologies is to prevent (or minimize) a driver's use of the cellphone while the person is actively driving, thereby preventing the phones from causing distraction. The section begins by defining the types of blocking approaches before reviewing studies that examine driver knowledge, attitudes, and opinions of them. The section concludes with a review of studies that examine how cellphone blocking technologies affect driver PED use, performance, and safety.

Types of Cellphone Blocking

There are several approaches to "blocking" cellphone activity while driving. "Complete blockers" interfere with the cellphone signal itself by way of a hardware implementation that impedes cellphone signal reception. "Soft blockers" use software solutions which permit some phone functionality (e.g., navigation, music applications) while preventing others (e.g., texting, talking). Soft blockers often allow specific types of notifications through to the driver about incoming calls or messages and may provide notifications to callers or other senders of messages that the driver is unavailable and will receive the message or call notification later (Funkhouser & Sayer, 2013).

Some software cellphone blocking applications activate automatically based on detected vehicle speed, while others require manual activation prior to the start of a driving session. Some phone-based blocking systems are native to a particular smartphone such as Google's *Android Auto* and Apple's *Driving Focus* (originally named *Do Not Disturb*). Other systems interact with the car itself through the vehicle's diagnostic port and enable blocking depending on current gearing and speed.

"Streamliners" are another class of blocker that aims to simplify phone use during driving. Streamliners are somewhat like soft blockers but differ in that they attempt to reduce the cognitive load of phone use while driving by making interactions with the phone easier. Speech-to-text is one method of streamlining, and another is the provision of large hardware or "soft" buttons that are easy to locate and touch during driving.

Driver Knowledge, Attitudes, and Opinions of Cellphone Blocking

Given that cellphone blocking technologies are relatively new, it is important to understand whether drivers who know of their existence comprehend how the systems work, their attitudes towards the technologies, and their opinions about the usefulness of the systems. Although most of the research involves non-U.S. based drivers, the interviews and questionnaires of these drivers have revealed important insights on driver knowledge, attitudes, and opinions of cellphone blocking. In general, drivers report cellphone blocking technologies, particularly the ones native to the cellphone, are beneficial and promote safer driving (Funkhouser & Sayer, 2013; Oviedo-Trespalacios, Truelove, & King, 2020). The perceived utility and acceptance of these technologies, though, is affected by the extent of a driver's direct experience with them (Oviedo-Trespalacios, Williamson, and King, 2019; Ponte et al., 2016), the activities that the blockers restrict (Oviedo-Trespalacios, Williamson, & King, 2019), and the driver's overall need for phone calls (Musicant et al., 2015). For example, a study of corporate fleet drivers found that after exposure to blocking technology, the surveyed drivers were more likely to think that blocking technology would negatively impact their work and expressed doubt that the technology would improve safety (Ponte et al., 2016). Similarly, those inexperienced with these technologies tended to feel that apps that block a wide-range of cellphone activities, including calling, texting, and social media, are desirable (Oviedo-Trespalacios, Williamson, & King, 2019). In the study, those experienced with blockers, however, were less likely to install and use these technologies in the future because they did not want to have their social interactivity limited.

Regardless of their experience with cellphone blocking technologies, drivers consistently report higher acceptance of approaches that do not restrict navigation and music playback (Delgado et al., 2018; Oviedo-Trespalacios, Truelove, & King, 2020; Oviedo-Trespalacios, Vaezipour, Truelove, et al., 2020; Oviedo-Trespalacios, Williamson, & King, 2019). Additionally, drivers also prefer blocking technologies that include the ability to enable hands-free talking, deliver automatic responses to calls or messages indicating the driver is currently driving and cannot respond now, and include voice command features (Oviedo-Trespalacios, Williamson, & King, 2019). In one instance, while the preference for automatic responses was confirmed among drivers after a weeklong trial of the native cellphone blocking technologies, diary entries from the trial participants also revealed the auto-reply feature and other preferred features did not always work as intended (Oviedo-Trespalacios, Vaezipour, Truelove, et al., 2020). For example, the auto-reply feature would send driving-status messages when the user was no longer driving. Also, some language issues emerged with voice-activated functions, such as trouble with the voice recognition understanding certain driver accents. While this issue likely involves the voice recognition support provided by the phone itself and not the blocking, it still must be considered from a total user acceptance perspective.

Survey studies have revealed other issues drivers have with cellphone blocking technologies. A major concern of drivers was the possibility that the presence of the cellphone blocking technology could ultimately prove a greater distraction than its absence. If this proves to be true, these purported countermeasures could be detrimental to driver performance and safety. This concern was evident in two trials involving non-U.S. based drivers using blocking technologies (Oviedo-Trespalacios, Vaezipour, Truelove, et al., 2020; Ponte et al., 2016). Given that the blocking apps would not allow certain features, users reported manually deactivating the blocking while driving to gain access to those desired features (Oviedo-Trespalacios, Vaezipour, Truelove, et al., 2020; Ponte et al., 2016). The deactivation process itself can be a complex and distracting task during driving that may be further complicated by the fact that the apps change the layout of the phone's display while the blocking technology is active, making it more difficult and time consuming to access a feature when a person is not familiar with the new layout (Oviedo-Trespalacios, Vaezipour, Truelove, et al., 2020).

Other issues uncovered by the two non-U.S. based trials of cellphone blocking technologies were a concern that the phone's battery drained too quickly when the technology was used (Oviedo-Trespalacios, Vaezipour, Truelove, et al., 2020; Ponte et al., 2016), and a user's privacy was at risk (Oviedo-Trespalacios, Vaezipour, Truelove, et al., 2020). The privacy issue likely arose because the phone would request permission to access other functions of the phone when the blocking app was first activated. Some drivers misunderstood the purpose and scope of this request and believed their privacy was at risk. These privacy concerns were replicated by a telephone survey of U.S. drivers aged 18 years and older who owned a smartphone. The results of this survey found that almost 80% of iPhone users do not set Apple's cellphone blocking function to start automatically while driving, and 12.3% of these people who opt out of having the feature start automatically do so because of privacy concerns (Reagan & Cicchino, 2020). Of the remaining manual activation users, 18.3% indicated they needed to access their phone while driving and 14.7% had a fear of missing important notifications. Another 12.3% of the total sample had a lack of awareness about the blocking function and its capabilities (Reagan & Cicchino, 2020).

Cellphone Blocking Effects on Driver PED Use

Studies using interview and survey data have provided self-report data on driver PED use while using cellphone blocking technology (e.g., Ponte et al., 2016). Other studies have assessed driver PED use while using cellphone blocking technology based on actual recorded usage (e.g., Funkhouser & Sayer, 2013). Together, these two study types provide the best available information concerning the effectiveness of cellphone blocking technologies in reducing driver PED use. Arnold et al. (2019; 2022) reviewed a set of these studies and consistently found decreased self-reported phone use as well as reduced workload when phones were used. The reductions included visual-manual (VM) and cognitive workload as well as actual driver phone use and interactions (e.g., screen touches/phone unlocks). One study of employees in Israel using a cellphone blocking application also showed that the reductions persisted, although with some decrement, a month post-intervention (Rispler & Luria, 2020). Arnold et al. (2019; 2022) noted, though, that some of the studies they analyzed revealed issues with the reliability of the technology and driver compliance with it. Together, these findings along with those related to driver knowledge, attitudes, and opinions of cellphone blocking suggest that a more reliable cellphone blocking solution combined with proper driver education/training materials to increase driver compliance have the potential to reduce driver PED use.

Cellphone Blocking Effects on Driver Performance and Safety

The previous section discusses studies that suggest cellphone blocking may be effective in reducing driver PED use. The reliability issues and limited driver compliance with voluntary blocking, however, casts doubt on whether the reduction in use is sufficient to result in improved driver performance and safety. Both the Arnold et al. (2019; 2022) reviews and the current

SOK's search strategy did not identify any experimental work or full NDSs that focused on cellphone blocking technologies and driving performance and safety. A few studies (e.g., Albert & Lohan, 2019; Delgado et al., 2017; Shelef et al., 2021) included measures of actual driving behaviors (driving speed, for example, was captured by several of the blocking applications). However, these measures were used to contextualize the driver PED use data (e.g., examine screen touches as a function of vehicle speeds) rather than examine how changes in PED use affected performance and safety.

The most comprehensive test of the effectiveness of cellphone blocking technology to date was by Benden et al. (2012). These authors conducted a randomized control intervention to measure the effectiveness of cellphone blocking technology on performance and safety outcomes but relied on surveys of the teen driver participants at 6-months and 12-months after the participants began using the cellphone blocking technology for self-reported traffic violations and crashes. While no differences in self-reported traffic violation or crash outcomes were found between the cellphone blocking and the control group, high drop-out rates (54% at 12-months), the restricted age range of the sample, and the limitations of self-report data suggest no strong conclusions can be made from this single study concerning cellphone blocking's impact on driver performance and safety.

Smartphone-Based Driver Monitoring and Feedback

Driver monitoring and feedback is another engineering approach to reduce driver distraction from PED use. Most monitoring and feedback approaches that have been reported in the literature are vehicle-based and therefore outside the scope of this SOK. However, smartphone-based approaches are also gaining popularity. The results of a single small-scale test track experiment suggests that at least some of these approaches, including one that provides warnings when the driver's attention is on a device for too long or the driving task is high-demand, foster trust, are acceptable to drivers, and are perceived to be useful by them (Kujala et al., 2016).

One smartphone-based approach focused specifically on reducing PED use among teens by treating distraction-free driving like a game. Specifically, teens using the application earned points for miles driven without using their phones. Achievements and rewards were associated with specific thresholds. Results from over 10,000 trips and more than 100,000 miles of data from the application and a comparison of trips both pre- and post-incentive showed that the application was successful in reducing the number of trips that involved driver phone use from 24% to 17% (Henk et al., 2021).

A few small-scale experimental studies also suggest that smartphone-based driver monitoring and feedback technologies may be effective at improving driver behavior, performance, and safety. The Kujala et al. (2016) test track experiment described above measured changes in driver's glance time on road in the presence of an alert that the driver's eyes were on the smartphone over a specific amount of time or the demands of the driving task were increasing (e.g., approaching an intersection or tight curve). The authors found a 5 to 30% increase in glance time on road because of the alerts, with visual tasks, such as reading a text message, showing the largest benefit (Kujala et al., 2016). The driver's phone conversation partner may also be an effective monitor of the driver's performance if technology permits the conversation partner to view the driving scene from the driver's perspective. Gaspar et al. (2014) tested this novel approach in a simulator and found that collision rates during the simulated driving scenarios for participants in the test condition were lower than for participants in a condition involving typical cellphone conversations and comparable to the rates in a condition involving conversations with passengers or when the driver was alone.

Finally, it is important to note that this SOK's search did not reveal any crash-based analyses or full NDSs that focused on smart-phone based driver monitoring and feedback technologies and safety. In the absence of findings based on this ultimate measure, the results presented above, while encouraging, should be interpreted with caution with respect to a safety benefit from monitoring and feedback approaches.

Other PED Software Approaches

Other smartphone-based software approaches attempt to reduce distraction by streamlining the user interface of a smartphone. Rather than blocking a driver's phone activity, these approaches typically involve providing larger icons, reducing clutter, and including assistance features such as voice commands and auto-responses. By streamlining phone activities, this approach attempts to reduce the need for visual, cognitive, and manual resources. A single study by Oviedo-Trespalacios, Briant, Kaye, and King (2020) compared the iPhone native cellphone blocker with a phone usage streamlining app. The evaluation employed a questionnaire that combined three psychological acceptance models: the technology acceptance model (TAM), the theory of planned behavior (TPB) model, and the unified theory of acceptance and use of technology (UTAUT) model. These models have been shown to have predictive power for behavioral intentions and acceptance of automotive technologies (see, for example, Martins et al., 2014). Hierarchical multiple regressions were used to test each model's ability to predict the intent to use the technologies. Participants expressed higher intention to use the cellphone blocker over the streamlined user interface (Oviedo-Trespalacios, Briant, Kaye, & King, 2020). While only a single study, this study is informative of driver preferences of cellphone blocking over other engineering approaches. The study did not evaluate how the streamlined technology affects driver, behavior, performance, and safety.

Combined Engineering Approaches

Theoretically, the combination of multiple likely effective smartphone-based approaches could produce a reduction of distracted driving due to PED use that will be greater than any single approach in isolation or could also increase complexity thereby causing distraction. Two studies examined a combination of cellphone blocking and driver monitoring/feedback—one with a sample of novice teen drivers (Creaser et al., 2015), and another with a small sample of older drivers (Davis, 2019). Surveys of drivers in both studies suggested that the two age groups diametrically differed in their acceptance of these combined approaches. While older drivers were highly receptive to the technology (Davis, 2019), novice teen drivers indicated a lack of acceptance of the approach (Creaser et al., 2015).

The latter study, Creaser et al. (2015), also known as the *Minnesota Teen Driver Study*, also collected data on PED use from a large sample of drivers to compare the effectiveness of a combined approach to a condition involving cellphone blocking only and a control condition. In this study, drivers in the condition with the more complex combined approach sent fewer texts and made fewer calls than drivers in the control condition without any treatment, but drivers in the simpler condition involving only cellphone blocking also sent fewer texts and made fewer calls than drivers in the control condition. Moreover, the more complex combined approach was not significantly different from the simpler condition involving only cellphone blocking (Creaser et al., 2015). Given the paucity of studies to date on the subject, more work is necessary to gain a better understanding of the efficacy of a combined cellphone blocking and monitoring/feedback approach, including its effects on driver behavior, performance, and safety. The limited available work, however, is not very encouraging since it suggests receptivity to the combined approach may depend on the target demographic, and effectiveness may not be better than cellphone blocking alone.

Education

This section reviews studies of education countermeasures. These education countermeasures include driver attention maintenance strategies, campaigns to increase driver awareness of the safety consequences of distraction, and approaches that provide driver feedback about their performance.

Driver Attention Maintenance Strategies

As discussed in Chapter 3, drivers often make conscious decisions concerning whether to use PEDs and when and where they will do so. Strategies to change drivers' willingness to use PEDs or relegate their use of PEDs to situations that are less likely to have safety consequences could be beneficial if proven effective. In this way, the strategies are teaching drivers how to more safely allocate their attention between the distracting activity and the forward roadway (see, for example, Pradhan et al., 2009). Young drivers could benefit from such strategies since, as discussed in Chapter 3, these drivers have a high likelihood of engaging in distracting activities.

Horrey et al. (2009) tested the effectiveness of video-based training designed to change young drivers' willingness to maintain their attention on distracting activities versus the forward roadway. The Horrey et al. study compared the reported willingness to engage in distracting activities between a group receiving training and a control group that viewed an unrelated video. In survey data, the trained drivers reported less willingness to engage in distracting activities after the training, while the control group did not show any change. A test track portion of the study involving an analysis of actual driver behavior also showed that the trained drivers were actually more likely than drivers in the control group to engage in potentially distracting activities, but only while parked when the activities were not a hazard. There was no difference in engagement while the vehicle was in motion.

App- or web-based programs like the one tested by Horrey et al. (2009) have also been evaluated. A small-scale simulator evaluation of a web-based program called *Let's Choose Ourselves* designed specifically to increase young driver's attention to the forward roadway found no reductions in self-reported or observed distracted driving activities (McDonald et al., 2021). Another app-based approach called *Mindful Messaging* targeted impulsive phone use (i.e., texting) more generally. While the young adults reported high acceptance for the app, no significant reduction in texting while driving was observed (Trub & Starks, 2017).

Finally, a simplistic approach to encourage mindfulness that involved distributing a bumper sticker with the message "Drive in the Moment" was evaluated with medical students and found to reduce reported rates of sending/reading texts and using social media while driving compared to a no treatment control group (Rohl et al., 2016). More studies with a broader segment of drivers are needed to determine the effectiveness of these types of driver mindfulness approaches.

If drivers do choose to use PEDs, some attention maintenance strategies may be possible that can help these drivers avoid at least some of the negative effects that this behavior can have on performance. As discussed in Chapter 4, glances greater than 2 seconds away from the forward roadway are generally considered detrimental to driver performance. Forward Concentration and Attention Learning (FOCAL) is a computer-based training program designed to teach drivers to reduce the length of their glances away from the forward roadway to less than 2 seconds (Pradhan et al., 2009; Fisher et al., 2010). In this way, drivers may avoid some of the negative effects of taking their attention off the forward roadway when they choose to engage in distracting activities. Arnold et al. (2019) and Arnold and Horrey (2022) reviewed a total of four studies that evaluated FOCAL in the driving simulator and on active roadways and determined it was effective in focusing novice drivers' attention on the forward road by increasing their awareness of where they were distributing their attention. However, Arnold et al. (2019) and Arnold and Horrey (2022) suggest caution is warranted because none of the studies evaluated the long-term effects of FOCAL or its effects on driving performance measures. Similarly, no study was identified in the current review's search that evaluated the program's effects on safety.

Programs to Change Driver Behavior by Increasing Awareness of Safety Consequences

Some programs attempt to change the behavior of high-risk drivers, often high school students, by increasing the awareness of the driver PED use problem and its consequences. These types of programs include mass media and social media campaigns using public service announcements involving fear appeals, high-visibility enforcement efforts (see Enforcement section below), and focused education programs that rely on expert demonstrations. The process of identifying and reviewing documents for this SOK did not identify any research of high methodological quality that evaluated distraction-related mass or social media campaigns. Professionals with extensive experience dealing with the health (e.g., nurses) or legal consequences (e.g., law enforcement, lawyers) of distraction-affected crashes are potential educators who may be effective at convincing drivers with a propensity to use a PED not to do so because of the health or legal consequences. Accordingly, professionals in these domains have been a part of a number of these types of programs. Arnold et al. (2019) and Arnold and Horrey (2022) reviewed evaluations of programs involving health and legal professionals and found that most of the smaller-scale programs (e.g., consisting of just a single class, demonstration, or discussion group) produced short-term changes in a participant's reported attitudes or intent to engage in distracting activities while driving. Long-term benefits, however, were not typically found.

Three of the reviewed studies from Arnold et al. (2019) and Arnold and Horrey (2022) were more extensive, long-term programs, involving activities such as hospital tours, presentations, and workshops. One of these programs found changes in behavior—observed reductions in distraction activities among the high school student attendees. Another found reductions in distracted driving citations post-intervention, and the third found reduced crashes pre- to post-intervention whereas a control group did not see the same changes. Similar long-term employer-based programs targeting medical staff or commercial drivers have also shown reductions in self-reported or observed distracted driving behaviors, including longer-term reductions that lasted 3-months (Hill et al., 2020), 6-months (Joseph et al., 2016) and a year (Rana et al., 2018).

Programs that aim to increase awareness of the safety consequences of distracted driving often use computers or driving simulators to provide participants with a more hands-on experience of the potential negative consequences of engaging in distracting activities while driving. Arnold et al. (2019) reviewed four studies that used an experiential-based approach and found that these approaches generally increase participant's awareness of the problem and positively change their attitudes and intention to engage in distracting activities. The authors caution, however, that none of these studies of hands-on approaches examined long-term effects greater than two weeks, and none used actual driver behavior, performance, and safety as outcome measures (Arnold et al., 2019).

Programs That Provide Feedback to Drivers

As discussed in Chapter 3, drivers often overestimate the quality of their driving performance, particularly while using a PED. Educational strategies that provide drivers feedback about their performance have the potential to inform drivers to the extent their performance is affected using a PED. Wang et al. (2010) examined an approach of this type in a simulator by providing novice and experienced drivers feedback of their driving performance with and without cellphone tasks. The authors then assessed the extent this feedback changed attitudes towards cellphone use relative to a control group that received no feedback. Results showed that drivers receiving feedback experienced an attitude change while those in the control group did not. This positive outcome persisted for a month after the intervention, but more so for the experienced drivers in the experimental group than for the novices (Wang et al., 2010). Note, though, that changes in driving performance because of this feedback were not examined, so it is unclear the extent to which the attitude changes resulted in improved behavior or safety.

Other feedback approaches have focused on providing drivers with information about the behavior of other, safer drivers with the hope of producing behavioral improvement. Merrikhpour and Donmez (2017) and Donmez et al. (2021) had teens complete a driving simulator experiment and provided them with information on their parents' and peers' distraction engagement. The simulator experiment involving feedback about parents' behavior showed that the social norm feedback resulted in teens spending less time looking off-road, having better steering control, and having faster brake response time compared to no feedback (Merrikhpour & Donmez, 2017). The Donmez et al. (2021) simulator experiment similarly showed that providing teens with feedback about their peers' low distraction engagement helped improve the targeted teen's behavior and driving performance.

Enforcement

This section reviews studies of enforcement countermeasures, including studies of laws restricting driver cellphone use, regular enforcement of these laws, and the application of HVE, i.e., the combination of increased enforcement and intensive publicity about the enforcement.

Laws

There is no national framework with respect to laws restricting driver cellphone use. Variations in State and local laws have resulted in a patchwork of legal prescriptions and proscriptions, making it difficult to interpret the effectiveness of these laws. This subsection begins by describing the types of laws that restrict driver PED use and then describes research that examined the effectiveness of these laws. Examples are highlighted from national, State, and international studies.

Overview of State Driver Cellphone Use Laws

Several sources maintain databases of State laws that restrict driver cellphone use (e.g., NHTSA, 2012). The legislative landscape changes quickly, though, and these sources can become outdated. At the time of this writing, the Governors Highway Safety Association (GHSA) maintained the most up-to-date database of the existence of State laws that restrict driver cellphone use (GHSA, 2023). This database classified States' laws into those that ban:

- All driver cellphone use for specific groups (e.g., school bus drivers, novice drivers),
- Handheld (HH) driver cellphone use, and
- Driver text messaging.

At this writing, 36 States and D.C. ban all cellphone use for novice drivers. Twenty-five States and D.C. do the same for school bus drivers. Thirty-four States and D.C. ban driver HH cellphone use, and 49 States and D.C. ban driver text messaging (GHSA, 2023).

Laws Banning School Bus Driver Cellphone Use

Even though nearly half of the States ban all cellphone use by school bus drivers, no study was identified from the literature search that examined knowledge, attitudes, or opinions of school bus driver cellphone prohibitions or the effectiveness of these laws on PED use, driver performance, or safety.

Cellphone Use Laws and Their Effect on Young Drivers

As discussed in Chapter 3, young drivers have a higher reported and observed incidence of PED use than older age groups, and, as discussed in Chapter 5, also a higher incidence of crashes with distraction as a cause. These findings suggest that laws that target young driver cellphone use may be particularly helpful in reducing a significant portion of the distracted driving problem if young drivers understand, accept, and comply with these laws. The same may be true for laws that more broadly target all driver HH use.

North Carolina is one of the States with a general prohibition on cellphone use by young drivers. Most teenagers (64%) surveyed in North Carolina after the ban went into effect were aware of the ban, and even more (78%) were aware 2 years later (Foss et al., 2009; Goodwin et al., 2012). A national survey of drivers of various ages, however, suggests that awareness of these age-specific laws is lower than awareness of the distracted driving laws applicable to all drivers (Braitman & McCartt, 2010). Also, a survey of U.S., Canadian, and European drivers suggests that the zero tolerance laws banning all cellphone use by drivers may be unpopular in all the studied countries, at least among young drivers. Young drivers were the least likely among all age groups to accept these zero tolerance laws (Lyon et al., 2020). Analyses of AAAFTS Traffic Safety Culture Index 2011-2017 data also suggest that most young drivers (87%) look more favorably upon laws that target specific distraction activities (e.g., texting, emailing) compared to those that ban all activities involving PEDs (Pope et al., 2021). Only 66% of young drivers supported the latter, more general, laws (Pope et al., 2021).

Ehsani et al. (2016) systematically reviewed 11 studies on the effects of driver cellphone use laws on young driver cellphone use and safety. Six of the 11 studies focused on young driver reported or observed cellphone use and found that driver cellphone use laws of any type were not widely associated with reductions in use. Only two of the six reviewed studies reported a reduction in young driver cellphone use, and these reductions were only associated with the more general driver HH use or texting bans—not laws specifically targeting young drivers. The Youth Risk Behavior Surveillance System (YRBSS) is a survey conducted since 1991 to examine risk taking behavior among a nationally representative sample of high school students (e.g., Underwood et al., 2020). The Rudisill and Zhu (2015) analysis of 2013 YRBSS data suggested that bans affecting all drivers may be more effective than ones that target young drivers specifically.

Analyses of YRBSS data also suggest that concurrent implementation of age-specific young driver and general HH cellphone use bans led to a greater reduction in self-reported HH calls while driving than no ban or a young driver ban alone (Li et al., 2020). Analyses of AAAFTS Traffic Safety Culture Index 2011-2014 survey data, however, show that HH bans may be more effective than texting bans for young drivers (Rudisill et al., 2018). These somewhat inconsistent findings could be due to enforcement difficulties associated with targeting specific age groups or proving that specific cellphone activities occurred (see *Citations for Violating Cell Phone Use While Driving Bans* section for additional discussion).

The remaining five of the 11 studies that Ehsani et al. (2016) systematically reviewed examined the effectiveness of cellphone restrictions in reducing crashes involving young drivers. Two of these five studies involved multi-State samples. These two studies reported reductions in young driver fatal crashes or fatalities and saw more consistent reductions in these crashes from a more general restriction applicable to all drivers. The remaining three single-State studies reported by Ehsani et al. (2016) involved analyses of insurance claim data or crashes of varying severity and saw minimal or no benefit associated with cellphone restrictions. Ehansi et al. (2016) suggest that differences in analytical approaches, difficulties in disentangling age-specific bans from more general bans when States have both, and the limitations of crash data discussed in Chapter 5 render findings from the reviewed studies inconclusive.

Laws Banning Driver HH Cellphone Use

As discussed in the previous section, drivers generally are aware of HH cellphone use bans (Braitman & McCartt, 2010). Based on surveys of non-U.S.-based drivers, knowledge of cellphone use laws is higher among highly-educated, urban drivers (Sagberg & Sundfør, 2016) and when concerning cellphone bans that are more simplistic (Jamson, 2013). Some legislation in Europe attempts not only to restrict drivers' HH cellphone use, but also to limit interaction with other PEDs, such as navigation or entertainment devices, in certain circumstances where these devices may pose a VM distraction. A survey of European drivers showed that this more complex legislation was understood and complied with less than were more simplistic laws pertaining to driver cellphone use (Jamson, 2013).

Arnold et al. (2019) and Arnold and Horrey (2022) reviewed 9 studies that evaluated the effect of driver HH cellphone use bans on driver reported or observed use of these devices. These studies generally found reductions in reported or observed cellphone use, but the reductions in HH use were sometimes associated with increases in other types of cellphone activities such as HF use. The same pattern was also noted in a New Zealand observational study identified as part of the search for this SOK (Starkey et al., 2013).

Arnold et al. (2019) and Arnold and Horrey (2022) also reviewed 11 studies focusing on driver HH ban's effects on safety. As with the effects on use rates, HH bans were generally associated with reductions in fatal and injury crashes and driver and other road user fatalities. Of the 11 studies, those that did not show a crash and/or fatality reduction typically only looked at a subset of crash types such as freeway crashes or crashes that resulted in insurance claims.

Laws Banning Driver Texting

As discussed earlier, young drivers (especially younger females) tend to favor laws banning texting over stricter laws banning all cellphone use (Pope et al., 2021; Pope et al., 2019). Arnold et al. (2019) and Arnold and Horrey (2022) reviewed three studies examining the effects of these bans on driver's reported texting behavior. These studies only found reductions of driver texting behavior among specific subgroups (e.g., teens, non-Whites and non-Hispanics) and not among adults more generally. Similarly, the reviewed studies that involved crashes as an outcome measure were inconsistent, with some of the studies finding an increase in crashes, including distraction-affected ones. Arnold et al. (2019) and Arnold & Horrey (2022) attribute this increase to improved reporting of distraction in crashes spurred by knowledge of the ban.

Citations for Violating Cellphone Use While Driving Bans

Drivers who violate the laws restricting their phone use can be given a traffic citation for engaging in this illegal behavior. Only one large-scale study that examined the extent these laws are enforced was identified from the search (Rudisill & Zhu, 2016). Other studies discussed in the HVE section below examined the extent of enforcement (e.g., number of citations given as part of an HVE campaign), but only on a smaller scale. The identified large-scale study by Rudisill and Zhu pooled citation data gathered from enforcement agencies in 14 States and D.C. The State agencies provided data for a varying number of years, but all within the 2007 to 2013 timeframe. The results of the study showed that cellphone use while driving citations represent a very small proportion (perhaps as little as 1%) of citations issued for all traffic violations. Within the cellphone use while driving offenses, HH use is cited much more frequently than texting or young driver restrictions. While only a single study, the comprehensive look at enforcement of cellphone use while driving by Rudisill & Zhu suggests that cellphone use while driving laws are sparsely enforced and are largely for the general offense of HH use.

The analyses in studies on citation issuance for cellphone use while driving also suggest there are potential difficulties in enforcing these laws. Research with police officers tend to confirm the existence of these difficulties, such as social pressure not to issue citations (Nevin et al., 2017; Rudisill et al., 2019), police perceptions of lack of support from the judicial system, poorly constructed distracted driving laws, and the inability of police to observe the offenses as they happen (Retting et al., 2017; Rudisill et al., 2019).

High Visibility Enforcement

HVE is an approach that involves increased enforcement coupled with intense publicity to enhance the effect of enforcement and deter undesirable behaviors (see, for example, Blomberg et al., 2022). This type of combined enforcement and education approach is particularly applicable to cellphone use restrictions considering the potential difficulties in enforcing these laws. HVE has the potential to deter illegal behaviors by increasing a potential violator's perceived risk of apprehension and sanction. HVE campaigns often include the use of community surveys to assess the extent the people who received the HVE were aware of and understood the intent of the program. The community surveys that were part of three NHTSA-sponsored evaluations of HVE targeting driver HH cellphone use (Chaudhary et al., 2014; 2015;

Retting et al., 2017) and studies from Japan (Nakano et al., 2019) and Canada (Wickens et al., 2020) provide information about HVE and its effects on the awareness, opinions, and intent to engage in distracted driving behaviors of exposed drivers.

The community surveys that were part of the NHTSA studies found that drivers are aware of the enforcement and publicity components of HVE following their implementation (Chaudhary et al, 2014; 2015; Retting et al., 2017). The evaluation of the Canadian HVE campaign found reductions in reported texting behavior by drivers after the campaign and even larger reductions among those who reported that they previously texted frequently while driving (Wickens et al., 2020).

The survey of Japanese drivers suggested methods that increase police visibility may also heighten driver awareness of HVE campaigns (Nakano et al., 2019). Drivers surveyed in the Japanese study reported more vigilance and lower intent to engage in distracted driving activities in situations with as little as one police unit visible at the roadside (Nakano et al., 2019).

The NHTSA-sponsored HVE studies evaluated the effectiveness of HVE in reducing driver HH cellphone use and crashes associated with it. Roadside observations were conducted before and after the implementation of the HVE programs to examine changes in driver HH cellphone use. Reductions in driver HH use were observed at each of the NHTSA-sponsored HVE sites from before to after application of the HVE, but similar reductions were sometimes observed at the control sites as well (Chaudhary et al., 2014; 2015; Retting et al., 2017). For the two evaluations that gathered crash data, no significant changes in distraction-related crashes were found, but the authors acknowledged that the small number of crashes overall and even smaller number of distraction-related crashes made it difficult to examine the HVE campaigns' effects on safety (Chaudhary et al., 2014; 2015).

Summary

Relatively little literature was found on large-scale activities to prevent distracted driving from the use of PEDs or lessen its consequences. Engineering, education, and enforcement approaches have been suggested, and some have been developed, deployed, and evaluated. The small number of tests and their limited scale precludes arriving at a data-driven conclusion on the relative effectiveness of the various approaches. While several approaches appear promising based on the limited available information, the lack of compelling findings and the limitations inherent in the few studies conducted precludes the identification of preferred approaches. Advances in technology and further research on the problem and its solutions in the future should add clarity and enable a more confident definition of remedial approaches.

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Appendix A: Screening and Quality Assessment Forms

<table>
<tr><th colspan="2">Study Descriptive Information</th></tr>
<tr><td colspan="2">APA Citation:</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Abstract</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">In what chapter does the study belong? (select all that apply.)</td></tr>
<tr><td>Chapter 3: Driver Use of Portable Electronic Devices
Chapter 4: Effects of Driver Behavior and Performance
Chapter 5: Effects on Safety
Chapter 6: Reducing Driver Distraction</td><td>3 4 5 6

None of the above</td></tr>
<tr><th colspan="2">Study Inclusion Criteria</th></tr>
<tr><td colspan="2">1. Is the study from an appropriate English-language source?</td></tr>
<tr><td>Include:

Journal Article Conference Proceeding/Abstract Technical Report Thesis/Dissertation
Other ___________________
Exclude: Not one of the above sources; Above sources not available as an English Language</td><td>Yes No</td></tr>
<tr><td>2. Was this study published after January 1, 2008?</td><td>Yes No</td></tr>
<tr><td>3a. Is this study an original empirical investigation or review of original investigations of portable electronic device use and driving?
3b. Does this study seem like a duplicate publication of a prior study?</td><td rowspan="2">3a Yes No

3b Potential Duplicate</td></tr>
<tr><td>Include: Investigation Review

Exclude: Duplicate publication of same study/review</td></tr>
<tr><td>4. Does this study have appropriate study methodology?</td><td rowspan="2">Yes No</td></tr>
<tr><td>Include:
Chapter 3: Roadside observation; Naturalistic driving; Self-report
Chapter 4: Naturalistic driving; Experimental (Closed track, Live roadway, simulator)
Chapter 5: Naturalistic driving; Crash-based; Experimental- Live roadway
Exclude:
Chapter 3: Crash-based (prospective and retrospective); Experimental
Chapter 4: Self-report; Crash-based
Chapter 5: Experimental- Closed track, Simulator; Self-report</td></tr>
<tr><td>5. Is the study sampled from the U.S. population or findings relevant to the U.S. population?</td><td>Yes No</td></tr>
<tr><td>Include:
Chapter 3 and 5: U.S. samples or a non-U.S. based sample with a novel finding/approach
Chapter 4 and 6: U.S. and/or non-U.S. based samples</td><td>Yes No</td></tr>
<tr><td>6. Recommended decision based on relevance criteria:</td><td rowspan="2">Include Exclude
Potential Duplicate</td></tr>
<tr><td>Exclude: If "no" answer to any item 3a-9 above or does not fit any of the chapter topics.
Flag: Potential duplicate (yes to 3b)</td></tr>
<tr><td colspan="2">Comments:</td></tr>
</table>

Internal Validity	
1. Were the same underlying inclusion/exclusion criteria used consistently for all the cases or subjects involved?	Yes No Not reported Send to Team 2
2. Did the researchers adequately deal with potential external confounding factors when making their conclusions?	Yes No Not reported Send to Team 2
3. Were the independent variables valid, reliable, and implemented consistently across all study cases/participants?	Yes No Not reported Send to Team 2
4. Was an appropriate sample size justification, power description, or variance and effect estimates provided?	Yes No Not reported Send to Team 2
Construct Validity	
5. Were the outcome measures (dependent variables) valid, reliable, and consistently assessed across all study cases/participants?	Yes No Not reported Send to Team 2
Statistical Validity	
6. Was an appropriate analysis conducted?	Yes No Not reported Send to Team 2
6a. Are estimates of variability/dispersion included or calculable from the data?[2]	Yes No Not applicable Send to Team 2
6b. Are estimates of effect size included or calculable from the data?	Yes No Not applicable Send to Team 2
6c. Are sample sizes for weighting effect sizes included or easily obtainable?	Yes No Not applicable Send to Team 2

[2] For statistical validity numbers 6a, 6b, and 6c, the assessment was for potential meta-analyses. Meta-analyses were not conducted on the documents.

External Validity	
7. Is the study population representative of distracted drivers?	Yes No Not reported Send to Team 2
8. Are the outcome measures relevant to the chapter(s) focus?	Yes No Not reported Send to Team 2

Other Threats to Validity	
9. Is there a conflict of interest that could affect the objectivity of the author(s)?	Yes No Not reported Send to Team 2

Recommended Level of Author Attention

Probably important
Likely important
Probably not important'

Retain beyond bibliography and re-review in context of other studies

Recommend re-examination after full context of pool of studies is known

Comments:

Summary

10. Does the abstract sufficiently summarize the study? (If not, note key information omitted)

Yes
No ____

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December 2024

U.S. Department
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National Highway
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Administration

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