Emergency Vehicle Operator On-Board Device Distractions

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Abstract

For emergency response professionals, including police officers, fire fighters, and emergency medical technicians, driving emergency vehicles (such as police cruisers, fire engines, and ambulances, among others) is a major part of their daily activities. The vehicles serve to transport the professionals when responding to dangerous situations or community members in distress, store supplies and technologies needed to perform emergency response duties, and serve as a makeshift workstation for information gathering and documentation related to these duties. The in-vehicle information technologies onboard these vehicles have become essential in the provision of effective and timely response, and new technologies are being introduced regularly. While they can support emergency operations by facilitating easy access to necessary information, there is a potential downside to the introduction of these technologies in that they can endanger the professionals and other drivers on the road when drivers choose (or are required) to interact with the technology while piloting the vehicle.

In an emergency situation, the drivers of these vehicles may need to take drastic steps to minimize the time required to travel to the emergency location, such as driving above the posted speed limit, running red lights, and driving off-road or on the wrong side of the road. As these steps heighten the risk and/or severity of potential consequences associated with crashes, it is critically important for the drivers to keep their attention focused as much as possible on their surroundings as they navigate the vehicle. Despite operating in emergency mode a fairly small percentage of time that the vehicles are in use, in the last ten years 49.3% of the fatalities that involved emergency vehicles in the United States took place when the vehicle was operating in emergency mode (NHTSA FARS and GES Reports, 2002-2012). The higher degree of cognitive workload and stress for drivers that can be associated with emergency mode likely contributes to these crashes, and interactions with in-vehicle technologies under these conditions can further increase workload, thus exacerbating the risk of errors and accidents. Operations in emergency mode, however, are not the only cause for concern, as at least anecdotal evidence suggests that the technologies increase crashes related to driver distraction under benign non-emergency contexts as well.

The following report aims at exploring the technologies and required interactions with those technologies that show the potential for introducing problems for emergency vehicle operators related to high cognitive workload and distraction, and how these problems impact driving performance and safety. The report also delves into the theory of human information processing as it relates to these issues, and applies it to create some basic design guidelines to minimize the likelihood and severity of consequences associated with these problems, ultimately reducing crash rates and informing the design of safer and more efficient in-vehicle systems for emergency vehicles.

Keywords: Emergency vehicles, distraction, mobile computer terminal (MCT), in-vehicle technology

Introduction

In most communities, emergency services include crisis intervention personnel in three primary categories: firefighting, emergency medical services (EMS), and law enforcement. The organization and size of the workforce for each service differs according to the population and resources available in each community. Across the 30,100 fire departments (Karter & Stein, 2012), and 17,985 state and local law enforcement agencies (Reaves, 2011a) providing emergency services in the United States, a wide range of different vehicles and onboard technologies are employed. Despite differences in departmental resources and equipment, a common growing problem in these domains is that the increasing availability and sophistication of in-vehicle information technologies may be contributing to a rise in problems related to emergency vehicle driver distraction.

Introduction of modern Mobile Data Terminal (MDT) systems (see Figure 1) has supported rapid, secure access to comprehensive information for emergency personnel (Hampton & Langham, 2005). MDTs have evolved to today’s Mobile Computer Terminals (MCTs) which host functions such as Computer Aided Dispatch (CAD) – an in-vehicle dispatch system software which permits 1-to-1 contact between responders and dispatchers (or the dispatch database) – can keep responders better informed during response activities, thus supporting strategic and tactical planning without overwhelming radio communication channels. Interacting with the MCT has become so integral in police patrol vehicles that it is now the most frequently performed in-vehicle task by the drivers (McKinnon, Callaghan, & Dickerson, 2011). A driver will use the MCT for approximately 13% of their shift time in a typical day (Girouard, Rae, Croll, Callaghan, McKinnon, & Albert, 2013).

Across the United States, almost all police departments use MCT systems to some extent (Brewer, 2008), and 90% of departments serving communities of at least 25,000 people use some form of in-field computer systems (Reaves, 2011b). This percentage will continue to rise with ongoing technological advances. Similar systems are commonly installed in fire engines and EMS vehicles to serve similar functionality. With the widespread implementation of this technology, not enough attention has been given to the potential downside that these technologies embody, in that they increase the potential for distracting an emergency vehicle driver, as evidenced by an increase in distraction-related emergency vehicle accidents. In order to improve safety for emergency operators and members of their communities, there is a need to know more about how the technology can affect the cognitive workload or orientation of attentional resources for emergency response personnel.

Emergency response personnel experience higher physical demands and, at times, higher cognitive demands than those in most other occupations (Anderson, Plecas, & Segger, 2001). Therefore the introduction of technologies that effectively increase this workload can be especially problematic for their driving performance and safety. Although safety protocol will commonly dictate that interactions with the in-vehicle information systems be conducted only while the vehicle is stationary and/or by personnel other than the driver, most in-vehicle systems are capable of being operated by the driver when the vehicle is in motion, and response duties can require the driver's attention or response at any given time. Whether due to necessity because of the time constraints and/or severity of an emergency, temptation to work around inefficient regulations, and/or overconfidence in one's ability to multitask, emergency vehicle drivers frequently use the system while in motion. This is despite the fact that frequent activities such as looking for information or acknowledging notifications sent by dispatchers (Hampton & Langham, 2005) can be thought of as similar activities to reading and/or responding to text messages while driving, for which the dangers are well-studied (e.g., Fitch et al., 2013; Strayer, Drews, & Johnston, 2003; Yager, 2013).

In addition to installed equipment, mobile devices such as smartphones also must be considered as technologies that are potentially distracting to emergency vehicle drivers. Using a cell phone for texting is a common means of communication among emergency operators on the job, and texting is very similar in terms of cognitive and motor requirements to interactions with MCTs. Both tasks impose high demands on the Visual-Manual-Spatial resources of the driver, and these resources are also in demand for the driving task. Most mobile technologies and embedded technologies have a visual display that engages the visual channel of the user, and most have either a physical-button or touchscreen interface requiring manual interaction to operate. Both types of systems require spatial attentional resources to orient oneself within the environment and within the display, and to manually interact with the systems, and these resources are also required in orienting the vehicle in the external driving environment. Although there is no evidence comparing the complexity of use between cell phones and MCTs which would inform relative impact on distraction, each system is used to conduct a diverse set of tasks that can increase the cognitive workload of the operator, possibly to the detriment of driving performance and safety.

Figure 1. Types of MCTs installed in emergency vehicles (left: in a fire engine; right: in a police cruiser)

A recent article by retired Chief of Police Richard J. Ashton entitled “Distracted Driving: An Ongoing Problem” explains how the required duties of a police officer involve multitasking that can divert an officer’s attention away from driving. For example, while en route to respond to an emergency situation, officers may need to activate emergency equipment, query or acknowledge calls from dispatchers or other responders, monitor and respond to messages on mobile data terminals or communicate over the radio. Additionally, police officers may choose to engage in the same types of activities as many civilian drivers, such as eating or talking on a cell phone, while performing the required multitask set (Ashton, 2012). Attempting to undertake multiple tasks simultaneously often compromises one’s ability to perform any of the tasks as effectively as when they are conducted in isolation, and therefore driving performance and safety will decline considerably when the multitask workload is sufficiently high.

Technology Overview

To better understand the scope of the study, it is important to identify the key elements emergency vehicle operators commonly interact with. Common emergency vehicles for police officers include large sedans such as the classic Ford Crown Victoria, Chevrolet Impala, Dodge Intrepid and Charger, or SUVs such as the Chevrolet Tahoe or Suburban. Fire engines and related fire response vehicles are commonly manufactured by Pierce, Spartan ERV, and FWD Seagrave. Ambulance makes and models have a bit more diversity depending on their classification: Type I ambulances are built with the chassis-cabs of light duty pickup-trucks; Type II ambulances are modeled from modern passenger/cargo vans; and Type III Ambulances are built from chassis-cabs of light duty vans. Typically, types I and II have advanced Life Support equipment and capabilities and Type III ambulances provide Basic Life Support. The layout of the in-vehicle information systems can vary across the police/fire/medical domains and also from department to department within a domain (see Figure 2). Across all domains, common in-vehicle information technologies include:

- Mobile Computer Terminals (MCTs)
- Video cameras and displays
- Multi-channel radio systems
- Siren and light control panels
- Speed-measuring RADAR or LIDAR systems

Each of these systems will be briefly described in the next sections.

Mobile Computer Terminals (MCTs) and Video Cameras and Displays

The MCT provides essential information for emergency response, and also serves as a portal for communicating with dispatchers/other responders and entering reports. MCTs commonly run customized Computer Aided Dispatch (CAD) software that provides information in a visual form, supplementing or replacing the need for the information provided by dispatchers via mobile radio. Operators in an Emergency Operations Center (EOC) can relay most or all of the information present in the MCT via the radio when requested. The option of radio communications reduces the need to interact with the MCT, but the advantage of a visual format is that the information can be processed at the convenience of the emergency responder, rather than requiring immediate attention to each incoming radio communication.

An MCT often consists of a rugged laptop or tablet with an attached keyboard and touchpad and/or touchscreen functionality for selecting fields or functions. The laptop/tablet may be mounted on a swivel base that allows it to be within easy reach of the driver, at least with one hand. Touchscreen-enabled monitors can make navigation though MCT software faster, but often the touchpad is preferred for better precision in selection and/or for easier conduction of tasks which require alternating selection and keyboard input. Some MCT systems also have functionality that supports auditory notifications and verbal annunciation of notifications and notes related to the response situation (commonly referred to as “call notes”).

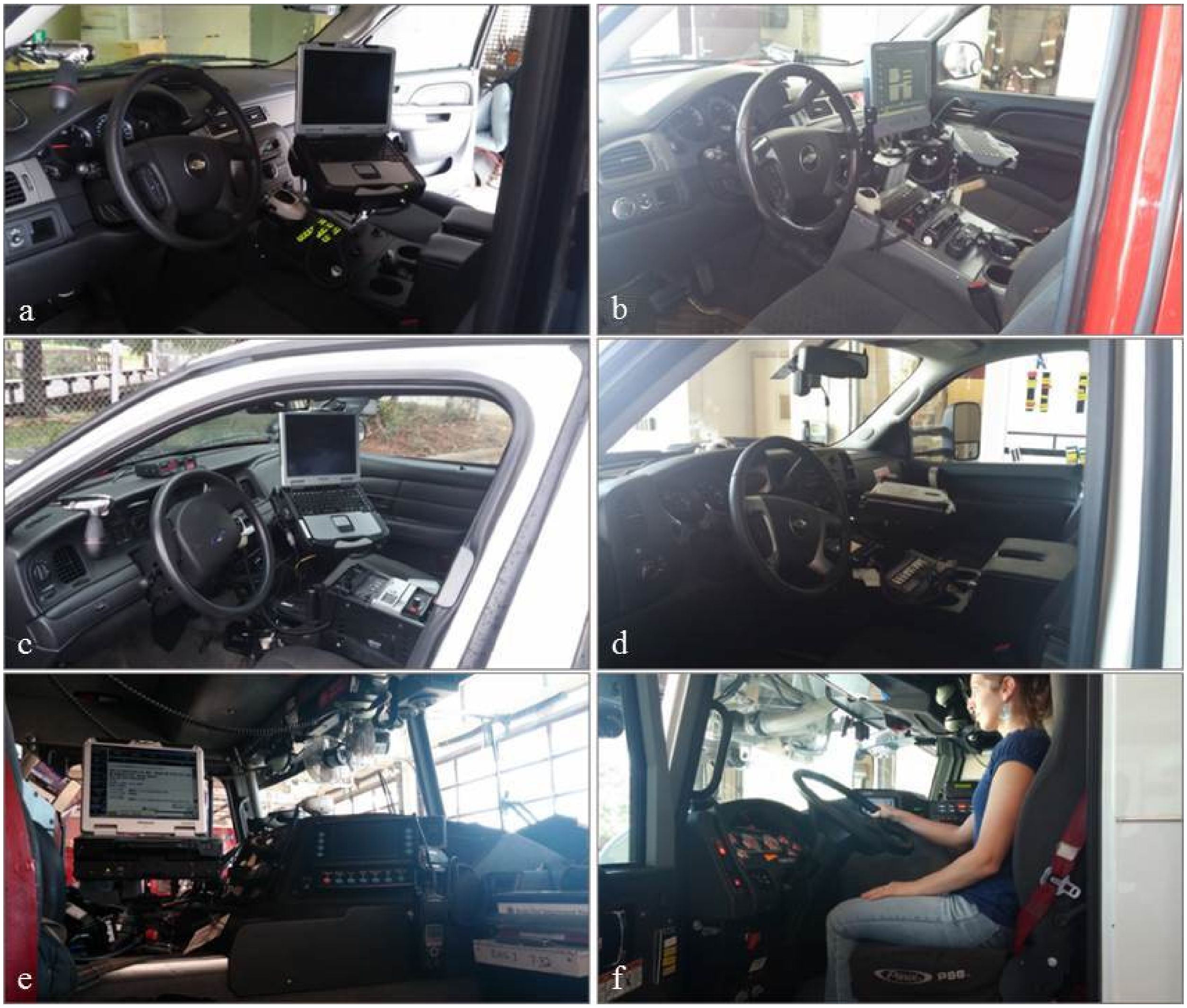

Figure 2. Typical emergency vehicle cockpit setup (from left to right, top to bottom) a) Police SUV (Chevrolet Tahoe), b) Fire Battalion Chief truck, c) Police cruiser (Ford Crown Victoria), d) Fire EMS vehicle, e) Fire ladder truck (passenger side), f) Fire ladder truck (driver side)

Common software capabilities on MCTs include a map/GPS system, access to call notes, current locations and assignments of fellow personnel, and video recording modules. The call notes module provides the user with information relevant to the case being responded to, including time-stamped notes entered by dispatch or other responders related to the associated address/telephone number/individual. Commonly, responders need to know information related to the present emergency call as well as any associated previous calls linked to the person requiring assistance or the location of the call. The response crew can then prepare en route, plan strategies, and communicate tactical information among multiple response units. Call notes are updated in real time whenever any new information is entered into the system. Figure 3(a) shows an example of call notes being displayed on an MCT.

An example of an electronic local map display can be seen in Figure 3(b). These maps can be loaded via an internet connection but are commonly preloaded and stored on the MCT in order to avoid problems associated with network outages. Some MCTs require manual updates to assure up-to-date and accurate map information. Also, unlike most common GPS navigation systems, some MCTs include only static map images rather than dynamically updating maps based on location. Turn-by-turn GPS-guided navigation instructions are also usually not included, as these are unnecessary for a driver who is familiar with the area and therefore may be unnecessarily distracting. Other key objects of interest can also be included in these maps; for example, MCT maps in fire engines also commonly mark the positions of water hydrants. Other modules can also display building layouts and hazards, as well as blocked streets and detours.

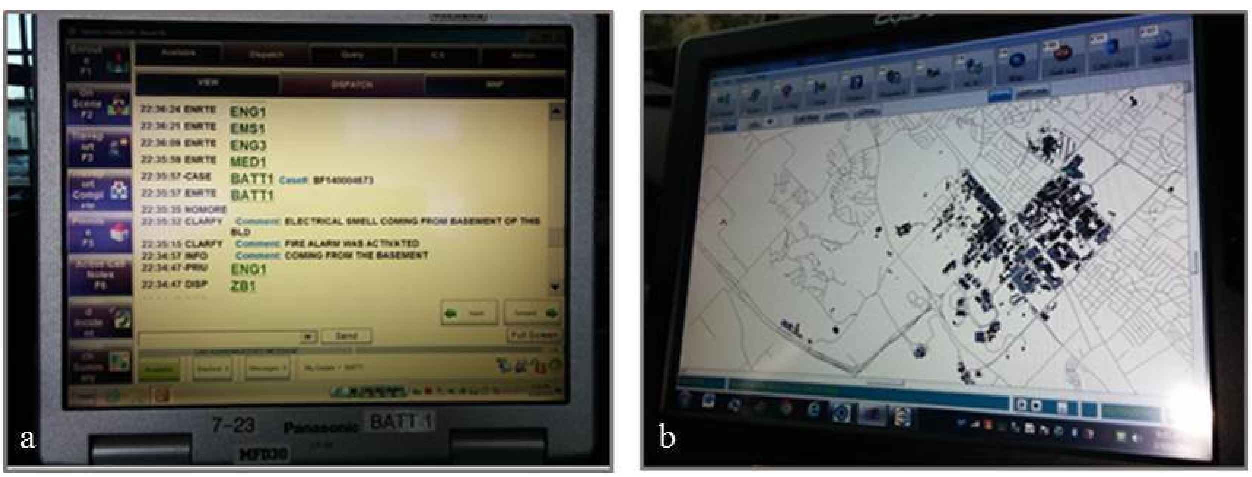

Figure 3. a) Call notes module, b) Map module

Figure 4 illustrates the diversity in the types of MCT display screens and interaction methods, which is due in part to specialized functional needs in each domain.

Figure 4. Additional MCT functionalities (clockwise from top left) a) Ambulance home screen, b) Video recording module, c) Dispatch record log, d) Live unit status listing

Many emergency vehicles are outfitted with video cameras and video display systems. These are activated and controlled either manually or by MCT software (see Figure 4(b)) and may be automatically activated under some contexts (such as when in emergency mode). Larger vehicles such as fire engines can also be outfitted with cameras that support the driver by providing views of the rear and blind spots of the vehicle. These feeds may be displayed on the MCT or on a separate monitor that is accessible to drivers and dedicated to this purpose. The driver can benefit from these video feeds when making difficult turns or maneuvers when in close proximity to outside obstacles and pedestrians.

In police patrol vehicles, CAD software can also show the current status of other patrol vehicles on duty, providing the officer with details on the current locations and tasks being carried out by each active unit. This information is vital for recognizing if a fellow officer is inside his or her vehicle (and thus likely more available for communication), or if they require assistance. Police CAD software is also capable of looking up driver information by querying driver's licenses or vehicle license plates to obtain related records about previous offenses or owner information. While responders are instructed and trained to access these functions only when the vehicle is stationary, it is not always practical or even advisable to pull over a moving vehicle to perform this necessary interaction. This results in an inherent motivation to at least minimally interact with CAD software while driving. This motivation is also present in other emergency domains; for example, ambulance drivers may use the system to identify the closest hospitals for their destination and enter patient information before departing from the response site (see Figure 5). However, sometimes circumstances surrounding the patient's state or the availability of resources at hospitals change en route and new information must be communicated while making all attempts to avoid delaying the patient's transportation to a care facility.

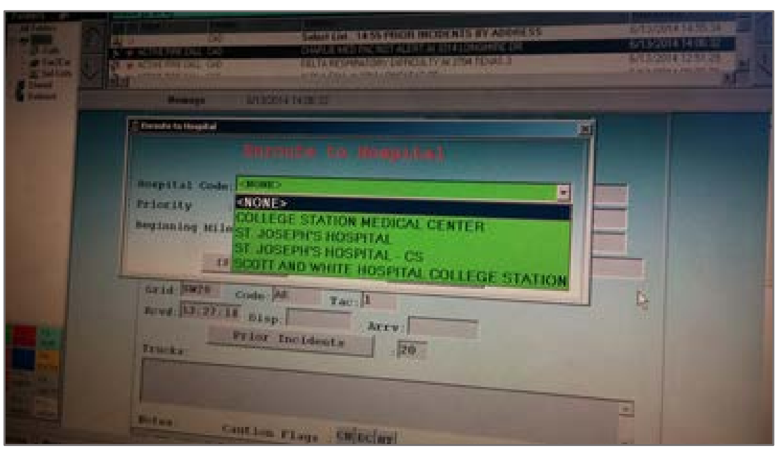

Figure 5. Ambulance reporting module

Another feature common to MCT systems is instant messaging, for which drivers can contact dispatchers or other active units through personal or group messages. This communication channel is frequently used in the same contexts in which text messages would be a preferred mode of communication. MCTs can also be programmed with a “single button response function” which allows the driver to acknowledge a message from the dispatch. Some departments, such as the Tarrant’s Sheriff’s Office in the Dallas/Fort Worth Metroplex (Friedman, 2013) have policies that allow the driver to use only these single button responses while driving and instruct the driver to pull over to a safe location to perform any advanced functions.

Finally, MCTs can also support submission of reports of response activities when a situation has been resolved and personnel must continue to another activity before returning to an office location. Some MCTs allow access to e-mail (which can be used for official business) and limited internet access.

Multi-channel Radio Systems

Multi-channel radios are one of the most crucial systems in emergency vehicles. Emergency responders will commonly keep the radio tuned to a primary channel which may involve several concurrent conversations among dispatchers and other responders (“radio chatter”). Secondary radio channels may also be used if the primary channel is overcrowded or if specific information needs to be provided only to a subset of personnel, such as those responding to one particular call. The radio is usually the quickest way for responders to reach dispatchers, and if they cannot use the MCT or another information technology device, the dispatcher is capable of providing him/her with the information requested via the radio. Often in-vehicle radios are activated via handsets, however some include headsets which can facilitate radio and/or intercom communications with other personnel, such as a team of fire fighters in a fire engine. Figure 6 shows examples of a few radio modules, many of which also include integrated siren and light control panels.

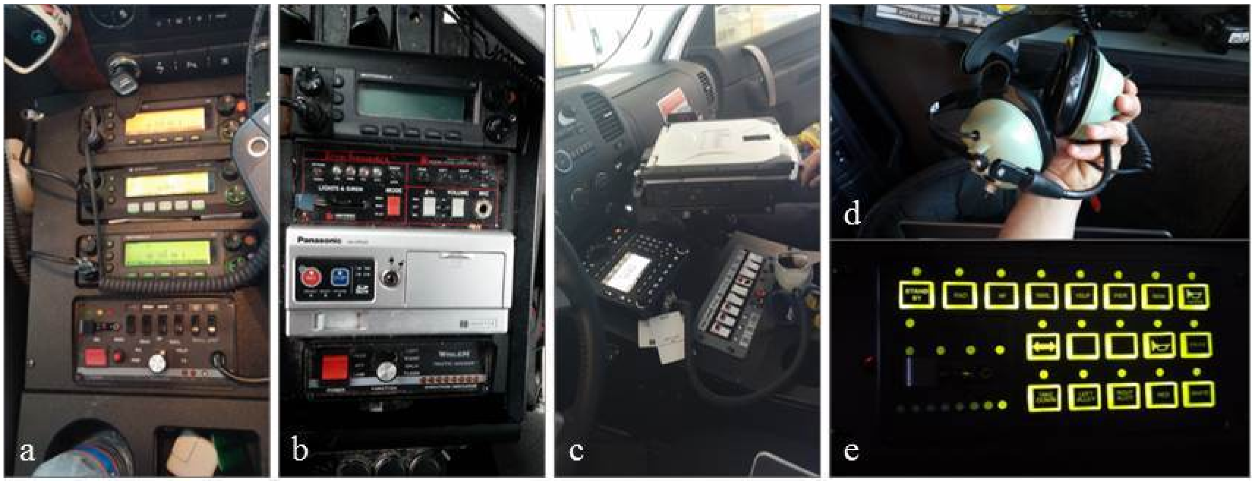

Figure 6. Various multi-channel radio systems (from left to right) a) Active primary and secondary radios in Battalion Chief's vehicle, b) and c) Integrated multi-channel radio controls with siren and light control panel, d) Headset with radio and intercom communication, e) Siren and light control panel

Siren and Light Control Panels

These systems (see Figure 6(e)) are commonly controlled through physical buttons/dials/switches which provide haptic feedback to minimize the amount of visual attention that must be given to activate the controls. Some newer systems may include multifunctional hot keys, which can be physical buttons or reconfigurable touchscreen buttons that activate pre-programmed functions. Because there are many siren and light combinations that emergency responders may need to activate, these control panels can be fairly complex.

Speed Measurement Systems

RADAR and LIDAR systems can be used by police officers to measure the travelling speed of nearby vehicles (see Figure 7). Some systems include functionality for automated detection of the speeds of vehicles within the sensor range, displaying the speed in a digital readout. Additionally, some systems include auditory feedback which maps the pitch or another dimension of the auditory signal to the vehicle speed. While these systems vary broadly, similar controls are used to activate them or modify system settings.

Figure 7. RADAR System

In addition to the equipment described in the above sections, many emergency response vehicle drivers carry personal or department-issued smartphones and use them to send and receive messages (whether job-related or personal). Many departments will provide official cell phones, and may even discourage the use or carrying of a personal device. Responders can use these familiar technologies to place calls to dispatchers, look for route guidance (e.g., using GPS functionality) and to communicate privately with co-workers or other acquaintances, since these conversations are not automatically recorded like those conducted via the official radio system or MCT-supported instant messaging.

Emergency Vehicle Driver Distraction Statistics and Anecdotal Data

Driver distraction is of a major concern to road safety. According to the National Highway Traffic Safety Administration (NHTSA), 10% of fatal crashes and 18% of injury related crashes in the United States are caused by a driver being distracted at the time of the incident. In 2012, driver distraction was listed as a contributing factor in 3,328 vehicle fatalities and 421,000 injuries (NHTSA, 2014b). In addition to fatalities for passengers in the distracted driver's vehicle and in other vehicles involved in the crash, non-occupant (e.g., pedestrian) fatalities are also attributable to driver distraction, with 540 non-occupant fatalities due to driver distraction in 2012 (NHTSA, 2014b).

Cell phone usage is listed as the main source of driver distraction in 13% of fatal crashes and 7% of all crashes (NHTSA, 2014b). An observational study by NHTSA's National Occupant Protection Use Surveys (NOPUS) showed that at any given time during daylight hours an estimated 660,000 drivers are using a cell phone or electronic device while driving (NHTSA, 2014c). This number is increasing despite recent research illustrating the clear distracting effects of cell phone use during driving (Fitch et al., 2013; Strayer et al., 2003; Yager, 2013), numerous campaigns to highlight the dangers and discourage this practice, and legal restrictions in many parts of the United States. NHTSA publishes the total number of vehicle-related fatalities and injuries every year in the Fatality Analysis Reporting System (FARS) and the General Estimates System (GES) reports (NHTSA, 2014a), and often the data can be parsed to show how often crashes are associated with emergency vehicles and the mode of operation. The most recently-published reports show that in 2012 emergency vehicle crashes recorded 131 fatalities, with 60 of these (about 46%) occurring while in emergency mode. Most of these fatalities (71%) were occupants in other vehicles or people outside the vehicle (NHTSA, 2014a). Unfortunately, these reports offer limited use for determining the causal factors of the crashes, but it might be assumed that the percentage of crashes involving distracted emergency vehicle drivers are similar to those of the general crash statistics.

Table 1 below shows FARS and GES data from 2002 to 2012. As can be seen, police vehicles are involved in considerably more fatalities than fire or emergency medical vehicles. There are a number of potential reasons for this difference, likely heavily influenced by a larger number of police patrol vehicles on the road at any given time. Another factor that will be discussed later in this report is that police patrol vehicles are more likely to be single-crewed, leaving the driver responsible for carrying out all tasks in the cockpit, thus increasing the risk of being distracted. The number of fatalities that occur in emergency and non-emergency mode for each type of vehicle are roughly equal, although the vehicles operate in emergency mode less often.

Table 1. Fatalities involving emergency vehicles from 2002-2012 (NHTSA FARS and GES report)

Year	Police Vahicles			Fire Vehicles			Ambulances			Total Fatalities	In emergency use	%
	Fatalities	In emergency use	%	Fatalities	In emergency use	%	Fatalities	In emergency use	%			
2002	119	59	50	12	8	67	22	10	45	153	77	50
2003	141	69	49	24	19	79	29	18	62	194	106	55
2004	112	46	41	21	14	67	35	21	60	168	81	48
2005	108	44	41	29	19	66	49	27	55	186	90	48
2006	117	39	33	19	16	84	25	12	48	161	67	42
2007	132	62	47	22	21	95	37	25	68	191	108	57
2008	106	54	51	26	15	58	31	15	48	163	84	52
2009	90	33	37	17	9	53	35	18	51	142	60	42
2010	84	43	51	14	9	64	31	15	48	129	67	52
2011	81	38	47	6	4	67	21	9	43	108	51	47
2012	83	35	42	14	9	64	34	16	47	131	60	46

Inattention has been listed as a major cause in ambulance crashes. For ambulances en route to a scene but in non-emergency mode, inattention of the ambulance driver was the second most frequent cause at 22.6% (failure to yield being the first at 58.1%). In emergency mode (with sirens and lights activated), inattention was the most frequent cause of crashes at 45.9% (Saunders & Heye, 1994).

In a study of a sample of 378 police-involved vehicle crash claims between 2006 and 2010, distracted driving was a factor in 14% of the crashes (Citrowske et al., 2011). This same study found that 12% of crashes were attributable to distraction caused by technology in police vehicles, with the MCT (7%) being the most frequently-cited technology (Citrowske et al., 2011).

A data collection effort was conducted by the study team to clarify the extent of distraction-related accidents through Public Information Requests to police departments in major metropolitan locations and state Department of Transportation officials across the United States. Metropolitan areas were targeted for their higher likelihood of maintaining crash statistics, but nevertheless the vast majority of requests were responded to negatively, most often with officials stating that they do not maintain these records and thus cannot provide them.

Though only a few of these requests have been satisfactorily answered at the time of this report, the collected data show that as expected, a high number of crashes can be attributed to distracted driving. Unfortunately, accident reporting is often not completed at a level of detail that can be used to pinpoint the specific causes of distraction.

The Kansas City (Missouri) Police Department (KCPD) recorded a total of 181 crashes from the year 2009 up to November 30, 2014, an average of over 30 per year. The yearly distribution has been shown in Table 2. All of these crashes were deemed preventable and the primary cause was listed as inattentive/distracted, however the causes for these distraction were not recorded (M. Luster, personal communication, December 4, 2014).

Table 2. Total number of police vehicle crashes in Kansas City Missouri Police Department

Year	Number of Crashes
01/01/2009 - 12/31/2009	45
01/01/2010 - 12/31/2010	29
01/01/2011 - 12/31/2011	34
01/01/2012 - 12/31/2012	29
01/01/2013 - 12/31/2013	21
01/01/2014 - 11/30/2014	23
Total	**181**

In the state of Texas, 1021 total crashes of emergency vehicles were recorded from 2010 to 2014. All these crashes were attributed to distraction/inattention, although as was the case with the KCPD data, specific causes of these distractions have not been recorded. Out of these crashes 310 caused some sort of injury, and 4 crashes were fatal (A. Hatchitt, personal communication, December 1, 2014). The Austin (Texas) Police Department experienced 48 patrol car crashes from 2010 through October, 2014 that were attributed to distracted driving. In 25 of these 48 instances, the police officer was interacting with the MCT at the time of the accident, and in 8 other instances, they were interacting with a cell phone or other on-board equipment (L. Cortinas, personal communication, October 29, 2014).

The Illinois Department of Transportation recorded a total of 137 emergency vehicle crashes attributed to distraction from inside the vehicle from the years 2010 to 2012. Table 3 shows the distribution of these crashes, although these attributes were assigned to the crash as a whole and does not indicate the fault of a particular person or vehicle (C. Adams, personal communication, November 14, 2014).

Table 3. Total number of emergency vehicle crashes attributed to distracted driving in the state of Illinois.

	2010	2011	2012
Ambulance			
Distraction - From Inside Vehicle	1	4	1
Distraction – operating a wireless phone	2	1	-
Distraction – Other Electronic Device (Navigation Device, DVD Player, etc.)	1	-	-
Fire			
Distraction - From Inside Vehicle	4	1	3
Distraction – operating a wireless phone	1	-	-
Police			
Distraction - From Inside Vehicle	24	35	28
Distraction – operating a wireless phone	4	3	6
Distraction – Other Electronic Device (Navigation Device, DVD Player, etc.)	8	4	6
Total	**45**	**48**	**44**

The Florida Department of Transportation recorded 1881 crashes from 2011 – 2013. Table 4 shows how injuries occurred in most reported crashes (79%), and that there were roughly 6 fatalities in each of the three years. Additionally, the Florida DOT provided data on emergency vehicle crashes that resulted only in property damage; most other data sources did not provide this level of detail (L. Ringers, personal communication, December 15, 2014).

Table 4. Total number of emergency vehicle crashes attributed to distracted driving in the state of Florida.

Year	Fatal Crash Statistics			Injury Crash Statistics		Property Damage Only	Totals		
	Crashes	Fatalities	Injuries	Crashes	Injuries	Crashes	Crashes	Fatalities	Injuries
2011	5	5	2	334	556	406	745	5	558
2012	6	6	3	303	483	290	599	6	486
2013	6	6	2	265	437	266	537	6	439
Tota	**17**	**17**	**7**	**902**	**1476**	**962**	**1881**	**17**	**1483**

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Abdelwanis (2013) investigated emergency vehicle crash causes in South Carolina between 2001 and 2010, and findings are concurrent with data collected from other states. The South Carolina Department of Public Safety reported that 803 emergency vehicle accidents causing injury (5.69%) were attributable to driver distraction. Along with driver fatigue, distraction is listed as one of the primary contributing factors to these accidents (Abdelwanis, 2013). Furthermore, distracted emergency vehicle drivers were more likely to be in head-on collisions with other vehicles than in single-vehicle collisions. Head-on collisions were also identified as more likely to result in fatalities than the other types of collisions investigated (Abdelwanis, 2013).

Although these statistics begin to illustrate the extent of the problem, it is difficult to draw generalized conclusions about the causes, and in particular, how often driver distraction issues are the largest contributor to emergency vehicle incidents and crashes. Due to this limitation of accident databases, insight can be gained into the nature of the problem with anecdotal data, which is used to inform a large body of studies on this topic (Richtel, 2010). These data can be found through personal exchanges with officials and public sources such as Firefighterclosecalls.com or news outlets reporting isolated cases in the local community. Often these data are sensitive and may impact the job security of those involved; as a result it is expected that the details of similar accidents tend to be under-reported. Some examples of impactful anecdotes from across the United States that illustrate the nature of emergency vehicle driver distraction and the effects on crash risk are given below:

- In August 2014 an ambulance driver in Columbus, OH veered off the road and crashed into the guardrail and rolled over multiple times. The patient onboard died due to injuries experienced when he was ejected from the vehicle. The driver admitted to being distracted and looking at the GPS device, trying to determine the estimated time of arrival to the hospital (Shea, 2014).
- In May of 2010, a distracted officer in Austin, TX ran a stop sign and crashed into a 74-year-old man on a motorcycle, who suffered multiple injuries. The police report showed that the officer was adding notes into the MCT when the crash occurred (Friedman, 2013).

- In 2009 a police officer was hurt and her vehicle was totaled after crashing into a tank truck that had stopped at a rail crossing in Jacksonville, FL. Reports from the scene stated that the officer was looking at her dashboard-mounted laptop computer moments before the crash (“Police Vehicle Crash,” 2009).
- In 2011 an ambulance was responding to a non-emergency call in Huntington Beach, CA. The ambulance when it hit multiple vehicles stopped at an intersection. The police report states: "(The driver) was reading about the medical call he was headed to on the ambulance mobile data computer and as he was reading the call, he heard his partner in the passenger seat yell 'whoa.'" Without the passenger’s verbal warning this crash may have been even more severe (“Claim: Ambulance without Siren,” 2011).
- In early 2014, a New York police officer was looking at the computer inside his patrol car when he ran a red light and collided with an unmarked police vehicle. Fortunately, neither officer was injured (Associated Press, 2014).
- In 2010, a New York paramedic was keying in information into his MCT on his way to a hospital and narrowly avoided hitting a female pedestrian who had stepped into the street when he happened to look up just in time to slam on his brakes (Richtel, 2010).
- In 2008, an emergency medical technician in West Nyack, NY, was watching his GPS screen when he swerved and hit a parked flatbed truck. The crash sheared off the side of the ambulance and left his partner in the passenger seat paralyzed (Richtel, 2010).
- In 2007, a sheriff’s deputy in St. Clair County, Ill., was driving 35 miles per hour when a dispatcher radioed with an assignment. He entered the address into the mapping system and then looked back to the road too late to avoid hitting a sedan stopped in traffic. Its driver was seriously injured (Richtel, 2010).

For a number of reasons, crashes and near-misses associated with a distracted emergency vehicle driver are not often clearly reported as such (Richtel, 2010), with these anecdotes serving as exceptions to general reporting trends. However, other circumstantial evidence suggests that driver distraction is a growing problem for emergency service drivers. For example, in a personal communication with the research team, an official familiar with police operations in the state of New York reported that recent years have seen an unusually high number of single-car crashes involving police personnel attributed to “swerving to avoid wildlife”. Because the numbers for these types of accidents have not similarly risen in the general population, speculation is that a significant number of these reports may be attributable to causes, such as distracted driving, that officers are not willing to admit to for open records.

Theory of Distracted Driving

Existing theory of human information processing can be consulted to determine how in-vehicle distraction occurs, why it is problematic for performance, and how emergency vehicle technologies and protocol may be re-designed to reduce the negative effects of distraction on driving performance and safety.

Driver Distraction

Driver distraction "occurs when a driver is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object, or person within or outside the vehicle compelled or tended to induce the driver's shifting attention away from the driving task" (Treat, 1980). The Model Minimum Uniform Crash Criteria (MMUCC) Guideline provides a classification system for the different sources/types of driver distraction involved in documented crashes, which helps in identification of crash root causes (MMUCC, 2012) and can guide the development of countermeasures. The different distraction classifications as defined by the MMUCC are:

1. Not Distracted
2. Manually Operating an Electronic Communication Device (texting, typing, dialing)
3. Talking on Hands-Free Electronic Device
4. Talking on Hand-Held Electronic Device
5. Other Activity, Electronic Device
6. Passenger
7. Other Inside the Vehicle (eating, personal hygiene, etc.)
8. Outside the Vehicle (includes unspecified external distractions)
9. Unknown if Distracted

The scope of this paper concentrates on identifying vehicular crashes that fall under the categories 2, 3, 4 and 5, as they may be applied to driver tasks and behavior in emergency vehicles.

A considerable amount of recent research has illustrated how performing secondary tasks, such as interacting with in-vehicle technologies (e.g. mobile phones, navigation devices, entertainment systems) while driving can be problematic. This research highlights driver safety-related effects, such as increased response times to critical roadway events and overall poorer performance in both the driving and secondary tasks (e.g., Strayer, et al., 2003; Horberry, Anderson, Regan, Triggs, & Brown, 2006).

Humans have a limited ability to multitask, and with an understanding of human information processing theory and models, we may be able to identify task sets that are particularly difficult (or not difficult) to perform concurrently. One such theory, Wickens' Multiple Resource Theory, states that if two tasks carried out simultaneously require similar perceptual, cognitive, or response resources, then multitask performance will suffer to the extent that the tasks compete for these limited resources. For example, two tasks requiring visual resources will have a higher likelihood of interference, which can negatively affect performance in one or both tasks, compared to a task set which includes one visual and one auditory task (Wickens, 2002).

As an example, consider the common technological driving aid of a GPS-based navigation system. Entering information into the navigation system while driving has been shown to bring about a reduction in mean speed, compared to a driving-only scenario (Chiang, Brooks, & Weir, 2001), which illustrates compensation behavior due to the multitask performance decrement. Similar performance effects have been found while carrying out relatively simple tasks like adjusting the radio and holding a conversation over a mobile phone (Horberry et al., 2006; Strayer et al., 2003). Phone conversations while driving are some of the most well-studied, resulting in higher cognitive workload, reduction in mean speed, and higher speed variability due to sudden accelerations and heavy braking (Rakauskas, Gugerty, & Ward, 2004).

Decrements in driving performance when performing concurrent secondary tasks can be attributable to attentional allocation issues (Liu, 1996), driving experience (Summala, Lamble, & Laakso, 1998), and high levels of attentional and mental workload associated with an operational context (Hancock & Verwey, 1997). Emergency vehicle drivers are especially susceptible to these issues, as they are commonly operating under higher levels of workload and are required (or at least motivated) to interact with multiple in-vehicle technologies simultaneously. They are commonly faced with even more than one secondary task while driving, which has been shown to impose greater workloads than while performing a single secondary task (Lansdown, Brook-Carter, & Kersloot, 2004).

Secondary Tasks Affecting Driver Performance: Radio Conversation

One of the more frequent activities engaged by emergency vehicle operators is communicating over the radio system with other responders and/or dispatchers. Police patrol vehicles and fire engines commonly have earpieces or headsets and use the radio to allow drivers to keep a relatively constant awareness of radio communication. This level of attention is required to be able to answer an emergency call and/or receive other updates with regard to location, route, or status of the incident in order to respond accordingly. Carrying out a conversation over a remote communication device (such as a cellphone or radio) has been shown to negatively affect driving performance, with slower reaction times and a higher likelihood of missing safety-critical events (Strayer et al., 2003). The task of conducting a conversation requires cognitive resources to process the auditory information and respond to it appropriately, increasing workload demand over driving alone regardless of whether a handheld or hands-free device was used for the conversation (Matthews, Legg, & Charlton, 2003). Because the increase in workload is often attributed more so to the use of a handheld device because of the requirement to engage at least one hand, there can be a tendency to overestimate the relative safety of using hands-free phones while driving (Mazzae, Ranney, Watson, & Wightman, 2004).

Because listening to radio chatter for updates and other information is a routine and well-practiced task for most emergency vehicle drivers, the increase in workload may not always be sufficient to result in observable performance effects. Indeed, even when dual task conditions of driving and listening to the radio show higher levels of cognitive load when measured via physiological markers, the tasks can still be carried out at the same performance level as in single task conditions (Collet, Clarion, Morel, Chapon, & Petit, 2009). A learning curve phenomenon can be observed when driving and performing a secondary task – such as having a cell phone conversation – is practiced over time, illustrating how relative performance improves as the imposed workload for increasingly automatic tasks is reduced (Shinar, Tractinsky, & Compton, 2005). The multitask performance improvement can even reach a level where some driving measures show similar performance in the baseline and dual-task/distraction conditions. One way to explain this observation is that performance effects are not observed until humans approach their personal “redline” of cognitive workload (e.g., Grier et al., 2008), and thus information processing resources remain available to allocate to secondary tasks without impacting the primary task. The problem that this explanation illustrates is that operators may be overconfident in their ability to handle multiple tasks and apparently higher workload. Because people can't easily identify their particular cognitive "redline", they may continue to take on additional tasks, raising their overall levels of workload until they suddenly exceed the redline and performance can steeply decline in either one task or multiple tasks, including maintaining sufficient awareness of one's surroundings and piloting the vehicle (Grier, et al. 2008).

Secondary Tasks Affecting Driver Performance: MCT Interaction

According to a usability analysis using the "Safety Checklist for the Assessment of In-Vehicle Information Systems" (Stevens & Rai, 2000), most current MCT systems are incompatible with the task of driving a vehicle. In addition to requiring a reorientation of attention (away from the road/outside surroundings to the MCT interface), interactions also increase cognitive workload. A common subjective workload survey developed by NASA, the Task Load Index (NASA-TLX; Hart & Staveland, 1988) has been used to show significantly higher levels of driver workload for several MCT interaction tasks, compared to a baseline driving-only scenario (Mitsopoulos-Rubens, Filtness, & Lenné, 2013). Because the design of the MCT requires visual and manual resources for interactions, and these resources are also required for the task of driving the vehicle, this competition among the limited resources can more quickly lead operators to reach workload levels approaching their cognitive redline (Grier et al., 2008; Wickens, 2002)

Double-crewed police patrol vehicles were found to involve interactions with MCT systems almost twice as often as single-crewed vehicles, with some interviews indicating that at times it may be as high as five times as frequent (Hampton & Langham, 2005). This suggests that when more resources are available (as the officer riding in the passenger seat does not have the competing demands of driving the vehicle), there is a tendency for a greater degree of interaction, likely benefitting the response unit by increasing the officers' levels of situation awareness and thus supporting planning and execution of response activities. However, many police departments find that double-crewed vehicles are less cost-effective than single-crewed units, thus tend to assign a single officer to each patrol vehicle. Perhaps an MCT design that better supports informing an officer as they drive their vehicle, which may be done by reducing the competition for information processing resources required to drive the car, might similarly improve the officer's overall situation awareness during response activities.

It is important that emergency responders gain many types of information en route to a response, but one constant in almost every response is a need to know the location where they are needed, as well as the quickest route to get there. Although experienced drivers can benefit from familiarity with locations in their district, both experienced and inexperienced emergency vehicle drivers will inevitably encounter situations which require the aid of a map and/or navigation directions. Emergency vehicles are commonly equipped with a book of printed maps which can be consulted in these cases, and a digitized version of this map book is often available via the MCT. With the ability to execute a speeded search, using the MCT can be a considerably faster method to find specific locations. MCT maps, however, do not always include the provision of route options or turn-by-turn guidance to a given location as do most common navigation systems. Additionally, because the accuracy of these maps can be dependent on manual updates, which may not be done frequently, they may be out-of-date or incomplete.

One potential area to explore further is MCT systems that vocalize some information, and may be controlled by voice input. Such designs can help offload visual resources and thus better support the driver's ability to keep eyes on the road and surroundings, which can lead to better/safer driving performance overall. For example, Srinivasan and Jovanis (1997) showed the best driver performance with a voice-controlled navigation system compared to with a visual map representation similar to those in the MCTs or with paper-based maps. The voice-controlled system supported drivers travelling at more appropriate speeds, committing fewer navigational errors, and reporting lower overall workload (Srinivasan & Jovanis, 1997). Even if voice control is impractical due to environmental constraints, an audible vocalization of some key information, such as navigation instructions, may be beneficial at times. For example, a 1995 study by Dingus et al. found that the addition of vocalized instructions to paper maps and electronic maps reduced visual attention demand and resulted in fewer glances and glance durations at the map screen and away from the road (Dingus et al., 1995). As a result fewer braking errors and lane deviations were observed as compared to without the turn-by-turn vocalized instructions.

While many MCT systems include some sort of vocalization functionality, anecdotal data suggest that they are not commonly used due to a number of usability issues and unaccounted for contextual factors, such as the already high demand for auditory resources imposed by radio communication tasks. However, if these issues can be resolved, the inclusion of voice control and vocalization of some types of information in emergency vehicles might improve the driver's ability to gather information while driving. As evidence for this point, a recent driving simulator study (Filtness, Mitsopoulos-Rubens, & Lenné, 2013) showed how police officers interacting with an MCT system that included an audio-voice interface made fewer safety-critical off-the-road eye glances (defined as glances greater than 2 seconds, which have been linked to increased risk of accidents; Dingus & Klauer, 2008; Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Ryu, Sihn, & Yu, 2013) than systems with the traditional visual-manual interface.

Law enforcement may especially benefit from MCT redesign for a few reasons: 1) police officers tend to be in single-crewed vehicles much more often than are firefighters or EMTs; 2) commonly, officers require or desire more information as they prepare for response activities, due to the unpredictability and potentially malicious intent of people at the root of the incident they are responding to; and 3) the higher degree of codification in common police language (compared to the more naturalistic conversations usually used in fire and EMT responses) may make police communication better suited for vocal-auditory exchanges than for visual text-based messages. On the other hand, an advantage of the more heavily-coded language is that it requires less time to process a complex message, and the ability to quickly re-read/verify the message via a traditional visual display is valuable. A recent study found that the amount of time spent looking at the MCT was lower in the condition where information was displayed in the coded language as compared to the naturalistic language mode (Garrison, Williams, & Carruth, 2012), suggesting a lighter visual load with coded messages. However, since this study also showed an unusually high percentage of time in which participants were looking at the MCT while the vehicle was in motion – 25 to 30% of the time – rather than the road (Garrison et al., 2012), even the more coded data could benefit from further exploration of nonvisual display methods.

Data Collection with Emergency Response Departments

Due in part to the underwhelming response to Public Information Requests and a general lack of published work on this topic, the research team consulted local emergency response departments to gain a deeper understanding of characteristics of tasks and technologies in emergency services domains that may lead to driver distraction problems. This was done by structured and unstructured interviews with professionals in each domain, and a generalized online survey for which data collection is ongoing.

Structured and Unstructured Interviews

The research team visited with several professionals at three police departments and three fire departments in College Station and Bryan, Texas. These meetings consisted of structured and unstructured interviews with front-line responders (police patrol officers, fire fighters, emergency medical technicians), their supervisors (police chief, fire battalion chief), and also training and safety specialists associated with each department. The primary goal of these interviews was to identify problematic contexts involving interactions with in-vehicle technologies with regard to the potential for driver distraction. The research team primarily asked about contexts that responders found themselves in which their job duties required, or at least strongly motivated, interactions with the technologies while driving a vehicle; however common behaviors that were not part of job duties were also noted. In some cases, this included behavior that was explicitly discouraged by supervisors/trainers/safety officers but still was commonly observed (although not necessarily by the particular departments consulted for this research). The interviewees were encouraged to describe both routine and non-routine tasks and situations they had encountered which were especially problematic to conduct while driving.

These interviews provided detailed information to the research team with regard to common equipment installations, the functionalities of the equipment and the frequency of use. They also provided insight into the different routine and non-routine task sets and the various steps involved in performing these actions, as well as behavioral tendencies which could affect the distraction potential of the actions. This allowed the research team to describe task activities according to the basic perceptual, cognitive, and physical resources required by the human operator to process and perform them. As discussed in the previous section, the competition for resources required for driving a vehicle and performing secondary tasks are at the root of performance decrements associated with driver distraction. Some noteworthy examples of these activities, sorted according to the primary resources engaged, are listed in Table 4.

Table 4. Distribution of operator resources required for common in-vehicle tasks

VISUAL TASKS • Driving: visually monitoring the roadway/surroundings and driving-related displays • Monitoring MCT for notifications and activity changes • Reading call notes • Searching for and identifying locations of interest on maps • Viewing live video feeds • Reading environmental data, such as vehicle license plates • Observing speed detection system visual displays	AUDITORY TASKS • Driving: listening for sounds related to the driving/navigation task • Monitoring radio communications from dispatchers or other responders • Communicating directly or over an intercom with other responders in the vehicle • Receiving and interpreting audible cues or vocalizations from MCT • Listening to read-aloud call notes from MCT • Listening to speed detection system auditory output
PHYSICAL TASKS • Driving: manually controlling the speed and heading of the vehicle • Interacting with MCT through touchscreen, touchpad, and keyboard controllers • Interacting with radio controls (handset and console) • Interacting with light and siren controls • Adjusting onboard video system cameras	COGNITIVE TASKS • Driving: cognitive tasks such as route planning, hazard avoidance • Strategic and tactical decision making and planning for response activities • Interpreting call notes and other MCT data • Processing related to in-vehicle control tasks during response activities • Navigating between various MCT function screens

Online Survey of Emergency Responders

In addition to the interviews, an online survey (See Appendix A) was designed to formally collect information from a wider range of fire, rescue, and law-enforcement departments from across the country. The survey was designed to collect data on the most frequently performed tasks and in-vehicle technology interactions. These data can then be used to identify key practices and technology interactions that are contributing to distracted driving. The survey additionally collected data on departmental policies for use of in-vehicle devices and cell phones while driving, and any personal anecdotes of distracted driving that respondees may have encountered.

Though many contacted departments gave positive feedback on the survey effort, a delay in getting Institutional Review Board (IRB) approval to collect these data and general end-of-year business have contributed to a limited response to date. We summarize the response results below, and will update accordingly as more response data become available.

In a response from Austin-Travis County Emergency Medical Services, the most commonly-used equipment was the MCT, and interactions with MCT consumed approximately 10% of on-the-job time. The MCT is mainly relied upon for maps, reading call notes and updating unit status. Radio and cellphones were the next most commonly-used equipment. Responders felt that MCT and cellphone interactions rated considerably higher than radio interactions in terms of imposed mental workload. Communicating with onboard crewmembers and family members in the vehicle were listed as the tasks most frequently performed while driving; neither requires interacting with equipment unless speaking over an in-vehicle intercom system.

The departmental policy for Austin-Travis County responders allow the drivers to read messages on the MCT, but the vehicle must be parked to perform any function that requires the driver to input information into it. The use of cell phone is strictly prohibited unless it is being used in contacting medical control, a patient's family members, or a hospital while the patient is in the ambulance.

Common Task Factors Affecting Workload and Distraction Risk

This section compiles data collected from the interviews and surveys to note common factors that may be targeted in addressing driver distraction-related problems, also noting where there is concurrence with literature on the topic.

Personnel configurations and roles

One contextual factor that affects how tasks are conducted is the personnel configurations in an emergency vehicle. While police vehicles are most commonly single-crewed, they may at times be double-crewed, such as when training new officers. Ambulances are mostly required to be double-crewed, with both EMTs in the vehicle cab on the way to a scene, but usually only one in the cab (the driver) when en route to deliver a patient to a care facility (the other EMT will be tending to the patient). In the case of ambulances, the EMT in the passenger seat uses the MCT to perform any required action when travelling to the patient, thus freeing the driver to focus on that driving task; however after loading the patient and during travel to a care facility, MCT interactions, such as entering any patient and hospital information, must be completed by the driver. Although these interactions can be completed prior to leaving the scene, because of the motivation to get the patient to a care facility as quickly as possible or because at times plans may need to be changed while en route (such as if a patient's condition changes dramatically or care resource availability changes), sometimes MCT interactions are performed by the driver while they are driving.

In fire engines, commonly a fire officer is required to be present in the passenger seat, and additional crewmembers are often in the vehicle cab as well. Only in very rare situations will the fire engine driver drive alone. The officer in the passenger seat is responsible for the use of the MCT en route and communicates critical information to the crewmembers through the intercom system. In emergency scenarios it is often necessary for everyone in the vehicle to put on protective gear, including Self-Contained Breathing Apparati (SCBA), en route to the location. When wearing a gas mask the officer may not be clearly audible for the driver or other crewmembers, or may have difficulty seeing and interacting with the MCT. The officer may also be unable to focus on MCT activities when communicating with crewmembers as part of strategic planning or instructing. Due in part to these reasons, at times the driver may need to attempt to interact with the MCT or other technology normally controlled by the officer to gain critical information from the MCT. In fact, some MCT mountings will be designed to support rotating and moving the MCT within reach of the driver, although commonly departmental regulations will specify that doing so is only recommended in extreme circumstances, if at all.

Fire battalion chiefs commonly travel to an emergency scene in their own vehicle, which serves as a mobile command station, and often they are the only person in the vehicle. A battalion chief is therefore commonly performing several demanding tasks while driving en route to the scene, such as developing and communicating (over radio) strategic and tactical plans with dispatchers and other response units. Often the battalion chief's vehicle is equipped with all the in-vehicle information technologies present in fire engines and other multi-crewed vehicles, and they are expected to operate these technologies with the same proficiency alone and while driving. The task set may be more difficult in some ways; for example, battalion chiefs may have to monitor up to three or more active radios simultaneously so as to not miss out on any essential information being discussed over different channels.

Technology distribution and access

The large number of pieces of equipment installed in vehicle cockpits leaves very little room for movement in the cockpit, especially in police vehicles. Accessing all of the equipment may require awkward postures, taking eyes off the road, and also may lead to musculoskeletal issues. To back up this anecdotal observation, a recent study found that in addition to prolonged seated exposure, MCT use and on-paper documentation in a mobile police environment are the activities most associated with risk factors for musculoskeletal pain and injury (McKinnon, Callaghan, & Dickerson, 2011).

In some vehicles, visibility through the windshield is severely restricted by mounted technologies, such as the MCT screen and forward-looking affixed video cameras (see **Error! Reference source not found.**). This is especially the case in police vehicles, which tend to have a "sleeker" design that already reduces visibility through the windshield. Several interviewed officers reported visibility issues related to in-vehicle equipment as major challenges.

Some controls, such as siren and light controls in some police vehicles, are difficult to access and lack direct visibility of the controls. This is especially problematic for relatively inexperienced officers, as they must contort into uncomfortable positions to see the controls, at least until they have enough experience to recognize controls by haptic feedback.

Figure 8. Example of emergency vehicle technologies causing potential visibility restrictions through police cruiser windshield

Other factors

Fatigue is an interacting factor with many of the aforementioned task characteristics that can increase the risk of driver distraction and crashes (Nelson, 1997). Fatigue can build due to long shift times and/or shifts during times of day or night when circadian rhythms can introduce feelings of sleepiness. Some of those interviewed mentioned how some operators work multiple jobs, which means less rest time and further increases fatigue risk.

Like most technologies, many of the onboard systems experience temporary outages or failures that require troubleshooting from time to time. For example, network services that support a number of MCT functions can go out. A common report associated with "close calls" is the CAD software failing during emergency conditions (e.g., www.firefighterclosecalls.com). Troubleshooting may require personnel (often a driver) to restart the system or perform other actions to resolve the outage, and these activities can take several minutes to complete. Because the information gathered from these systems can be critical to the success of response activities, there is a motivation to get the technologies back online while driving, especially when radio communications are cluttered.

Potential Solutions

The problem of distracted driving will likely continue to be an issue for emergency vehicle operators, just as it will be for the general driving population. However, some measures can be taken to reduce the distraction potential of technologies in emergency vehicles. Indeed, some emergency response departments have identified the severity of the problem and are working to reduce it. For example, in 2010 the state of Washington enacted legislation to make texting and handheld cell phone use while driving a primary offense, but specifically made on-duty law enforcement personnel exempt from this legislation.

Following this enactment, the Washington State Patrol proactively issued an agency order stating that its troopers must additionally refrain from performing these activities while driving. Other states are similarly following suit, with general-population legislation or emergency response agency-mandated restrictions on mobile device use while driving (Ashton, 2014).

As discussed in this report, technology redesign may also better support necessary multitasking for emergency vehicle drivers. The integration of voice control and audible/vocal outputs in MCT interfaces can reduce the amount of mental workload considerably, as well as the demand for specifically visual and manual resources required to drive safely (Vollrath & Torzke 1990). If designed appropriately, these systems may be well-received, as in simulation studies officers have rated voice-based systems higher than the standard visual-manual interface in terms of acceptability and preference, and also voice-based systems reduced physical demand (Mitsopoulos-Rubens, Filtness, & Lenné, 2013).

Table 5 below summarizes some of the most commonly-cited problematic tasks, an estimate of the extent to which they load the visual, spatial, and manual tasks also required for driving the vehicle (e.g., Fitch et al., 2013), and some potential solutions from the literature and as suggested by emergency personnel in interviews and survey responses.

Task	Problems	Visual	Spatial	Manual	Solutions	References
Reading Call Notes	• Information in the form of textual phrases • Need for search through timeline • Increased glance time • Look for any updates on the current scenario	🔴	🟡	🔵	• Use of coded language as compared to naturalistic language • Use of audio-voice interface to interact with MCT	• Garrison, Williams, & Carruth, 2012 • Filtness, Mitsopoulos-Rubens, & Lenné, 2013
Using Map Function	• No turn-by-turn voice guided navigation system on MDT • Basic maps may not show current relative position with respect to destination • Map may not show traffic movement direction	🔴	🔴	🔵	• Use of voice based, turn-by-turn navigation system • Information on landmarks, current relative position displayed	• Srinivasan and Jovanis,1997
Touch and Mouse-pad based interaction	• Requires continuous visual attention to identify current cursor location • Touch screen makes it difficult to access smaller icons/buttons • Requires arm to be rested on a support surface for stability	🔴	🟡	🟡	• Use of audio-voice interface to interact with MCT • Use of larger buttons to improve ease of use through touch-screen (40x40 pixels)	• Filtness, Mitsopoulos-Rubens, & Lenné, 2013 • Sun, Plocher, & Qu, 2007
License plate search (patrol vehicle)	• Involves reading a license plate number and entering it on the MCT • 7 character license plate number to be entered on a keyboard • Reading textual data about vehicle status and background, insurance information, vehicle owner background	🔴	🔴	🟡	• Use of coded language as compared to naturalistic language • Use of audio-voice interface to interact with MCT	• Garrison, Williams, & Carruth, 2012 • Filtness, Mitsopoulos-Rubens, & Lenné, 2013
Hospital Reporting (EMS vehicle)	• Locating closest hospital notifying them on the MDT • Input information on patient status and reason of emergency • Check for updates from hospital or dispatch	🟡	🔵	🔵	• Operation to be performed over the radio to dispatch	
Placement and location of in-vehicle devices	• Multiple equipment can obstruct the view of the driver by creating blind-spots • Require movement of the head away from the road and need to perform uncomfortable manual actions to interact with devices • Prolonged working in non-ergonomic environment can lead to musculoskeletal fatigue and injuries	🔴	🟡	🟡	• More ergonomically designed driver cockpit • Better location of in-vehicle devices	

Table 5. Summary table of potentially distracting tasks: 🔴High Demand; 🟡Moderate Demand; 🔵 Low Demand.

Based on the interviews and survey, a list of frequently performed tasks have been listed. The color coding is assigned based on the level of demand these tasks impose on the visual, spatial and manual resources and the respective problems have been tabulated. Solutions based on past research and practices to improve the system efficiency and safety have also been listed.

Conclusion

Distracted driving is especially problematic and ill-understood in emergency vehicle operations. Although limited, statistical and anecdotal evidence reported here shows that driver distraction is a major cause for emergency vehicle crashes, often resulting in injury and/or death for emergency responders and/or bystanders. Crash data does not commonly record the sources of distraction, however, human information processing theory and empirical evidence from distracted driving research can be consulted to determine likely causes. An extensive body of research has shown secondary tasks which require the same human resources as does the driving task (e.g., vision – to see the roadway and relevant objects, spatial working memory – to process where things are relative to the vehicle, and manual control – to manipulate steering angle and throttle/brake) substantially increase the risk of distraction-related accidents. For example, one of the most problematic secondary tasks to attempt while driving is texting on a smartphone, which requires vision to see incoming and entered texts, spatial working memory to orient oneself to the smartphone and within its interface, and manual resources to manipulate the phone and type.

Data collected from accident databases and also a survey created for this research have identified MCT and/or radio interactions as some of the most frequently-conducted and most problematic from a workload- and distracted-driving perspective. These interactions are integral and essential to most current emergency response paradigms (i.e., they are part of the job description), but they share many processing characteristics as does texting, and frequently induce an even heavier load on human resources than does texting. Compounding this problem is the fact that emergency vehicle drivers is the need to operate in emergency mode, which imposes higher demand on human resources than normal driving, as well as increases risk factors.

In addition to highlighting problematic technologies, there are additionally human, task, and context factors that contribute to distracted driving problems in the emergency response domain. Human factors include experience/expertise in the domain, fatigue from extended or off-schedule shifts and the nature of response work, and a prevalence of personality types that are more likely to be overconfident in one’s ability to multitask while driving. Certain tasks are inherently more problematic than others, such as consulting electronic map displays in MCTs (requires vision and spatial working memory resources) or reading call notes. Context factors include the severity of the response event (inducing stress and affecting information processing and decision making, as well as affecting the load imposed by the driving task), complexity of the response (affecting the types and amount of communication required among cooperating responders), vehicle personnel configuration (single-crewed vehicles are at a much higher risk than double-crewed), and organizational characteristics (such as the presence of state- or department-managed regulations for in-vehicle driver interactions, variations across departments in emphasizing efficiency vs. safety in operations). In seeking technological solutions to the emergency vehicle driver distraction problem, these other factors must be considered in the design process, and these factors themselves may be targeted in solution efforts.

A major challenge in this research effort was the scarcity of causal data available on emergency vehicle crashes. Though many departments/DOTs collect and maintain accident data, there is a lack of standardization in the collection and recording procedures, making it difficult to compare across departments/states. In addition to DOTs, officials in emergency domains at major metropolitan areas were targeted for data requests, but a combination of lack of maintaining these records, ambiguity in point of contact, and the effort required to compile statistics contributed to a limited data collection, and we believe there is a strong need for more research on the causes and effects of emergency vehicle driver distraction. Perhaps a more extensive survey inviting anonymous responses and motivation may serve to provide more specific and honest answers from these domains to get a more accurate understanding of the extent of the problem. Additionally, as we have mentioned in this report, basic human factors research on information processing and multitask performance in emergency vehicle contexts may help increase the understanding of the root causes of the distracted driving problem in emergency operations.

Additionally, human factors research can help identify potential solutions to this problem. This report references a small body of research that tested new interface designs for their potential to better support multitasking and/or safe and effective driving. Such improved designs may help reduce fatalities and injuries and make it safer for emergency response operators as well as the people in the community that they serve. Additionally, our research team has designed a police vehicle driving + MCT interaction simulation study for more extensive evaluation of basic interface characteristics, such as audible annunciation of data, voice input functionality, and the visual format/organization of the data. This research will also measure workload profiles while performing driving and interaction tasks to get a deeper understanding of the information processing load imposed by interface characteristics.

As the problem of emergency vehicle distracted driving permeates public knowledge, we are encouraged by recent steps being taken to address it. Technological solutions, such as the Single Button Response Button facilitate simple communication – such as acknowledgement of a received message – with the touch of an easily-located MCT interface button, reducing the driving risk factors for these sorts of communications. A number of states and individual departments are issuing new regulations to restrict or prohibit device interaction while the vehicle is in motion. Driver and operator training programs, such as the SAFE Driving Campaign's "Did You Know?" ("SAFE Driving Campaign," 2014) are also becoming more commonplace. And we are seeing more attention called to the issue, as evidenced by commentaries and calls to action in emergency response trade journals, such as a recent article in Police Chief (Ashton, 2014). It is our hope that this report, and additional publications which will come from this work, will contribute to this call to action for more attention on this serious issue, and for resources to continue to research the problem and potential solutions.

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Appendix A: In-vehicle Technology Usage Survey

City, State and Department type (Fire, Police, EMS): ________________________

____

1. Please list, in order, three types of equipment with which you most frequently interact with while driving (such as cell-phone, radio, RADAR, MCT/MDT, GPS, etc.).

a.

b.

c.

When interacting with the equipment while driving, please rate the degree of mental workload, from 1 (lowest) to 10 (highest).

a.________________ b.________________ c.________________

2. Please list common tasks you can think of which you sometimes (or often) perform while driving your vehicle (such as talking on radio, using maps/GPS on MCT/MDT, reading data on MCT/MDT, etc.)

a.

b.

c.

d.

When conducting the tasks while driving, please rate the degree of mental workload, from 1 (lowest) to 10 (highest).

a.______________ b.______________ c.______________ d.______________

3. Please list the most commonly used functions/operations which involve interaction with the MCT/MDT. (Such as Maps, Call notes, etc.)

Rating of Visual Requirement (see #4)

a. ____________________________ ______________

b. ____________________________ ______________

c. ____________________________ ______________

d. ____________________________ ______________

4. For the functions/operations you listed in question 3, please rate them in terms of how long/how often you need to look at the MCT/MDT to perform them satisfactorily, on a scale from 0 (don't need to look at all) to 10 (have to look at the display constantly until completing the operation), with a 5 representing a need to look at the display during 50% of the time spent performing the operation.

5. Please estimate the percentage of time (0% = never; 100% = always) in which deployed vehicles in your department are single-crewed (as opposed to at least 2 crew members in the vehicle).

______________________ %

6. Please estimate the percentage of time (0% = never; 100% = always) in which the MCT/MDT is in use while the vehicle is in motion, and also the average number of interactions performed with this equipment per hour spent in your vehicle.

_____________________ % _________________________ interactions/hr

7. Does the MCT/MDT in use have voice control capabilities? Yes No

If yes, how often (% of time) do the drivers in your department use the voice control functionality? ____________________ %

Which is your most preferred form of interaction with the MCT/MDT? (circle one)

Touchscreen Mouse/trackpad Voice control

8. Have you personally, or have any of your colleagues been in an accident or near-miss that you feel was caused by the need to interact with onboard equipment while driving? Please explain in the space below.

9. Please briefly explain any policies that exist in your department with regard to the use of MCT/MDT and mobile phones while driving.