Guidelines on Limiting Distraction from Visual Displays in Vehicles

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Title

Guidelines on Limiting Distraction from Visual Displays (VDs) in Vehicles

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Abstract

Emerging technologies, especially those with visual displays (VDs), present increasing amounts and types of information to drivers. Although some VDs may present task-relevant safety information (e.g., back-up cameras, blind spot cameras), their implications for safety are not yet fully understood. Devices, especially those with VDs, used by drivers must be safe and compatible with driving. In September 2013, a high-profile crash occurred between an OC Transpo city passenger bus and a Via Rail train in Ottawa, Ontario, Canada. The Transportation Safety Board of Canada made the following recommendation in response to this crash, R15-01, to "…develop comprehensive guidelines for the installation and use of in-vehicle video monitor displays to reduce the risk of driver distraction" (p. 180). The impetus of the current report is this Transportation Safety Board of Canada recommendation. The objective of this study was to produce a set of recommendations intended to reduce distraction through the safe design, installation, and use of in-vehicle VDs.

Disclaimer

EXECUTIVE SUMMARY

In September 2013, a high-profile crash occurred between an OC Transpo city passenger bus and a Via Rail train in Ottawa, Ontario, Canada. The Transportation Safety Board of Canada investigated this crash (R13T0192) and found that driver distraction was one of the contributing factors (there were several contributing factors identified; in this report, we focus only on those related to distraction from a visual display [VD]). Based on their investigation, the Transportation Safety Board of Canada made recommendation R15-01, to "…develop comprehensive guidelines for the installation and use of in-vehicle video monitor displays to reduce the risk of driver distraction" (p. 180). The impetus of the current report is this Transportation Safety Board of Canada recommendation.

Overview of Current Canadian Regulations and Legislation for Distracted Driving

At the time of this report, there are no Federal Canadian regulations to combat distracted driving (for light or heavy vehicle drivers), although it has been discussed recently in response to the increased use of smartphones by drivers. The regulatory responsibility regarding distracted driving is the purview of the 13 Provinces and Territories. However, drivers may face criminal charges under the Federal Criminal Code when distraction results in the unsafe operation of the motor vehicle (Canadian Criminal Code, 2016).

All 13 Provinces and Territories have at least one section of regulations aimed at distraction caused by electronic communication devices or VDs. Nunavut appears to have the least-stringent regulations, as the Nunavut Motor Vehicle Act (2007) only regulates cathode ray tube (e.g., televisions) or similar display screens (§145). However, Bill 29 has been introduced in Nunavut that includes regulations banning handheld device use (with a hands-free mode exemption) and display screens that are directly or indirectly visible to the driver (with exemptions for manufacturer-installed built-in screens, back-up display screens, and screens used for navigation via a Global Positioning System [GPS]). Additionally, distracted drivers may be charged for operating a vehicle without due care and attention (§154). Drivers in the other 12 Provinces and Territories can be charged with dangerous or careless driving in addition to the distracted driving violation.

Study Objectives

The objective of this study was to produce a set of recommendations intended to reduce distraction through the safe design, installation, and use of in-vehicle VDs. This was accomplished though critical reviews of the available latest research, guidelines, standards, and best practices; legislation and regulations; and trends in mitigation strategies and technologies.

Methods

The Virginia Tech Transportation Institute (VTTI) team conducted a literature review to identify existing guidelines and best practices for VDs, research on distraction arising from VDs, safety and crash-avoidance applications of VDs, and distraction countermeasures. The VTTI team reviewed and critically assessed existing guidelines and best practices for the design, installation, and use of in-vehicle VDs to reduce the risk of driver distraction. The review included relevant

aspects, such as VD location/position, size, viewing angle, resolution, glare and night modes, design, and the content displayed (e.g., maps and other dynamic and static visual information, real-time video, and other video information, including static overlays on moving displays). The review also included international approaches and research to determine the best-available human factors information on driver distraction in passenger vehicles, trucks, motor coaches, and transit buses. This review covered approaches to manage distraction used by various fleets as well.

Summary of Guidelines for Original Equipment Manufacturer Video Displays

- Any information presented on a VD should not cause the driver to gaze at the VD continuously (Japan Automobile Manufacturers Association [JAMA], 2004).
    - Each glance should not exceed 1.5 seconds (Ryu et al., 2013) to 2.0 seconds (National Highway Traffic Safety Administration [NHTSA], 2013).
    - The total time the driver is looking at the VD (from the start of the task to the end of the task) should not exceed 8 seconds (JAMA, 2004) to 12 seconds (NHTSA, 2013).
- A VD system's functions that are not to be used by the driver during driving should be inoperative or presented in a way the driver cannot see while the vehicle is in motion (Campbell et al., 2016; European Union, EU, 2008; JAMA, 2004; NHTSA, 2013).
    - Display of motion pictures, including broadcasted television pictures and replayed video and DVD pictures, should be forbidden while driving (JAMA, 2004).
        - Exclusions include the area directly behind a vehicle under specific conditions (i.e., moving image of the vehicle's rear view, but only when the vehicle is in reverse), map displays, and information deemed to be related to the safe operation of the vehicle (NHTSA, 2013).
    - Manual text entry (e.g., text-based messaging, other communication, or Internet browsing), scrolling text, displaying text to be read, and displaying images should be prohibited while driving (NHTSA, 2013).
        - Exceptions include driving-related images, including maps, images displayed for aiding a driver to efficiently make a selection in the context of a non-driving-related task, internationally standardized symbols and icons, and information deemed to be related to the safe operation of the vehicle (NHTSA, 2013).
- If non-safety-related messages are presented on the VD, the device should provide a means by which it can be turned off or disabled (European Union [EU], 2008; JAMA, 2004; NHTSA, 2013).
- Instructions should clearly state which functions of the VD system are intended to be used by the driver while driving and those which are not to be used while driving (EU, 2008; NHTSA, 2013).
- The VD system should be capable of providing information to the driver on any detected malfunction that may have an adverse impact of safety (NHTSA, 2013).

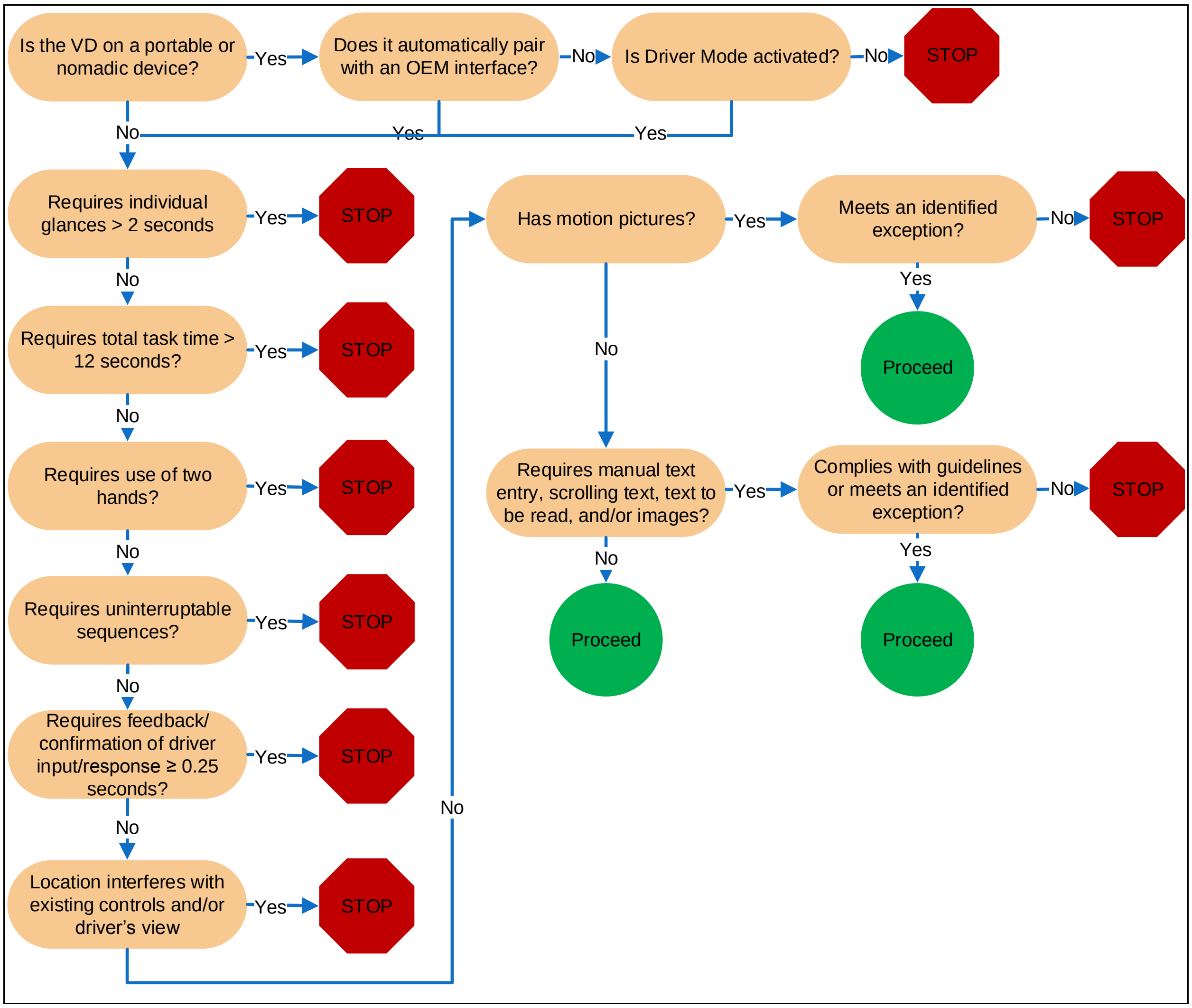
- The VD system should allow the driver to maintain one hand on the steering wheel (but reaching through the steering wheel is prohibited). The VD system should never require the driver to remove both hands from the steering wheel (EU, 2008; JAMA, 2004; NHTSA, 2013).
- Uninterruptable sequences should be prohibited; the sequence should resume at the point the task was interrupted (Campbell et al., 2016; EU, 2008; NHTSA, 2013).
- The VD system should not require an immediate response from the driver (JAMA, 2004; NHTSA, 2013).
    - The VD system should provide feedback or confirmation of the driver's response and the response to the driver's input should not exceed 0.25 seconds (JAMA, 2004; NHTSA, 2013).
    - Feedback should be provided to the driver if the system's response speed exceeds 2 seconds [i.e., to make it clear a change occurred] (NHTSA, 2013).
- The location of the VD should minimize distractions due to visibility (including fare box, blind spots, glare, and mirror placement), controls, instrumentation, and seat design and location (American Public Transportation Association [APTA], 2009a).
    - The location of the VD should not interfere with existing controls to displays required for the primary driving task from the driver's normal seating position (Stevens et al., 2002), or obstruct the driver's view outside the vehicle (EU, 2008; JAMA, 2004; NHTSA, 2013).
    - The mounting location of the VD should be in a location that is easy to reach and see (EU, 2008; JAMA, 2004; NHTSA, 2013).
    - The VD should be mounted where the downward viewing angle, measured at the geometric center of each active display area, is less than the 2D Maximum Downward Angle or the 3D Maximum Downward Angle (NHTSA, 2013).

Summary of Guidelines for Portable or Nomadic Video Displays

- Portable and nomadic devices with VDs should follow the same guidelines as original equipment manufacturer (OEM) devices with VDs.
- Portable and nomadic devices with VDs should be easily paired with an OEM interface.
    - Once paired, those tasks that are not related to the safe operation of the vehicle should be locked out (e.g., displaying video not related to driving, scrolling texts, etc.; NHTSA, 2016b).
- Portable and nomadic device should have a "Driver Mode," which is used when pairing is unavailable or the driver chooses not to pair the device.
    - Driver Mode is either: (1) automatically activated when the device is not paired with the OEM interface and distinguishes that it is being used by a driver who is driving (i.e., it distinguishes between a driver and a non-driver), or (2) manual activation of Driver Mode.
    - When in Driver Mode, the portable or nomadic device should lock out any visual-manual secondary tasks that do not meet the OEM guidelines (NHTSA, 2016b).

- Transit bus drivers should turn off and stow all personal electronic devices (e.g., cell phone, pagers, MP3 players, etc.).
    - These devices should never be used while the vehicle is in motion.
    - Use of these devices should be restricted to times when the vehicle is parked (APTA, 2009b).

The flowchart below illustrates the recommended guidelines for VDs. This flow chart is for illustrative purposes to determine if and how a VD system should be used while driving. Any OEM, portable, or nomadic devices with VDs should follow the appropriate motor vehicle standards and guidelines under which they are intended to operate (including any exceptions).



Flowchart of recommended guidelines for VDs while driving.

Distraction Countermeasures

Five types of inattention monitoring technologies were identified:

(1) Lockout/blocking and interrupting technologies and workload managers: Lockout/blocking technologies are in wide use today. These technologies eliminate distraction; however, they are only as effective as (a) the ability of a driver to circumvent the lockout, and (b) the driver installing and using the technology on their personal devices with VDs. Interrupting technologies and workload managers monitor the driver and/or driving environment and interrupt the secondary task or adjust driving performance if the driving situation is deemed overly demanding.

(2) Physiological sensors: Physiological variables (e.g., electrical activity of the brain) are used to assess the driver's attentional state. However, these technologies are far from being ready for use in real-world driving.

(3) Driver performance measures: These technologies assume that a change in the driver's workload can result in a change in driving performance. Recent efforts to monitor driver distraction have used steering and lane position. At present, technologies that use driver performance to monitor driver distraction are unproven and not applicable to real-world driving.

(4) Computer vision: Distraction countermeasures that rely on computer vision have been the most widely studied. Several commercially available distraction monitoring systems use computer vision. These technologies rely on hardware and computer software that detects and measures a driver's pupil size, gaze location, blink frequency, head position, hand position, or some combination thereof.

(5) Hybrid measures: Hybrid measures use multiple inputs and more reliable countermeasures compared to any single approach as they minimize the number of false alarms and increase the recognition rate.

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1 BACKGROUND

Driver distraction is the diversion of attention from activities critical for safe driving toward a competing activity (US-EU Bilateral ITS Technical Task Force, 2010). Distraction jeopardizes the safety of drivers, passengers, and non-occupants alike. In 2014, crashes involving distracted drivers resulted in 3,179 deaths (10.6 percent of all fatal crashes) and 431,000 injuries (26.1 percent of all injury crashes) in the United States (National Highway Traffic Safety Administration [NHTSA], 2016a). Although the rate of fatal and injury crashes has been steadily declining in the U.S., the 2014 statistics reflect a 10 percent increase in fatal and injury crashes resulting from distraction compared to 2013. Canadian crash statistics mirror those of the United States. Although the rate of fatal and injury crashes has been in decline in Canada, the number of crashes resulting from distraction has increased according to data from Transport Canada's National Collision Database (Transport Canada, 2016). In 2014, Manitoba, Newfoundland, and Labrador reported that distracted driving was equal to or exceeded driving while impaired (CBC News, 2015; Singh, 2015).

Naturalistic driving studies performed by the Virginia Tech Transportation Institute (VTTI) have demonstrated that visual distractions, especially those associated with looking at a visual display (VD), have the highest risk estimates (Dingus et al., 2016; Fitch et al., 2011; Hickman et al., 2010, 2015; Klauer et al., 2006, 2014; Olson et al., 2009). More specifically, eyes-off-road time greater than 2 seconds significantly increases crash and near-crash occurrence (Simons-Morton et al., 2015; Klauer et al., 2006). Most recently, Dingus et al. (2016) estimated the crash risks of several visual-manual tasks using only crash data from the Second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study. They found that texting increased crash risk by five times compared to an alert driver and that reaching for an object increased crash risk by eight times compared to an alert driver. Talking on a smartphone, which is primarily a cognitive task, also significantly increased crash risk, but only by two times compared to an alert driver. These findings suggest that designing communication devices to use only voice commands as opposed to requiring visual-manual tasks could improve crash rates.

However, recent research suggests that the cognitive distraction associated with performing certain tasks via voice-control systems might also pose a serious risk to driving safety. In particular, Strayer et al. (2015a,b,c) suggested that voice-control systems, particularly speech-to-text messaging systems built into smartphones, are associated with a variety of driving performance decrements. The performance decrements observed when using voice-control systems included subjectively higher mental workload, increased following distances,[1] reduced likelihood of glances to potentially hazardous locations, and significant increases in manual response time to a peripherally mounted light (dynamic response task). Unfortunately, the above studies were hindered by several potentially serious limitations. For example, there is limited evidence that the dependent measures emphasized in these studies (primarily response time to an artificial stimulus and subjective workload) have any direct relation to crash risk. Driver glance behavior, which is strongly associated with crash and near-crash risk (Klauer et al., 2010), was

[1] Increased following distances is a performance *decrement* in the cited work; however, this is more likely a performance *difference* between drivers using a smartphone versus those who were not using a smartphone while driving.

only cursorily examined; thus, how the performance decrements identified by Strayer et al. translate into crash rates remains unclear.

Emerging technologies, especially those incorporating VDs, present increasing amounts and types of information to drivers. A VD is an output surface that uses a cathode ray tube, liquid crystal display, light-emitting diode, or other image projection technology to present video images (e.g., navigation device, mobile phone, backing camera display, passenger monitoring display, driver/vehicle safety warnings, heating, ventilation, and air conditioning display, etc.). Although some VDs may present task-relevant safety information (e.g., back-up cameras, blind spot cameras), their implications for safety are not yet fully understood. Devices, especially those with VDs, used by drivers must be safe and compatible with driving.

In September 2013, a high-profile crash occurred between an OC Transpo city passenger bus and a Via Rail train in Ottawa, Ontario, Canada. The Transportation Safety Board of Canada investigated this crash (R13T0192) and found that driver distraction was one of the contributing factors (there were several contributing factors identified; in this report, we focus only on those related to distraction from a VD). More specifically, the driver was likely visually distracted as he was looking at a VD while the bus was in motion. This bus had a VD, located on the driver's side above the driver, which showed a quad image from four cameras located throughout the bus. The driver was instructed to use the VD (only at stops) to ensure to passengers were not standing. However, in this particular crash, the driver looked at the VD while the bus was in motion to ensure that passengers were not standing. Based on their investigation, the Transportation Safety Board of Canada made recommendation R15-01, to "…develop comprehensive guidelines for the installation and use of in-vehicle video monitor displays to reduce the risk of driver distraction" (p. 180). The impetus of the current report is this Transportation Safety Board of Canada recommendation.

This crash also highlights the responsibilities beyond driving that transit bus drivers are asked to perform on a daily basis. Salmon et al. (2011) performed a hierarchal task analysis on Australian bus drivers. They identified seven categories of tasks that bus drivers performed while operating buses, including preparation tasks, physical vehicle control tasks, cognitive vehicle control tasks, route/timetabling tasks, passenger-related tasks (42 separate tasks identified), communication tasks, and personal comfort tasks. Although the driver's primary task is safe control of the vehicle, sometimes this may get lost in the myriad of other responsibilities. Thus, there is an urgent need to document the risks (and potential benefits) of VDs and identify appropriate strategies for limiting distraction to ensure that devices with VDs used by drivers are safe and compatible with driving.

1.1 Current Canadian Regulations and Legislation for Distracted Driving

One method to reduce driver distraction is through Federal and Provincial/Territorial regulations that specifically target driver visual-manual tasks. This method requires the Canadian Federal Government and/or the 13 Provinces and Territories to pass legislation and penalties to discourage drivers from engaging in secondary tasks that may remove a driver's attention from the task of driving. This section of the report reviews the current Canadian Federal and Provincial/Territorial distracted driving regulations.

At the time of this report, there are no Federal Canadian regulations to combat distracted driving (for light or heavy vehicle drivers), although it has been discussed recently in response to the increased use of smartphones by drivers. The regulatory responsibility regarding distracted driving is the purview of the 13 Provinces and Territories. However, drivers may face criminal charges under the Federal Criminal Code when distraction results in the unsafe operation of the motor vehicle (Canadian Criminal Code, 2016).

All 13 Provinces and Territories have at least one section of regulations aimed at distraction caused by electronic communication devices or VDs. Nunavut appears to have the least-stringent regulations, as the Nunavut Motor Vehicle Act (2007) only regulates cathode ray tube (e.g., televisions) or similar display screens (§145). However, Bill 29 has been introduced in Nunavut that includes regulations banning handheld device use (with a hands-free mode exemption) and display screens that are directly or indirectly visible to the driver (with exemptions for manufacturer-installed built-in screens, back-up display screens, and screens used for navigation via a Global Positioning System [GPS]). Additionally, distracted drivers may be charged for operating a vehicle without due care and attention (§154). Drivers in the other 12 Provinces and Territories can be charged with dangerous or careless driving in addition to the distracted driving violation.

As shown in Table 1, 12 Provinces and Territories ban the use of handheld electronic communication devices (i.e., cell phones) while driving unless using hands-free mode. Additionally, five Provinces and Territories prohibit the use of all handheld electronic devices (Alberta, Manitoba, New Brunswick, the Northwest Territories, and Ontario). Furthermore, 10 Provinces and Territories have a regulation regarding at least one type of visual display (Alberta, Manitoba, New Brunswick, Nova Scotia, Nunavut, Ontario, Prince Edward Island, Quebec, Saskatchewan, and Yukon). For example, Saskatchewan prohibits televisions, video, or computer screens that are directly or indirectly visible to the driver and/or obstruct the driver's view of the roadway (§241).

Also shown in Table 1, all Provinces and Territories (with the exception of Nunavut) provide exemptions to the regulations. Many of these exemptions are listed here:

1. All Provinces and Territories reserve the right for the Minister to exempt prescribed classes of individuals, vehicles, or technologies. Exemptions for specific vehicle or driver classes are noted in Table 1.
2. All regulations allow the use of a handheld communication device in hands-free mode. However, three jurisdictions do not allow any communication use for drivers in a graduated driver's license program (British Columbia, Saskatchewan, and Yukon).
3. All regulations exempt emergency personnel or the use of a handheld device to contact emergency personnel.
4. Many of the jurisdictions allow the use of handheld devices while the vehicle is safely parked and not obstructing traffic (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Ontario, Prince Edward Island, and Yukon).
5. Six jurisdictions exempt the use of a communication device or display when used as part of employment (Alberta, New Brunswick, the Northwest Territories, Ontario, Quebec, and Saskatchewan). Employment is defined differently in each jurisdiction. For example, Alberta allows two-way radios to contact an employer or for drivers in an escort vehicle;

however, New Brunswick allows two-way radios while operating a vehicle for commercial purposes. Additionally, some jurisdictions only allow the use of two-way radios for employment purposes, while others allow drivers to use VDs. New Brunswick, Ontario, Quebec, and Saskatchewan allow VDs to be visible to a driver in certain situations. For example, Saskatchewan allows a VD that only provides information to ensure passenger safety and security.

6. Six jurisdictions explicitly exempt two-way radio or family and citizen's band radio (Alberta, Manitoba, New Brunswick, Newfoundland and Labrador, Prince Edward Island, and Quebec).
7. Five jurisdictions exempt collision avoidance systems or other instruments, gauges, devices, or systems needed to safely operate the vehicle (Alberta, New Brunswick, Ontario, Quebec, and Saskatchewan).
8. Four jurisdictions specifically exempt GPS navigation displays (Alberta, New Brunswick, Ontario, and Saskatchewan). Of these four jurisdictions, Alberta is the only one that specifically bans manual entry on a GPS navigation device while the vehicle is in motion.
9. Three jurisdictions provide exemptions for built-in displays (or screens securely mounted) following manufacturer instructions that provide information on the status of vehicle systems, road, or weather conditions (New Brunswick, Ontario, and Quebec).
10. Nine jurisdictions exempt displays that are not directly or indirectly visible to the driver (Alberta, Manitoba, New Brunswick, Nova Scotia, Nunavut, Ontario, Quebec, Saskatchewan, and Yukon).

Twelve of the jurisdictions (all except Nunavut) have penalties for violating the distracted driving regulations (see Table 1). These penalties include fines and merit point deductions. Fines range from $80 to $1,200 across all jurisdictions, and merit point deductions range from 3 to 5 demerits. Overall, Prince Edward Island has the strictest penalties (fines ranging from $500 to $1,200 and 5 demerit points), although, Newfoundland and Labrador and Ontario, ($300 to $1,000) also have expensive fines. Manitoba also has a 5-demerit point penalty. Quebec has the least expensive fine ($80 to $100).

Table 1. Current regulations and penalties for distracted driving across all Canadian provinces and territories.

Jurisdiction	Devices Prohibited	Exemptions	Fine	Demerit Points
Alberta	1. All hand-held electronic devices (115.1[1]) 2. Display screen visible to the driver (115.2[1]) 3. Manual input into a GPS navigation system while the vehicle is in motion (115.3[1])	1. Using a hand-held device in hands-free mode (115.1[2]) 2. 2-way radio communication device/cellular telephone when by the driver of an escort, pilot, or trail vehicle (115.1[3]) 3. 2-way radio communication device/cellular telephone to maintain contact with an employer while on-duty (115.1[3]) 4. 2-way radio communication device/cellular telephone when used in search, rescue, or emergency operations (115.1[3]) 5. Cellular telephone use to contact emergency personnel (115.1[3]) 6. Drivers of emergency vehicles (115.1[4]) 7. Does not apply when the vehicle is off a highway or safely parked (115.1[5]) 8. Pre-programed GPS navigation device affixed to the vehicle (115.3[2]) 9. Logistical transportation tracking device (115.2[2]) 10. Transportation dispatch system (115.2[2]) 11. Collision avoidance system (115.2[2]) 12. Instrument, gauge, device, or system used to provide information regarding the status of vehicle systems (115.2[2])	$287	3
British Columbia	1. Hand-held electronic communication device (214.2)	1. Using a hand-held device in hands-free mode (214.4) 2. Emergency personnel (214.3) 3. Does not apply when the vehicle is safely parked (214.4) 4. Used to contact emergency personnel (214.4)	$368	4
Manitoba	1. Hand-operated electronic device (215.1[1]) 2. Television directly or indirectly visible to the driver (214[3])	1. Hand-held electronic device use in hands-free mode when the device is secured to the vehicle within reach of the driver (215.1[2]) 2. Hand-held electronic device use when the vehicle is safely parked (215.1[2])	$203.80	5

Jurisdiction	Devices Prohibited	Exemptions	Fine	Demerit Points
		3. Hand-held electronic device to contact emergency personnel (215.1[4]) 4. Hand-held electronic device use by emergency personnel (215.1[5]) 5. 2-way, citizen's band, or family band radios (215.1[5])		
New Brunswick	1. Hand-operated electronic device (265.02) 2. Display screen visible to the driver (265.04[1])	1. Hand-operated electronic device use in hands-free mode (265.03) 2. Use by emergency personnel (265.03) 3. Hand-operated electronic device use to contact emergency personnel (265.03) 4. 2-way radio use while operating a vehicle for commercial purposes (265.03) 5. 2-way radio use while operating a commercial motor vehicle (265.03) 6. 2-way radio use with a radio operator certificate (265.03) 7. Only for the use of GPS navigation (265.03) 8. Hand-operated electronic device use while the vehicle is safely parked (265.03) 9. Display screen in a taxi (265.04[2]) 10. Display screen used by a telecommunications employee (265.04[2]) 11. Built-in display screen installed by the vehicle manufacturer or following manufacturer instructions that provides information on the status/condition of vehicle systems or road/weather conditions, (265.04[2])	$172.50	3
Newfoundland and Labrador	1. Hand-held communication device (176.1[1])	1. Hand-held communication device use in hands-free mode (176.1[2]) 2. Use by emergency personnel (176.1[3]) 3. Use to contact emergency personnel (176.1[4]) 4. The device is linked to non-public short-wave radio communication (176.1[4]) 5. Use while the vehicle is off the road or safely parked (176.1[5])	$300-$1,000	4

Jurisdiction	Devices Prohibited	Exemptions	Fine	Demerit Points
Northwest Territories	1. Portable electronic device (155.1[2])	1. Use in hands-free mode (155.1[3]) 2. Use by emergency personnel (155.1[4]) 3. Use in a vehicle during construction/maintenance activities (155.1[4])	$322-$644	3
Nova Scotia	1. Hand-held cellular telephones or communication device (100D[1]) 2. Television viewer or screen located forward of driver's seat or visible to the driver (184[7])	1. Use in hands-free mode (100D[2])	$237.50-$582.50	4
Nunavut	1. Cathode ray tube or similar display screen that is visible by the driver in front of the driver's seat (145)	N/A	N/A	N/A
Ontario	1. Television, computer, or other display screen visible to the driver (78[1]) 2. Hand-held electronic communication device (78.1[1]) 3. Hand-held electronic entertainment device (78.1[2])	1. Hand-held electronic device use in hands-free mode (78.1[3]) 2. Hand-held two-way radio exemption until January 1, 2018 for operators of commercial vehicles, municipal fleet vehicles, public transit, courier, tow truck, and taxi/limousines. 3. A GPS navigation display while used for navigation (78[2]) 4. Use of a logistical transportation tracking system (78[2]) 5. Collision avoidance system (78[2]) 6. Instrument, gauge, device, or system used to provide information regarding the status of vehicle systems (78[2]) 7. Use by emergency personnel (78[3], 78.1[4]) 8. Used to contact emergency personnel (78.1[5]) 9. Use when the vehicle is stationary off the roadway or safely parked (78.1[6]) 10. Displays securely mounted and used by couriers, drivers of roadside assistance vehicles, taxis, road	$300-$1,000	3

Jurisdiction	Devices Prohibited	Exemptions	Fine	Demerit Points
		authorities, spectrum management, telecommunications, and automobile technicians (Ontario Regulation 366/09) 11. Commercial vehicle drivers may use a mobile data terminal display screen when securely mounted (Ontario Regulation 366/09) 12. Securely mounted displays that only provide information on road or weather conditions (Ontario Regulation 366/09) 13. Audio displays that only provide static images (Ontario Regulation 366/09)		
Prince Edward Island	1. Television set (133) 2. Hand-held wireless communication device (291.1[1])	1. Hand-held communication device use in hands-free mode (291.1[2]) 2. Hand-held communication device use by emergency personnel (291.1[3]) 3. Hand-held communication device used to contact emergency personnel (291.1[4]) 4. Hand-held device linked to a non-public shortwave radio system (291.1[4]) 5. Hand-held device use when the vehicle is off the roadway or safely and legally parked (291.1[5])	$500-$1,200	5
Quebec	1. Television or display screen affixed to the vehicle with an image that is directly or indirectly visible to the driver (439, 178.1). Display must also not: (1) obstruct the driver's view; (2) interfere with driving, operation of equipment, or reduce its efficiency, (3) incorporate easily accessible control buttons, (4) not limit a driver's time to respond, (5) only allow the driver to modify or delete an	1. Use by emergency personnel (439.1) 2. 2-way radio devices (439.1) 3. Display screen installed by vehicle manufacturer according to manufacturer instructions (178.1) 4. Display only provides information regarding the immediate environment surrounding the vehicle (178.1) 5. Solely used for business purposes of collecting passenger fees or managing messages(178.1) 6. Display used by a telecommunications/utility company employee (178.1)	$80-$100	4

Jurisdiction	Devices Prohibited	Exemptions	Fine	Demerit Points
	information block, and (6) only has a simple and short message (178.2) 2. Hand-held device with a telephone function (439.1)			
Saskatchewan	1. Television, video, or computer screen visible to the driver and/or that obstructs the driver's view (241[1]) 2. Hand-held electronic communication device (241.1[2])	1. Television, video, or computer screen that only provides information to safely operate the vehicle, ensure passenger/cargo safety and security, navigate, display time, be used by emergency personnel, or collect passenger fees (241[2]) 2. Hand-held electronic device use in hands-free mode (241.1[3]) 3. Hand-held electronic device use to contact emergency personnel (241.1[3])	$280	4
Yukon	1. Television set (132[1]) 2. Electronic communication device (210.1[2])	1. Television set screen is not visible by any means while the vehicle is in motion (132[2]) 2. Electronic communication device use by emergency personnel (210.1[1]) 3. Electronic communication device use in hands-free mode (210.1[3]) 4. Electronic communication device use when the vehicle is safely parked (210.1[3])	$250	3

1.2 RESEARCH OBJECTIVES

The objective of this study was to produce a set of recommendations intended to reduce distraction through the safe design, installation, and use of in-vehicle VDs. This was accomplished though critical reviews of the available latest research, guidelines, standards, and best practices; legislation and regulations; and trends in mitigation technologies and strategies. The study considered the following areas (driver education and training countermeasures were excluded):

(1) Information relevant to passenger vehicles, trucks, motor coaches, and transit buses;
(2) Devices with VDs, including original equipment manufacturer (OEM) and aftermarket devices (including portable and nomadic devices);
(3) Functionality including, but not limited to, systems that provide assistance and safety features for vehicles (e.g., navigation, back-up cameras, blind spot cameras, passenger monitoring cameras, etc.) as well as systems for scheduling, information display, and management. Safety and work-related functions were considered as well as other uses, such as infotainment;
(4) Various forms of VD content, such as graphical or photographic images, scrolling information, and video, which included pre-recorded images, live images, closed-circuit television, and broadcasts via television or the Internet; and
(5) Management policy and practices, and corporate policy.

2 METHODOLOGY

This section describes how the VTTI team developed the report.

2.1 LITERATURE REVIEW AND DOCUMENTATION

The VTTI team conducted a literature review to identify existing guidelines and best practices for VDs, research on distraction arising from VDs, safety and crash-avoidance applications of VDs, and distraction countermeasures. The VTTI team reviewed and critically assessed existing guidelines and best practices for the design, installation, and use of in-vehicle VDs to reduce the risk of driver distraction. The review included relevant aspects, such as VD location and position, size, viewing angle, resolution, glare and night modes, design, and the content displayed (e.g., maps and other dynamic and static visual information, real-time video, and other video information, including static overlays on moving displays). The review also included international approaches and research to determine the best-available human factors information on driver distraction in passenger vehicles, trucks, motor coaches, and transit buses. The review covered approaches to managing distraction in various fleets as well. The *Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices* (NHTSA, 2013) and *Visual-Manual NHTSA Driver Distraction Guidelines for Portable and Aftermarket Devices* (NHTSA, 2016b) are comprehensive guideline documents regarding driver distraction; thus, the VTTI team focused on these guidelines as well as guidelines and best practice publications from 2012 to today, though some publications prior to 2012 were also included.

In developing these guidelines, the VTTI team also considered recent reviews and current research on VD-related distracted driving in various vehicle types, current and near-term safety and crash avoidance systems with VDs, and best practices. This review covered current and near-term products of OEMs along with aftermarket technologies that include VDs.

Lastly, the VTTI team compiled, reviewed, and summarized technologies designed to mitigate or eliminate distraction from VDs, including currently available technologies and near-term approaches that are legal to implement. This review was limited to technologies that directly reduce and/or eliminate driver distraction. Technologies that focus on driver behavior (e.g., onboard safety monitoring systems) and/or the adverse consequences of distraction (e.g., crash imminent braking) were not included in the review. Although regulatory and educational distraction countermeasures were excluded, employer methods to reduce distraction were included in the discussion on distraction countermeasures.

The VTTI team worked with a librarian from the Virginia Tech Newman Library to refine the keyword search to address the four areas. The goal was to include a large number of search terms to avoid missing relevant publications. After running the keyword search and removing duplicates, the VTTI team reviewed each remaining publication to determine its relevance for inclusions in the study. See Appendix A for the keyword search terms, which resulted in 3,818 publications. After an initial review of these 3,818 publications, 254 publications were reviewed in more detail for inclusion in the study.

3 SUGGESTED GUIDELINES FOR VISUAL DISPLAYS

The guidelines in this report are germane to in-vehicle VDs in passenger vehicles, trucks, motor coaches, and transit buses and include OEM and aftermarket devices (including nomadic devices). Per NHTSA (2013; p. 24882), the guidelines are valid for "driving-related tasks that are neither related to the safe operation and control of the vehicle nor involve the use of a system required by law." These driving-related tasks include (i) operating the driving controls (steering wheel, throttle pedal, brake pedal, etc.) of the vehicle; (ii) proper use of a driver safety warning system; and (iii) use of any other electronic device that has a function, control, and/or display specified by either a motor vehicle safety standard, another Canadian law or regulation, or a province or territory law or regulation. A list of driving-related tasks are shown on pages 248834 and 248835 (Table 2) in NHTSA (2013). The guidelines are intended for drivers that use VDs while driving, and to a limited extent VD use by front seat passengers. These guidelines are not applicable to VDs located behind the front seat of the vehicle. Per NHTSA (2013; p. 24883), driving is defined as:

> …whenever the vehicle's means of propulsion (engine and/or motor) is activated unless one of the following conditions is met: a. For a vehicle equipped with a transmission with a ''Park'' position—The vehicle's transmission is in the ''Park'' position. b. For a vehicle equipped with a transmission without a ''Park'' position—All three of the following conditions are met: i. The vehicle's parking brake is engaged, and ii. The vehicle's transmission is known (via direct measurement with a sensor) or inferred (by calculating that the rotational speed of the engine divided by the rotational speed of the driven wheels does not equal, allowing for production and measurement tolerances, one of the overall gear ratios of the transmission/vehicle) to be in the neutral position, and iii. The vehicle's speed is less than 5 mph."

Below are general guidelines for VDs, followed by specific considerations. These specific considerations include system functionality, message complexity, sensory modality, safety-related messages, location of a VD, color in messages, character height, text legibility, temporal characteristics, glare from a VD, information entry on VDs, and other special considerations (e.g., indirect camera monitoring systems and heads-up displays [HUDs]). The suggested guidelines are largely derived from Campbell et al. (2016), the Japan Automobile Manufacturers Association (JAMA, 2004), the European Union (EU, 2008); and NHTSA (2013, 2016b).

3.1 GENERAL GUIDELINES FOR OEM VISUAL DISPLAYS

VDs are useful in the driving environment as they are well suited to presenting complex information to the driver (whereas simple information is better presented using an auditory signal; Stevens et al. 2002). Although use of VDs while driving is associated with distraction (primarily visual distraction), guidelines on their safe use while driving, or when they should not be used, can "minimize" these adverse effects. However, guidelines should be viewed as a necessary but not sufficient approach to reduce driver distraction.

In general, any information presented on a VD should not cause the driver to gaze at the VD continuously. The information presented in the VD should relate to driving (i.e., information must be relevant to the safe operation of the vehicle), but should not necessitate the driver gazing at for a long period of time (JAMA, 2004). If non-safety-related messages are presented on the

VD, the device should provide a means by which it can be turned off or disabled (EU, 2008; JAMA, 2004; NHTSA, 2013). The instructions should clearly state which functions of the VD system are intended to be used by the driver while driving and those which are not to be used while driving (EU, 2008; NHTSA, 2013). The VD system should be capable of providing information to the driver on any detected malfunction that may have an adverse impact of safety (NHTSA, 2013).

3.1.1 Task Complexity using Visual Displays

Although VDs are best at presenting complex information to the driver, it is best to limit the amount of information presented to the driver (Green et al., 1995). The information presented to the driver should not be so complex that the driver does not to know what is happening, feels out of control, or is unable to control the pace of the interaction (Hammer et al., 2007). The VD system should be designed so that the driver can complete the task with brief, sequential glances that do not adversely affect driving (Campbell et al., 2016). Each glance should not exceed 1.5 seconds (Ryu et al., 2013) to 2.0 seconds (NHTSA, 2013) and the total time the driver is looking at the VD (from the start of the task to the end of the task) should not exceed 8 seconds (JAMA, 2004) to 12 seconds (NHTSA, 2013). However, the usability paradox indicates that well-designed, highly usable systems, although less distracting per interaction, may result in higher cumulative distraction as they are likely to be used more frequently (Reed, 2012).

3.1.2 Functions of the Visual Display Allowed during Driving

VD system functions that are not to be used by the driver during driving should be inoperative or presented in a way the driver cannot see while the vehicle is in motion (Campbell et al., 2016; EU, 2008; JAMA, 2004; NHTSA, 2013). For example, the display of motion pictures, including broadcasted television pictures and replayed video and DVD pictures, should be forbidden while driving (JAMA, 2004). NHTSA (2013) recommends exceptions to the display of motion pictures while driving, including the area directly behind a vehicle under specific conditions (i.e., moving image of the vehicle’s rear view when the vehicle is in reverse) and map displays. Other VD functionalities that should be prohibited by the driver while driving include manual text entry (e.g., text-based messaging, other communication, or Internet browsing), scrolling text, displaying text to be read, and displaying images. Exceptions include driving-related images, including maps; images displayed for aiding a driver to efficiently make a selection in the context of a non-driving-related task; and internationally standardized symbols and icons (NHTSA, 2013).

3.1.3 Entry of Information

The VD system should allow the driver to maintain one hand on the steering wheel; however, reaching through the steering wheel with one hand should be prohibited. At no time should the VD system require the driver to remove both hands from the steering wheel (EU, 2008; JAMA, 2004; NHTSA, 2013). The system should prohibit uninterruptable sequences; in other words, the system should allow the driver to resume the sequence at the point the task was interrupted and show previously entered data to remind a driver of where the task was interrupted (Campbell et al., 2016; EU, 2008; NHTSA, 2013). The driver should, in general, control the pace of the interaction with the VD system (Campbell et al., 2016; EU, 2008) and be allowed to erase driver inputs (NHTSA, 2013). The VD system should not require an immediate response from the driver; however, the system should provide feedback or confirmation of the driver's response and the response to the driver's input should not exceed 0.25 seconds (JAMA, 2004; NHTSA, 2013). Feedback should be provided to the driver if the system's response speed exceeds 2 seconds (i.e., to make it clear a change occurred; NHTSA, 2013).

3.1.4 Location of Visual Display

The location of the VD should minimize distractions due to visibility (including fare box, blind spots, glare, and mirror placement), controls, instrumentation, and seat design and location (APTA, 2009a). Nor should the location of the VD interfere with existing controls to displays required for the primary driving task from the driver's normal seating position (Stevens et al., 2002), or obstruct the driver's view outside the vehicle.

3.1.5 Visual Display Interface

The VD interface should be consistent (in layout, structure, rules, etc.) and information should be grouped according to task, function, and sequence principles (Hammer et al., 2007). Information with higher safety relevance should be given higher priority (EU, 2008). In general, text should be presented left justified in fields, and numbers should be right justified when they are used alone (Green et al., 1995). To increase ease of use and understanding, designers should (i) allow for personalization of the VD interface; (ii) place alarms/alerts across the top of the page; (iii) position key data center left and buttons and controls on the lower left; (iv) include clearly marked exits and a help menu to minimize or prevent driver frustration; and (v) only present necessary and immediately useable data to the driver (Hammer et al., 2007).

3.2 General Guidelines for Portable or Nomadic Visual Displays

NHTSA (2016b) makes several distinctions between OEM devices and portable or nomadic devices with VDs; however, the guidelines largely follow those indicated in NHTSA (2013). "Driving" is defined as indicated in NHTSA (2013). The distinctions between OEM devices and portable or nomadic devices with VDs include the following: (1) portable and nomadic devices with VDs are designed to be used in a variety on contexts that may (or may not) include driving; (2) portable or nomadic devices with VDs may be used by vehicle occupants other than the driver; (3) portable and nomadic devices with VDs can be placed and/or mounted in variety of locations on the vehicle; and (4) portable and nomadic devices with VDs likely have a different user interface (e.g., use of thumb rather than finger). Given these distinctions, NHTSA (2016b) recommends two approaches. The first approach recommends that portable and nomadic devices with VDs should be easily paired with an OEM interface (assuming the OEM interface conforms to the NHTSA, 2013, guidelines). Once paired, those tasks indicated in NHTSA (2013) that are not related to the safe operation of the vehicle should be locked out (e.g., displaying video not related to driving, scrolling texts, etc.).

The second approach should include a "Driver Mode." Driver Mode is a simplified interface for devices that are unpaired while driving because pairing is unavailable or the driver chooses not to pair the device (NHTSA, 2016b). NHTSA (2016b) recommends two methods for activating Driver Mode: (1) the portable or nomadic device automatically activates Driver Mode when the device is not paired with the OEM interface and distinguishes that it is being used by a driver who is driving (i.e., it distinguishes between a driver and a non-driver), and (2) manual activation of Driver Mode. The clear preference is for the automatic activation of Driver Mode.

If the initial (or subsequent) pairing process requires visual-manual interaction by the driver, the initial process of pairing should be disabled while driving. When in Driver Mode, the portable or nomadic device should lock out any visual-manual secondary tasks that do not meet the NHTSA (2013) guidelines (NHTSA, 2016b). APTA (2009b) recommends that all personal electronic devices, such as cell phones, pagers, MP3 players, and video games should be turned off and stowed out of the driver's sight. These devices should never be used while the vehicle is in motion. Use of these devices should be restricted to times when the vehicle is parked.

3.3 Specific Considerations for Visual Displays

The following guidelines for VDs (OEM and portable or nomadic) are likely to reduce overall driver distraction from VDs, and thus make it more likely that the general guidelines above are followed.

3.3.1 Provide Drivers with Information on System Function and System Messages

Detailed information on system limitations should be provided in the owner's manual using best practices documents. The owner's manual should also provide a description of the VD interface and examples of behavioral options that correspond with what is presented on the interface. Information should be short, meaningful, concise, and eye catching (Campbell et al., 2016; JAMA, 2004). Reporting of VD system state and operation (e.g., when it can accept speech input) should be quickly and easily understandable (Green et al., 1995; JAMA, 2004).

3.3.2 Message Complexity on Visual Displays

In general, the longer the text to be read, the greater the distraction. A task should be able to be completed using a series of short glances or presented in small volumes (EU, 2008; Hammer et al., 2007; JAMA, 2004; Peng et al., 2016). Information should be presented in a simple manner (Campbell et al., 2016). To accomplish this, use layman's terms, understandable graphics, international symbols to supplement words, avoid abbreviations (unless they are commonly used), and use short, unambiguous text messages (EU, 2008; Green et al, 1995; Ross et al, 1996). A combination of visual and auditory information reduces distraction in route guidance (Yang et al., 1998).

3.3.3 Sensory Modality

Visual messages are best for presenting complex or non-safety information that does not call for immediate action, whereas audio information is best for simple or safety information that requires immediate action (Campbell et al., 2016; Kantowitz, 1998). If visual messages are used for safety information, they should be accompanied by auditory information, and presented in a location where the driver is expected to see the visual warning (e.g., a visual imminent crash warning for a lane departure warning system that is presented on the rearview and side-view mirror, or on an A-pillar; Campbell et al., 2016). See Table 2 for rules on when to provide auditory versus visual information in a VD (Lee et al., 1999). A VD system should have controllable volume, and the sound should not cancel out from inside or outside the vehicle (EU, 2008; JAMA, 2004; NHTSA 2013).

Table 2. Rules for selecting auditory versus visual displays.

Auditory information when	Visual information when
The message is simple.	The message is complex.
The message is short.	The message is long.
The message will not be referred to later.	The message will be referred to later.
The message deals with an event in time.	The message deals with location in space.
The message calls for immediate action.	The message does not call for immediate action.
The visual system is overburdened.	The auditory system is overburdened.
The receiving location is too bright or dark.	The receiving location is too noisy.
The user must move about.	The user can stay in one place.

3.3.4 Safety-Related Messages

For safety-related messages, high frequencies with short gaps between bursts and increasing number of bursts minimize response time and increase perceived urgency (Green et al., 2008). Safety information presented to the driver through a VD should be accurate, simple (no more than four units of information), and clear (JAMA, 2004; Stevens et al., 2002). Symbols or iconic representations that do not require reading to interpret minimize response time (Campbell et al., 2016). Campbell et al. (2016) developed Figure 1 to illustrate appropriate locations for VDs that convey safety information. Locations "BC" are VDs located on the side mirrors and A-pillars. They provide information when checking the mirrors or looking to the sides (e.g., lane departure warning). Location "B" is located in either corner of the rearview mirror and can provide information regarding a lane change maneuver (e.g., lane departure warning). Location "AC" is the location of a HUD, which is optimal for presenting information about hazards directly ahead (e.g., forward collision warning). "D" shows locations for the VD that are shielded from glare by a cowling that are suitable for presenting information about forward hazards (e.g., forward collision warning). Location "E" is for safety information presented on a multi-function VD. Given the number of indicators on the dashboard in a heavy vehicle, warnings provided on a VD within the instrument panel of heavy vehicles should be avoided (Campbell et al., 2016)

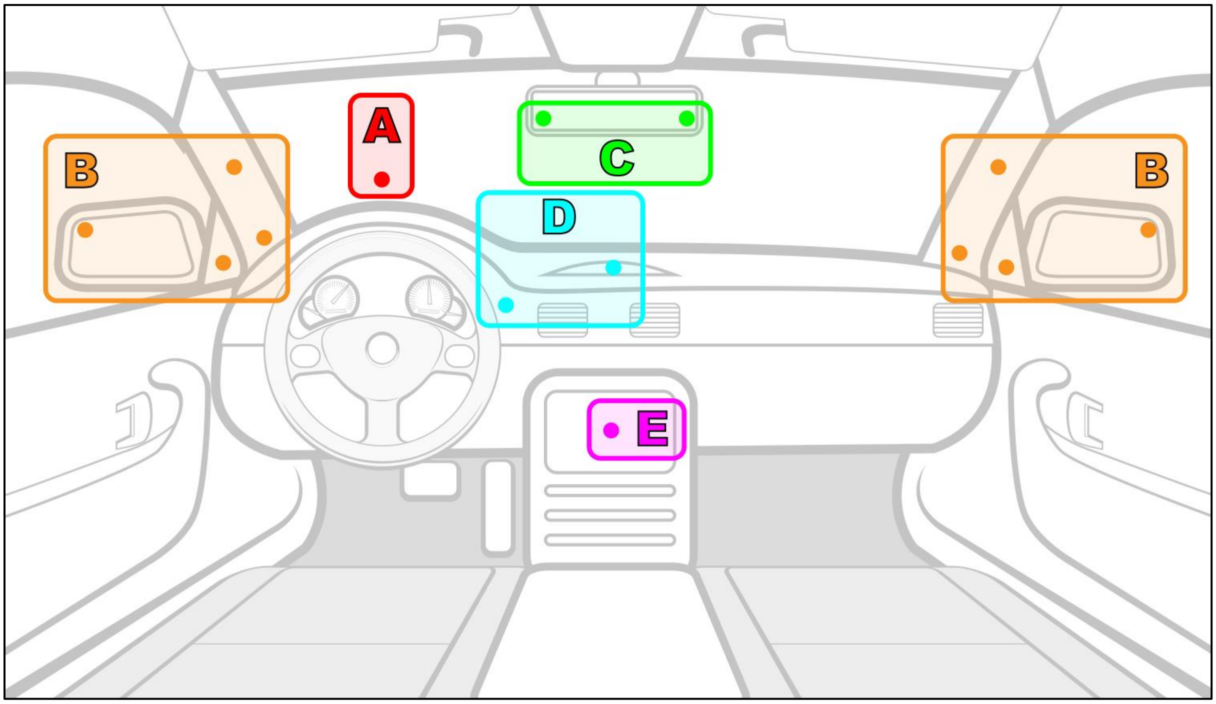

Figure 1. Appropriate locations for VDs that convey safety information (adapted from Campbell et al. 2016).

3.3.5 Color in Visual Display Warnings

Campbell et al. (2016) summarized the optimal colors and color combinations for safety-related warnings. The color red is associated with hazards, and yellow is normally associated with caution. The color green is associated with normal operations. Designers should use colors that are compatible with symbols based on prior association (e.g., red for octagonal stop signs). The use of too many colors should be avoided, and four colors should be the limit (Campbell et al., 2016; Stevens et al. 2002). Certain color combinations should be avoided due to conspicuity and/or color blindness, such as green/red, green/blue, yellow/red, yellow/blue, and violet/red (Campbell et al., 2016; Stevens et al. 2002).

3.3.6 Location of a Visual Display

The mounting location of the VD should be in a location that is easy to reach and see; however, no part of the physical device should obstruct a driver's view of the roadway, any vehicle controls, or displays required for driving (EU, 2008; JAMA, 2004; NHTSA, 2013). In general, VDs that present safety-critical information should be laterally positioned as close as practical to a driver's forward line of sight so that the angle of incidence is a maximum of 15 to 30 degrees (Green et al., 1995; NHTSA, 2013; Stevens et al., 2002; Ross et al., 1996). The monitor of the VD should be located in a place where (i) its reflection on the windshield does not obstruct the visibility of the forward field of view (JAMA, 2004); (ii) the incoming light does not disturb the driver's perception of the VD; (iii) the VD is not covered by functional parts of the vehicle (e.g., the gear lever; Ross et al., 1996); and (iv) the VD does not vibrate or change position when driven (Ross et al., 1996).

NHTSA (2013) recommends that the VD should be mounted where the downward viewing angle, measured at the geometric center of each active display area, is less than the 2D Maximum Downward Angle or the 3D Maximum Downward Angle. It is recommended that VD containing information relevant to driving and all VD requiring long sequences of interface be placed within approximately a 30° downward viewing angle of the driver's normal forward view (EU, 2008). See *SAE Recommended Practice J941* (SAE, 2010) for information on the location of the drivers' eyes inside a vehicle. *ISO 16121-3:2011* (2011b) recommends that bus designers place VDs and their controls on the roof console over the driver's workplace. The monitor and controls should be out of the reach of the driver while seated. This is where the VD was located in the OC Transpo crash. See *ISO 16121-2:2011* (2011a) for visibility requirements pertaining to the driver's workstation in line-service buses.

3.3.7 Character Height

Per Campbell et al. (2016), the optimal visual angle of graphical elements on a VD should be 86 arcminutes. The minimum visual angle of primary graphical elements should be 41 arcminutes for time-critical applications, and 34 arcminutes for non-time-critical applications. Text size on VDs (within an icon or free standing) should be 20 arcminutes. The minimum height for text on a VD should be 16 arcminutes for time-critical applications, and 12 arcminutes for non-time-critical applications.

3.3.8 Text Legibility

Whenever possible, pictograms or icons should be used, especially if quick and accurate recognition of the message is needed (Campbell et al., 2004; Ross et al., 1996). In general, the larger the button on the VD, the less visual distraction (Eren et al., 2015). However, if text messages are to be used, they should be kept to a one-line display of no more than 31 to 55 characters (JAMA, 2004; Tijerina, 1996). A number (e.g., 100) or a unit (e.g., km/h) should be considered a single letter irrespective of the number of digits. Punctuation marks are not included in the count of letters (JAMA, 2004). The space between lines of text should be at least 1/30 the line length (Campbell et al., 2004) or 0.6 mm (0.025 in) wide (Green et al., 1995).

Optimized VD typefaces may mitigate some interface demands; the humanist (Frutiger) approach shows promise (Reimer et al., 2014). Humanist-style type is significantly more legible than a square grotesque style, and black-on-white text is significantly more legible than white-on-black (Dobres et al., 2016). Sans serif fonts are recommended (Hammer et al., 2007: Stevens et al. 200s). No more than two different fonts should be used, and boldface, italics, underlining, or differences of color to emphasize words should be avoided (Campbell et al., 2004; Stevens et al. 2002). Mixed case should be used instead of all capital letters for messages in excess of two to three words, abbreviations, and signal words (Campbell et al., 2004, 2016; Green et al., 1995).

Minimum character height should be a visual angle between 15 degrees when the vehicle is stopped and 24 degrees when the vehicle is in motion (Stevens et al. 2002). Characters should have a width-to-height ratio range of 0.6 to 0.85 (Campbell et al., 2016). The stroke width-to-height ratio range for text should be 0.08 to 0.2, with 0.167 to 0.2 preferred for critical information (Campbell et al., 2016). Visually presented text should meet the legibility recommendations contained in *ISO 15008:2017*.

3.3.9 Temporal Characteristics

Sequential illumination should be used to convey motion and/or direction (keep text stationary), whereas flashing should be used for important, suddenly occurring situations (Campbell et al., 2016). Motion cues, such as bouncing or zooming, should not be used due to increased driver distraction (Campbell et al., 2016). Flash rates should be 3 to 10 Hz; however, the optimal rate is 3 to 4 Hz (Campbell et al., 2004, 2016; Kantowitz, 1998; Stevens et al., 2002). Flash rate and duty cycle should be adjusted depending on the message, with rapid pulses of flash for each flash cycle used in more urgent situations (Campbell et al., 2016).

3.3.10 Display Glare

Reflection of light and glare from the surface of the VD should be minimized (EU, 2008; Ross et al., 1996). To mitigate the glare on the VD during the day, sufficient luminance is needed and high-contrast display technologies and anti-glare coatings or films are recommended. Safety-critical messages should be in a location that minimizes glare from the sun (e.g., cowling or an inset bezel; EU, 2008; Campbell et al., 2016). To mitigate the glare from the VD in darkness, drivers should be able to adjust the level of lighting on the VD (Campbell et al., 2016; Stevens et al. 2002) or sensors should automatically reduce the VD's brightness (Campbell et al., 2016; Ross et al., 1996). A dark background can minimize the luminance, and the VD can be mounted in a location that reduces reflections on windows. Non-safety-critical messages (but not critical safety messages) should be presented in highly eccentric locations relative to the forward gaze (e.g., center stack; Campbell et al., 2016).

3.3.11 Information Entry

Speech entry requires less time and distraction compared to manual entry (Filtness et al., 2013; Maciej & Vollrath, 2009; Tsimhoni et al., 2004), but should have a hit rate of 98% and false alarm rates less than 5% (Stevens et al. 2002). A VD with a capacitive touchscreen (input is received when a capacitive field is broken by the electrical presence of a finger or hand) was associated with less distraction compared to a resistive touchscreen (input from force or pressure applied to the screen; Burnett et al., 2013). VDs with a touchscreen interface should provide synthetic (e.g., auditory or vibro-tactile) feedback in response to driver input (Ferris et al., 2016). Proximity activation should be avoided as it is easy to inadvertently activate the wrong control (Stevens et al. 2001). Certain information entry gestures, such as flicking and pinching, increase distraction, whereas panning limits the distraction when operating while driving (Kim & Song, 2014). Page-by-page scrolling and a grid-style menu should be avoided for information searches (Large et al., 2013); a list-style menu should be used instead (Kujalaa & Saariluoma, 2011).

3.4 Special Guidelines for Visual Displays

In this section, we describe special guidelines for VDs that are less prevalent in vehicles but likely to become more widely used in the future, including HUDs and indirect visibility systems.

3.4.1 Heads-up Displays

HUDs can minimize distraction as they present information close to the driver's forward field of view; however, the information should not be displayed in the driver's central field of view (Stevens et al., 2002). Information should be limited to the driving situation and should not include non-driving-related information or complex information (Campbell et al., 2016; Stevens et al., 2002). The information presented in the HUD should not require visual reference to other displays for interpretation (Campbell et al., 2016). The HUD should allow drivers with polarized sunglasses to see the information (Campbell et al., 2016).

3.4.2 Indirect Camera Monitoring Systems

Back-up cameras are widely used in passenger cars and straight trucks; however, mirrors in large trucks and buses still have many blind spots. Indirect camera monitoring systems have the potential to reduce these blind spots; however, the VDs where this information is presented may be distracting to drivers. Fitch et al. (2011) and Wierwille et al. (2011) conducted pilot tests with an indirect camera monitoring system to reduce the blind spots on the sides and back of a tractor-trailer truck. The authors indicated that the cameras should have daytime color capability and nighttime monochrome capability, and be sensitive at night to visible and near infrared (IR) radiation illumination (which reduces glare at night due to ambient light and headlights as well as improving visibility during adverse weather, such as fog and heavy rain). The camera for such a system should be housed in a waterproof enclosure and mounted at the driver- and passenger-side front fender (in trucks). The corresponding monitors should be placed in the cab in a position at the driver- and passenger-side A-pillar (i.e., corresponding to the general direction the driver would look using his/her side- and rearview mirrors). See *ISO 16505:2015* (2015) for ergonomic and performance aspects of camera monitor systems (i.e., camera systems that replace mirror systems).

4 DISTRACTION COUNTERMEASURES

This section reviews inattention-monitoring technologies, which can include distraction and fatigue. Only technologies that reduce distraction were included in this review. A technology was included as a distraction countermeasure if it reduces distraction or fatigue and distraction, but was excluded if it is only a fatigue countermeasure. In this section, we summarize approaches to reduce driver distraction by dividing the technologies into the following five different types of countermeasures: (1) lockout/blocking and interrupting technologies and workload managers; (2) physiological sensors; (3) driver performance measures; (4) computer vision; and (5) hybrid measures. Again, as indicated above, only those technologies that directly mitigate and/or prevent distraction were included; thus, technologies that mitigate and/or prevent the deleterious effects of distraction (e.g., crash avoidance systems, onboard safety monitoring systems, etc.) and driver education and training approaches were excluded. Here we provide a brief summary of distraction-monitoring technologies. Readers who desire a more thorough review should see Fernandez et al. (2016), Dong et al. (2011), and Regan et al. (2008). These sources provide a comprehensive review of different distraction-monitoring technologies as well as commercially available systems from OEMs and third-party vendors.

4.1 Lockout/ Blocking and Interrupting Technologies and Workload Managers

OEMs and third-party vendors have developed different lockout or blocking technologies. We will not explore those technologies here. Obviously, these technologies eliminate distraction; however, they are only as effective as (a) the ability of a driver to circumvent the lockout, and (b) the driver installing and using the technology on their personal devices with VDs. The European

Commission (2015) characterized several OEM technologies as “workload managers,” meaning that the technologies interrupt a secondary task or adjust driving performance if the driver’s attention lapses or the driving environment is considered overly demanding. For example, Saab’s ComSense interrupts a mobile phone call, Lexus’s Driver Monitoring System provides corrective steering, and Toyota’s Wakefulness Level Judging System applies emergency braking. Engstom and Victor (2009) suggested that the benefits of workload managers are found in highly demanding driving situations and are dependent on the type of information being rescheduled or locked out.

One potential workload manager using video analytics technology could alleviate one of the contributing factors identified in the OC Transpo double-decker bus crash. Goldgof et al. (2009) developed an evaluation framework for video analytics systems to review video for the purposes of threat detection (identifying crime and terrorism). Although the technology is far from commercial development, one could envision such a system taking over for a driver once the vehicle was in motion. Thus, rather than relying on drivers to continually monitor passengers to ensure that they are seated, a video analytics system could be used to monitor passengers. For example, while the vehicle is stopped, the driver would be responsible for monitoring passenger behavior. Once the vehicle is in motion, the VD would lock out and the video analytics technology would be responsible for monitoring the passengers, thus removing a source of distraction and reducing the driver’s workload (so he or she can focus on driving).

4.2 Physiological Sensors

There has been some effort to use physiological variables to assess a driver’s attentional state. However, these technologies are far from being ready for use in real-world driving. Most of these sensors have been used to assess driver fatigue. Several recent efforts have attempted to use these sensors as a distraction-monitoring system. Sonnleitner et al. (2011) successfully used electroencephalogram (EEG; electrical activity of the brain) during real-world driving to assess drivers’ attentional shift during auditory and visual secondary tasks. The authors reported that alpha spindles showed a significantly higher occurrence rate during auditory secondary tasks and a significantly lower rate during the visual secondary tasks compared to baseline driving with no secondary tasks. Healey and Picard (2005) collected various physiological data (electrocardiogram, electromyogram, skin conductance, and respiration) during real-world driving tasks to determine a driver’s relative stress level. Although the analysis distinguished between three levels of driver stress with an accuracy of over 97 percent, driver stress has not been shown to be a proxy for engagement in secondary tasks while driving. Several other studies (Brookhuis et al., 1991; Garcia-Constantino et al., 2014) have incorporated heart rate or heart rate variability as a measure of driver workload; however, this is a somewhat flawed variable as heart rate variability changes in response to emergencies and physical stress, but not in secondary task engagement per se (unless the other two conditions are met).

4.3 Driver Performance

A change in the drivers’ workload can result in a change in driving performance. Recent efforts to monitor driver distraction have used steering and lane position. Kountouriotis et al. (2016) had drivers perform various nonvisual and visual secondary tasks while they drove in a high-fidelity simulator. They found that steering wheel reversal rates distinguished between nonvisual distraction (increase of 0.5 degree reversals) and visual distraction with offset gaze concentration (increase of 2.5 degree reversals). Dababneh et al. (2016) assessed steering wheel performance of truck drivers in a truck simulator as they performed various secondary tasks. They found that a steering rate threshold of 43 degrees/second was the most suitable for distraction detection. Lindman et al. (2012) reported promising results from the European Field Operational Test. A Driver Alert Control system monitored the vehicle's progress between the lane markers and warned the driver if his or her driving pattern changed. Of the 125 Driver Alert Control warnings, 96 percent were related to driver distraction or fatigue (56 percent distraction, 20 percent fatigue, 20 percent were distracted and fatigued, and 4 percent were false alarms). At present, technologies that use driver performance to monitor driver distraction are unproven and not applicable to real-world driving.

4.4 COMPUTER VISION

By far, distraction countermeasures that rely on computer vision have been studied the most. Several commercially available distraction-monitoring systems use computer vision. Many of these technologies were initially developed to combat driver fatigue; however, their developers found they could also to detect distraction. These technologies rely on hardware and computer software that detects and measures a driver's pupil size, gaze location, blink frequency, head position, hand position, or some combination thereof.

Most distraction-monitoring systems have focused on gaze direction and head position. These systems measure the reflectance from the eye to assess blinking and/or pinpoints on the face to detect head position and gaze direction. For example, Kircher et al. (2009) described a stereoscopic camera system that measured the driver's gaze direction and head position. A real car shell was used in the simulator experiment. "Road center" was defined as a circular area with a radius of 8 degrees centered around the road center point. The road center point and the center area were redefined each session to account for changes in the driver's seating. Results indicated the percent road center algorithm was effective at identifying a distracted driver (with attentive drivers having percent road center around 70 percent). However, during a small pilot test of the algorithm, drivers did not increase their percent road center after receiving a haptic warning. Lee et al. (2013a,b) used the National Advanced Driving Simulator to assess four different vison algorithms that used eye- and head-tracking inputs to assess driver distraction. Drivers in the study drove with and without secondary tasks (e.g., reaching behind the seat) over three types of roadways (urban, freeway, and rural). Although all four algorithms performed well, the algorithms performed differently under the different secondary tasks and roadways. The most-complex algorithm, or multi-distraction detection (combining percent of glances to the road and long glances away from the road), consistently performed better than the others in all driving environments and visual secondary tasks. This was the only algorithm that was able to detect cognitive distraction (albeit somewhat imprecisely). The least-complex algorithm, eyes off forward roadway, performed best in the urban environment. The study illustrates the need to assess algorithms in different driving environments and secondary tasks.

Niezgoda et al. (2015) evaluated a novel approach to assess cognitive demands during auditory and verbal tasks (e.g., such as using voice commands) while driving. Using a driving simulator, the authors had drivers perform the n-back test while driving. The participants wore glasses that collected information on their eye movements. Dependent variables included pupillometry, blink rates, driving performance (lateral and longitudinal control), and fixation locations. In a somewhat impractical countermeasure, Ebrahim et al. (2013) used electrooculography in real-world driving while drivers performed visual-manual and auditory tasks. The authors found that gaze shift blinks predicted visual distraction. Overall, the detection of visual distraction via gaze direction has been the most promising in driving simulators or constrained conditions. However, real-world driving presents different challenges, such as changing backgrounds, variations of lighting, glasses, hairstyle, and jewelry.

Bergasa et al. (2008) used a stereoscopic camera system to assess distraction by detecting head movements, facial expressions, and cues that reflected the driver's level of alertness. Head movements were estimated using a 3D face model and facial expressions were recognized with a model-based method (different expressions were represented by samples). The algorithm was tested in a simulator and real-world drive with a detection rate of 92 percent. Masala et al. (2014) used a camera system with two layers to detect distraction. Once the face detector identified the face of the driver using facial geography, it compared the video frame to an existing dictionary of head poses. If the pose was labeled as attentive, the second layer detected whether the eyes were open or closed in that frame. This method was very robust, working in various noise and adverse light conditions and drivers with a beard and eyeglasses.

Jimenez et al. (2012) was one of the few studies that assessed a distraction-monitoring system with truck drivers in a truck driving simulator. Using a stereoscopic camera system, the system inferred gaze direction using facial landmarks and estimated gaze location (angle of horizontal and vertical eyes). One of the problems with this system was that it required calibration with the intended driver prior to the detection system operating automatically. Vicente et al. (2015) evaluated a similar system; however, no calibration was needed, and the system worked when drivers wore glasses or sunglasses as well as in daytime and night. If a driver's eyes were detected by the system, the driver's pupils and eye corners were used to estimate gaze locations. However, if the eyes were not detected (as with a driver wearing sunglasses), gaze position was estimated using 3D head position. Vicente et al. (2015) reported an impressive 90 percent accuracy for eyes-off-road in a variety of different conditions. Not surprisingly, Mbouna et al. (2013) found that reliance on only one feature resulted in poorer distraction detection rates than multiple features, such as head position, pupil activity (eyes closed or open), and eye index (ratio of pupil height to eye height).

Cheng and Trivedi (2010) described a computer vision system that determined which of the front-row seat occupants accessed the infotainment controls. Using a visible and infrared device, the system had a 97.9 percent classification rate for detecting one of three image classes (driver, passenger, no one accessing control) using the infotainment controls located between the driver and passenger seats. Such a system could be used to lock out the driver from using the infotainment given the demands in the driving environment, but allow a passenger (if present) to access these controls. Craye and Karray (2015) found a novel use for a Kinect system for the Microsoft Xbox. They used the Kinect and computer vision tools to detect driver distraction using eye behavior (detecting gaze and blinking), arm position (is the right arm up, down, right of forward), head orientation, and facial expressions. Drivers were introduced to various secondary tasks while in a driving simulator. Results showed that the system was 85 percent accurate in detecting the type of distraction and 90 percent accurate for detecting the presence of distraction. Distraction mitigation technologies that rely on computer vision are already in the marketplace; see Fernandez et al. (2016) for a review of these systems.

4.5 Hybrid Systems

Hybrid measures are more reliable countermeasures compared to any single approach as they minimize the number of false alarms and increase the recognition rate. Fletcher and Zelinsky, (2007) explored this concept and hypothesized that the combination of driver gaze information and lane tracking along with road scene monitoring (machine vision) could minimize and manage distractions via a Driver Assistance System (DAS). The DAS would warn the driver about an upcoming event and possibly take control of the vehicle. Similarly, Dingus (2013) described a pilot project to integrate hardware and software to develop, among other things, a distraction detection system using lane keeping and head pose tracking.

Koesdwiady et al. (2015) combined pressure sensors in the steering wheel and seat with upper body movements captured by a camera. The accuracy of the pressure data alone was 84.82 percent, the accuracy of the video data alone was 83.94 percent, but the combined sensors had an accuracy of 91.46 percent of detecting driver distraction in a simulator. Liu and Ko (2013) described an integrated method that detected driver's alertness using vehicle steering and inattention facial features (driver's gaze direction). Preliminary results suggest the proposed modeling technique would achieve greater than 99 percent accuracy with a 0.12 percent false positive error (0.12 times per hour). Miyaji et al. (2009) used a stereo camera system to track a driver's eyes, head movements, and diameter of the pupil, as well as the interval between heart R-waves from an electrocardiogram as a means for detecting cognitive distraction. The combined accuracy of these sensors was 91.6 percent, which is fairly robust for a system that detects driver's cognitive distraction.

4.6 Employer Methods

Employers can protect themselves by implementing policies that prohibit distracted driving and by monitoring compliance. Ideally, the guidelines and considerations described above illustrate what types of VD systems should be used while driving. In general, the best practice would be to instruct drivers that attention to the road is their primary responsibility, not instructions on how to use dangerous equipment "safely." New Jersey developed a sample cell phone use policy for businesses (www.nj.gov/lps/hts/downloads/Sample_Cell_Phone_Policy.pdf). The National Safety Council developed a policy kit to assist employers with implementing or strengthening a cell phone policy (http://www.nsc.org/learn/NSC-Initiatives/Pages/PolicyTool.aspx). A sample employer policy is available at www.distraction.gov/content/get-involved/employers.html.

5 KEY RECOMMENDED GUIDELINES

Below is a summary of the key recommended guidelines for OEM and portable and nomadic devices with VDs.

Summary of Guidelines for Original Equipment Manufacturer Visual Displays

- Any information presented on a VD should not cause the driver to gaze at the VD continuously (JAMA, 2004).
    - Each glance should not exceed 1.5 seconds (Ryu et al., 2013) to 2.0 seconds (NHTSA, 2013).
    - The total time the driver is looking at the VD (from the start of the task to the end of the task) should not exceed 8 seconds (JAMA, 2004) to 12 seconds (NHTSA, 2013).
- VD system functions that are not to be used by the driver during driving should be inoperative or presented in a way the driver cannot see while the vehicle is in motion (Campbell et al., 2016; European Union, EU, 2008; JAMA, 2004; NHTSA, 2013).
    - Display of motion pictures, including broadcasted television pictures and replayed video and DVD pictures, should be forbidden while driving (JAMA, 2004).
        - Exclusions include the area directly behind a vehicle under specific conditions (i.e., moving image of the vehicle's rear view, but only when the vehicle is in reverse), map displays, and information deemed to be related to the safe operation of the vehicle (NHTSA, 2013).
    - Manual text entry (e.g., text-based messaging, other communication, or Internet browsing), scrolling text, displaying text to be read, and displaying images should be prohibited while driving (NHTSA, 2013).
        - Exceptions include driving-related images, including maps; images displayed for aiding a driver to efficiently make a selection in the context of a non-driving-related task; internationally standardized symbols and icons; and information deemed to be related to the safe operation of the vehicle (NHTSA, 2013).
- If non-safety-related messages are presented on the VD, the device should provide a means by which it can be turned off or disabled (EU, 2008; JAMA, 2004; NHTSA, 2013).
- Instructions should clearly state which functions of the VD system are intended to be used by the driver while driving and those which are not to be used while driving (EU, 2008; NHTSA, 2013).
- The VD system should be capable of providing information to the driver on any detected malfunction that may have an adverse impact of safety (NHTSA, 2013).
- The VD system should allow the driver to maintain one hand on the steering wheel (reaching through the steering wheel is prohibited). The VD system should never require the driver to remove both hands from the steering wheel (EU, 2008; JAMA, 2004; NHTSA, 2013).

- Uninterruptable sequences should be prohibited, and a sequence should resume at the point the task was interrupted (Campbell et al., 2016; EU, 2008; NHTSA, 2013).
- The VD system should not require an immediate response from the driver (JAMA, 2004; NHTSA, 2013).
    - The VD system should provide feedback or confirmation of the driver's response, and the response to the driver's input should not exceed 0.25 seconds (JAMA, 2004; NHTSA, 2013).
    - Feedback should be provided to the driver if the system's response speed exceeds 2 seconds (i.e., make it clear a change occurred; NHTSA, 2013).
- The location of the VD should minimize distractions due to visibility (including fare box, blind spots, glare, and mirror placement), controls, instrumentation, and seat design and location (APTA, 2009a).
    - The location of the VD should not interfere with existing controls to displays required for the primary driving task from the driver's normal seating position (Stevens et al., 2002), or obstruct the driver's view outside the vehicle (EU, 2008; JAMA, 2004; NHTSA, 2013).
    - The mounting location of the VD should be in a location that is easy to reach and see (EU, 2008; JAMA, 2004; NHTSA, 2013).
    - The VD should be mounted where the downward viewing angle, measured at the geometric center of each active display area, is less than the 2D Maximum Downward Angle or the 3D Maximum Downward Angle (NHTSA, 2013).

Summary of Guidelines for Portable or Nomadic Visual Displays

- Portable and nomadic devices with VDs should follow the same guidelines as OEM devices with VDs.
- Portable and nomadic devices with VDs should be easily paired with an OEM interface.
    - Once paired, tasks that are not related to the safe operation of the vehicle should be locked out (e.g., displaying video not related to driving, scrolling texts, etc.; NHTSA, 2016b).
- Portable and nomadic device should have a "Driver Mode," which is used when pairing is unavailable or the driver chooses not to pair the device.
    - Driver Mode is either (1) automatically activated when the device is not paired with the OEM interface and distinguishes that it is being used by a driver who is driving (i.e., it distinguishes between a driver and a non-driver), or (2) manual activation of Driver Mode.
    - When in Driver Mode, the portable or nomadic device should lock out any visual-manual secondary tasks that do not meet the OEM guidelines (NHTSA, 2016b).
- Transit bus drivers should turn off and stow all personal electronic devices (e.g., cell phone, pagers, MP3 players, etc.).
    - These devices should never be used while the vehicle is in motion.
    - Use of these devices should be restricted to times when the vehicle is parked (APTA, 2009b).

Figure 2 is a flowchart that illustrates the recommended guidelines for VDs. This flowchart is for illustrative purposes to determine if and how a VD system should be used while driving. Any OEM and portable and nomadic devices with VDs should follow the appropriate motor vehicle standards and guidelines under which they are intended to operate (including any exceptions).

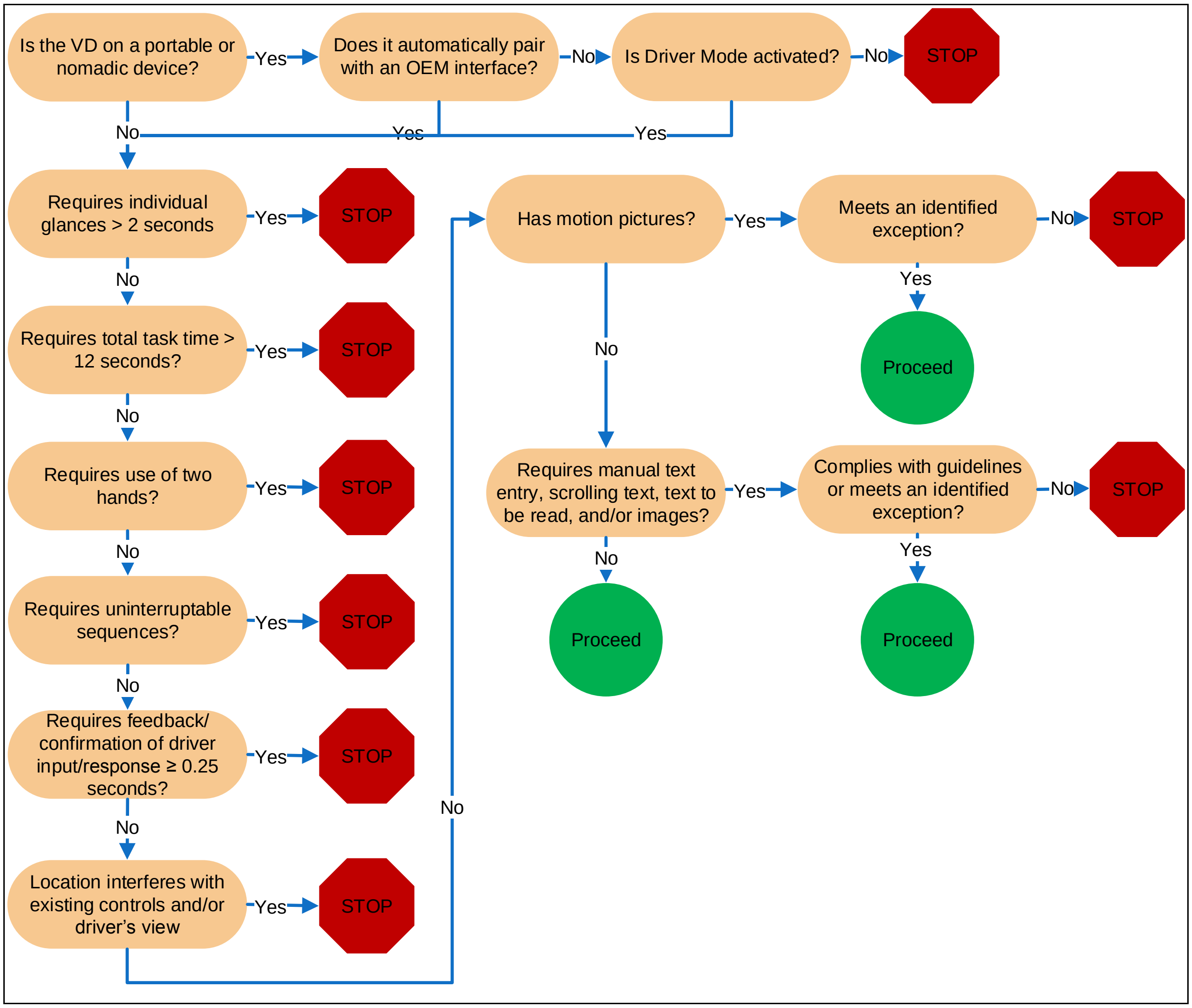

Figure 2. Flowchart illustrating recommended guidelines for VDs while driving.

6 APPENDIX A: KEYWORD SEARCH TERMS

Key Word List:

1. Digital video interface
2. Screen
3. Video display
4. LCD
5. Monitor
6. Closed circuit television
7. In-vehicle display
8. Navigation system
9. Rear facing camera
10. Reversing camera
11. Blind spot camera
12. Passenger monitoring camera
13. Safety camera
14. Infotainment
15. Scheduling display
16. Management system
17. Blind spot monitoring
18. Indirect visibility
19. Crash avoidance system
20. Crash mitigation system

Exclude key words:

1. Cell phone
2. Mobile phone
3. telephone

Searches:

1. Key word list AND distraction(s)
2. Key word list AND guideline
3. Key word list AND best practice
4. Distraction AND guideline
5. Distraction AND best practice

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