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UNIT IV AUTOMATED VEHICLE TECHNOLOGY

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Warning Effectiveness Within the Connected Vehicle Concept This report presents the findings of research studies on human factors issues related to effective crash avoidance warnings within the context of the U.S. Department of Transportation's CV program. The CV program is a major initiative that will improve surface transportation safety and mobility. As described on the DOT's Research and Innovative Technology Administration (RITA) Web site (www.its.dot.gov), "Connected Vehicle research at U.S. Department of Transportation is a multimodal program that involves using wireless communication between vehicles, infrastructure, and personal communications devices to improve safety, mobility, and environmental sustainability." Specifically regarding the safety component, the RITA site states that "Connected vehicle safety applications are designed to increase situational awareness and reduce or eliminate crashes through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) data transmission that supports: driver advisories, driver warnings, and vehicle and/or infrastructure controls. These technologies may potentially address up to 82 percent of crash scenarios with unimpaired drivers, preventing tens of thousands of automobile crashes every year (further research will incorporate heavy vehicle crashes including buses, motor carriers, and rail)." The key to the CV concept is connectivity. "Connectivity" in this context means that there is a wireless network supporting communications between vehicles, the transportation infrastructure, and personal communications devices. The mature program is envisioned to provide a driver with "360-degree awareness" of surrounding traffic, as well as the status of roadway and traffic conditions and travel options. This represents a new context in which drivers will acquire many sorts of information, including a wide range of safety-related messages. The human factors issues concern how to integrate and display all of the information a driver may want or need in a manner that is safe and usable. A wide variety of important safety messages may ultimately be included within CV applications. Among the potential applications that have been suggested are: ν B ν F lind spot warning/lane change warning, orward collision warning, 1 2 ν Electronic emergency brake lights (vehicle ahead that driver cannot see is braking), ν Intersection movement assist (unsafe to enter intersection due to conflicting traffic), ν Intersection violation warning (driver is about to commit a violation), ν Do not pass warning (opposing traffic, insufficient gap), ν Vehicle control loss warning (driver is on verge of loss of vehicle control), ν School zone, ν Curve speed warning, other warnings about road geometry (e.g., lane drop), ν Work zone warning, ν Pedestrian or bicyclist presence, ν Slippery road warning, ν Dangerous weather conditions (snow, fog, heavy rain), ν Stopped traffic ahead (e.g., backup on a freeway), ν Traffic signal status ν Road departure, lane departure The specific issue of concern for the present project is how to ensure that important safety messages are effective (i.e., result in high rates of driver comprehension and proper responses). The challenge is that the CV concept may provide drivers with a large number of safety messages, many types of non-safety information, and a variety of different design and display concepts as implemented by various manufacturers and applications developers. Within this context, the driver's reaction to any particular urgent safety message must remain rapid and appropriate. The project under which the research studies presented here were conducted is one of several complementary parallel projects dealing with human factors aspects of the driver interface within the CV context. The purpose of this project was to conduct new empirical research to address key knowledge gaps that limit the ability to provide supportable guidance for CV system developers. Based on the findings, implications for warning interface design were derived. While the initial research findings related to these complex issues are preliminary, they provide an 3 improved basis for effective CV warning interfaces. Together these efforts provide human factors guidance on how the CV driver interface can support effective, safe, and user-acceptable displays.

The National Highway Traffic Safety Administration (NHTSA) defines automated vehicles as those in which at least some aspects of a safety-critical control function (e.g., steering, throttle, or braking) occur without direct driver input. Different levels of vehicle automation require drivers to perform different tasks while interacting with the vehicle. For example, Level 1 automation requires the driver to be physically operating the vehicle with either their hands or their feet (but not necessarily both) at all times. Adaptive cruise control is an example of Level 1 automation. Level 2 automation requires the driver to monitor the roadway and to be available for control at all times and on short notice. Self-parking technology is an example of Level 2 automation. With Level 3 automation, the driver is expected to be available for occasional control, but with sufficiently comfortable transition time. An example of a Level 3 vehicle is one that can navigate on the highway, including on-ramps and off-ramps, on its own without driver intervention. At Level 4, the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. Although there are no Level 4 vehicles currently on the market, a Level 4 vehicle is capable of completing an entire trip from origin to destination without driver input or intervention. Levels 1 through 4 all require drivers to monitor the automated system to make sure it is performing as expected and to intervene (resume control) in situations that the automation cannot handle. Alexander Eriksson & Neville Stanton, *Takeover Time in Highly Automated Vehicles: Noncritical Transitions to and from Manual Control*, Human Factors: J. Human Factors and Ergonomics Soc'y, June 2017, at 689.

One of the major human factors issues with automated vehicles is that many automated vehicle features are intended to be used only under certain conditions (e.g., on highways, in clear weather, etc.) and, therefore, suffer from "brittleness" Micra R. Endsley, *From Here to Autonomy: Lessons Learned from Human-Automation Research*, Human Factors: J. Human Factors and Ergonomics Soc'y, Feb. 2017, at 6. Brittleness means that the automated features of the vehicle function well under the conditions in which it was intended to be used, but the system requires human intervention to handle situations that the software was not designed to handle. The resulting challenge for the human driver is that they may not realize that the automation is not performing correctly or not understand why the automation is not performing correctly. Human factors research on automated systems has shown that people are slow to detect a problem with automation and slow to understand the problem after it is detected. When automation failures occur, unexpected automation transitions that require a driver to take over or resume manual control of the vehicle will occur suddenly and the driver may not be ready to take over.

A driver's ability to intervene and avoid a collision after vehicle automation fails is dependent upon the driver's level of situation awareness and workload, as well as the roadway conditions and the time available to avoid a collision. A driver must either realize that the driving situation is beyond the capabilities of the automation on their own or be alerted to that fact by the vehicle user interface. The driver must then have sufficient time to take over manual control of the vehicle. The time needed for takeover depends on the complexity of the driving situation and how long the driver needs to gather information from the driving environment and formulate an appropriate response. Christian Gold, Daniel Damböck, Lutz Lorenz & Klaus Bengler, *"Take Over!" How Long Does It Take to Get the Driver Back into the Loop?*, Proceedings of the Human Factors and Ergonomics Soc'y 57th Annual Meeting, 2013, at 1938. The time available to avoid the collision is a function of the range of the system's sensors and their ability to predict automation failure and the need for human intervention.

In situations where drivers must resume control of the vehicle to avoid a collision, it is critical to understand that vehicle automation negatively affects mental workload, situation awareness, and perception-reaction time—several key factors that affect a driver's ability to avoid a collision. In fact, recent research indicates that the braking reaction time of drivers using Level 1 and Level 2 automation is up to 1.5 seconds longer than drivers who are manually operating the vehicle. Eriksson & Stanton, *supra*, at 690. Perhaps even more importantly, it is known that higher levels of automation breed complacency that induces drivers to engage in non-driving-related tasks such as talking on a cell phone or reading from a tablet. Raja Parasuraman & Victor Riley, *Humans and Automation: Use, Misuse, Disuse, Abuse*, Human Factors: J. Human Factors and Ergonomics Soc'y, June 1997, at 230; *see also* Gold et al., *supra*. Thus, as the level of automation increases (e.g., Level 3 and Level 4 automation), so does the likelihood that drivers will engage in non-driving-related tasks. Those drivers who are engaged in secondary non-driving-related tasks may need significantly longer to regain situation awareness, reenter the driving control loop, and successfully respond to a takeover request. In fact, depending on the secondary task being performed, a driver can take as long as 25 seconds to successfully take over. Eriksson & Stanton, *supra*, at 699. Therefore, it is critical that semi-autonomous systems be designed to accommodate drivers who take the longest to intervene, not the "average" driver.