Preface to the Special Section on Driver Distraction

Beginning with the introduction of the car radio, there have been concerns regarding how in-vehicle technology might undermine driving safety. Those concerns are particularly apparent today as many worry about the safety consequences of introducing vastly more complex technologies into the car, most prominently regarding the use of cell phones while driving. Developments in the areas of wireless communication, computing, and GPS technology make an increasing variety of navigation, E-mail, and Internet systems available to the driver. This availability, coupled with increased commute times, productivity pressures, and the diffusion of work beyond the office, makes it likely that drivers will use these devices while driving. For example, 90% of all cell phone owners report that they use the phone while driving (Goodman, Tijerina, Bents, & Wierwille, 1999). The increasingly common use of existing technology and the rapidly emerging new technology make it imperative to understand how in-vehicle technology affects driving safety. Properly designed, the new technologies may enhance driving enjoyment and safety; poorly designed, they can be deadly.

A large and rapidly growing body of research shows that using a cell phone while driving degrades driving performance and increases crash risk (Alm & Nilsson, 1995; Brown, Tickner, & Simmonds, 1969; Haigney & Westerman, 2001; McKnight & McKnight, 1993; Redelmeier & Tibshirani, 1997; Violanti, 1997). By one estimate, crashes related to cell phones cause approximately 2600 deaths, 330 000 injuries, and 1.5 million instances of property damage in the United States per year (Cohen & Graham, 2003). The true safety impact of these devices in terms of crashes and fatalities may be underestimated. Compared with alcohol-related crashes, for which there is a clear marker of a causal agent, crashes related to cell phones do not leave a telltale trace. Even in the portion of cases for which cell phone records are available, it is often difficult to precisely time-stamp the crash and relate it to the distraction. Many telematic devices leave an even weaker trace.

Although hands-free cell phones may eliminate some of the visual and manual demands that undermine driving performance, many studies have shown that the cognitive demands of conversation are not eliminated with hands-free devices (Brown et al., 1969; Strayer & Johnston, 2001) and may even increase if the intelligibility of the hands-free devices is less than that of the handheld device (Matthews, Legg, & Charlton, 2003). New telematic devices have the potential to impose visual, manual, and cognitive demands that may greatly exceed those of cell phones, further undermining driving safety. Controversy regarding this new technology points to a need for a scientific basis to help legislators and designers make scientifically based decisions. Legislators and designers cannot make accurate cost-benefit analyses if they do not know the true costs and benefits.

This special section brings together recent research to address the distraction potential of cell phones and emerging telematic devices. Twenty papers were submitted for consideration and eight were accepted for publication. Those accepted for publication went through a rigorous review process that was made possible by the substantial efforts of the following reviewers: D. Boehm-Davis, L. Boyle, T. Brown, J. Caird, J. Campbell, J. Casali, D. Fisher, A. Fisk, P. Green, L. Gugerty, J. Harbluk, B. Kantowitz, W. Karwowski, A. Kramer, N. Lerner, M. Manser, M. Reyes, N. Sarter, T. Schnell, R. Srinivasan, L. Tijerina, and N. Ward.

The papers included in this special section demonstrate the diversity of potential distractions and diversity of methods to understand the safety consequences of these distractions.

Sheridan provides a theoretical framework that uses control theory to describe distraction according to qualitatively different disturbances to various control functions associated with driving (e.g., sensing and responding). This theoretical framework provides a foundation for interpreting epidemiological and experimental investigations of distraction.

Many studies of driver distraction capitalize on the controlled, yet realistic, situations afforded by driving simulators. This special section includes four such studies. Each of these papers capitalizes on the realistic demands of a driving simulator to explore the consequences of visual, manual, and cognitive distractions.

Tsimhoni, Smith, and Green used a driving simulator to evaluate the distraction potential of text entry methods for navigation systems. Their results show that the visual-manual demands of typing an address with a touch screen substantially degrade driving performance; however, similar to the hands-free/handheld debate with cell phones, entering this information through speech recognition can also degrade driving performance. Horrey and Wickens used a driving simulator to explore the distraction potential of presenting information to drivers, and they show that auditory displays can actively compete for drivers' attention more aggressively than visual displays and so can be surprisingly distracting. Jamson and his colleagues used a driving simulator and explored the distraction potential of E-mail interactions. They show that giving the driver control over when the E-mail is presented can have negative or positive effects on driving performance, depending on the demands of the driving situation. Drivers are not a homogeneous population, and one of the most important differences as it relates to distraction is age. Strayer and Drews examined the effect of age on driving performance while conversing on a cell phone. They show that cell phone conversation impairs driving performance for both age groups. Interestingly, the impairment was equivalent for younger and older drivers.

Driving simulators replicate many features of the natural driving environment; consequently, drivers' responses to distractions are often complex and the specific mechanism of the distraction can be obscured. More controlled part-task studies provide an artificial but more precise view of how human cognitive limits contribute to distraction-related safety problems. As an example, Monk, Boehm-Davis, and Trafton used a VCR programming task and a tracking task, which, on the surface, have little connection to driving but reveal how fundamental limits of switching attention, goal rehearsal, and the timing of interruptions contribute to distraction. Atchley and Dressel examined how the demands of a conversation undermine drivers' visual attention, as measured by the useful field of view (UFOV). This part-task study is particularly valuable because reduced UFOV performance has been systematically related to increased crash risk among older drivers (Owsley et al., 1998). McPhee and her colleagues used a different part-task approach to identify how secondary task demands undermine visual search in traffic scenes. These part-task studies provide a detailed view into the fundamental human performance limits that can compromise driving safety.

These papers demonstrate the range of potential distractions, the diverse effects on driver performance, and the variety of methods used to study the complexity of the driver distraction issue. The ultimate effect of new technology on driving safety depends on a wide array of interacting factors. Figure 1 reveals some of these interactions by distinguishing among three levels of driving behavior associated with distraction (Michon, 1985; Ranney, 1994). Strategic behavior describes driving and telematic activities at a very molar level, with a time scale of minutes to days. Tactical behavior describes driving and telematic tasks at a finer level, with a time scale of 5 to 60 s. At the bottom of the figure, operational behavior describes tasks at a micro level, with a time scale of 0.5 to 5.0 s. Each of these levels provides a different description of how the characteristics of new technology interact with the driver to influence distraction-related safety problems.

With regard to cell phones, the top of Figure 1 describes the factors that might lead drivers to bring a cell phone into the car. At the strategic level, societal norms and regulations might discourage drivers from bringing a cell phone into the car, but hands-free technology and productivity pressures might encourage drivers to do so. At the tactical level, the immediate roadway
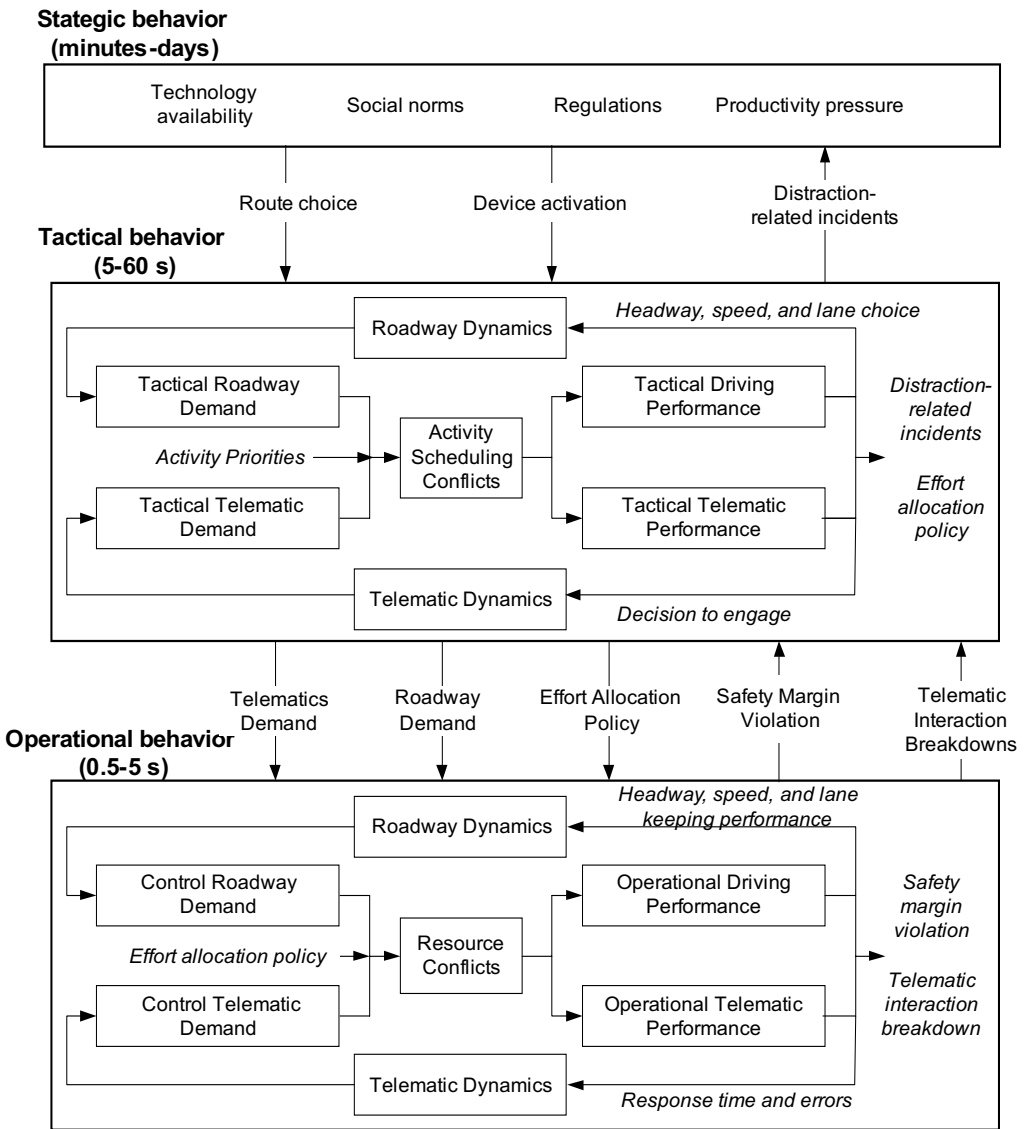
Figure 1. Distraction results from breakdowns of multilevel control that is shared between telematic interactions and driving.

demands might influence the decision to answer the phone, and the perceived demands of a conversation might lead drivers to adopt longer headways or slower speeds. At the operational level, the cognitive demands of the conversation influence headway, speed, and lane-keeping performance.

This framework points to several fundamental problems confronting the design and regulation of in-vehicle technology. Addressing these issues depends on integrating the results from a range of studies, such as the ones included in

this special section. First, a well-designed device that reduces distraction at the operational level may actually undermine driving safety if it encourages drivers to use the device more frequently while driving. This *usability paradox* occurs when increased ease of use reduces the distraction of any particular interaction but increases overall risk by encouraging drivers to use the device more frequently. This tendency for drivers to adapt to improvements and thereby undermine the expected safety benefits is a common phenomenon. For example, when roadway

improvements are made (lanes widened, shoulders added, lighting improved), speeds increase. Drivers may view hands-free cell phones as safe to use while driving and so make more calls than they would with a handheld cell phone.

Second, it shows that drivers are not passive recipients of distracting stimuli. Distraction-related behavior results from a dynamic closed-loop process at three different levels of behavior. This makes evaluating the distraction potential of a device difficult because the evaluation must consider the distraction posed by the interaction and the effect of the design on drivers' ability to adapt their interaction to the dynamic demands of the roadway. To the extent that an experiment does not facilitate this adaptive process, the results may not generalize to real driving. Forcing older drivers to engage in cell phone conversations in a simulator experiment may overestimate the true risk of cell phones for older drivers because they might make the strategic decision not to use them.

Third, it shows that driving performance and interactions with the in-vehicle technology can both suffer from competition from the other activities. For example, business negotiations by cell phone while driving suffered in comparison with those conducted when not driving (Parkes, 1993). Importantly, breakdowns in telematic interactions can increase the telematic demand, which may have a surprisingly negative effect on driving performance.

Fourth, the most powerful factors governing distraction may be the most difficult to quantify and shape. In particular, social norms governing acceptable risks – specifically, whether it is socially acceptable to use a cell phone while driving – may have the largest effect on driving safety. Subtle design modifications that reduce distraction at the operational level of behavior may have a much smaller effect on driving safety as compared with changes in societal norms that influence the strategic level and make the use of a device while driving taboo. The driving behaviors influenced by telematic devices and the complex feedback processes make a comprehensive understanding of driver distraction a substantial challenge. A range of theoretical, naturalistic, simulator, and part-task investigations, such as the ones represented in this special section, are needed to address these complex issues.

Papers in this special section touch on all three levels of behavior and provide a first step to addressing the challenge of driver distraction. Naturalistic driving studies reveal strategic and tactical behavior regarding in-vehicle technology, whereas simulator studies provide an insight into the interaction between tactical and operational levels of driving. Part-task studies provide a more precise description of the cognitive mechanisms underlying driver distraction. The theoretical framework that begins the special section provides a detailed description of the closed-loop dynamics that govern the influence of distraction on driving performance. Each paper in this special section contributes toward the technical understanding of distraction needed to guide design, education, and legislation.

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