Estimating Crash Risk

BY THOMAS A. DINGUS, RICHARD J. HANOWSKI, & SHEILA G. KLAUER

Accident data must be considered in the context of real-world driving if they are to lead to realistic preventive behavior.

Empirical studies of driver behavior (lab, test track, simulator, on-road controlled experiments) enable human factors/ergonomics researchers, to a reasonably precise degree, to determine the impact of a variety of devices, systems, and training methods on driving behavior and performance. These are very necessary, but insufficient, tools for achieving our ultimate goal in this domain of study: to determine whether drivers will crash more (or less) often when the design, system, or training method is implemented and to what degree. What we are referring to in this context is a quantitative estimate of *crash risk*.

In this article, we discuss the benefits of naturalistic driving studies as a new tool in the safety practitioner's toolbox. We also describe the relative risk of specific distraction tasks, including cell phone use, as calculated from naturalistic studies. Finally, we provide a path forward for further reducing fatalities and injuries on our nation's roadways.

Limitations of Existing Data

To date, we do not have the requisite knowledge to reasonably assess crash risk from empirical data because there is no link between empirical measures of driving behavior (e.g., texting while driving, driver drowsiness) and performance (e.g., reaction time, eyes-off-road time, frequency of lane departures) and crash risk in the driving environment. That is, although we know that increases in reaction time, eyes-off-road time, and other valid performance measures increase the risk of a crash (at least in the vast majority of cases), we have no idea to what degree.

Conversely, precise epidemiological sources of crash data are available in the form of crash databases published by the National Highway Traffic Safety Administration (these publicly available databases can be downloaded from http://www.nhtsa.gov/NASS). These data are very useful for determining a variety of particulars about the crash (e.g., time, road condition, driver demographic), but they rely on post hoc police reports of events leading up to the crash. Despite the well-meaning officers who are their source, such data are inaccurate for determining what the driver was doing in the meaningful period leading up to a crash. Specifically, many of the critical factors related to what we are most interested in (e.g., distraction) often cannot be determined because drivers and other eye witnesses are deceased, dazed, inattentive, or fearful of embarrassment or prosecution.

So to understand crash risk, we need to understand driving performance and behavior in the larger context of the driving environment. Otherwise, results that we find in the laboratory, simulator, or test track may not translate from "task-based" performance and behavior to crash risk in the actual driving environment.

Driving is risky. In fact, crashes are the leading cause of death between ages 4 and 34. Many factors increase or decrease that risk. Such factors that are related to driver behavior and performance include the following:

1. Driver risk adaptation
2. Driver state (alert, distracted, impaired, drowsy)
3. Frequency with which the driver chooses to engage in a potentially risky behavior
4. Environmental and roadway factors
5. The presence, awareness, and/or action of other vehicles, pedestrians, animals, or objects
6. The type of vehicle being driven
7. Interactions of the above.

Failure to somehow account for all these factors will lead to inaccurate conclusions regarding the factors that change the risk of a crash. A salient and timely example is the crash risk associated with driving while engaged in a cell phone conversation. Many empirical and epidemiological studies have been conducted in the past decade in an attempt to determine the degree to which this particular task increases crash risk (Redelmeier & Tibshirani, 1997; Strayer, Drews, & Crouch, 2004).

A good empirical example is a study conducted by Lee, McGehee, Brown, and Reyes (2002). Lee et al. showed in a simulator study that reaction time to an unexpected event was on the order of 300 ms slower while the driver was

FEATURE AT A GLANCE: Naturalistic driving research involves the instrumentation of vehicles, including video cameras, for the purpose of precisely recording participants as they normally drive as well as in the seconds leading up to crashes and near-crashes. The results provide new insight into driver behavior and performance that cannot be gained through traditional empirical approaches. Naturalistic driving studies provide context of the overall driving environment, information that is absent from other methods. This article highlights how results from naturalistic driving research have reshaped our understanding of driver behavior and crash risk, including the fact that some findings are contrary to results from other empirical approaches.

KEYWORDS: cell phone, distraction, distracted driving, driving, inattention, naturalistic driving studies, texting while driving

engaged in a distraction task than when he or she was not. This was a very solid study (and Human Factors and Ergonomics Society's Jerome H. Ely Award winner), but the question remains: How does this performance decrement translate to crash risk on actual roadways? For example, one could argue that in the vast majority of cases, a driver (at least a prudent driver) will give himself or herself a buffer of space and time that will be greater than this 300-ms delay.

Other studies have shown that talking on a cell phone increases reaction time to an unexpected obstacle (Caird, Willness, Steel, & Scialfa, 2008; Horrey & Wickens, 2006) and also increases headway (Sayer, Devonshire, & Flanagan, 2007).

To try to make a real-world link to crash risk, researchers in other empirical studies have attempted to compare talking on a cell phone with drinking alcohol (Strayer et al., 2004) or with older drivers' response times (Strayer & Drews, 2004). These studies generally have failed on two fronts. First, as with all empirical studies, they are unable to capture the performance and behavior in the larger context of driving. Second, and most important, they fail to recognize critically important differences between alcohol impairment and talking on a cell phone; for instance, its impact on judgment and decision making often changes the scenarios and circumstances in the driving environment (e.g., speeding, overconfidence in abilities). In other words, trying to make such comparisons in a simulation environment and translating the results (expressed or implied) to crash risk in the actual driving context is inaccurate, from scientific and theoretical perspectives.

Other researchers have taken an epidemiological approach to assessing the crash risk of cell phone use (Redelmeier & Tibshirani, 1997). A recent study conducted by the Insurance Institute for Highway Safety (IIHS; McEvoy et al., 2005) in Australia provides some interesting findings. Australia has the advantage of access to cell phone records for a wide variety of circumstances. Review of these records indicated that cell phone use resulted in a fourfold increase in crash risk relative to the absence of cell phone use. This study is very compelling, particularly because it involved the use of actual crash records in conjunction with objective cell phone use.

The unavoidable issue with all studies of this type, however, is the inability to precisely know what the driver was doing just prior to the crash. Two factors may affect these results: First, the timing of cell records in comparison with crash times is imprecise (e.g., perhaps 5 and 10 minutes of resolution), meaning that the driver could have completed his or her cell interaction up to 10 minutes prior to having to react to a crash circumstance. Second, the driver could have been doing a number of tasks with the cell phone, only one of which is a conversation. It is clear from decades of empirical driving research that a cell phone is used for many tasks that are likely more risky than talking, including dialing, texting, searching for a number, and reaching for a ringing phone.

What Are the Actual Risks Associated With Cell Phone Use?

So do any of these studies provide accurate, quantitative insight into the crash risk associated with a cell phone conversation? To answer this question, let us consider, at a top level, the impact that cell phone use has had on the overall rate of crashes (Figure 1, next page). As shown, the rate of cell phone use has grown exponentially since 1990. The National Highway Traffic Safety Administration (NHTSA) recently estimated that 10% to 11% of drivers are using a cell phone while driving at any given time (Traffic Safety Facts, 2009). In contrast, the crash rate has declined steadily over the same period. Thus, the question becomes, if crash risk increases fourfold, as suggested by the IIHS study, or sevenfold (the approximate increase in risk associated with driving under the influence of alcohol), as suggested by Strayer et al. (2004), could this impact be "hidden" or absorbed by other traffic or vehicle safety improvements?

If one assumes that 10% of drivers are using a cell phone at any given point (Traffic Safety Facts, 2009), one would expect the crash rate to have increased (all else being equal) from 200 to 250 crashes per 100 million vehicle miles (Figure 1) using the NHTSA numbers, and from 200 to 275 crashes per 100 million vehicle miles using the estimates from the Strayer et al. (2004). These very large numbers would mean that other huge safety improvements would have to be occurring during the same period. This situation is highly unlikely, particularly given that advanced technologies, such as electronic stability control or active crash avoidance systems, have not penetrated much of the overall fleet at this point in time.

The issues with empirical and epidemiological data described in the preceding paragraphs have left a gap in our ability to understand crash causation and thus develop the most effective crash countermeasures. This gap has spawned a relatively new method for answering some of these questions, called *naturalistic driving research* (Dingus, 2002). This new approach involves unobtrusive vehicle instrumentation, installed on a large number of driver-owned vehicles, to assess driving behavior and performance in the minutes and seconds leading up to a crash or near-crash event. The vehicle instrumentation includes several kinematics sensors (e.g., accelerometers), video cameras, and data from the vehicle's own data bus (e.g., speed, brake activation). A near-crash, in this case, is operationally defined as an event containing all of the elements of a crash with the exception of the presence of a last-second successful evasive maneuver by one of the involved parties. A growing body of research (e.g., Guo, Klauer, Hankey, & Dingus, 2010; Hickman, Hanowski, & Bocanegra, 2010; Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2009) indicates that near-crashes are similar to, and predictive of, crash occurrence.

To date, a number of naturalistic driving studies have been conducted with the use of both light vehicles and heavy vehicles. In addition, several more large-scale efforts (e.g., thousands of cars and hundreds of trucks) are currently under way. In these studies, continuous data are collected for the entire time that the car is driven across a typically long time span (e.g., 1 to 2 years). Participants typically participate in a number of predrive assessments but are not given any instructions other than to drive as they normally would. Although there is some risk that drivers will modify their behavior because of the presence of the instrumentation, several analyses (e.g., Dingus et al. [under review]) have shown that any measurable changes in performance or behavior disappear after a few hours or days.

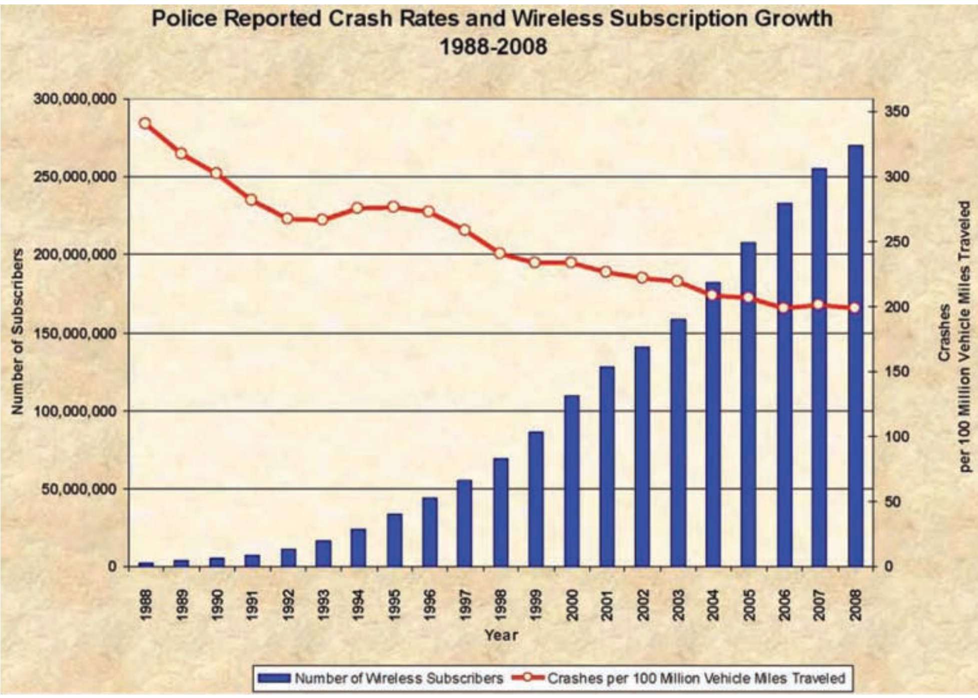

Figure 1. Cell phone trends and crash rates.
Data from Tijerina (2011).

Considering that the number of miles involved in these studies is very high (e.g., often several million miles or more), actual crashes are captured even though they are rare events. In addition, a larger number of near-crash events are captured (typically an order of magnitude larger than crashes). By combining these two sources of data, we have a reasonably large sample from which to make assessments regarding crash and near-crash risk.

These studies can help us understand crash risk associated with driver performance and behavior by closing two important gaps: First, they allow us to determine the driver state, driver behavior, and driver performance in the seconds leading up to a crash or near-crash event. Second, they allow us to estimate exposure related to the circumstances in question. For example, if one is interested in the crash or near-crash risk associated with cell phone use, one can sample the continuous video stream and accurately estimate the frequency and total time in which drivers use cell phones while driving. Knowing not only the frequency of crashes and near-crashes involving and not involving cell phone use but also the frequency of noncrashes involving and not involving cell phone use allows for the calculation of an odds ratio as an estimate of the crash or near-crash risk.

What Are the Riskiest Distraction Tasks?

Now let us use the results of a series of naturalistic studies (from the authors) to assess the crash and near-crash risk of a variety of tertiary (i.e., potentially distracting) tasks. A metasummary of such data from recent results is shown in Figures 2 and 3. The data are shown in two figures because of scaling issues with some of the crash and near-crash risk with the tasks. Figure 2 shows the entire scale and Figure 3 shows a close-up view of the lower part of the crash and near-crash scale.

As shown in Figure 2, a number of tasks stand out as posing the highest risk to perform while driving. There are several important differences between the light- and heavy-vehicle data shown. The light vehicle data come from the 100-Car Naturalistic Driving Study (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006), and the data collection period was prior to some cell phone tasks, such as texting. In addition, the truck ratios (data from Olson, Hanowski, Hickman, & Bocanegra, 2009) are somewhat higher than the light-vehicle data. This difference could be attributable to the additional attention required to control a heavy truck. The operational definitions of near-crashes were slightly different as well: The truck study included significant unplanned lane deviations as near-crash events (in part because of the differences in vehicle dynamics aspects required for correction), whereas the light-vehicle study did not.

One of the most striking results in Figure 2 is the magnitude of the risk estimates. Specifically, these tasks increase crash and near-crash risk roughly 600% to 2,300%. So what characterizes the riskiest tasks performed in moving vehicles? First, all the tasks are visual-manual in nature. Second, most of them require multiple steps to complete and will require multiple glances away from the roadway in almost all cases. Third, most of them are not associated with built-in features that come as original equipment on cars and trucks.

Looking at the lower portion of the scale depicted in Figure 3, one sees the same trends continue. In essence, all the tasks shown that are greater than an odds ratio of 2.0 are relatively complex, visuomanual tasks. Tasks that are conspicuously absent from this high-risk group include eating, drinking, adjusting an in-dash control, and talking on and listening to a cell phone or CB radio, among others. Some of these tasks are even significantly safer than merely driving

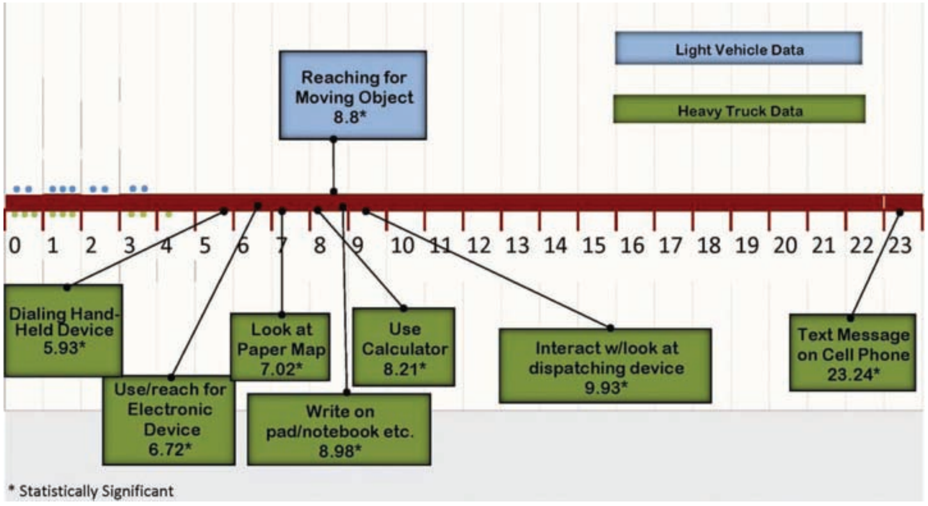

Figure 2. Secondary task–related relative crash and near-crash risk estimates (odds ratio).

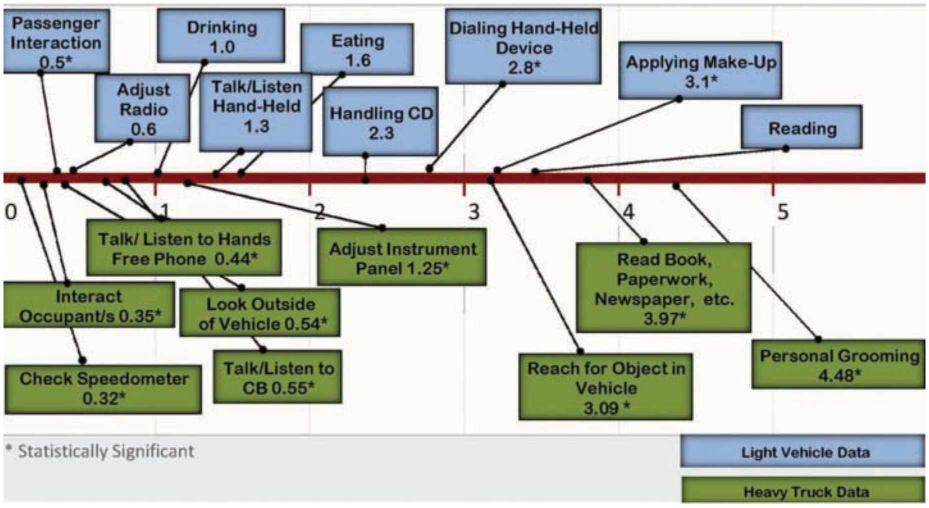

Figure 3. Secondary task–related relative crash and near-crash risk estimates (odds ratio), detail.

(i.e., odds ratio significantly less than 1.0) or are protective in their effect. These tasks include talking to passengers and, for heavy vehicles, talking and listening via CB radio or a hands-free phone, or checking the speedometer.

How can this be the case? A number of studies have shown that passenger presence leads to reduced crash risk because of factors such as more conservative driving, the presence of "another set of eyes" to scan the environment, and increased alertness attributable to the presence of a companion with whom to talk. Similarly, we feel that increased alertness in the heavy-truck case afforded by the ability to communicate via CB or phone is the reason for the protective effect in those instances.

These results certainly help explain the trends present in Figure 1. That is, listening and talking on cell phones while driving is not particularly risky, at least for adult light-vehicle and commercial drivers. In contrast, the tasks that we should focus heavily on correcting are the less frequent and newer cell phone tasks of texting, typing, reading, dialing, and reaching for a phone.

What Can Safety Practitioners Do to Mitigate the Effects of Driver Distraction?

It is clear that we have to consider the impact of factors such as distraction in the larger context of driving in order to make recommendations regarding countermeasures. For example, we believe that looking at the combination of crash data and naturalistic driving data leads to the following conclusions.

First, vehicle manufacturers and aftermarket suppliers need to focus on minimizing visuomanual interaction with devices and thereby minimizing eyes-off-road time. A reasonable way to accomplish this goal is through simple interfaces that lock out features while the vehicle is in motion as well as the use of auditory or voice interfaces.

Second, manufacturers of nomadic devices need to develop "vehicle" modes, similar in concept to "airplane" mode. Specifically, such devices should integrate via Bluetooth or wireless to interact seamlessly with an in-vehicle interface that has the features in the first item, or that simply lock out all the most complex features while a vehicle is in motion (as detected by GPS).

Third, the public needs to be informed of the relative risks of the various tasks that are commonly accomplished in a moving vehicle. Consumers will modify their behavior if they understand the risks and have reasonable alternatives. In contrast, blanket messages that communicate that "all distraction is bad" are ineffective and unrealistic.

Finally, measured legislation is warranted. Specifically,

a. Texting bans are appropriate, though it will take time and other alternatives (e.g., integrated systems with limited functionality) to make an impact.
b. Handheld cell phone bans – particularly as applied to smartphones – may be necessary. Such laws or administrative rules, if enacted, should be primary laws with a reasonable enforcement strategy.
c. Total cell phone bans that include true hands-free voice input-output devices are unwarranted.
d. Other devices, such as mobile data terminals in trucks, need to be seriously and immediately assessed from a legislative viewpoint.

References

Caird, J. K., Willness, C. R., Steel, P., & Scialfa, C. (2008). A meta-analysis of the effects of cell phones on driver performance. *Accident Analysis & Prevention*, *40*, 1282–1293.

Dingus, T. (2002). Human factors applications in surface transportation. In *Frontiers of engineering: Reports on leading-edge engineering from the 2002 National Academy of Engineering Symposium* (pp. 39–42). Washington, DC: National Academies Press.

Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., & Knipling, R. R. (under review). *The 100-Car Naturalistic Driving Study: Phase II – Results of the 100-Car field experiment* (Interim Project Report for DTNH22-00-C-07007, Task Order 6; Report No. TBD). Washington, DC: National Highway Traffic Safety Administration.

Guo, F., Klauer, S. G., Hankey, J. M., & Dingus, T. A. (2010). Near-crashes as crash surrogate for naturalistic driving studies. *Transportation Research Record: Journal of the Transportation Research Board*, *2147*, 66–74.

Hickman, J. S., Hanowski, R. J., & Bocanegra, J. (2010). *Distraction in commercial trucks and buses: Assessing prevalence and risk in conjunction with crashes and near-crashes* (Report No. FMCSA-RRR-10-049). Washington, DC: Federal Motor Carrier Safety Administration. Retrieved from http://www.fmcsa.dot.gov/facts-research/research-technology/report/Distraction-in-Commercial-Trucks-and-Buses-report.pdf

Horrey, W. J., & Wickens, C. D. (2006). Examining the impact of cell phone conversations in driving using meta-analytic techniques. *Human Factors*, *48*, 196–205.

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2006). *The impact on driver inattention on near crash/crash risk: An analysis using the 100-Car Naturalistic Driving Study Data* (Report No. DOT HS 810 594). Washington, DC: National Highway Traffic Safety Administration.

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2009). *Comparing real-world behaviors of drivers with high vs. low rates of crashes and near-crashes* (Report No. DOT HS 811 091). Washington, DC: National Highway Traffic Safety Administration.

Lee, J. D., McGehee, D. V., Brown, T. L., & Reyes, M. L. (2002). *Driver distraction, warning algorithm parameters, and driver response to imminent rear-end collisions in a high-fidelity driving simulator.* Washington, DC National Highway Traffic Safety Administration.

McEvoy, S. P., Stevenson, M. R., McCartt, A. T., Woodward, M., Haworth, C., Palamura, P., & Cercarelli, C. (2005). Role of mobile phones in motor vehicle crashes resulting in hospital attendance: A case-crossover study. *British Medical Journal*, *338*, 428–430.

Olson, R. L., Hanowski, R. J., Hickman, J. S., & Bocanegra, J. (2009). *Driver distraction in commercial vehicle operations, final report* (Report No. FMCSA-RRR-09-042). Washington, DC: Federal Motor Carrier Safety Administration. Retrieved from http://www.fmcsa.dot.gov/facts-research/research-technology/report/FMCSA-RRR-09-042.pdf

Redelmeier, D. A., & Tibshirani, R. J. (1997). Association between cellular-telephone calls and motor vehicle collisions. *New England Journal of Medicine*, *336*, 453–458.

Sayer, J. R, Devonshire, J. M., & Flanagan, C. A. (2007). Naturalistic driving performance during secondary tasks. In *Proceedings of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.* Retrieved from http://drivingassessment.uiowa.edu/DA2007/PDF/039_SayerDevonshire.pdf

Strayer, D. L., & Drews, F. A. (2004). Profiles in driver distraction: Effects of cell phone conversations in younger and older drivers. *Human Factors*, *46*, 640–649.

Strayer, D. L., Drews, F. A., & Crouch, D. J. (2004). *A comparison of the cell phone driver and the drunk driver* (Working Paper 04-13). Washington, DC: AEI-Brookings Joint Center for Regulatory Studies.

Tijerina, L. (2011, April). *Driver distraction: Understanding the problem.* Presented at the SAE World Congress, Detroit, MI.

Traffic Safety Facts. (2009). *Driver electronic device use in 2008* (Tech. Rep. No. DOT HS 811 184). Washington, DC: National Highway Traffic Safety Administration.

Thomas A. Dingus is director of the Virginia Tech Transportation Institute and the Newport News Shipbuilding Professor of Engineering at Virginia Tech. He has conducted transportation safety and human factors research since 1984. Focuses have included the safety and usability of advanced in-vehicle devices, crash avoidance countermeasures, truck driver fatigue, and driver distraction and attention. He is a Fellow of the Human Factors and Ergonomics Society.

Richard J. Hanowski is director of the Center for Truck and Bus Safety at the Virginia Tech Transportation Institute. He has led more than $27 million of contract research for government and industry. He is an expert on fatigue and distracted driving, and his research has influenced national transportation policy, including hours-of-service and distracted-driving regulations for truck drivers. He is vice chair of the ITS America Safety Forum and is an ITS America Coordinating Council member.

Sheila G. "Charlie" Klauer is a research scientist at the Virginia Tech Transportation Institute. She served as the project manager for the 100-Car Naturalistic Driving Study and is the co–principal investigator and project manager for the Naturalistic Teenage Driving Study and the Supervised Practice Driving Study, which are funded by the National Institutes of Health. Her primary research interests include the impacts of driver distraction and fatigue on driving performance.