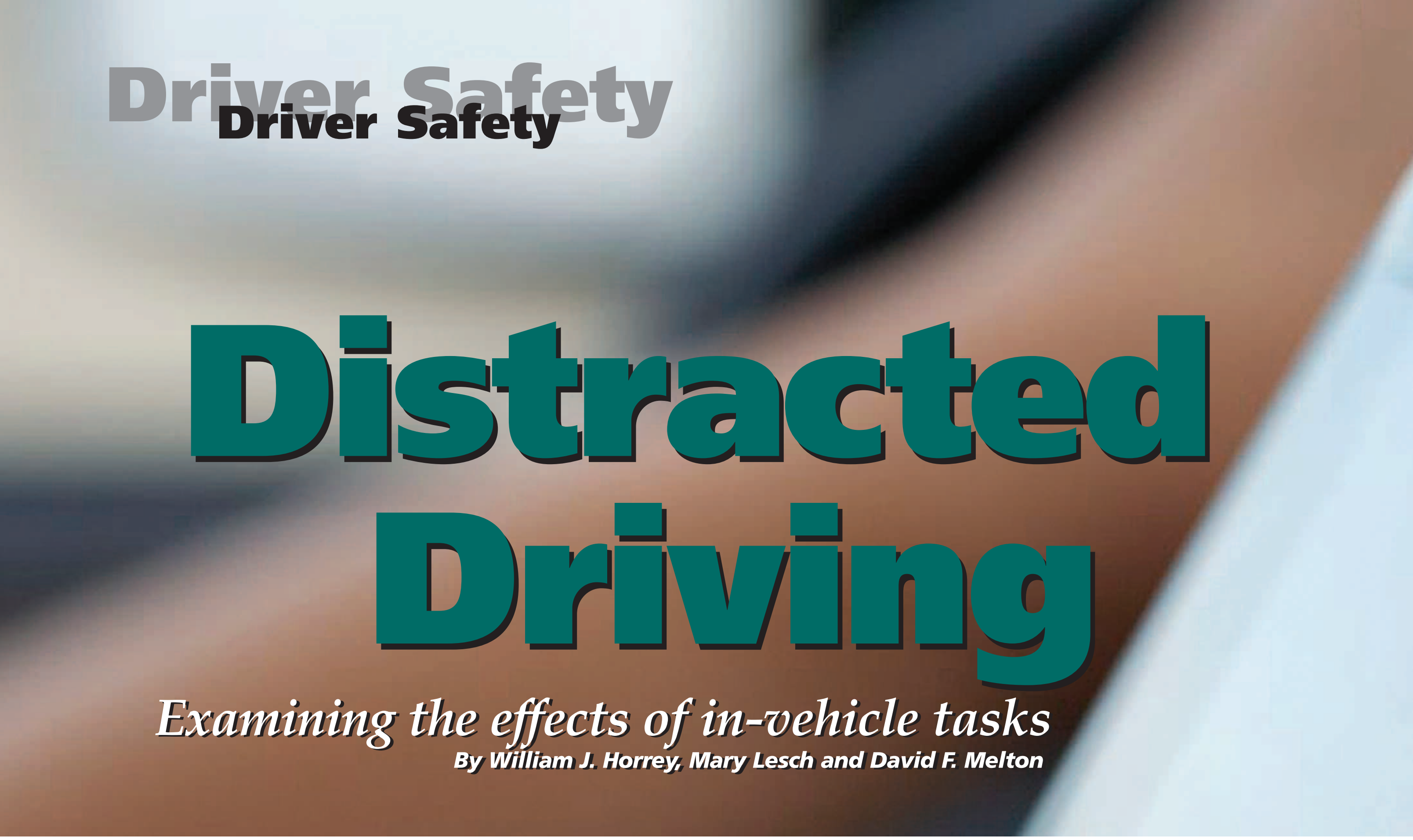

Driver Safety

Distracted Driving

Examining the effects of in-vehicle tasks

By William J. Horrey, Mary Lesch and David F. Melton

DRIVER DISTRACTION, especially that caused by in-vehicle devices, is a growing concern. Vehicles are being equipped with new embedded technologies and drivers are using more portable devices, such as cell phones and PDAs. Commercial drivers are often required to perform in-vehicle tasks as part of their job, while many private drivers extend their productive workday by performing in-vehicle tasks during long commutes. Thus, these devices afford drivers, both commercial and private, an opportunity for increased connectivity and productivity.

Despite their advantages, these devices also create obvious concerns for safety. Data on police-reported crashes suggest that driver distraction is a factor in 25% to 50% of traffic crashes (NHTSA, 1997). Recent on-road studies suggest that this percentage could be even higher (Klauer, Neale, Dingus, et al., 2005). The amount of research devoted to driver distraction is extensive, particularly regarding cell phone use. In general, studies have shown that distracted drivers have slowed responses to critical traffic events and are more likely to miss important events such as a changing traffic light (Alm & Nilsson, 1994; Brookhuis, de Vries & de Waard, 1991; Caird, Scialfa, Ho, et al., 2004; Horrey & Wickens, 2006).

Despite the extensive literature on distraction and driving, several issues have not been examined in-depth. This article describes two recent studies conducted at the Liberty Mutual Research Institute for Safety that examined two of these issues: 1) the degree to which drivers are aware of their own level of distraction; and 2) whether drivers' awareness of traffic demands will improve their decisions regarding the timing and use of distracting devices.

For the former, drivers' perception of their own performance while distracted has implications for their decisions to engage in distracting activities. To the extent that their perceptions are inconsistent with their actual performance, safety concerns arise.

For the latter, when drivers control the initiation of in-vehicle tasks (as is usually the case in the real world), it is unknown whether they do so based on their understanding of current and upcoming road conditions, or whether they just try to accommodate multiple tasks as best they can. This article describes each study, followed by a general discussion of the implications and recommendations for mitigation.

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Awareness of Distraction Effects

How well-calibrated are drivers with respect to distraction effects? Drivers who are unaware of the consequences of distraction may engage in in-vehicle activities simply because they do not realize that their performance is degraded, or they may be overconfident in their skills and their ability to deal with distractions while behind the wheel (Wogalter & Mayhorn, 2005).

Lesch and Hancock (2004) report that drivers' self-rated confidence in dealing with distractions while driving was not related to their actual performance. Understanding drivers' perception and awareness of distraction effects may also help in the development of driver-based or technology-based interventions aimed at mitigating distraction by helping drivers better manage the engagement and disengagement of in-vehicle activities.

Abstract: *This article describes two recent studies conducted at the Liberty Mutual Research Institute for Safety that examined two issues related to distracted driving: 1) the degree to which drivers are aware of their own level of distraction; and 2) whether drivers' awareness of traffic demands will improve their decisions regarding the timing and use of distracting devices.*

In this study, younger and older drivers drove an instrumented van on a closed test track while performing a mental arithmetic task on a handheld or hands-free cell phone. Unlike previous research, which often has focused on drivers' estimates of confidence, the researchers measured drivers' subjective estimates of distraction effects and compared these to actual performance on multiple measures of driving performance. Complete details for this study can be found in Horrey, Lesch and Garabet (2008).

Experimental Setup

Twenty younger drivers (*M* = 22 years; *SD* = 4) and 20 older drivers (*M* = 64 years; *SD* = 8) were recruited for this study through newspaper and online advertisements. Participants were screened for visual function (acuity and color blindness) and for hearing loss. In addition, participants were screened for medications known to impair driving performance. Males and females were balanced across the two age groups.

The test track is a two-lane, closed-loop course, approximately 0.5 mile in distance. The vehicle was equipped with several computers and sensors. During a short training session, drivers practiced several tasks:

1) Lane keeping. Trying to keep the vehicle positioned in the center of their lane.

2) Speed control. Five large clocks were positioned around the track. The clock face was split into a green and a red portion (Photo 1, p. 36). The arrow hand moved around at a relatively high rate (*M* ~ 12 seconds per rotation). Drivers were told to adjust their speed during the approach to a clock, either by speeding up or slowing down, in order to pass the clock when the arrow indicator was in the green portion of the clock.

3) Stopping. A traffic light at an intersection changed from green to red on a random subset of laps. Drivers were instructed to bring the vehicle to a complete stop as quickly as possible and to try to stop before they reached a stop line marked by two traffic cones.

While driving, participants performed a continuous mental arithmetic task, intended to mimic some of the cognitive demands of a cell phone conversation. Numbers between 1 and 9 were randomly presented every 7 seconds, either through a handheld phone or through a hands-free system. The task involved adding two consecutive numbers and responding verbally. This task has been used in previous studies of distraction (Brookhuis, et al., 1991).

Drivers completed three test blocks of eight laps, each block lasting approximately 15 minutes. In two blocks, drivers performed the arithmetic task (once using the handheld phone, once using the hands-free system). In the other block, drivers performed the driving tasks alone, with no additional task (baseline condition). Objective performance measures including variability in lane keeping, pace clock errors, braking reaction time and stopping errors were recorded during each block. After each block, drivers rated their own performance on each task as well as their overall workload using the NASA-TLX, which comprises several subscales for perceived mental effort, time pressure, frustration and demands, among others (Hart & Staveland, 1988).

Results & Discussion

Driving Performance

An analysis of the objective driving performance measures showed that compared to the baseline condition drivers:

1) had more erratic lane keeping while performing the phone task;

2) made more errors on the pace clock task while performing the phone task (Figure 1a, p. 36);

3) had slower braking response times to the changing traffic light;

4) made more errors while performing the stopping task (Figure 1b, p. 36).

In general, there were no differences between the two phone types (handheld versus hands-free), nor were there any significant effects of age or gender on task performance.

Driver Awareness of Distraction Effects

To examine drivers' awareness of distraction effects, the research team compared drivers' subjective estimates of distraction with actual distraction effects using a correlation approach. If drivers' perceptions are well-calibrated to their level of distraction, one would expect a positive correlation between the estimated and actual distraction effects.

Overall, no significant relationships were noted between estimates of distraction effects and actual performance decrements, lending support to the notion that drivers were not well-calibrated to the distracting effects of the concurrent in-vehicle task. One significant relationship was noted for stopping errors in the hands-free condition. Importantly, however, this relationship was in the negative direction, indicating poor calibration; drivers who estimated the smallest performance decrements were actually exhibiting the largest ones.

A breakdown of these data by driver age and gender reveals an interesting pattern. For example, older male drivers were actually well-calibrated to the magnitude of distraction effects for the stopping task. In contrast, younger males showed some significant associations in the opposite direction. That is, young male drivers who thought they were doing better were actually doing worse than others. In general, female drivers did not exhibit any significant relationships between estimated and actual performance loss (similar to Lesch & Hancock, 2004). It follows that younger male drivers may be an important group for targeted remediation.

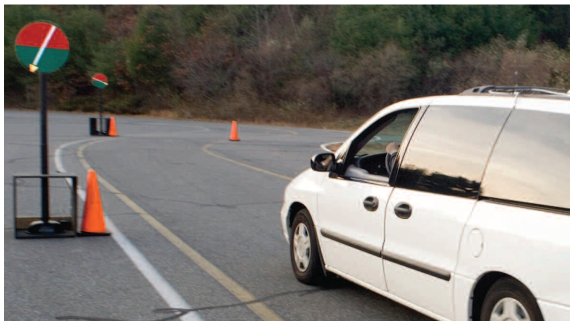
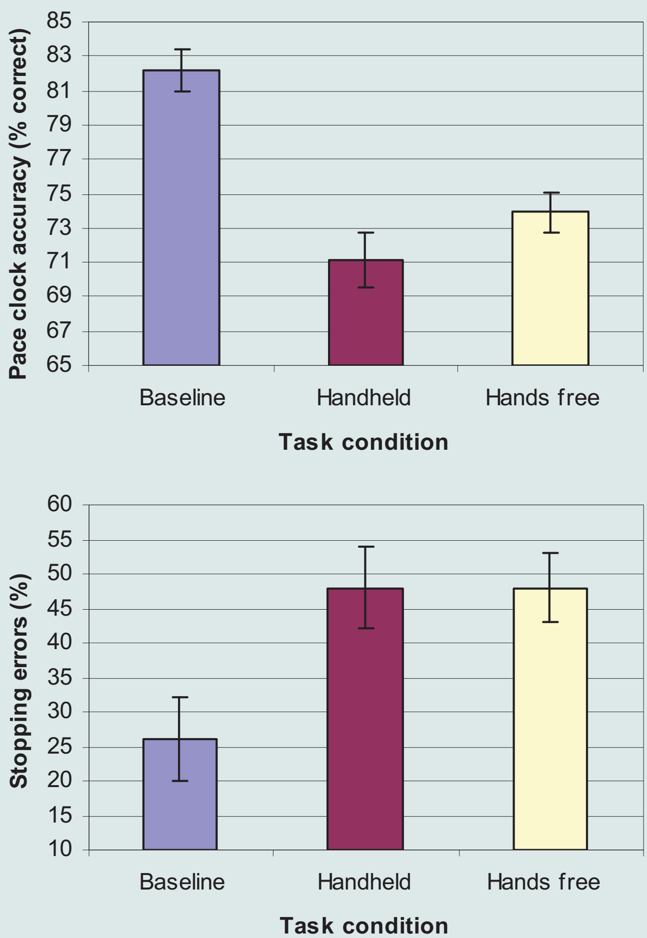


Photo 1: Five large clocks whose faces were split into green and red portions were positioned around the track. Drivers were told to adjust their speed when approaching a clock so that they passed it when the arrow was in the green section.

Figure 1

Measures of Driving Performance

Select measures of driving performance across the three task conditions: a) (top) pace clock accuracy; b) (bottom) percentage of stopping errors.



In summary, the results from this study suggest that for the most part drivers are not well-calibrated to the distracting effects of a handheld or hands-free cell phone conversation. Across all measures of performance, subjective estimates of distraction were not related to the actual magnitude of distraction. In general, a disconnect between performance and awareness was consistent across driving measure and phone type.

Driver-Initiated Distractions

Although many studies have shown that drivers' performance suffers when they perform concurrent in-vehicle activities, these studies often do not give the drivers control over the pace or the initiation of these tasks. That is, experimenters try to constrain task performance so that in-vehicle activities coincide with some critical event, such as a changing traffic light.

While this approach can help establish the worst-case scenario for in-vehicle distractions, it does not afford drivers the opportunity to engage in adaptive or compensatory behaviors to reduce risk. As Lee and Strayer (2004) suggest, drivers in the real world are not passive recipients of distracting activities; they play an active role in initiating and managing these activities. That is, drivers are usually responsible for the decision to become distracted (Lerner, 2005).

Research suggests that drivers will engage in in-vehicle activities as long as driving conditions allow (Laurier, 2002; Esbjörnsson, Juhlin & Weilenmann, 2007; Stutts, Feaganes, Reinfurt, et al., 2005). As the momentary demands of driving exceed some tolerance level, or when uncertainty of the current vehicle state exceeds some threshold (e.g., lane position), the in-vehicle task is interrupted.

Thus, some evidence suggests that drivers moderate their in-vehicle activities according to the momentary demands of driving and also in terms of outright avoidance of certain activities for some drivers (Pöysti, Rajalin & Summala, 2005).

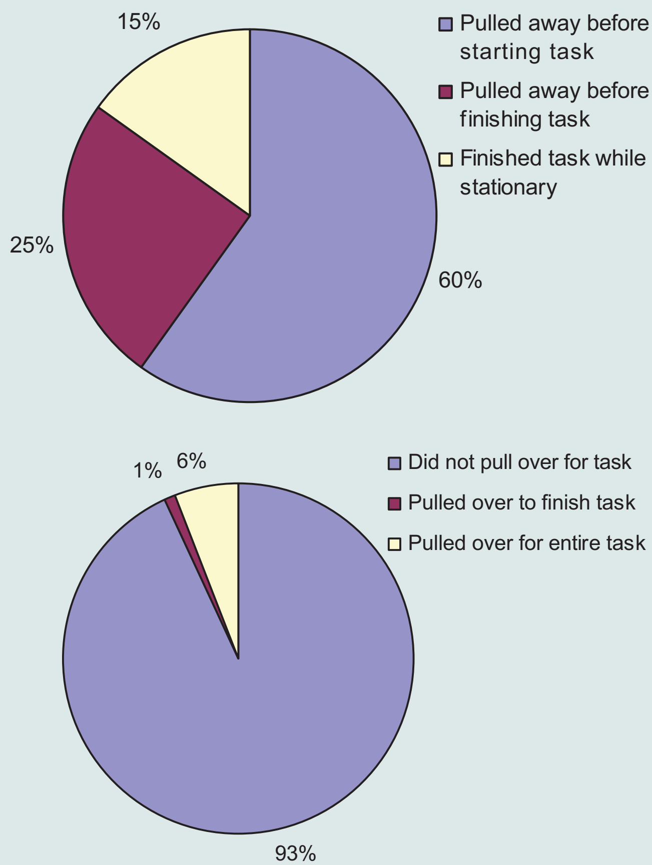
Drivers also may postpone or delay certain in-vehicle activities within a given trip based on the knowledge of the route as well as reasonable estimates of the expected challenges and difficulties. However, Lerner (2005) found that drivers' self-reported willingness to engage in a series of in-vehicle activities did not vary as a function of road type (including major arterial roads with significant levels of traffic, suburban freeways and two-lane winding roads).

The main goal of this study was to examine whether drivers who were familiar with the demands and difficulty of the driving environment would strategically postpone in-vehicle activities until the relative road demands were reduced. In contrast to Lerner's (2005) study (which reported willingness ratings), the research team examined whether, and when, drivers actually engaged in distracting activities while driving.

Figure 2

Measures of Driving Performance

a) (top) Initiation of in-vehicle task on trials that started with vehicle parked on shoulder; b) (bottom) in-vehicle task initiation for trials that started when vehicle was in motion.



Experimental Setup

Twenty drivers age 25 through 55 (*M* = 43 years; *SD* = 6) were recruited through advertisements in local newspapers. As was done for the first experiment, participants were screened for visual function as well as for certain medications, and there was an equal balance of males and females.

A closed-loop test track was divided into sections of varying demands and difficulty (e.g., narrow sections requiring precise handling, easy straight sections), thereby simulating the fluctuating and varied demands of different road conditions one might encounter during a routine trip. (A pilot study was completed to quantify the level of demand associated with each section and to ensure that there was variability across sections.)

Following practice of the driving task, the experimenter explained the in-vehicle tasks and demonstrated them for the drivers. Drivers were given the opportunity to practice these tasks several times. Three tasks used a touch screen interface developed for the study. In-vehicle tasks were presented on an LCD touch screen mounted near the center console. The tasks were:

1) Phone conversation. Drivers initiated a cell phone conversation that lasted approximately 20 seconds. Drivers were not cued for this task (i.e., as if the phone rang); rather, they treated it as if the caller were initially on hold and they were resuming the conversation at their discretion. The task involved listening to a list of five random letters, followed by a true or false statement regarding the order of presentation (e.g., "A, H, Y, P, N" (pause) "P was before H"). Drivers called out whether the statement was true or false. For each call, drivers heard two sequences of letters.

2) Reading text. Drivers accessed and read a brief e-mail message from a list of 20 messages. Each message was two to four sentences long.

3) Stored address. Drivers searched for a stored address in a list of 20 alternatives.

4) Object recovery. Drivers were asked to pick up a specific object (from among several) from the floor and return it to the driver side pocket.

Drivers were told that they were free to perform the tasks "however and whenever" (words were emphasized) they wanted. Thus, drivers were free to decide when and where they would initiate the task, whether in the lower demand or higher demand areas; they could also elect to pull onto the shoulder to perform the tasks. The only stipulation was that they complete the tasks before they reached a given

In-Vehicle Policies

Companies and organizations should establish specific policies on use of in-vehicle telematics to address the distraction issue. Those policies should include:

- eliminating or reducing the number of tasks that require operating telematics while driving;
- integrating driver/vehicle interfaces into a minimal number of devices and displays;
- mounting telematics in vehicles where they are less likely to cause distraction;
- prioritizing warnings from driver assistance devices (e.g., lane departure warning, collision avoidance) to ensure that they interrupt or override noncritical use of in-vehicle telematics;
- limiting mobile phone calls to employees known to be driving at the time of the intended call;
- asking all call recipients whether they are driving and suggesting that they move to a safe place before taking or placing a call;
- educating all drivers and equipment operators about hazards associated with in-vehicle telematics and that driving is their top priority while behind the wheel.

destination (i.e., a specific number of laps). Complete details for this study can be found in Horrey and Lesch (2009).

Results & Discussion

Distraction Decisions

The research team was primarily interested in the vehicle's location when drivers elected to initiate the in-vehicle task. This decision point reflects where drivers felt comfortable enough to take on the additional task load (from the in-vehicle activity), given the relative demands of the road. If drivers were strategically postponing in-vehicle tasks, these decision points would tend to fall in areas of reduced demand.

The team found no systematic tendency for drivers to target the areas of reduced demands in their decisions to initiate in-vehicle activities. This result suggests that drivers did not strategically adapt their performance of in-vehicle tasks based on their knowledge of the roadway even though they were given the opportunity to do so. Moreover, decisions to initiate the in-vehicle tasks did not appear to be moderated by the task type or by the given deadline.

Thus, knowledge of and familiarity with upcoming road conditions did not significantly influence strategic planning and decisions to postpone in-vehicle tasks. However, regardless of their location on the track, drivers did switch back and forth between the driving and in-vehicle tasks (Laurier, 2002; Esbjörnsson, et al., 2007; Wierwille, 1993). This adaptive strategy was not always effective as indicated by the error rates in driving performance.

Driving Errors

Several types of driving errors were recorded: 1) lane departures (or knocking down a traffic cone); 2) pace clock violations (passing on the red, failing to advance on the green); 3) stoplight violations (running a red light). These errors were expressed as the number of errors per in-vehicle task repetition. On average, drivers made one error every five times they performed a task.

Parking Situations

Lerner and Boyd (2005) described situations in which drivers initiated in-vehicle activities shortly after a trip begins (i.e., shortly after the vehicle was stationary, as in a parking lot). The research team had data from several blocks that could be used to examine this phenomenon more closely. To do so, the team isolated those trials that began while the vehicle was parked on the shoulder (in these cases, the next section of the test track was a moderately challenging section).

For these, drivers had the opportunity to initiate and perform the in-vehicle activities while stationary (unlike the other trials, which began while the vehicle was already in motion). As shown in Figure 2a (p. 37), drivers started moving and pulled out onto the road before initiating the task in 60% of these trials. That is, they elected to distract themselves after starting their trip, rather than use the opportunity to perform the activities before the trip began. In another 25% of these trials, drivers initiated the task while stationary, then elected to pull onto the road before the task was finished. As such, drivers did not appear to have much appreciation for the upcoming increase in driving demand.

The researchers also examined instances in which the drivers elected to pull over before initiating a task (i.e., the most active form of adaptive behavior; Figure 2b, p. 37). This occurred on only 8 of 138 trials (5.7%). In another 1.2% of trials, drivers pulled over after having initiated the task while in motion (i.e., they pulled over to complete the remaining steps).

The finding that drivers did not employ strategic planning when initiating distracting activities suggests that their decisions may be based on the perception that the activities can be effectively partitioned into manageable chunks (as evidenced by switching attention back and forth between the driving task and the in-vehicle tasks) (Wierwille, 1993). While this may be effective most of the time, the strategy breaks down in some obvious instances. Furthermore, as discussed in the first study, drivers do not tend to be well-calibrated to their own level of performance. As such, drivers may not be effective at gauging the appropriate times to perform in-vehicle tasks.

Conclusions

In-vehicle devices will become even more prevalent in the coming years, not only embedded in-vehicle systems and displays, but also portable devices that drivers bring into the vehicles. These devices can help drivers be more efficient and productive but they also create potential problems related to distraction and inattention. Additionally, drivers themselves initiate a significant portion of in-vehicle activities. For example, Palen, Salzman & Youngs (2000) show that the number of outgoing cell phone calls exceeded incoming calls by 2.5 to 1 for their sample of drivers, and Stutts, et al. (2005), report that drivers who used their cell phones while driving placed 1.7 calls per hour on average, but only received 0.2 calls or pages per hour.

The results from the two studies described in this article suggest that:

1) Drivers' perceptions of their own level of distraction are not very accurate.

2) Given the opportunity to strategically plan tasks, drivers instead rely on less strategic forms of adaptation in response to increases in roadway demands. That is, drivers appear willing to engage in distracting activities under various driving conditions, but will try to protect the driving task by switching back and forth between the tasks. While such task switching may be essential in the performance of any in-vehicle activity, more strategic task planning should be of considerable benefit to drivers.

While the findings of these studies are suggestive, it is important to note that because the experiments were performed on a closed test track, the study could not replicate true risk—at least to the extent that would be experienced in normal traffic. As such, the findings are expressed in terms of relative risk (versus absolute). That is, difficult road conditions were highly demanding relative to the easiest (low demand) roads and vice versa. One encouraging sign was that drivers in the pilot study reported that they would experience positive and varying degrees of discomfort in performing in-vehicle activities on the different sections of track, suggesting that the test scenario was not entirely risk-free.

Strategies for improving drivers' calibration to distraction effects include both driver- and technology-based approaches. For the former, training to attend more closely to driving activities may help drivers determine when their performance is below baseline. For example, Lichtenstein and Fischhoff (1980) found that intensive performance feedback could help improve calibration in people who were initially overconfident in their judgments.

Furthermore, training in more strategic forms of adaptation may be an important consideration. That involves training drivers not only to recognize current driving conditions, but also to consider where they are going and how the road demands are likely to change in the near future. Drivers should always consider possible locations where they can safely pull over to perform those activities that are most demanding or engaging. The Liberty Mutual Research Institute for Safety has already initiated studies looking into the possibility of this form of intervention. ■

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