Driving Attention: Cognitive Engineering in Designing Attractions and Distractions

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Driving confronts people with many of the same demands as other high-tempo, high-consequence, multi-task domains. Drivers must divide their attention between navigation, hazard detection, speed control, and lane maintenance. In addition, drivers often engage in non-driving tasks, such as conversations with passengers and adjusting entertainment systems. In such multi-task situations attention is a limited and critical resource and safety degrades when drivers fail to direct their attention to the right place at the right time.

A recent study collected detailed data from 100 vehicles over a year and found that distraction and inattention (e.g., fatigue) contribute to approximately 80% of crashes and that distraction contributes to approximately 65% of rear-end crashes (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). The rapid advances in wireless, computer, and sensor technology will confront drivers with a range of new distractions (Regan, Lee, & Young, 2008). Not only do drivers need to manage cell phones, radios, and CD players, but they may be increasingly tempted to use text messaging, select from MP3 music catalogs, and retrieve a broad variety of information from the Internet. Rapid changes in vehicle design illustrate this trend: nearly 70% of the 2007 model vehicles are compatible with MP3 players and in 2009 all Chrysler vehicles will have a wireless connection to the Internet (Bensinger, 2008). These infotainment devices have the potential to make driving more enjoyable and productive, but they might also distract drivers.

Sensor, data fusion, and control technology promises to enhance driving safety by mitigating the distraction potential of infotainment devices. Increasingly, vehicles are equipped with sensors that monitor surrounding vehicles to identify potential collision situations, warn drivers, and even respond with emergency braking. Similar technology is also automating driving during routine situations: adaptive cruise control accelerates and brakes the vehicle to maintain a constant speed or constant distance from the vehicle ahead {Walker, 2001 #4792}. Although promising, this driver support technology may not deliver its promised safety benefit because it responds imperfectly and it may encourage people to disengage from driving if they think the system will protect them from distraction-related lapses.

Similar to technology insertion in other domains, the introduction of infotainment and driver support technology will fundamentally change driving. The complexity of driving means that a focus simply on improving technology (e.g., crafting a more capable automatic braking system) will not ensure increased driving safety—technology will remain imperfect and improved safety depends on leveraging drivers' capabilities. Ensuring that technology is designed in a way that attracts drivers' attention to what matters and does not annoy or distract them from safety-critical events represents an important challenge.

Augmenting rather than automating

Rather than automating driving to eliminate driver error, greater safety benefits may accrue by augmenting drivers' capabilities. Technology can increase the capacity of the vehicle to monitor both the roadway and the driver. Such a capacity could be used to enhance drivers' awareness of the roadway demands and drivers' awareness regarding their capacity to respond to these demands. Cognitive engineering techniques combine engineering approaches with a sensitivity to human cognitive characteristics. Technology might improve driving safety through either model-based distraction estimation to enhance self-awareness or through alerting and informing technology to enhance awareness of roadway demands.

Model-based distraction estimation to enhance self-awareness

Most drivers believe they drive more safely than the average person. A survey of 1000 drivers found that 80% thought they drove more safely than the average driver (Waylen, Horswill, Alexander, & McKenna, 2004). This tendency is one factor that encourages drivers to divide their attention between the roadway and infotainment systems. Augmenting drivers' awareness of their current capacity, may be a powerful way to mitigate distraction by helping drivers become more expert in deciding if and when to engage in a distracting activity.

Estimating the degree of distraction experienced by the driver may be a critical element in helping drivers manage distraction. Figure 1 shows the output of a model of a driver switching attention between the roadway and an in-vehicle device (Hoffman, 2008). This model is based on dynamic field theory (Erlhagen & Schoner, 2002) and captures the time varying factors that cause drivers to persist in looking away from the roadway (e.g., task inertia) and factors that draw drivers' attention back to the roadway (e.g., increasing uncertainty regarding the roadway situation). Such an approach provides a top-down or model-driven estimate of how drivers distribute their attention that can complement a bottom-up or data-driven approach to estimating driver state. Bayesian networks and Support Vector Machines are effective data-driven techniques to estimate distraction from eye movements and steering behavior (Liang, Reyes, & Lee, 2007, In press).

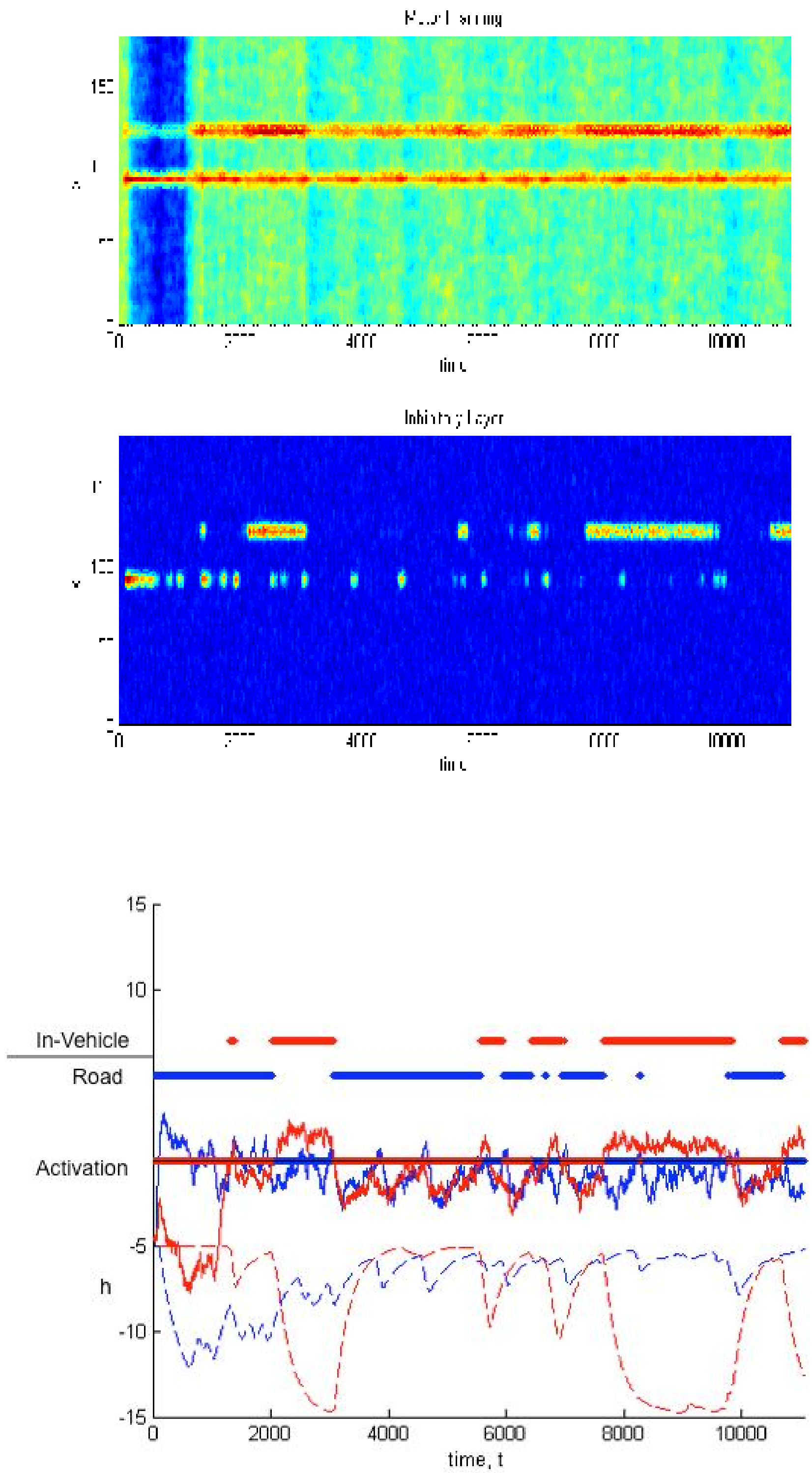

Figure 1. A field theoretic approach to describing the dynamic distribution of attention between the roadway and an in-vehicle device.

Estimates of distraction-related impairment associated with distractions, such as text messaging, can be used to augment drivers' awareness of this impairment in three ways (Donmez, Boyle, & Lee, 2006; Donmez, Boyle, Lee, & Scott, 2007). First, a model-based prediction of distraction could be used to alert the driver to upcoming conflicts so that the driver can direct attention to the roadway in a proactive manner. Second, the history of distraction and the associated driving performance decrements could be shared with drivers after the drive to help them calibrate their estimation of how well they can manage distractions. A third approach considers the current state of the driver when redirecting drivers' attention to demanding roadway situations, a topic addressed in the following section.

Alerting and informing to enhance roadway awareness

Sensor and algorithm technology makes it possible for the vehicle to detect hazards and alert or inform the driver, reducing reaction time to imminent collisions (Lee, McGehee, Brown, & Reyes, 2002). Unfortunately these systems generate many false alarms—signaling a hazard when none exists. Such false alarms can annoy and distract drivers, but making such systems useful and trusted to drivers requires more than a technological focus on better sensors and algorithms. For example, drivers perceive seat vibrations as less annoying than auditory alerts (Lee, Hoffman, & Hayes, 2004). Furthermore, not all false alarms are created equal. False alarms that drivers can associate with events in the environment lead drivers to trust the system and comply with subsequent alerts more than false alarms that appear as if they occur randomly (Lees &

Lee, 2007). Drivers respond differently to various alerts that might all be labeled “false alarms” from a technological perspective.

Adapting the threshold for alerts according to the degree of driver distraction could reduce false alarms by raising the threshold for attentive drivers. Such an approach could lead to an interesting paradox in that drivers who most need alerts are most likely to view them as false alerts. Drivers are likely to view true alerts as false alarms if the hazard is not apparent—distracted drivers might not notice the hazard (even with the alert), and so might not appreciate the value of the alert.

Providing drivers with information regarding the roadway demands and hazards experienced after a drive, similar to the post-drive feedback for distraction, could help drivers understand the reason for the alerts. Recent studies suggest substantial promise of post-drive feedback (McGehee, Raby, Carney, Reyes, & Lee, 2007; Tomer & Lotan, 2006). Teen drivers drove with a camera that captured abrupt braking and steering responses. The resulting video and a summary of their events was shared with their parents weekly, leading to a 89% decline in the number of events triggered by risky drivers compared to the baseline period. Even after the feedback was removed, the rate of events remained low until the end of the study six weeks later. Whether such feedback would be accepted or effective in helping experienced drivers manage distracting technology remains to be seen.

Conclusion

Technology changes the nature of driving and introduces new vulnerabilities and capacities, reflecting the cognitive system composed of the driver and the technology (Woods & Dekker, 2000). Infotainment systems will introduce new distractions that could undermine safety. Driver assistance technology promises to mitigate these distractions and enhance safety, but a technology-oriented focus will fail to achieve the full potential of this technology. Drivers will tend to reject or misuse imperfect technology that automates driving rather than augments driver capabilities. Cognitive engineering methods point towards how technology can leverage human capabilities to improve safety and performance of complex systems by enhancing self-awareness and awareness of system demands.

Increasingly pervasive and powerful technology in driving, as in other domains, begins to blur the boundaries between the human and the technological. This poses important practical, theoretical, and philosophical issues as safety and performance increasingly depends on a complex interaction of the driver, the in-vehicle technology, and the driving situation (Lees & Lee, 2008). Cognitive engineering challenges include:

- Philosophical concerns regarding technology that generally helps but could specifically hinder human performance, as in last minute braking that generally improves crash outcomes, but can also thwart driver responses in rare situations.
- Practical concerns regarding how to draw meaning from large and complicated streams of sensor data in real time and from petabytes of accumulated data to provide feedback to operators and to designers.

- Theoretical concerns regarding the dynamics of attention and how technology can affect those dynamics, and generally how the nature of cognition changes as technology shapes and is shaped by operators activity.

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