Situation Awareness: a Holistic Approach to the Driver Distraction Problem

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Abstract

There is little doubt that cell phone use while driving is dangerous. Unfortunately, legislation alone will not make the problem go away: there will always be someone who will ignore the evidence and the law, whatever the risks.

If we consider that cell phones are just a small part of the problem: 5% of distraction-related accidents resulting in injury, and 18% of these accidents resulting in death, it is clear that a holistic approach to the problem of driver distraction could be more effective than prohibitions on any one activity, such as cell phone use. To this end, in this paper we describe Situation Awareness (SA), and suggest how it can provide a framework for understanding and reducing driver distraction, whatever its cause.

The Driver Distraction Problem

Since Radiolinja launched the first 2G mobile phone network in 1991, cell phones have become both ubiquitous and the source of considerable controversy, particularly as an easily identifiable cause of driver distraction. Legislators have reacted by prohibiting texting and the use of hand-held (or even hands-free) phones while driving. Simply

Figure 1: Situation Awareness, based on M. R. Endsley.
banning technology won't make the problem go away, however. There will always be those who ignore the law, often attempting to conceal their actions and thereby making their behavior even more risky.

Though the exact causal relationship between cell phone use and traffic accidents is still being studied, there is little doubt that using cell phones while driving can be dangerous. For example, a study published by the Hawaii’s Legislative Reference Bureau recognizes the difficulty of proving a causal relationship between cell phone use and traffic accidents, but does state that “use of a cell phone while driving ... increases non-responses or slows response time to traffic situations and traffic signals in driving simulators and on-road test tracks. Also, it does not appear that a hands-free phone is much safer than a hand-held phone.”

It’s Not Just the Phones
It is important to note that cell phones are just a small part of the problem; according to the U.S. Department of Transportation, in 2009 they accounted for only about 5% of distraction-related accidents resulting in injury, and 18% of these accidents that resulted in fatalities, compared to other distractions: map reading, eating, grooming, etc., which are responsible for 95% and 82% of these accidents, respectively.

Considering these statistics, we suggest that the best strategy for reducing distraction-related accidents is a holistic approach that addresses the larger problem of driver distraction rather than any single source of distraction. We should strive not to reduce single sources of distraction, such as cell phones, but rather to optimize the entire automotive cockpit based on driving conditions and the myriad tasks a driver may engage in.

The concept of Situation Awareness (SA) provides an excellent framework for this optimization. It can be used to a) increase driver perception of significant objects and events, and b) model the impact on the driver of specific tasks in order to dynamically adapt user interfaces for in-vehicle devices.

Situation Awareness
Situation Awareness is "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". Figure 1 illustrates the relationships between the different elements of SA.

SA models all the important factors that contribute to driving performance, and the relationships between these factors. It is no surprise that the military and aviation industry have used SA to understand pilot performance.

Fundamental to accident-free driving is awareness of the roadway environment. The driver must, for example, notice that the stoplight has turned red, accurately track the location of rapidly approaching emergency vehicles, and be aware that traffic has stopped just over the hill. When a driver is aware of the current driving situation he has high SA, and is able to act promptly and appropriately to prevent accidents.

The crux of the driver distraction problem is that distractions and high workload interfere with the driver’s developing high SA in a timely manner.

The Situation Awareness Model and Types of Driver Distraction
In the context of our discussion, we must consider four basic types of distraction: visual, auditory, cognitive, and biomechanical/physical.

Visual distraction interferes with the perception of objects in the current situation (Level 1 of SA). For example, if the driver looks at a mobile phone on the passenger seat, he may fail to detect a car pulling onto the roadway, and this failure may result in an accident.
The SA model shows how visual distraction can interfere with SA, and offers clues about ways to compensate for visual distractions. Specifically, the model shows that, at least initially, seeing the event is less important than perceiving the event. This distinction means that SA can be enhanced by an audible warning facilitating perception of the event—in this case, the car pulling onto the road.

**Auditory distraction** can interfere with the perception of objects and events (Level 1 of SA). For example, an audible prompt localized at a center display may cause the driver to look away from the roadway, and thus prevent him from detecting an approaching vehicle.

**Cognitive distraction** interferes with the comprehension of the current situation (Level 2 of SA). It exhausts shared cognitive resources, such as working memory and attention, which are required for SA. For example, a conversation over a poor quality telephone connection may engage the driver’s working memory and attention to the extent that he misses or is late detecting a critical object or event.

**Biomechanical/physical distraction** can interfere with the perception of objects or events (Level 1 of SA), or with the driver’s ability to make corrections based on current SA (Performance of Actions stage of SA). For example, a driver reaching for an object on the floorboard may take his eyes off the road; or a driver steering with his knees while texting may be unable to make an evasive maneuver (Performance of Actions).

Finally, we should note that framing the driver distraction problem and its solutions in terms of the SA model allows us to find ways to improve driver performance and safety even when, strictly, there is no distraction. For example, an obstructed view due to terrain is not generally considered a distraction. Nevertheless, technology (a collision-avoidance system using vehicle-to-vehicle communications) can increase the driver’s SA and, consequently, improve his driving.
Optimizing Situation Awareness with a Connected and Integrated Cockpit

It should now be clear that the so-called driver distraction problem is, in fact, not a problem of distraction, but of SA. It should also be clear that techniques that improve the driver’s object and event perception, and situation comprehension can improve his SA, and hence his driving performance.

We believe that the solution to “driver distraction” is to use a connected and integrated vehicle cockpit to optimize SA. This cockpit (Figure 2) monitors the roadway environment, vehicle-related information, and the state of the driver. It also manages the flow of information between driver and cockpit, and optimizes the multi-modal format of these messages based on human factors principles.

Monitoring the roadway environment
A vehicle that monitors the roadway environment increases the driver’s SA by augmenting his ability to perceive what is going on around the vehicle. It supplements his eyes and ears with important indicators and warnings, based on information from sensors and through communication with other vehicles and stationary roadside stations. For example, if the current vehicle speed suggests that the driver may not be aware of ice on a bridge ahead, the vehicle could provide an appropriate alert of the danger.

Monitoring vehicle information
Vehicle information useful to an SA system includes audio levels and sources, movement in the vehicle, and active instrumentation and media—in short, anything that might distract or add to the driver’s cognitive load and reduce his SA. It also includes data about vehicle operating conditions such as steering angle, turn-signal state, and vehicle speed. This data can be used to change application interfaces and outputs to optimize SA. For example, if vehicle information suggests that there is high cognitive load because the vehicle is merging or the driver is currently interacting with another application, then a non-critical application prompt may be delayed.

Monitoring driver state
Since a driver’s situational awareness ultimately depends on his capacity to perceive, understand and act on information, an SA system should include a third data set, which describes the driver’s state. Built from measurements of response times, driving patterns, and even fatigue indicators collected by a driver-facing camera, this description would be used to approximate the driver’s capacity for SA and to determine if his cognitive load should, if possible, be reduced.

SA could also be used to combat situations of under-stimulation. For example, the co-occurrence of driving at highway speeds for an extended period of time, onset of high variability in steering angle, and analysis of driver-facing camera images indicating drowsiness could result in an audible warning to the driver. Indications of boredom or daydreaming could result in offering the driver entertainment options.

Figure 3: An apparently bored driver playing a flute, albeit while waiting at a traffic light.

Benefits of a Situation Aware Vehicle Cockpit
A vehicle cockpit that optimizes SA would bring together information from monitoring of the roadway environment, the vehicle, and the driver state to:

- Recognize potential roadway hazards and driving errors, and supplement the driver’s senses to improve his SA.
• Predict the cognitive load and distraction created by in-vehicle applications and other factors, such as noisy children inside the vehicle and traffic conditions outside the vehicle.
• Estimate the driver’s SA in order to determine if SA enhancement could help him drive more safely.

The vehicle’s SA system would then combine the information from these monitored sources to take actions that increase accuracy, and reduce response times for object perception and situation comprehension. These actions would include:
• Formatting multi-modal messages from applications based on current conditions.
• Managing the flow of information between the driver and cockpit.
• Generating multi-modal messages to the driver that improve SA.

A holistic approach to the driver distraction problem and a solution conceived in terms of the SA model offers us the means to improve driver safety by monitoring and optimizing his SA capacity and level. It helps us not only to manage his cognitive load and the various forms of distraction appropriately, but also to extend his senses so that he can understand any given situation better and sooner, and make the correct, safe driving decisions.

References