MIND WANDERING WHILE DRIVING: WHAT DOES IT MEAN AND WHAT DO WE DO ABOUT IT?

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Distracted driving has been identified as a major concern in highway safety. Research to-date, however, has largely focused on distraction related to external events or intentional engagement in non-driving activities. Internal distraction ("mind wandering") is now being recognized as a significant source of driver distraction that requires rigorous study. There are substantial challenges in detecting, measuring, and addressing mind wandering while driving. Panelists with expertise in driver distraction in general, and mind wandering in particular, will discuss both scientific and pragmatic issues in addressing this problem. Each panelist will present a brief perspective on the problem from the point of view of their experience and expertise. This will be followed by an open discussion period.

Driver distraction has been recognized as a serious issue in roadway safety and is associated with a substantial proportion of vehicle crashes and corresponding deaths and injuries. For example, the National Highway Traffic Safety Administration (NHTSA) estimated that in 2012 there were 3,328 fatalities and 421,000 injuries in distraction-reported crashes (NHTSA, 2014a). Driver distraction therefore has been a focus of research and policy for NHTSA as well as numerous other agencies, safety advocacy organizations, and research groups.

There are various forms of distraction and various means of classifying them. Driver distraction itself has been defined as "a diversion of attention away from activities critical for safe driving toward a competing activity" (Lee, Young, and Regan (2009). Most of the driving-related research to date has focused on distraction due to some external source. External distractors might include some object or event that draws attention (e.g., roadside activity, passenger activity, vehicle-generated information display) or some driver-initiated task (e.g., texting, adjusting a vehicle infotainment system). NHTSA has recently developed guidelines for assessing the magnitude of visual/manual distraction associated with in-vehicle displays and is developing distraction assessment guidelines for voice interaction systems and for mobile devices brought into vehicles (NHTSA, 2014b).

In contrast to this effort directed at external distraction, relatively little work has been done on the issue of internal distraction while driving. Yet internal distraction may be of comparable concern. Internal distraction can be defined as the decoupling of attention from an individual's perception of the outside world coincident with a shift in focus to internal thought processes. Terms such as "mind wandering" and "daydreaming" are descriptive of internal distraction, which might be conscious or unintentional. Research outside the driving domain has indicated that mind wandering can be ubiquitous and may interfere with a variety of tasks and cognitive processes (e.g., Mooneyham and Schooler, 2013). Limited research within the driving domain suggests that there may be substantial effects on driver performance and safety. The magnitude of the problem may be difficult to specify since internal distraction is hard to detect and document and in practice may be difficult to discriminate from fatigue, stress, or impairment. An analysis of Fatality Analysis Reporting System (FARS) data (Erie Insurance, 2013) indicated that the most frequent type of distraction associated with fatalities was mind wandering (62% of "distracted" cases, vs. 12% for cell phone use), although details of the analysis not provided. A French case-control study of injured crash victims in a hospital emergency department (Galera et al., 2012) reported "intense" mind wandering to be a factor in in 17% of the cases in which the driver had crash responsibility, vs. 9% for cases where they were not responsible for the crash (adjusted odds ratio of 2.12), which exceeded the observed magnitude of effect for other factors such as alcohol, sleep deprivation, and external distraction. Experimental studies carried out in driving simulators have reported vehicle control deficits associated with internal distraction, based on user self-report of distraction episodes (He, Becic, Lee, and McCarley, 2011; Yanko and Spalek, 2014). While there may be limitations or methodological issues related to some of the existing literature, the studies point to internal distraction as a meaningful source of driving performance degradation and an important contributor to crash causation.

While the need for a better understanding of driver mind wandering is apparent, there are very significant challenges to studying this phenomenon and to finding ways to address its consequences. Among the issues to be confronted are the following:

- How can internal distraction be reliably detected and measured? This question must be answered for both lab/driving simulator environments and for on-road driving conditions.
- How can internal distraction be reliably discriminated from other factors, such as fatigue, impairment, or external distraction?
- What is the frequency with which mind wandering occurs and what are the circumstances that promote it?
- What is the magnitude of the safety problem associated with mind wandering?
- What countermeasures might be developed to address the problem?

- How will the evolution of the driving task influence the occurrence and consequences of internal distraction? Technology is rapidly influencing the design of vehicle systems, roadway design, and communications. Vehicles increasingly provide support to the driver in terms of warnings, alerts, and intelligent vehicle control input. Increasing levels of vehicle automation are emerging and important effects of automation on operator attention are evident from other domains.

This panel brings together a group of leading researchers that have expertise in the areas of driver performance, driver attention, and internal distraction. Together they will provide insights on the issues associated with making progress on the driver mind wandering problem and provide a basis for panel discussion and audience participation.

The researchers on this panel are James Higgins (National Highway Traffic Safety Administration), Jonathan Schooler (University of California – Santa Barbara), Carryl Baldwin (George Mason University), and John Lee (University of Wisconsin). Their work represents a range of applications that include driver behavior, attention and distraction, mind wandering, the nature of mental life, neuropsychological aspects, algorithm development for detection of operator state, and technology for vehicle safety countermeasures. Each discussant will present a brief perspective of key issues from the point of view of their experience. This will be followed by an open discussion period. The session chair will have a number of prepared questions, including one to start the discussion. After this question is discussed, the floor will be opened to additional questions and comments from the audience.

Mind-wandering in the Highway Safety and Policy Context: Dr. J. Stephen Higgins, National Highway Traffic Safety Administration

The National Highway Traffic Safety Administration (NHTSA) is an integral part of the United States Department of Transportation (DOT) with a mission to save lives, prevent injuries, and reduce traffic-related health care costs and other economic burdens. In 2012, 10% of all fatal crashes (3,050 of 30,800 total crashes) and an estimated 421,000 people were injured because of distraction-affected crashes. Because of this, NHTSA is greatly interested in further researching this issue to produce a basis for creating effective anti-distracted-driving public safety programs.

Currently, a major share of all distracted driving research and programmatic efforts are directed toward cell phone use (talking, texting, dialing, and now many smart phone functions). However, only 12% (378) of Distraction-Affected crashes were related to cell phone use. Even if this estimate is conservative, this leaves many thousands of deaths and injuries associated with other types of distraction and inattention. At this time, we do not have the tools, as a scientific community, to evaluate reliably whether mind wandering contributes to crashes. We are working toward this goal.

We are in the process of working to evaluate current—and create new—algorithms to detect and quantify the magnitude and types of “mind wandering” present during driving. We seek to understand how non-invasive and continuously collected physiological, behavioral, and vehicle-based data can predict non-task-related internal cognitive states, even when a driver’s eyes are focused on the road.

Once we as an industry, government, and academic community better understand methods for detecting mind wandering, we can begin the process of determining how mind wandering affects crash risk as well as safety risks in other environments, such as control rooms and other modes of transportation. We can explore whether or not certain types of mind wandering—for example, emotional states, episodic memories, future planning, and others—are associated with crash risk compared to others. In addition, we can more fully understand the interactions between other related mental states and mind wandering: for example, alcohol and drug intoxication, drowsiness, or fatigue from long drives. In the future, we may be able to use these findings to design better vehicles that more effectively interact with our cognitive states, and, most importantly, come up with new countermeasures to prevent mind-wandering-involved injuries and fatalities.

Mind-wandering: A review and consideration of its potential relevance to driving: Dr. Jonathan Schooler, University of California – Santa Barbara

To be internally distracted is to be mind-wandering (MW), a common everyday experience for all people. Notably, scientists estimate that as much as 50% of waking life is spent MW (Killingsworth & Gilbert, 2010; Mooneyham & Schooler, 2013; Schooler et al., 2011; Schooler et al., 2013; Smallwood, 2013; Smallwood & Schooler, 2006; Smallwood & Schooler, in press). For lay people as well as cognitive scientists, MW means "thinking about something else" instead of focusing attention on a particular task such as driving a car or having a conversation. MW has been extensively investigated during the last decade and has become a prominent topic in mainstream cognitive psychology and cognitive neuroscience (Schooler et al., 2011; Smallwood & Schooler, in press). While the research literature on MW has grown to be extensive and diverse, there are a number of domain-general principles related to MW, such as perceptual decoupling, current concerns, and loss of meta-awareness, that can be brought to bear on the problem of continuously detecting and predicting MW while driving a car. MW is often measured in the laboratory using a self-report instrument, such as experience sampling "thought-probes" presented concurrently during a task (referred to as "probe-caught" MW; Smallwood & Schooler, 2006), or instructions to press a key whenever one notices one is MW during a concurrent task (referred to as "self-caught" MW; Schooler et al., 2011). Experience sampling methods have also been used to measure MW in the field, using remote communication devices to occasionally query individuals about MW as they go about their daily lives (Franklin et al., 2013; Killingsworth and Gilbert, 2010; McVay, Kane, and Kwapil, 2009). Correlating self-reports about mental state and attentional focus with behavioral and neurophysiological measures has allowed cognitive scientists to uncover a wealth of facts about the precursors, correlates, and consequences of MW, in terms of both brain and behavior. MW has been most extensively investigated in the laboratory in relation to the related abilities to sustain vigilant attention and withhold execution of a habitual response, using the SART (Robertson et al., 1997). Reaction time (RT) measures such as average RT may also be assessed, but more commonly, RT variability is used as a more subtle measure of failures in sustained attention. Greater RT variability is associated with MW. Specifically, whereas modest attentional disengagements tend to produce a speeding of RTs, more pronounced disengagements produce slower RTs; when combined this produces an overall increase in RT variability (Cheyne et al. 2009). These same principles are also likely to apply to measures of driving performance such as braking behavior, steering error, and lane position. As such, this insight from the cognitive MW literature could lead to the development of more effective algorithms to predict MW while driving.

Challenges and Lessons Learned in Driver State Assessment – Applications in Mind Wandering: Dr. Carryl Baldwin, George Mason University

Developing methods for assessing the cognitive-mental state of a driver has been a human factors goal dating back well over half a century. This goal- and the on-going challenges that accompany it – are as important today as ever before and are key to maintaining automotive safety. Numerous methods of mental assessment have been proposed and explored ranging from behavioral performance assessment, subjective assessment, and physiological metrics. More recently vehicular metrics have been proposed as a way of determining the mental state of the driver.

Technological advances in physiological sensor capabilities make using physiological metrics increasingly promising. Relatively low cost and unobtrusive measures (e.g., eye gaze entropy, blink rate) can be used as indices of fatigue, alertness, and attentional state. Physiological indices have numerous advantages over other techniques. Behavioral and subjective metrics are frequently insensitive to attentional state and effort and vehicle metrics may be rendered uninformative by advances in vehicle automation.

Developing a method of detecting when a driver's mind has wandered away from the task of driving can be informed by previous efforts towards operator state classification. At the same time, additional challenges must be overcome. For example, mind wandering metrics will need to be effective and functional in a wind range of driving environments (e.g., extreme changes in lighting conditions, temperature, and motion) with an extremely diverse set of the drivers (e.g., the newly licensed teenage male and the over-worked highly stressed executive).
For example, factors such as age impact the sensitivity of different metrics with different patterns of neurophysiological activity demonstrated across the lifespan (McEvoy, Pellouchoud, Smith, & Gevins, 2001). Further, pharmaceutical and illicit drugs alter pupillometry, eye movements and neurophysiological activity (llan, Smith, & Gevins, 2004)

Detection methods will similarly need to be effective at different times of day and sensitive to changes in mental state independent of environmental state, and day to day fluctuations in physiological state, sleep loss, diet, and pharmacological interventions. These challenges and methods of addressing them are a focus of the current discussion.

Previous efforts at operator state classification indicate that multiple metrics are frequently needed to achieve sensitive classification and this can be expected to be the case in this application. Different combinations of metrics are often more sensitive for one individual relative to another. Fortunately a number of metrics can be obtained from a small set of relatively low cost sensors and algorithms that can be developed that determine which metrics or features of metrics are the best classifiers for specific individuals at specific points in time relatively quickly.

Developing classifiers that are tailored to a specific individual at a specific point in time are currently more feasible than the development of classifiers that generalize across individuals and even within individuals at different points in time (Baldwin & Penaranda, 2012). Further research is needed to examine additional means of developing more robust and generalizable algorithms.

Statistical models of the nested indictors and influences of mind wandering: Dr. John Lee, University of Wisconsin

Increasingly computerized and connected vehicles provide a wealth of real-time data. These data can indicate driver state—weaving may indicate alcohol impairment. Mind wandering represents an important mental state (Schooler et al., 2011), and vehicle instrumentation might be used to detect it. As an example, gaze concentration can indicate cognitive distraction (Victor, Harbluk, & Engstrom, 2005). Vehicle instrumentation also can identify factors that influence mind wandering, such as route familiarity (Yanko & Spalek, 2013). Unfortunately, no one-to-one mapping links data from vehicle to driver state.

Complicating the identification of indicators and influences of mind wandering is the complex nested context of driving. In the case of route familiarity influencing the propensity for mind wandering, a simple matching of GPS locations that indicate a frequently traveled route might be insufficient. Familiarity likely depends on geographic matching as well as time of day, weather, and traffic patterns, which define the broader context of the trip. This nested structure differs substantially from the orthogonal sets of factors found in experimental designs and presents important challenges to identifying the indicators and influences of mind wandering.

Recent advances in statistical modeling and machine learning offer promising approaches to meet the challenges of mind wandering. Three approaches merit particular attention. Dynamic Time Warping can identify similar trajectories. These trajectories can be defined by GPS locations and by other features, and so can provide a systematic basis for judging route familiarity that goes beyond simply matching spatial paths (Jeong, Jeong, & Omitaomu, 2011). Deep learning neural nets have recently emerged as a leading technique for many classification problems, such as machine vision applied to digit recognition and labeling natural scenes (Bengio, Courville, & Vincent, 2013). One source of power of deep learning flows from its multi-level representation of the problem domain. Dynamic Bayesian Networks represent a third approach that can model the nested influences on driver state. In the context of fatigue, Bayesian Networks can represent the influence of the previous night's sleep, the time of day, and the type of road on the conditional probability that a driver is drowsy given a certain distribution of steering wheel movements (Yang, Lin, & Bhattacharya, 2010). These and other machine learning techniques, complement the more traditional regression models. Machine learning techniques offer particular value in untangling the nested hierarchy of behavior that ranges from milliseconds to months.

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