Cognitive Distraction: Something to Think About

Lessons Learned from Recent Studies

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EXECUTIVE SUMMARY

Distracted driving, though not a new phenomenon, has attracted significant attention in recent years due to the proliferation of cell phones and other portable technologies that are often used behind the wheel. Experts generally agree that driver distraction stems from three sources: visual (eyes off the road), manual (hands off the wheel), and cognitive (mind off the task). Of these, cognitive distraction is the most difficult to observe and measure. While there is evidence of public and policymaker understanding of the risks involved with visual and manual distractions (especially texting while driving), there appears to be less appreciation for the risks involved with cognitive (or mental) distractions. Despite this, existing research has found evidence of the effects of this third source of distraction, suggesting that hands-free does not mean risk-free.

In addition to reviewing the literature on distracted driving, this paper introduces a landmark study by the AAA Foundation for Traffic Safety and the University of Utah of mental workload imposed on drivers by the performance of a variety of common secondary tasks: listening to the radio, listening to an audio book, conversing with a passenger, conversing on a hand-held cell phone, conversing on a hands-free cell phone, and interacting with an advanced speech-to-text system similar to those that are increasingly found in new vehicles. In addition to isolating the cognitive elements in each distracting task, this study uses advanced metrics (such as brainwave measurements, reaction time tests, and other indicators) to create a rating scale that assesses how mentally distracting each task is relative to two extremes: non-distracted driving, and driving while performing a complex math and verbal activity.

> This paper introduces a landmark study by the AAA Foundation for Traffic Safety and the University of Utah of **mental workload** imposed on drivers by the performance of a variety of common secondary tasks.

The principal finding that driver use of in-vehicle speech-to-text technologies is the most distracting of the six tasks has important implications given the skyrocketing growth in voice-activated infotainment and other dashboard systems available to consumers. The findings also challenge prevailing public assumptions that hands-free devices are safer than their hand-held counterparts.

PART I – DISTRACTED DRIVING BACKGROUND

Overview

Distracted driving is not a new phenomenon. Whether behind the wheel or at the reins, drivers have been exposed to distractions for as long as vehicles of all types have traversed the roadways. While many of these attention-grabbing activities are decidedly "low-tech," the explosion in cell phones, portable electronics, and other technologies in recent years has increased the opportunity for driver distraction, and elevated the profile of this issue as a significant threat to traffic safety and a top-of-mind public concern. In fact, in a nationally-representative survey of U.S. residents ages 16 and older, 88.5

percent of respondents said that distracted drivers were a "somewhat" or "much" bigger problem today compared to three years ago, and nearly all (95.7%) said that drivers text messaging and emailing behind the wheel were a "very" or "somewhat" serious threat to their personal safety (AAA Foundation for Traffic Safety, 2013a).

The National Highway Traffic Safety Administration (NHTSA) defines distraction as a "specific type of inattention that occurs when drivers divert their attention away from the driving task to focus on another activity instead" (NHTSA, 2010). It is considered a category within inattention more broadly, the latter of which includes fatigue and other driver conditions (NHTSA, 2013). NHTSA reports that in 2011, the most recent year for which data are available, approximately 3,300 people were killed and 387,000 were injured in crashes involving distracted driving (NHTSA, 2013).

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Troublingly, data limitations likely mean that these numbers underestimate the true distracted driving problem (AAA Foundation for Traffic Safety, 2013b). Official distraction statistics generally rely on police-reported data in the Fatality Analysis Reporting System (FARS) and the National Automotive Sampling System (NASS) General Estimates System (GES). Because these data come from the states, there can be large differences in the quality, detail, and procedures involved in reporting distraction (NHTSA, 2010). Moreover, it can be very difficult for police officers responding to the scene of a crash that has already occurred to determine the pre-incident driver behaviors that were involved. While a speeding driver may leave skid marks, for example, and a drunk driver will have a measurable blood alcohol level, a distracted driver's decision to reach for a sandwich or adjust temperature controls does not necessarily leave a physical trace.

To gain a richer understanding of distracted driving, researchers at NHTSA and many other organizations have turned to additional methods for collecting data. Examples of these include surveys, observational studies, and naturalistic (e.g., in-vehicle camera recordings) research. Though each of these has limitations, they do offer insight and information that is simply not obtainable from police records. For example, the AAA Foundation's Traffic Safety Culture Index survey has consistently found that many motorists admit to engaging in distracted behaviors behind the wheel, with more than one third (34.7%) saying they read a text or email while driving in the past 30 days, more than a quarter (26.6%) admitting they typed or sent one, and more than two thirds (68.8%) reporting talking on a cell phone (AAA Foundation for Traffic Safety, 2013a).

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Three Sources of Distraction

Conceptually, sources of driver distractions can be divided into three categories (Strayer, Watson, & Drews, 2011):

- **Visual:** Visual distractions take the driver's eyes off the road. Turning to look at a passenger is an example of this kind of distraction.
- **Manual:** Manual distractions take the driver's hands off the wheel. For instance, when a driver is holding food or a beverage, he or she is manually distracted
- **Cognitive:** Cognitive, or "mental," distractions take the driver's mind off the task at hand (safe driving). Worrying about a job interview or dwelling on an intense conversation while behind the wheel might constitute cognitively-distracted driving. Any form of visual or manual distraction inherently involves an element of cognitive distraction, as well.

Research into these sources of driver distraction has helped clarify some of the risks associated with distracted driving, and raised the profile of this issue as a significant traffic safety concern:

- With regard to **visual** distractions, NHTSA, using naturalistic data, found that glances away from the forward roadway lasting more than two seconds increased the risk of a crash or near-crash to over two times that of "normal" driving (NHTSA, 2006).[1]
- Additionally, a naturalistic AAA Foundation-sponsored study of teen drivers found – through in-vehicle video recordings – that **manual** distractions (e.g., operating electronic devices, adjusting controls, etc.) were the most common behaviors observed (Goodwin, Foss, Harrell, O'Brien, 2012).
- In examining cell phone use and texting, which can involve **all three** sources of distraction, studies have found that these activities increase risk to drivers. Redelmeier and Tibshirani (1997), and McEvoy et al. (2005), for example, each found a fourfold increase in crash risk for drivers using cell phones, and research at the Virginia Tech Transportation Institute (VTTI) showed that commercial truck drivers who were texting were 23 times as likely to have a safety-critical event[2] than those who were not distracted (FMCSA, 2009).
- Cell phone use and other distractions may be particularly concerning in high-risk environments, such as school or work zones, where the potential for deadly conflicts between different road users is elevated. An observational study by Safe Kids USA, for example, found that one in six drivers in school zones were distracted, most commonly by use of cell phones or other electronics (Grabowski and Goodman, 2009).
- In looking at how the different types of distractions affect driver behavior, Angell et al. found that auditory-vocal tasks tended to affect visual behavior (e.g., reduced glances to mirrors), whereas visual-manual tasks increased the miss rates of important cues such as lead vehicle brake lights and deceleration (Angell, Auflick, Austria, Kochhar, Tijerina, Biever, Diptiman, Hogsett, and Kiger, 2006).

[1] The report did clarify, however, that shorter (less than two seconds) glances to scan the roadway periphery and surrounding driving environment were important for awareness and safe driving.
[2] "Safety-critical event" included incidents such as crashes, near-crashes, other conflicts, unintentional lane departures, etc.

Of the three types of distractions, cognitive is the most difficult to measure, since a driver's mental state is not necessarily apparent to an observer. Moreover, in practice, most distracted driving behaviors do not stem from any one of these sources in isolation, but rather reflect some combination of them. Even studies that have not specifically attempted to measure cognitive distraction have examined behaviors that involve elements of cognitive workload, such as talking on a cell phone or conversing with a passenger, without assessing that cognitive element itself (Stutts, Feaganes, Rodgman, Hamlett, Meadows, & Reinfurt, 2003). Despite the challenges surrounding the study of cognitive distraction, the aviation industry now has decades of research behind it pertaining to cognitive workload among pilots, and this provides a useful body of knowledge to turn to when looking at motor vehicle driver distractions (see Sidebar). Part II, therefore, explores these issues more fully.

In-Vehicle Technologies

Concurrent with growth in distracted driving research has been a proliferation of new infotainment[3] and other in-vehicle technologies, whose potential for creating driver distractions is not yet well understood. Though still relatively new – many automakers' systems were announced in 2010 and 2011[4] – these on-board technologies are gaining in sophistication and penetrating the vehicle fleet at a rapid pace. In 2012, for example, IHS Automotive reports that 80 percent of the new cars sold in Europe and North America featured voice-activated controls of some kind.[5] Additionally, a new study by ABI Research predicts that

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Drivers aren't the only people subject to mental distraction. With approximately 80 percent of aviation crashes and 50 percent of incidents attributed to pilot error, the importance of human factors and cognitive workload in aviation crashes has been recognized for decades (Li, 2001; Herbolsheimer, 1942). In fact, the highway safety community has been lagging behind the aviation industry in research into mental distraction.

Just like drivers, when flight crews don't focus their full attention on flight activities or are preoccupied with activities unrelated to flying, critical information can be overlooked or misunderstood, resulting in the pilot's inability to operate the plane safely.

To better understand what happens in a pilot's brain during flight, researchers have used brainwave measures (called EEG measures) as indicators of pilot performance and cognitive workload (see, for example, Sterman and Mann, 1995). In addition to showing that cognitive distraction can manifest itself in a number of ways (inattention, channelized attention, confusion, neglect of flight checklists, getting lost, etc.), studies have found that even highly-trained pilots can and do get distracted by non-essential tasks that can result in loss of life. A study of fighter aircraft crashes, for example, documented 14 fighter pilot deaths over a 10-year period, and the only common factor was that all but one of the fatalities occurred during cognitively-demanding portions of flight (Auten, 1996).

In order to preserve commercial airline pilots' concentration during critical phases of flight (taxiing, take-off, landing, and flying at low elevations), the U.S. Federal Aviation Administration (FAA) created a set of laws in 1981 that prohibited flight crews from performing non-essential activities (U.S. FAR 121.542/135.100). Commonly referred to as the "sterile cockpit rules," their main objective is to ensure flight crews operate aircraft safely and concentrate only on essential flight activities during phases that require their full attention.

With the "sterile cockpit" regulations now over 30 years old, the risks of cognitive distraction and mental workload are old news to pilots. While the AAA Foundation and University of Utah study may be groundbreaking research for traffic safety, it is familiar territory for others in the transportation community.

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[3] In this context, "infotainment" systems include built-in dashboard technologies that, among other things, may allow drivers to use social media, surf the internet, send and receive texts or emails, etc.
[4] Ashlee Vance and Matt Richtel. "Despite Risks, Internet Creeps Onto Car Dashboard." *New York Times,* January 6, 2010.
[5] Bruce Gain. "Automakers rethink cockpits to help save lives." *Automotive News Europe*, April 5, 2013.

automotive infotainment systems shipments will grow from 9 million this year to more than 62 million in 2018, and that key features of these technologies will include "connected navigation, multimedia streaming, social media, and in-car Wi-Fi hotspots."[6]

With motorists increasingly empowered to remain connected to their online and social media communities from the comfort of the driver's seat, the justifications for incorporating these technologies in new vehicles tend to rest on the notion that they are safe by virtue of the fact that they are hands-free. Even as legislative and regulatory efforts have been mounted to tackle the hazards posed by visual and manual sources of distracted driving, cognitively-demanding tasks have generally been approached with an "innocent until proven guilty" mentality. To highlight this third source of distraction, therefore, the next section discusses the findings to date of research addressing cognitively-distracted driving, and explores the discrepancies between responses to visual/manual distractions and to those which are cognitive.

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PART II – COGNITIVE DISTRACTION: SOMETHING TO THINK ABOUT

Before discussing cognitive distractions, consider for comparison purposes a distracted driving behavior that has gained significantly more recognition: texting. Reading and sending text messages behind the wheel is perhaps the driver distraction that has most resonated as a public concern. Between the alert of an incoming message, thinking about a reply, looking at the screen, and manipulating the keyboard, drivers who text behind the wheel face a combination of all three sources of distraction which can, as stated earlier, greatly increase crash risk.

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There are indications that the public understands some of the risk involved with texting and driving. The AAA Foundation's 2012 Traffic Safety Culture Index, for example, found that 94.5 percent of licensed drivers say sending text messages while driving is an unacceptable behavior, and 86.4 percent support banning this practice (AAA Foundation for Traffic Safety, 2013a). Perhaps not surprisingly, then, of the various legislative efforts to curb distracted driving, anti-texting laws have gotten the most traction. As of January 2013, 39 states and the District of Columbia have enacted texting bans, compared with just 10 (plus DC) that ban hand-held cell phone use statewide (AAA, 2013).

[6] ABI Research. "Connected Automotive Infotainment System Shipments to Exceed 62 Million by 2018 as Feature Set Explodes, According to ABI Research." Press release, March 13, 2013.

Hands-Free Does Not Mean Risk-Free

In stark contrast to the numbers above, public and policymaker concern regarding the dangers of texting and driving appears to dissipate when the conversation turns to sources of cognitive distractions. No state currently bans all driver use of cell phones (hand-held and hands-free), and whereas less than a third of licensed drivers believe hand-held cell phone use while driving to be acceptable, more than half (56.2%) believe it is okay for drivers to use hands-free devices (AAA, 2013; AAA Foundation, 2013a). Moreover, nearly three in four drivers say it is safer to use hands-free devices than hand-held ones, and more than half of drivers with vehicles that have on-board systems controlled by speaking (e.g., navigation, stereo, phone) believe it is not at all distracting to use these technologies (AAA Foundation, 2008; AAA Foundation, 2013a). Moreover, these perceptions appear to translate to less support for laws and regulations targeting sources of cognitive distraction. Whereas two in three drivers (66.5%), for example, support hand-held cell phone bans, less than half (48.6%) support bans that would include hands-free devices, and barely half (52.6%) support federal regulation of in-vehicle technologies to ensure they don't distract drivers (AAA Foundation, 2013a).

Despite the relatively low appreciation for the dangers of cognitive distraction, existing research does not support the notion that hands-free means risk-free. For example, a case-crossover study of 456 drivers in Western Australia found that driver use of a cell phone was associated with a fourfold increase in crash risk, and that no difference in this risk was seen between hand-held and hands-free device type (McEvoy, Stevenson, McCartt, Woodward, Haworth, Palamara, and Cercarelli, 2005). A fourfold crash risk increase from driver use of cell phones, with no difference between hand-held and hands-free devices, was also found by Redelmeier and Tibshirani (1997). Most recently, research by the Texas A&M Transportation Institute found no difference between manual-entry texting while driving versus use of voice-to-text technologies. In each case, reaction times were roughly two times slower and visual attention to the roadway was reduced for the texting drivers, regardless of whether hand-held or hands-free methods were used for the task (Yager, 2013).

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Additionally, in assessing driving performance using a simulator, Jenness, et al. found that driver use of a voice-activated dialing system was as distracting as eating a cheeseburger behind the wheel (Jenness, Lattanzio, O'Toole, and Taylor, 2002). In another simulator study, Strayer et al. found that participants talking on hands-free cell phones had a reduced ability to recognize billboards that they had passed in the course of the experiment. They attributed this impairment to "inattention-blindness," in which drivers fail to visually process what their eyes see (Strayer, Drews, and Johnston, 2003). Further supporting this claim, a meta-analysis of 23 studies found that driving performance (mainly reaction times) was degraded by driver use of a cell phone, and that the reductions were equivalent for hand-held and hands-free device usage.

> It is therefore the **cognitive, rather than manual, source of distraction that causes the most impairment** from driver use of cell phones

The authors suggested that it is therefore the cognitive, rather than manual, source of distraction that causes the most impairment from driver use of cell phones (Horrey and Wickens, 2006).

In addition to inattention-blindness, another type of visual concern related to cognitive distraction has been revealed in numerous studies: tunnel vision. By tracking eye movements as study participants drove a short city route, for example, Harbluk and Noy found that drivers who were engaged in cognitive exercises using a hands-free device scanned their surroundings less and gazed more centrally ahead (Harbluk and Noy, 2002). Evidence of this tunnel vision has been found in numerous other studies, as well (e.g., Reimer, 2010). As previously mentioned, NHTSA has reported safety benefits when drivers are fully aware of their surroundings and perform quick scans (not lasting more than two seconds) of their environment (NHTSA, 2006), so driver engagement in secondary tasks that result in tunnel vision can degrade driving performance.

In addition to inattention-blindness, another type of visual concern related to cognitive distraction has been revealed in numerous studies: **tunnel vision.**

While these findings are troubling and indicate that cognitive distraction is a concern worthy of greater attention, much is still unknown about this form of driver inattention and what the best methods for studying it might be in the context of passenger vehicle operations. For example, Angell et al. note that the effects of cognitive distraction may be subtle, and isolating their sources is very difficult when conducting research (Angell, Auflick, Austria, Kochhar, Tijerina, Biever, Diptiman, Hogsett, and Kiger, 2006). Also at issue is the selection of outcomes to measure. The McEvoy et al. study, for example, looked at crashes, whereas Harbluk and Noy analyzed eye movements and Strayer et al. (2003) tested participants' recall abilities. This can make it difficult to draw comparisons and assess the degree to which various research findings corroborate or contradict one another. There is significant space, therefore, for cutting-edge methodologies that can help us learn more than we have to date about the cognitive elements and workload associated with secondary tasks performed while driving.

PART III – MEASURING COGNITIVE DISTRACTION IN THE VEHICLE

Given general public acceptance of hands-free device use, legislative inaction to address cognitive distraction, the proliferation of in-vehicle infotainment systems, and a body of research suggesting that hands-free does not mean risk-free, the AAA Foundation for Traffic Safety initiated a landmark study in 2011 to better understand and assess cognitive sources of driver distraction. Conducted by researchers at the University of Utah Center for the Prevention of Distracted Driving, the main objectives of this research were to:

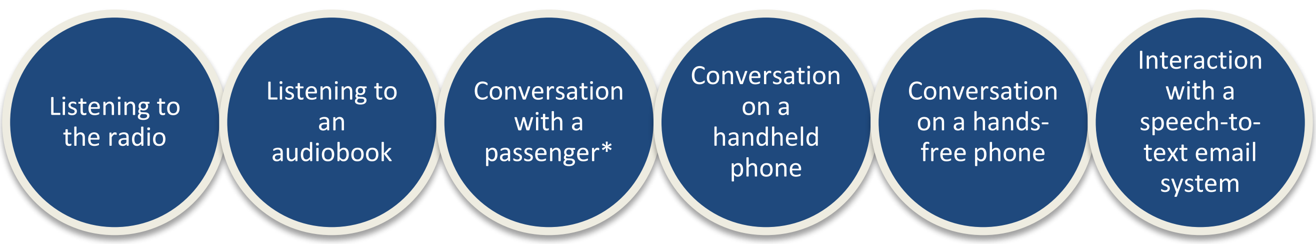
- Isolate the cognitive elements of distracted driving;
- Evaluate the amount of mental workload (using, among other things, brainwave measures and indicators of driving performance) imposed on drivers by various tasks performed behind the wheel; and
- Create a rating system that ranks potentially-distracting tasks according to the amount of cognitive burden they place on drivers.

Unlike much of the previous research in this area, the AAA Foundation/University of Utah study is not limited to assessing one specific behavior that "represents" cognitive distraction (e.g., a hands-free cell phone conversation) and relating it to one chosen outcome measure (e.g, response time, eye movement, etc.). Instead, this study combines the results of three experiments that assessed six cognitive tasks using several different measurements/outcomes. The result: a robust analysis that assesses common driver activities according to their cognitive elements and demonstrates the increased workload associated with the more demanding tasks, such as utilizing speech-to-text systems and maintaining conversations.

Though this is a groundbreaking highway safety study, it is worth noting that decades of research in the aviation field have contributed greatly to our understanding of cognitive workload among pilots, and have justified various federal regulations for the airline industry. With this study, the AAA Foundation and the University of Utah hope to leverage this aviation work to gain insight into cognitive distraction in motor vehicle "cockpits."

Study Methods – A Brief Synopsis

The AAA Foundation/University of Utah study assesses six common tasks:



Additionally, two other situations are included in order to provide anchors for comparison – a baseline "non-distracted" condition, and a difficult mathematical and verbal activity intended to provide the highest level of cognitive workload.[7] Separate samples of study participants were evaluated as they performed these tasks in three different experiments: one non-driving,[8] one in a high-fidelity simulator, and one in an instrumented vehicle on a short route in Salt Lake City, UT. Measurements and outcomes that were examined include:

- **Brainwave (Electroencephalographic – EEG) activity**[9]

* Conversations were not standard passenger conversations in which passengers could react to events outside of the vehicle. These passengers maintained a conversation, regardless of external events.

[7] Called the OSPAN Task (Operation Span), this final activity involves simultaneous math computation and word memorization; given its complexity, it was chosen to anchor the high end of the cognitive workload scale.

[8] By allowing participants to familiarize themselves with each task/technology before driving commenced, researchers intended to ensure that the cognitive workload measurements weren't simply due to the task being new and challenging to learn. Additionally, all participants indicated before the study began that they regularly use a cell phone while driving in the real world, so this type of communication activity is not unfamiliar.

[9] This is a measurement of brain activity associated with the processing of information necessary for the safe operation of a motor vehicle; prior research (Strayer and Drews, 2007) found that this activity was diminished when drivers engaged in cell phone conversations behind the wheel.

- **Reaction time and accuracy to a peripheral detection light test**
- **Subjective workload ratings (survey)**
- **Brake reaction time and following distance**
- **Eye and head movements**

The three experiments were conducted separately with the relevant measurements/outcomes assessed for each. The scores for each measure were then standardized so that the results could be aggregated and a rating of cognitive distraction could be created. It is this aggregate score that underpins the cognitive distraction rating scale that ranks each activity from 1 to 5, with 1 being the least mentally distracting (just driving without any additional tasks), and 5 being the most mentally distracting (mathematical problem solving and word recall).

New Insights into Cognitive Distraction

This study constitutes the most in-depth analysis to date of cognitive distractions behind the wheel, and makes a valuable contribution to the overall body of knowledge pertaining to this issue. By developing a rating scale using a direct measurement of brain activity, together with other metrics, this project isolates the cognitive components of distracted driving and rates common activities according to the amount of workload they impose on drivers. It is especially encouraging that all three of the experiments had nearly identical results, with each measurement demonstrating the same pattern of increasing cognitive workload across the six tasks. This suggests the strength and validity of the study methods and results, as well as the promise that simulator-based studies have for approximating real-world conditions.

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Rather than selecting one activity as a proxy for cognitive distraction and analyzing a specific measure in relation to it, this study zeroed-in on the cognitive workload itself, and allowed us to understand the effects of a variety of activities in relation to each other. Based on the rating system created, for example, we can state that driver interaction with speech-to-text systems – long a concern of researchers and safety advocates – does indeed create a greater demand on cognitive resources than does listening to the radio or even conversing on a handheld or hands-free cell phone, the latter of which have been shown to quadruple crash risk. This is particularly troubling given the popularity of these systems, their projected growth in the immediate future, and the rapidly-developing capabilities they have. This study provides the best evidence to date that even if drivers keep their eyes on the road and hands on the wheel, it may not be enough to keep them safe. Despite current public perceptions and the lack of legislative or regulatory actions, use of in-vehicle infotainment systems appears to be the most distracting cognitive task that drivers can perform, and automakers, consumers, policymakers, and others would be wise to consider these findings before continuing the rush to implement or adopt these technologies.

> Despite current public perceptions and the lack of legislative or regulatory actions, use of in-vehicle infotainment systems appears to be **the *most* distracting cognitive task that drivers can perform**

The value of this new rating system – which can be applied to assess additional activities beyond these initial six – is also suggested by recent research demonstrating that motorists who use cell phones with greater frequency are more likely to engage in a variety of other risky behaviors behind the wheel, as well. Researchers at MIT, for example, found that drivers who report greater cell phone use were also more likely to drive faster, change lanes more often, accelerate and brake more rapidly, and report more driving violations (Zhao, Reimer, Mehler, D'Ambrosio, and Coughlin, 2012). Additionally, the AAA Foundation for Traffic Safety noted a similar pattern in its safety culture data, finding that motorists who reported more frequent cell phone use were also more likely to engage in the other risky behaviors included in the survey.[10] This suggests that risk-prone driving in general – including but not limited to cell phone use – poses a threat to traffic safety (AAA Foundation, 2013b). Having a rating system, therefore, that provides greater insight into a variety of activities may be very helpful.

> This study provides some of the strongest evidence yet that **hands-free does not mean risk-free**

By isolating and rating the cognitive workload that is involved in a variety of common driver activities, this study provides some of the strongest evidence yet that hands-free does not mean risk-free. In the real world, even seemingly-stable driving environments can change rapidly and without notice. If a driver is looking at the radio, eating a sandwich, sending a text, or experiencing inattention-blindness from a cognitively-demanding task, attention may be withdrawn from the driving environment at a critical moment, such as when a slow vehicle suddenly "appears" on an otherwise deserted freeway. If life is a game of inches, driving is a game of seconds.

A Caveat

Although this study provides a rich look at cognitive distractions, when interpreting the results it is important to remember that crashes are not the measured outcome. As such, the study does not attempt to translate the relative cognitive workloads into associated crash risks. This is because the goal of the project was to isolate and analyze the cognitive elements of distracting tasks in order to highlight their effects on driver (in)attention. In a crash situation, there will likely be numerous contributing factors that can make it difficult to highlight these cognitive components specifically. A driver's age, pavement or weather conditions, vehicle speeds, or other better-understood distraction sources (e.g., typing a text message) may be more likely to capture the headlines and attention of all those involved in the crash and its aftermath, and overshadow the harder-to-pinpoint factors like inattention blindness. Even when distraction is coded in a police report as a contributing factor in a crash, for example, it is very tough to identify the inner workings of a driver's brain, and the extent to which these factors (in particular) contributed to the crash. In essence, then, this project was interested in proving the existence and relative strength of these "hidden" elements. Given that in the real world visual and manual elements of distraction may be layered on top of cognitive sources, it is important to consider the results of this study in relation to all of the other work discussed above.

> It is important to remember that **crashes are not the measured outcome.**

[10] For example, whereas 44 percent of licensed drivers who said they fairly often or regularly talked on the phone while driving also reported driving while extremely sleepy (within the previous 30 days), only 14 percent of drivers who reported never using a phone admitted to such drowsy driving. This pattern was consistent for every behavior on the survey, including red light running, speeding (by 15+ mph) on freeways, and texting.

Conclusion

Despite the challenges of studying cognitive distraction in the vehicle, this study makes a significant and valuable contribution to our knowledge base, and demonstrates that being an attentive driver requires three things at all times: eyes on the road, hands on the wheel, and mind on the task at hand. Degradations in peripheral detection, brake reaction time, brainwave measurements, and visual scanning all indicate that drivers who engage in secondary tasks while driving place a greater cognitive burden on themselves. This leaves fewer resources available for the driving task and impairs performance.

Given today's technological landscape – with its proliferation of voice-activated in-vehicle systems presumed to be safe on the basis that they don't require manual inputs or visual attention – this research has important implications. Previous studies have shown that even when drivers have their eyes on the road, they may not truly perceive their surroundings (Strayer, Drews, and Johnston, 2003). Now it's clear that some tasks – such as interacting with built-in speech-to-text systems – really do demand significant cognitive resources, and that these new technologies are not risk-free by virtue of being hands-free.

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There is still much work to be done in this field, and the rating system developed by the AAA Foundation and University of Utah is expected to be applied to new technologies and driver activities in the coming years. Among the highest priorities will be to assess additional tasks that increasingly-sophisticated in-vehicle infotainment systems allow drivers to perform. As new data sources are developed and research methods refined, researchers will continue to explore driver distraction and its impacts on traffic safety, in an effort to ensure that all road users are equipped to deal with distractions both old and new.

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