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Distracted Driving

Research Updates from 2013 and 2014

Car crashes rank among the leading causes of death in the United States.

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Title

Distracted Driving: Research Updates from 2013 and 2014 *(October 2014)*

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About the Sponsor

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Founded in 1947, the AAA Foundation in Washington, D.C. is a not-for-profit, publicly supported charitable research and education organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, from individual members, from AAA-affiliated insurance companies, as well as from other organizations or sources.

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Background

In June 2013, the AAA Foundation for Traffic Safety published the most comprehensive analysis to-date of cognitive distraction in the automobile. Conducted at the University of Utah, [the study developed and validated a rating system] for assessing the amount of mental workload created by six secondary (non-driving) tasks that drivers might perform behind the wheel. Using several different measurements/outcomes across three different experiments, the study rated the level of cognitive distraction associated with each of these tasks on a familiar 1-5 scale. Tasks such as listening to the radio or a book on tape created relatively low, category-1 distraction levels; conversing (with passengers or on handheld or hands-free devices) created a level 2 distraction; and interacting with a speech-to-text email system, similar to those increasingly found in new vehicles, created significant (category 3) mental workload (Strayer et al., 2013).

To complement and contextualize the release of this groundbreaking study, the AAA Foundation also prepared a thorough compendium that summarized relevant research on distracted driving (Hamilton and Grabowksi, 2013). Significantly, the report pointed to the relatively high volume of research conducted on the other components of distraction (visual and manual) as compared to the lesser-understood mental elements. Part of the difficulty in studying cognitive distraction has been the inability to isolate the mental components of various tasks. The compendium therefore highlighted the success of the University of Utah effort in using cutting-edge methods (such as measuring drivers' brain waves while operating an instrumented vehicle) to show that driver performance and brain activity are degraded by secondary tasks, even when eyes stay on the road and hands remain on the wheel. In short, "hands-free" doesn't mean "risk-free."

Though the development of the rating scale provided a substantial contribution to cognitive distraction research, it was just the beginning of a longer-term effort. With the principal finding that interacting with in-vehicle infotainment and communications systems created the highest level of mental workload of all the tasks analyzed, the AAA Foundation and the University of Utah delved deeper into the issue by studying additional tasks and situations related to these new technologies, and rating them on the previously-developed scale.

The purpose of this document is to update the 2013 research compendium by summarizing relevant studies published in the 14 months between the two phases of the AAA Foundation/University of Utah research, and to contextualize the new Foundation findings within the previously-established framework.

Measuring Cognitive Distraction in the Automobile – Review of Phase I

In 2011, the AAA Foundation and the University of Utah Center for the Prevention of Distracted Driving initiated the first phase of research to better understand and assess cognitive sources of driver distraction.

The main objectives of this research were to:

- Isolate the cognitive elements of distracted driving;
- Evaluate the amount of mental workload 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.

Methods

The study assessed six common tasks: listening to the radio; listening to a book on tape; conversation with a passenger; conversation on a handheld phone; conversation on a hands-free phone; and interaction with a speech-to-text email system. Additionally, two other situations were 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.[1] Separate samples of study participants were evaluated as they performed these tasks in three different experiments: one non-driving,[2] 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 included:

- Brainwave (Electroencephalographic – EEG) activity[3]
- 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).

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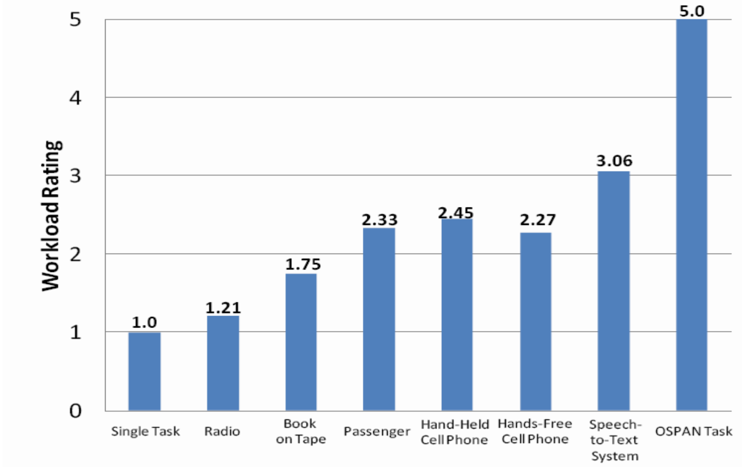
[1] Called the OSPAN Task (Operation Span), this final activity involves simultaneous math computation and word memorization; given its complexity, it was chosen to anchor the high end of the cognitive workload scale.
[2] By allowing participants to familiarize themselves with each task/technology <u>before</u> 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.
[3] This is a measurement of brain activity associated with the processing of information necessary for the safe operation of a motor vehicle.

The Rating Scale

The final scale created in Phase I plotted each task's rating as seen here:



Based on the above rating system, we can state that driver interaction with speech-to-text systems 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, as measured by suppressed brain activity, slowed reaction times, self-reported feelings of stress, and even increased "tunnel vision."

However, Phase I of this research only assessed one component of interacting with the types of in-vehicle infotainment and communications systems seen in new cars (speech-to-text functionality), and the system used in the experiments was a perfect-fidelity re-creation, not a real-world proprietary offering. As such, Phase II was designed to use the scale to rate additional tasks and technologies and fill in these knowledge gaps.

Contextualizing Phase I Findings

When the Phase I findings were published in June 2013, they made a valuable contribution to the state of knowledge pertaining to distracted driving. As the first edition of this research compendium demonstrated, much more was understood about visual and manual distractions (eyes off the road and hands off the wheel, respectively) than about mental sources. For example:

- A National Highway Traffic Safety Administration (NHTSA) study 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);
- Existing research (e.g., Redelmeier and Tibshirani, 1997; McEvoy et al., 2005) had estimated a roughly fourfold increase in crash risk for drivers using cell phones;
- A simulator study found that drivers text messaging behind the wheel are eight times as likely to be in a crash or near crash as drivers who are not texting (Drews et al., 2009); and
- Visual and manual tasks had been shown to increase the miss rates of important cues such as lead vehicle brake lights and deceleration (Angell et al., 2006).

Though mental distractions had received comparatively little assessment, the Phase I findings did corroborate much of the work that had been done in this area. For example:

- Several studies found no difference in the crash risk increase caused by handheld vs. hands-free devices (e.g., McEvoy et al., 2005; Redelmeier and Tibshirani, 1997; Horrey and Wickens, 2006; Yager, 2013); and
- One study (Strayer et al., 2003) found that participants talking on hands-free cell phones had a reduced ability to recognize billboards that they had passed in the experiment.

Unlike much of this prior research, however, the AAA Foundation/University of Utah study was not limited to assessing one specific behavior "representing" cognitive distraction (e.g., a hands-free cell phone conversation) and relating it to one chosen outcome measure (e.g, response time). Instead, this study combined the results of multiple experiments assessing six tasks across several different measurements. The result was a robust analysis that rated common driver activities according to their cognitive elements and demonstrated the increased distraction associated with the more mentally demanding tasks.

Research Update: Published Findings from June 2013 – Present

Since the release of Phase I, several additional distracted driving studies have been published that advance our understanding of these issues. A roadside observational study of 3,265 drivers at 11 intersections estimated the prevalence of distracted driving behaviors at 32.7 percent (Huisingh et al., 2014). Among those who were distracted, interacting with passengers, talking on the phone, texting/dialing a device, and being distracted by something outside the vehicle were the most frequently-observed behaviors. It should be noted, however, that of the three types of driver distractions, visual and manual sources are generally the easiest to identify using observational methodologies. Roadside studies may not capture cognitive distractions, such as listening to an infotainment system as it dictates emails to the driver.

In an effort to connect distracted driving behaviors to actual driving performance, Ferdinand and Menachemi (2014) conducted a meta-analysis of 206 articles published between 1968 and 2012, and found that 80 percent of the analyses found a detrimental relationship between non-driving tasks performed behind the wheel and overall driving performance. Additionally, a simulator-based study of teens and young adults found that distractions – particularly texting – led to more lane deviations and crashes, and had a deleterious impact on traffic flow and participant ability to maintain consistent speed (Stavrinos et al., 2013).

Also in 2013, Victor et al. used data from the SHRP2 naturalistic driving study to re-examine the two-second rule, a much-cited finding from earlier naturalistic research showing that glances of two seconds or more in a six-second window lead to significantly increased risk of a safety-critical event (Victor et al., 2013). The research team concluded that the volume and quality of SHRP2 data will allow refinement to this rule, and provide not only generic information on glance length, but a "more precise relationship between glance patterns and their associated risk around a sweet spot, a time when perceptual information is particularly valuable in crash avoidance." Using the data, researchers will be able to establish a "quantitative relationship between inattention and risk" (Victor et al., 2013). Finally, in an analysis of data from two naturalistic driving studies, Klauer et al. (2014) concluded that tasks involving visual distractions, such as texting or dialing a phone, significantly increased the risk of a crash or near-crash, especially among novice drivers. Citing earlier studies, however, they cautioned that the findings did not mean there is not a risk associated with manual and cognitive distractions.

Regarding cognitive distraction specifically, a study published in *Accident Analysis and Prevention* measured driving performance of 17- to 25-year-olds in relation to working memory load. Recognizing that hands-free technology is not a panacea to distracted driving given the omnipresent potential for cognitive interference with the driving task, Ross et al. (2014) measured performance on a lane change task as participants were subjected to increasingly-complex working memory loads. With this increasing load, they found that performance deteriorated across all measures (deviation in the lane change path, lane change initiation, and percentage of correct lane changes). Given the reduced working memory capacity of young novice drivers, the authors concluded that hands-free devices are not a safe alternative, and complete distraction elimination is required to minimize crash risk.

The topic of public perceptions of hands-free devices (compared with handheld ones) has surfaced in research, as well. In the AAA Foundation for Traffic Safety's 2013 *Traffic Safety Culture Index* report, seven in ten survey respondents said that hands-free devices were somewhat or much safer than their handheld counterparts (Hamilton et al., 2013). Additionally, whereas roughly two-thirds of respondents said driver use of handheld cell phones was somewhat or completely unacceptable, approximately the same proportion said hands-free devices were <u>acceptable</u> (somewhat or completely). Consistent with these attitudes, seven in ten motorists support banning handheld phone use for all drivers, but 53 percent <u>oppose</u> a ban that would include hands-free devices. However, even among the behaviors that are widely understood to be risky (such as handheld cell phone use and texting), a meta-analysis of studies of younger drivers found a willingness to engage in them due to norms, perceived social import, lack of effective law enforcement, and high perceived controllability of the behaviors (Cazzulino et al., 2013).

Overview of Phase II Findings

As noted earlier, the Phase I report isolated the cognitive elements of distracted driving, and developed and validated a system for rating the levels of mental workload caused by various secondary tasks. However, it left a number of questions unanswered, which the AAA Foundation and the University of Utah sought to address in Phase II. Below are some of these key questions, as well as answers suggested by the new research.

Q: *Even though interacting with a speech-to-text system was found, overall, to be a category-3 distraction (in Phase I), is there a cognitive difference between <u>listening</u> to and <u>speaking</u> at such systems?*

> A: YES. Simply listening to email/text messages generated a category-2 level of distraction (similar to conversing on a cell phone or with a passenger). However, when drivers were asked to listen to the messages and craft appropriate responses, a category-3 distraction level was observed. Interestingly, however, issuing short, simple car commands (e.g., climate control adjustments) remained a category-1 distraction, similar to listening to the radio. This suggests the added mental workload is associated with actually trying to compose and communicate messages.

Q: Does the type of voice drivers hear (i.e., synthetic vs. natural human[4]) impact the level of distraction caused?

A: Not significantly. Listening to messages, synthetic or natural, created an average 2.18 level of distraction, with a non-significant difference between them.

Q: In Phase I, the speech-to-text system was a perfect-fidelity replica, but in the real world no systems are 100 percent accurate – what effect, then, do system errors have on driver distraction (e.g., frustration, confusion, etc.)?

A: Significant effects. Using a perfectly accurate system for menu-based navigation (e.g., locate the nearest ATM) yielded a 2.83 distraction level. Once errors were introduced, this rose to 3.67.

Q: Moving forward from Phase I's generic tasks and technologies, how do real-world proprietary technologies (e.g., Siri) fare on the cognitive distraction scale, and how do different auto manufacturer's infotainment and communications systems compare with one another?

A: One of the key findings is that duration of interaction with a system – both the number of steps required to complete a task, and the number of errors and corrections drivers need to contend with – can vary greatly, and has a significant impact on distraction. For example, using Toyota's Entune system to place a call or make a music selection generated an overall cognitive distraction rating of 1.7 (similar to listening to an audiobook). Chevrolet's MyLink, on the other hand, was rated a 3.7 (among the most demanding of any task analyzed to-date) when completing these tasks. One likely reason? Placing a call took 20 seconds using Entune, whereas it took 29 seconds using MyLink. The difference was even more dramatic when making music selections, with participants needing almost twice the amount of time to complete the task with MyLink than with Entune (43 seconds vs. 22 seconds, respectively). Of all tasks analyzed, Siri generated the highest distraction level, rising to 4.15 on the rating scale.

The Rating Scale

Figure 1 on the next page shows the scale that was developed and the specific ratings for each task and technology assessed to date.

- Black bars represent the task ratings from Phase I;
- Red bars show the Phase II ratings of tasks associated with in-vehicle infotainment and communications systems; and
- Blue bars show the ratings of six vehicle manufacturers' real-world systems, based on two types of voice-activated tasks: phone call placement, and music selection.

[4] "Synthetic" voices are computerized; in Phase II, NeoSpeech was used to generate synthetic commands (NeoSpeech, 2012). "Natural" voices include pre-recorded phrases and speech dictated by real people.

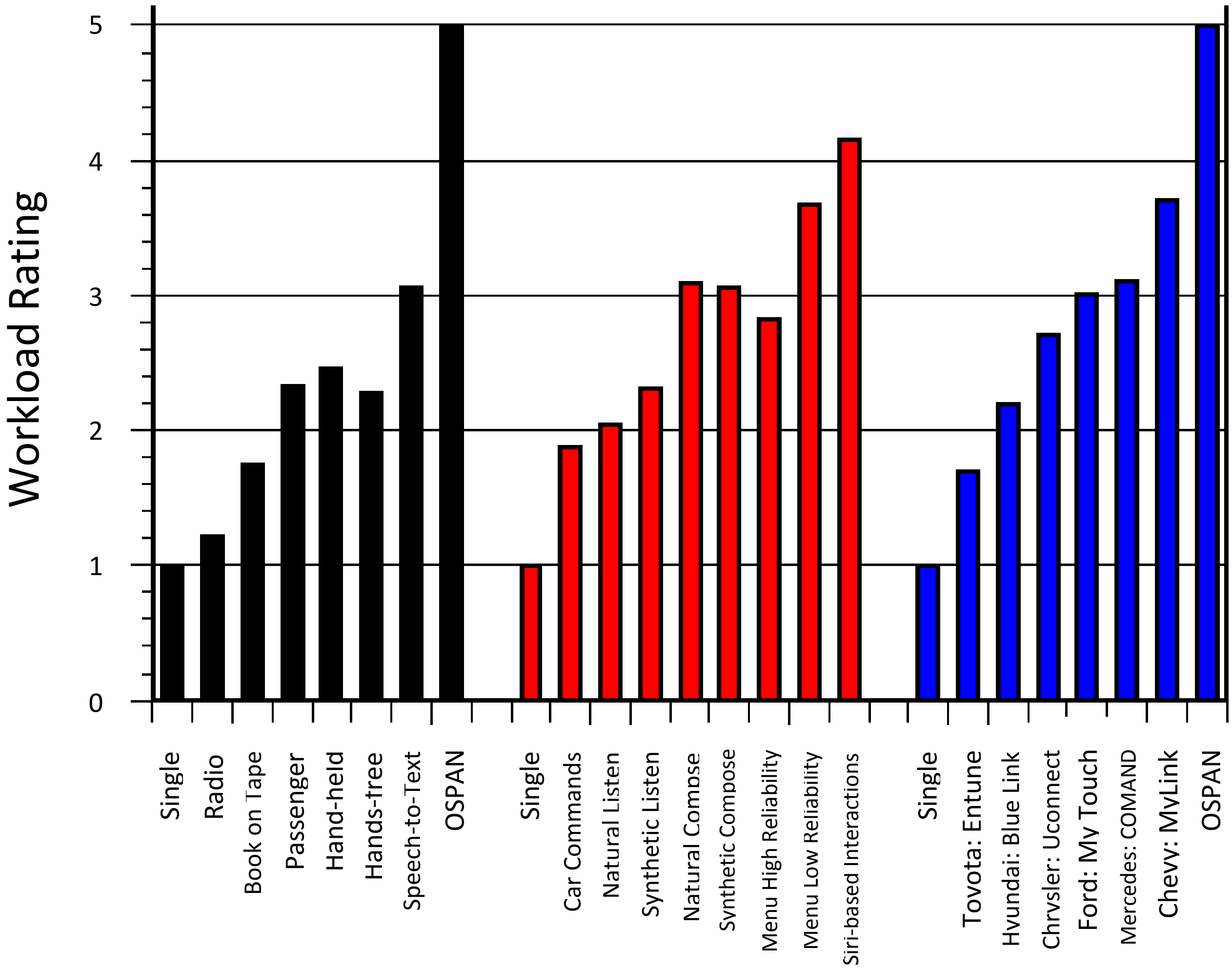


Figure 1. Ratings of all tasks/technologies assessed to date.[5]

A Caveat

Although this ongoing research 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 thus far has been to isolate and analyze the cognitive elements of distracting tasks in order to highlight their effects on driver (in)attention. 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 and in the first edition of this compendium. Future AAA Foundation work may seek to “translate” cognitive distraction measures into predicted crash risk increases, but such an effort is beyond the scope of the current study.

[5] It is important to note that the ratings for the manufacturer-specific systems are based solely on two tasks: call placement, and music selection. They are NOT derived from the range of tasks tested in the center cluster above (e.g., menu-based navigation, listening to text/email messages, etc.)

Discussion

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

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.

Simply put, 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. Moving forward, though, it may also help point the way toward safer communications and infotainment technologies, by distinguishing between functionalities that are more or less mentally taxing, and providing a nuanced look at differences in design and implementation.

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