

ESTIMATES OF PREVALENCE AND RISK ASSOCIATED WITH INATTENTION AND DISTRACTION BASED UPON *IN SITU* NATURALISTIC DATA

Thomas A. Dingus, Ph.D., CHFP
Virginia Tech Transportation Institute, Blacksburg, Virginia

ABSTRACT – By using *in situ* naturalistic driving data, estimates of prevalence and risk can be made regarding driver populations' secondary task distractions and crash rates. Through metadata analysis, three populations of drivers (i.e., adult light vehicle, teenaged light vehicle, and adult heavy vehicle) were compared regarding frequency of secondary task behavior and the associated risk for safety-critical incidents. Relative risk estimates provide insight into the risk associated with engaging in a single task. When such risk is considered in combination with frequency of use, it sheds additional light on those secondary tasks that create the greatest overall risk to driving safety. The results show that secondary tasks involving manual typing, texting, dialing, reaching for an object, or reading are dangerous for all three populations. Additionally, novice teen drivers have difficulty in several tasks that the other two populations do not, including eating and external distractions. Truck drivers also perform a number of risky "mobile office" types of tasks, including writing, not seen in the other populations. Implications are described for policy makers and designers of in-vehicle and nomadic, portable systems.

INTRODUCTION

For many years, estimates of the prevalence and risk associated with inattention and distraction have been based upon epidemiological data from crash databases, or, in the case of prevalence, observational studies typically conducted from a roadside vantage point. However, these sources of data have serious limitations, particularly in the case of risk estimates. Specifically, drivers involved in a crash are often unable, are unaware, are impaired by injury, or are purposely trying to avoid prosecution or embarrassment when reporting pre-crash behaviors and events. Law enforcement officials most often have no way of knowing what was occurring in the vehicle during the seconds leading up to a crash.

The absence of data regarding pre-crash driver performance and behavior motivated the development of naturalistic data collection techniques [Dingus et al., 2002]. Conceptually, this method involves the installation of highly capable sensors and cameras, typically in the subjects' own vehicles. Although the subjects are always under informed consent and know the purpose of the study, efforts are typically made to make the instrumentation as unobtrusive as practical for two reasons. First and foremost, it is important to avoid reminding the subjects that they are in an observational study. Second, it is important that the vehicle appear "normal" so that interacting drivers do not behave differently around it. Such real-world observation also has benefits over other data collection methods,

including simulator studies and test-track studies that often lack external validity and factors present in the larger context of driving. In addition, it would be difficult to estimate prevalence accurately in such controlled environments [Olson et al., 2009].

There is a growing body of evidence [Lee et al., 2007] that, at least within the limits of measurement capability, participants drive as they normally would within a few hours of installation of the instrumentation. That is, although they know the instrumentation is present, subjects dwell upon its presence for a very short period. Evidence of this includes the presence of driver fatigue, impairment, speeding, aggressive driving, and variable seat belt use.

Since inception, these data collection techniques have resulted in the capture of data associated with almost 1,000 crashes, and the overall crash rates are within the confidence limits of what one would expect to find based upon estimates from crash databases.

METHODS

The naturalistic driving studies that will be described in the Results section of this paper were all conducted using instrumentation and techniques developed by the Virginia Tech Transportation Institute (VTTI). Specifically, four sets of data were used to estimate both relative risk and prevalence of a variety of secondary tasks. The data sets include the 100-Car Naturalistic Driving Study [Dingus et al., 2002], the Naturalistic Teen Driving Study [Klauer et al., 2013], the Heavy Vehicle Drowsy Driver Warning System

CORRESPONDING AUTHOR:

Thomas Dingus, Ph.D., Virginia Tech Transportation Institute,
Virginia Polytechnic Institute and State University, 3500
Transportation Research Plaza, Blacksburg, VA 24060; Email:
tdingus@vtti.vt.edu

Field Operational Test [Olson et al., 2009], and The Impact of Hand-Held and Hands-Free Cell Phone Use on Driving Performance and Safety-Critical Event Risk [Fitch et al., 2013].

As the names imply, three of the studies used a purely naturalistic driving technique wherein the subject was instructed to only drive as he or she normally would, while the fourth was a field operational test. While the instrumentation was similar for all four studies, the truck drivers in the field operational test were also interacting with a drowsiness warning system. Thus, the only difference between the data sets was an additional safety system in the trucks.

The conduct of field operational tests using a naturalistic approach is important because it allows for minimal influence from the research circumstance, therefore reducing “the halo effect” and other such improved or demonstrative social driving behaviors. By unobtrusively observing drivers exhibiting typical driving behaviors without intervention, naturalistic driving behaviors can be captured and analyzed. In the case of the topic of this paper, it would not be beneficial to create practical countermeasures to mitigate secondary task behaviors that lead to safety-critical incidents, unless the behavior captured and observed is indeed what is performed on a daily basis without experimental bias or intervention.

Of course, there is always a threat to the study validity when a device is installed for a field operational test. Specifically, there is a chance that the device under test will significantly alter “natural behavior.” However, in the case of the drowsy driver warning system, this threat is believed to be minimal since: 1) Safety systems are often installed in fleets on a trial or permanent basis, and 2) The device gives specific and relatively rare feedback and requires minimal interaction.

Continuous data collection allows a capture of all secondary tasks and other behaviors that drivers exhibit, even behaviors that were not hypothesized by researchers prior to data collection. For example, in some cases, there were actually two distracting agents with which the driver was engaged prior to an event or during a baseline epoch. Continuous data collection also allows researchers to observe all factors that led up to crash and near-crash incidents, such as impairment or drowsiness.

Cameras that collect and facilitate an analysis of naturalistic driving data allow for an “insider’s” view into secondary task behaviors without relying on self-

report or past memory or recall. That is, a researcher is able to instantaneously record a behavior and quantitatively measure it. Also, crashes and near-crashes are measured in real time, not reconstructed by police reports or drivers. Eyewitness data have been notably unreliable, and reconstructing crash scenes requires significant deductive reasoning. However, with naturalistic driving video recording drivers, researchers can accurately review and analyze in great detail the secondary tasks and other factors leading to crashes and other safety-critical events.

Estimating Relative Risk: Odds Ratio Calculations

Each of the four studies cited in this paper used naturalistic driving data to estimate the risks associated with performing secondary tasks while driving. The associated methodologies are described in each of the referenced reports/papers. However, there were a number of common elements. First, safety-critical events occurring in the form of crashes and near-crashes were used for all four studies. For the heavy-truck study [Olson et al., 2009] and the cell phone-specific study [Fitch et al., 2013], other safety-critical events, including inadvertent road/lane departures, were analyzed. In addition, three of the studies only evaluated “at-fault” safety-critical events as determined by a manual assessment of the causal and contributing factors. However, the Fitch et al. (2013) study used all cases of involvement, regardless of fault.

All of the safety-critical events were identified by “trigger” criteria. The trigger criteria varied by vehicle type (i.e., light versus heavy) but generally comprised kinematic signatures that were indicative of some type of evasive maneuver on the part of the driver. For example, a longitudinal deceleration greater than 0.65g was a trigger criterion that indicated braking at greater-than-normal levels. Once a trigger identified a potential safety-critical event, the event was validated via video and kinematic data review to ensure that it was in fact a safety-critical event that resulted in an evasive maneuver. In addition, other safety-critical events were identified through baselines and other sampling of the data for other studies.

In addition, a number of “baseline,” or non-event, epochs were selected either randomly or by some matching criteria, creating either a case-cohort or case-crossover design. Calculations were then performed to create either crude odds ratios or logistic regressions to estimate the relative risk.

Again, greater detail regarding the calculations can be found in the referenced articles. It is important to note that, while the analysis techniques differ to some extent, the ultimate results were always consistent in direction and were typically consistent in magnitude and level of significance [Guo et al., 2010].

The operational definition of a “crash” in each of the four studies included physical contact with any vehicle, object, pedestrian, or animal. Thus, a crash in this case would include all injury and property damage crashes as defined in crash databases, as well as minor collisions that did not result in significant damage. While crash databases contain only police-reported crashes, the naturalistic driving data are continuously collected with cameras recording all events, so the research teams also collected property damage crashes that were not reported to police but were police reportable.

A “near-crash” was defined as any event that could have led to an eventual collision, but a successful evasive maneuver was performed as opposed to an unsuccessful evasive maneuver or no maneuver at all. As described, a successful maneuver was detected and classified by vehicle analytics collected by the data acquisition system (DAS) in such variables as hard braking, sharp turning, and other atypical avoidance behaviors used while operating a vehicle.

It should be emphasized that there is an inherent assumption when combining data from crashes at different levels of severity with near-crashes and other safety-critical events to estimate risk. The inclusion of lower severity crashes and near-crashes is generally necessary for naturalistic driving analyses simply because crashes are rare events, and researchers do not yet have enough naturalistic driving data.

There are several factors that make this assumption imperfect. For example, it has been well documented that there is a “severity shift” in the causal and contributing factors that lead to crashes of differing severities. The most notable case for this is the difference between fatal and non-fatal crashes. Fatal crashes have physical force factors that lead to fatalities, including resistive force (e.g., seat belts), accelerative force (e.g., speed), and how those forces impact the human body. These factors are obviously much less prevalent in property damage-only crashes. The same severity shift is also present when analyzing near-crashes. That is, there are near-crashes where an unsuccessful maneuver would have resulted in a fatal crash, and there are cases where only a minor collision would have occurred. Currently, due

to the amount of available data, all of these data are combined despite known differences.

Near-crashes and their relationship to crashes is still very much an evolving state of knowledge. There is a growing body of information that indicates that near-crashes are effective and predictive surrogates for crashes in terms of correlation and estimation of crash risk. For example, Guo et al. (2010) investigated the use of crashes combined with near-crashes compared to crashes alone. The authors found that the combined use of crashes and near-crashes is always in the correct direction and generally consistent with respect to significance. However, the combination generally results in a conservative estimate of risk relative to crashes only, although typically within the 95% confidence interval.

Estimating Secondary Task Prevalence

The frequency of engagement in each of the secondary tasks was calculated from the baseline (i.e., non-event) epochs. The event epochs were excluded, primarily because the secondary task engagement would potentially alter the frequency of the safety-critical events.

An asset of the naturalistic approach is that one can sample across the continuous data set to estimate the frequencies with which behaviors occur. In this case, all four of the studies had a sample of at least 5,000 baselines that were manually reviewed to determine if secondary task engagement was present. This allowed the simple calculation of a percentage of time that a given secondary task was present.

RESULTS

The results from each of the four studies have been summarized in Table 1 for adults, adult cell phone only, teens, and trucks. As shown and reported previously in the referenced studies, a number of tasks resulted in higher estimates of relative risk.

Secondary Tasks	100-Car		2013 Cell Phones		NTDS		CVO	
	Subjects 100 Participants	Drive for 13 months	Subjects 204 Participants	Drive for 3 months	Subjects 42 Participants	Drive for 18 months	Subjects 103 Participants	Drive for 4 months
	Frequency	O.R.	Frequency	O.R.	Frequency	O.R.	Frequency	O.R.
<i>Cell Phone Use:</i>								
Cell-related visual-manual	-	-	6.96%	3.34*	-	-	-	-
Text-related visual-manual	-	-	4.90%	2.12*	-	-	-	-
Hand-held text/Internet ±	-	-	0.89%	1.73	1.52%	3.87*	0.19%	23.24*
Hand-held dial	0.51%	2.79*	-	-	0.54%	8.33*	1.18%	5.33*
Reaching for a phone	0.08%	1.38	1.42%	3.65*	0.48%	7.05*	0.10%	6.72*
Talking/Listening hand-held	2.56%	1.29	2.25%	0.84	0.39%	0.61	5.19%	1.04
Talking/Listening hands-free portable	-	-	0.67%	1.19	-	-	4.99%	0.44*
Talking/Listening hands-free integrated	-	-	1.01%	0.61	-	-	-	-
<i>Vehicle Instrumentation:</i>								
Vehicle Operations	0.65%	0.55	-	-	1.78%	2.60	4.29%	1.25
Dispatch Device (heavy vehicle)	-	-	-	-	-	-	1.14%	9.93*
<i>Internal Distractions:</i>								
Reading (map)	-	-	-	-	-	-	0.46%	7.02*
Reading (other)	0.01%	3.38*	-	-	-	-	1.06%	3.97*
Writing	0.01%	-	-	-	0.02%	-	0.21%	8.98*
Reaching for an object	0.71%	1.38	-	-	1.95%	8.00*	6.49%	3.09*
Interact with a passenger	1.16%	0.50*	-	-	3.40%	1.40	1.39%	0.35*
<i>External Distractions:</i>								
Looking at roadside object	0.38%	3.70*	-	-	12.28%	3.90*	26.22%	0.54*
<i>Personal Habits:</i>								
Eating	0.51%	1.57	-	-	1.11%	2.99*	3.75%	1.01
Drinking	0.16%	1.03	-	-	0.24%	1.36	1.52%	0.97
Grooming	0.57%	0.70	-	-	0.50%	1.25	0.12%	4.48*
Applying make-up	0.14%	3.13*	-	-	0.06%	-	-	-
Smoking/Tobacco use	0.18%	-	-	-	0.06%	-	6.48%	0.81

For texting information, only the Fitch et al. (2013) study was used and cited for adult drivers as there was no texting available when 100-Car Study data were collected. Other categories of data were left blank for cases during which the behaviors were too rare to provide a reliable point estimate. All significance levels provided are $p < 0.05$.

***Statistical Significance**

Table 1. Frequency Rates and Odds Ratios for Secondary Tasks of all Driving Studies and Populations

In general, tasks that required significant eyes-off-road time had the highest levels of estimated risk. These included tasks that required *typing* (e.g., for a dispatching device in a heavy truck), *texting*, *reading* (e.g., generally complex reading on a smart phone or any other medium), *dialing*, or *reaching* for either a cell phone or non-cell phone item. In addition, for heavy-truck drivers, there were a number of cases during which the truck clearly served as a “mobile office” even while moving. Thus, *writing* also required significant eyes-off-road time and fell in the category of risky behavior.

It is also interesting to contrast the teen drivers with the adult drivers. Unlike the other two populations, the teens had significantly increased risk while *eating* and driving. This may be because novice drivers need to devote more resources to the driving task itself due to their relative inexperience; thus, they are more easily overloaded by relatively simple secondary tasks.

The findings were also very interesting when comparing glances to external, roadside objects. Light-vehicle adults and teens had increased risk, while truckers experienced a protective effect (defined in Olson et al. [2009] as decreasing the risk of a safety-critical event). This may be due to driving environment (i.e., open highway versus more mixed road and traffic conditions). It also may indicate that the truck drivers were more alert and scanning the roadway environment in these cases as opposed to being distracted by an object in the environment.

Why are the magnitudes of the odds ratios different for teens, adults, and trucks in Table 1? There are several important reasons and considerations. First, the assumptions were different for the heavy-truck data, the cell phone-only data, and the other light-vehicle data. For example, the operational definition of a “near-crash” for a truck driver included unintended lane/road departures beyond a certain

threshold. The logic behind this was that, because a heavy truck is more difficult to control and more difficult to maintain situational awareness around, such events should be counted as a more severe safety-critical event relative to light vehicles. It is difficult to argue that trucks swerving in and out of their lanes of travel is a desirable event and should not be avoided. However, the inclusion of these events probably did change the point estimate to some degree.

Secondly, and more importantly, is that all of the driving and vehicle populations that appear in the table are *very different* in their baseline levels of risk. For example, it is well known that novice teen drivers have approximately 2.5 times the risk of a fatal crash compared to their adult counterparts. Thus, with an odds ratio for a teen driver estimating a level of risk that is 3.0, the overall crash risk relative to the adult baseline would be much greater, perhaps in the range of 7.5, roughly speaking. The same logic applies to truck drivers. For a variety of reasons, heavy-truck drivers have a crash rate that is roughly 15 times lower per mile traveled than passenger car drivers. Thus, these drivers have a baseline (i.e., a component of the odds ratio denominator) so low one would expect the odds ratios to be greater in general.

A number of the secondary tasks were performed with high frequencies. As shown in Table 1, external distractions for teens and truckers have the highest frequencies. The cell phone tasks also tended to be high in general, although, with the exception of texting, novice teens tended to have a lower frequency-of-engagement than either of the adult cohorts. Other high-frequency tasks included *reaching for an object*, *vehicle operations*, and *interacting with a passenger*. Truck drivers also *eat*, *drink*, and *use tobacco products* frequently, while teens spend a fair amount of time *eating* while driving.

The next step in interpreting the frequency use rates and odds ratios is to expand upon the connection between the rate of a secondary behavior performed and the risk and danger of performing that task frequently. There is not a notable relationship between the frequency of a task and the odds ratio for that task. However, if both measures are used in tandem, the level of dangerous driving occurring on the nation’s roadways can be inferred from the observed behavior in these naturalistic research studies. It can also be inferred from this type of interpretation that a high odds ratio and high frequency of a secondary task would equate to a

dangerous driver because of frequent dangerous behavior exhibited.

When considering the combination of relative risk estimates and frequency of secondary task engagement, a few patterns emerge that indicate a high level of overall risk. For all drivers, handheld cell phones present a number of subtasks that are both risky and frequently performed. This does not include, however, handheld conversations or hands-free use. In fact, in the case of truck drivers, such conversations appear to have a protective effect. As was discussed in the original study, this may be due to an alerting factor present from the conversation for the long-haul drivers [Olson et al., 2009].

Other clearly high-risk/high-frequency tasks include: *reaching for an object* for all drivers, *interacting with a dispatching device* for truck drivers, and *eating and external distractions* for teen drivers.

DISCUSSION

Driving is in and of itself a complex visual-motor task that requires significant visual guidance and attention. Any additional complex visual-motor secondary tasks performed while driving, such as dialing a phone, texting/browsing the Internet, or reaching for an object, impede the ability of a driver to successfully complete the task of driving. This is evident by the odds ratio rates calculated for all four studies referenced in this paper. Therefore, at this stage, the author believes that there is little disagreement that demanding visual-manual tasks are risky. What this paper also shows, however, is that many of such tasks are performed frequently by drivers.

What is not widely agreed upon is the role and importance of *cognitive distraction* (i.e., that part of the processing of information that involves somewhat high-order processing *thought*). In this case, cognitive distraction is a level of thought about something other than driving that would potentially create a situation during which crash risk is elevated due to factors such as increased reaction time to an unanticipated external event. In other words, the driver is looking at the roadway but thinking about other things. Researchers can measure cognitive distraction using MRIs and other devices and can establish scenarios in simulation to show adverse effects that lead to crashes, but does cognitive distraction lead to increased crash risk in the larger context of driving? The fact that we are still asking this question after more than a decade of naturalistic driving results and other epidemiological studies almost certainly means that, at the very least, the

effect size is small relative to the aforementioned visual-manual tasks.

Tasks such as “talking or listening on a handheld or hands-free phone” are considered low-risk secondary behaviors for all three driver populations. Similarly, “dialing a handheld phone” is considered a very high risk and a dangerous secondary task because it is a complex motor-visual task that requires a great deal of eye gaze averted from the roadway.

These findings recall several case-study examples that may shed light upon some recent arguments about driving distraction.

Case Study: Handheld Phone Use

The debate about the risk of handheld phone use has been ongoing for more than a decade. There are now a number of laws banning handheld phones worldwide. However, many proponents point to the safety benefits of being able to use a mobile phone for emergencies and point out that there are many other in-vehicle distractions that are perhaps more problematic (e.g., putting on makeup or reading a paper).

Based on the results of this paper, it is clear that the greatest, most serious distracting agents in the vehicle today are handheld electronic devices (because smart phones do much these days beyond the phone function and will continue to do more). This is true both because of the relative risk of performing the related subtasks *and* the frequency with which drivers perform them. This corroborates the position that policy makers are correct in creating and enforcing laws banning handheld electronic devices.

It is important, however, to distinguish between “true hands-free” devices and headsets that plug into a handheld phone. As shown in Table 1, subtasks that create risk, such as *dialing* and *reaching*, are not improved by a headset. Therefore, the overall risk is probably very similar with no headset.

Case Study: Hands-free Cell Phone Conversations versus Passenger Interactions

For many years, it has been posited by a number of researchers that there is a meaningful difference between talking to a passenger and talking on the phone. Does having a conversation out of the driving context really increase the risk?

All of the studies referenced in this paper show that there is little, if any, detrimental effect to having a cell phone conversation. There was a small, non-

significant increase shown in the 100-Car results. However, none of the other studies showed even a trend in greater risk associated with cell phone conversations, either handheld or hands-free. It is interesting to note that teens actually experienced the trend of increased risk due to passenger presence (i.e., interacting with a passenger), which was shown in Klauer et al. (2013) and other studies. However, this same group experienced a trend in the opposite direction with respect to cell phone conversations.

Even more compelling is the significant protective effect of cell phone conversations for long-haul truck drivers. It is apparent here that a small (if any) amount of risk of having a cell conversation is outweighed by the benefit of helping a driver remain alert. The original study by Olson et al. (2009) found a similar protective effect for CB radios. The reasons for these protective effects are similar: A phone conversation is not really much riskier than a CB radio conversation, and the alerting effects outweigh any detriment.

Case Study: Use of Navigation Systems

Navigation systems have now been around for many years, and most studies [Dingus et al., 1997] have shown that a well-designed electronic navigation system is less distracting than the alternative of paper maps or direction lists.

Navigational tasks were not shown in Table 1 simply because they occurred so infrequently that meaningful findings could not be presented. This relative infrequency adds to the argument that such systems do not provide a significant risk to driving.

Another aspect of navigation that must be considered is that, unlike other secondary tasks described in this paper, navigation is part of the driving task. That is, drivers have to navigate *by some means* to complete some trips, and well-designed electronic navigation systems are the best option.

Implications of the Relationship between Cognitive Distraction and Crash Risk

Research has posited for many years that the driving task involves interactions of several levels. For example, Alexander and Lunenfeld (1990) described three levels associated with driving: navigation, guidance, and control. Control in this hierarchy is the physical control of the vehicle; guidance refers to interacting with other vehicles and traffic control devices; and navigation refers to higher order functions, such as route choice. The authors argued that a driver that is overloaded with information first

sheds the navigation layer while maintaining (or attempting to maintain) performance for the guidance and control layers.

This simplistic explanation has some merit in describing the current situation. That is, one could hypothesize that, when a driver has a high, non-driving cognitive demand, errors will occur. However, errors will primarily occur in the *navigation* level of the driving task [Alexander and Lunenfeld, 1990]. This would explain common phenomena that we have all experienced, often described by drivers as, “I was thinking about something and I missed my turn,” or “I don’t recall much of the drive home,” or “I took my normal route even though I was going to the baby sitter’s house,” etc.

However, there are two critical questions in this regard: 1) Does disruption of the navigation level of driving increase crash risk? And 2) Does cognitive distraction (as it has been operationally defined here) significantly detract from performance at the control and guidance layers?

Based on the naturalistic driving data collected thus far, the answers to these two questions is a qualified “no.” That is, there is almost no evidence in the millions of miles of data collected thus far that a driver can be so deep in thought that the crash risk is significantly increased.

However, it is clear that cognitive load can decrease dual-task performance. For example, in a simulator study conducted by Lee et al. (2002), brake reaction time was delayed by about 300 milliseconds (msec) in a high cognitive load condition. However, in the vast majority of actual driving situations, the driver has a sufficient time/space *buffer* to avoid an impending crash, even when reaction time is delayed at the 300 msec level. Contrast this, however, with the *four-second or longer* single glances away from the roadway that are not uncommon for many drivers engaged in complex visual-manual tasks, and the odds ratios shown in the previous section may be better understood. That is, drivers can avoid almost all obstacles when looking at them, but such obstacles cannot be avoided when drivers are not looking.

These findings have clear implications for designers, policy makers, and the driving public. If the driver’s eyes are on the road, the crash risk is elevated little, if any. A salient example includes well-designed, integrated hands-free interfaces for a cell phone that are becoming more common. A “well-designed” interface in this case refers to a situation during

which the visual-manual requirements of the task are minimal (e.g., an occasional single button press on the steering wheel and no glances away from the roadway to complete the task). In these cases, there is little evidence of elevated crash risk in naturalistic or epidemiological data, even though such systems are becoming more prevalent. Even though the data sources are still developing, there is a growing body of evidence to suggest that such systems are fine for use in the automotive environment [Fitch, 2013].

However, it is also important to note that there are interfaces available that are not well designed and are not included in this line of thinking. An example is a voice-only, non-integrated phone interface. These systems are generally not optimized for a dual task environment, such as driving. A study by Yager (2013) demonstrated this. Even though the cell phone interfaces studied were designed to be voice activated, the driver looked away from the roadway *more often* when using such interfaces for texting than when manually texting. Based on the results of the studies described in this paper, these results are not surprising and are attributable to the eyes-off-road time as opposed to a safety detriment with auditory-voice interfaces in general.

It is interesting that, as of this writing, the major debate in this field is the role and importance of cognitive distraction. In fact, it is generally agreed that visual distraction is of paramount importance, but there is no outcry from researchers, policy makers, or the public regarding systems that are *extremely distracting and risky*.

An ideal case study for this is dispatching systems for heavy trucks. These systems, as the name implies, typically allow dispatchers to send an electronic message to one or more drivers informing them of an additional load to be picked up. The messages are often complex and require the driver to respond in a timely manner to effectively interact. Thus, there is strong motivation to allow drivers to use the systems while moving. Some of these systems are well designed, with appropriate safeguards in place, such as interlocks that preclude system use while the truck is in motion or an automatic switch to simple messages with auditory voice features while in motion. However, some are designed so that the interlocks can be easily turned off, some are very visually demanding, and some have complex interfaces. Yet, there is effectively no regulation of such aftermarket devices, despite the potential to inflict great public harm with distracted drivers of 80,000-pound vehicles on the nation's highways. Arguments have been made that essentially claim that

truck drivers, unlike light-vehicle drivers, are trained professionals. Although this is true, there are two counterarguments to this. First, no one, regardless of how well they are trained, can avoid a crash if they are not looking at the roadway. Second, truck drivers, although they are professionals, do not undergo a particularly rigorous selection process and receive only a few weeks of training.

CONCLUSION

Determining the frequency rate of secondary tasks by different driver populations in addition to relative risk calculations reported in the publications cited herein allows for added quantitative knowledge in establishing why vehicles crash and the cause of the crash. By determining how often each driver population performs specific risky secondary tasks, such as texting, it is more likely that preventative measures and education can be tailored to the driving population about how to remain safer on the road and how to limit secondary task frequency as a whole. In addition, the availability of naturalistic data allows researchers to determine exposure based upon time, distance, or behavior and compare the rates between studies to confirm the frequency of secondary task behavior. This is simply an added layer of information to help decipher best practices in driving, alerting drivers to their levels of attention while driving, and the potential consequences of participating in secondary tasks at a great degree of frequency.

FUTURE RESEARCH NEEDS

Naturalistic driving studies, such as the ones described in this paper, constitute an evolving science. For example, studies to date have limitations in sample size and sample demographics. However, as of this writing, a number of large-scale studies are underway worldwide with thousands of drivers that will produce thousands of crash and near-crash events and tens of millions of baseline driving hours and miles. It will be important to replicate this paper and these results as data from these studies become available. While it is not believed that the results will markedly change, greater statistical power and a broader sample size will add substantively to the overall knowledge of driving distraction. Specifically, the Second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study data (www.trb.org) will be available during mid-2014 and could be used to duplicate the methodology for these studies.

ACKNOWLEDGMENTS

This paper was written as part of the Engaged Driving Initiative (EDI) created by State Farm Mutual Automobile Insurance Company (State Farm®). The EDI Expert Panel was administered by the Association for the Advancement of Automotive Medicine (AAAM) and chaired by Susan Ferguson, Ph.D., President, Ferguson International LLC. The views presented in this paper are those of the author(s) and are not necessarily the views of State Farm, AAAM, or Ferguson International LLC.

The author would like to thank all of the contributors to the reports and papers referenced herein from which data were gathered to draw the conclusions in this paper. Particular thanks go to Dr. Greg Fitch and Dr. Charlie Klauer for their assistance in helping to determine the frequency calculations.

The author would also like to thank Gabrielle Laskey for her considerable efforts in pulling the data together in a single table. In addition, Ms. Laskey and Mindy Buchanan-King made a number of useful suggestions regarding content.

REFERENCES

- Alexander G, and Lunenfeld H. A User's Guide to Positive Guidance. FHWA-SA-90-017. (1990)
- Dingus TA, Hulse MC, Mollenhauer MA, Fleischman RN, McGehee DV, Manakkal N. Effects of Age, System Experience, and Navigation Technique on Driving with an Advanced Traveler Information System. Human Factors and Ergonomics Society, 39(2), 177-199. (1997)
- Dingus TA, Neale VL, Klauer SG, Knipling RR, Holbrook GT, Petersen A. The 100-Car Naturalistic Driving Study: Experimental Design. DOT HS 809 536. (2002)
- Fitch GM, Socolich SA, Guo F, McClafferty J, Fang Y, Olson RL, Perez MA, Hanowski RJ, Hankey JM, Dingus TA. The Impact of Hand-Held and Hands-Free Cell Phone Use on Driving Performance and Safety-Critical Event Risk. DOT HS 811 757. (2013)
- Guo F, Klauer SG, McGill MT, Dingus TA. Evaluating the Relationship Between Near Crashes and Crashes: Can Near-Crashes Serve as a Surrogate Safety Metric for Crashes? DOT HS 811 382. (2010)
- Klauer SG, Guo F, Simons-Morton BG, Ouimet MC, Dingus TA, Lee SE. Naturalistic Teenage Driving Study (40-Teen Naturalistic Driving Study). (2004)
- Klauer SG, Guo, F, Simons-Morton BG, Ouimet MC, Lee SE, Dingus TA. (2014). Distracted driving and risk of road crashes among novice and experienced drivers. *New England Journal of Medicine*, 370: 54-59.
- Klauer SG, Dingus TA, Neale VL, Sudweeks JD, Ramsey DJ. The impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data. DOT HS 810 594. (2006)
- Lee SE, Llaneras E, Klauer SG, Sudweeks J. Analyses of Rear-End Crashes and Near-Crashes in the 100-Car Naturalistic Driving Study to Support Rear –Signaling Countermeasure Development. DOT HS 810 594. (2007)
- Lee JD, McGehee DV, Brown TL, Reyes ML. Collision Warning Timing, Driver Distraction, and Driver Response to Imminent Rear-End Collisions in a High Fidelity Driving Simulator. *Human Factors*. (2002)
- Neale VL, Dingus TA, Klauer SG, Sudweeks J, Goodman M. An Overview of the 100-Car Naturalistic Study and Findings. NHTSA Project 05-0400. (2008)
- Olson RL, Hanowski RJ, Hickman JS, Bocanegra J. Driver Distraction in Commercial Vehicle Operations. DTMC75-07-D-00006. (2009)
- Yager C. An Evaluation of the Effectiveness of Voice-to-Text Programs at Reducing Incidences of Distracted Driving. SWUTC/13/600451-00011-1. (2013)

APPENDIX

Below is a larger view of Table 1 presented within the text of the paper. The first column refers to the 100-Car Naturalistic Driving Study [Dingus et al., 2002], the second column is The Impact of Hand-Held and Hands-Free Cell Phone Use on Driving Performance and Safety-Critical Event Risk [Fitch et al., 2013], the third column of data is The Naturalistic Teen Driving Study [Klauer et al., 2013], and the fourth column is The Heavy Vehicle Drowsy Driver Warning System Field Operational Test [Olson et al., 2009].

Secondary Tasks	100-Car		2013 Cell Phones		NTDS		CVO	
	Subjects: 109 Participants	Drove for: 13 months	Subjects: 204 Participants	Drove for: 3 months	Subjects: 42 Participants	Drove for: 18 months	Subjects: 103 Participants	Drove for: 4 months
	Frequency	O.R.	Frequency	O.R.	Frequency	O.R.	Frequency	O.R.
<i>Cell Phone Use:</i>								
Call-related visual-manual	-	-	6.96%	3.34*	-	-	-	-
Text-related visual-manual	-	-	4.90%	2.12*	-	-	-	-
Hand-held text/Internet ±	-	-	0.89%	1.73	1.52%	3.87*	0.19%	23.24*
Hand-held dial	0.51%	2.79*	-	-	0.54%	8.32*	1.18%	5.93*
Reaching for a phone	0.08%	1.38	1.42%	3.65*	0.48%	7.05*	0.10%	6.72*
Talking/Listening hand-held	2.56%	1.29	2.25%	0.84	0.39%	0.61	5.19%	1.04
Talking/Listening hands-free portable	-	-	0.67%	1.19	-	-	4.99%	0.44*
Talking/Listening hands-free integrated	-	-	1.01%	0.61	-	-	-	-
<i>Vehicle Instrumentation:</i>								
Vehicle Operations	0.65%	0.55			1.78%	2.60	4.29%	1.25
Dispatch Device (heavy vehicle)	-	-			-	-	1.14%	9.93*
<i>Internal Distractions:</i>								
Reading (map)	-	-			-	-	0.46%	7.02*
Reading (other)	0.01%	3.38*			0.02%	-	1.06%	3.97*
Writing	0.01%	-			0.02%	-	0.21%	8.98*
Reaching for an object	0.71%	1.38			1.95%	8.00*	6.49%	3.09*
Interact with a passenger	1.16%	0.50*			3.40%	1.40	1.39%	0.35*
<i>External Distractions:</i>								
Looking at roadside object	0.38%	3.70*			12.28%	3.90*	26.22%	0.54*
<i>Personal Habits:</i>								
Eating	0.51%	1.57			1.11%	2.99*	3.75%	1.01
Drinking	0.16%	1.03			0.24%	1.36	1.52%	0.97
Grooming	0.57%	0.70			0.50%	1.25	0.12%	4.48*
Applying make-up	0.14%	3.13*			0.06%	-	-	-
Smoking/Tobacco use	0.18%	-			0.06%	-	6.48%	0.81

For texting information, only the Fitch et al. (2013) study was used and cited for adult drivers as there was no texting available when 100-Car Study data were collected. Other categories of data were left blank for cases for which the behaviors or events were too rare to provide a reliable point estimate. All significance levels provided are $p < 0.05$.

***Statistical Significance**

Table 1. Frequency Rates and Odds Ratios for Secondary Tasks of All Driving Studies and Populations