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Driver Distraction: Are We Mistaking a Symptom for the Problem?

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ABSTRACT

In recent years it seems we have been continuously bombarded by research and popular press articles dealing with the dangers of driver distraction, particularly that resulting from the use of cell phones or other telematic systems while behind the wheel. Based on the volume and vitriolic nature of these articles, one would suppose that the U.S. was undergoing a dramatic increase in the number of accidents on our roadways, largely as a function of operators focusing on these devices, rather than on the road. In reality, the opposite is true.

Fifty years worth of vigilance research suggests that our entire perspective on the "driver distraction" problem may be incorrect. It is possible that we are fixating on the *result* of a problem, rather than on a problem cause. Research has repeatedly demonstrated that high workload levels negatively affect performance; what is less well-recognized is that too low of a workload level has virtually the same impact. The last fifty years have seen a steady decline in driver task demand through the implementation of a variety of innovations. What if we have decreased it too far? If so, the current "increase" in "driver distraction" may simply indicate that we have reduced the vehicle-related driver workload to such a level that drivers are actively seeking alternative attention-demanding tasks in order to raise themselves back to a more optimal workload level.

IS THERE REALLY A PROBLEM?

In recent years it seems we have been continuously bombarded by research and popular press articles dealing with the dangers of driver distraction, particularly that resulting from the use of cell phones while behind the wheel. Based on both the volume and vitriolic nature of these articles, one would suppose that the U.S. was undergoing a dramatic increase in the number of accidents on our roadways, largely as a function of operators focusing on their conversations, rather than on the road. In reality, the opposite is true.

In 1997, there were approximately 55 million cellular telephone subscribers in the United States [1]; the police-reported accident rate per 100 million miles driven was 264.2 [2]. Twelve years later in 2009 (the most recent year for which national accident statistics were available at the time of this writing), there were over 270 million cell phones in use in the U.S., and the accident rate per 100 million miles driven had *dropped* to 195.4 [3,4]. This represents a reduction in the likelihood of a reportable accident of almost 30% while the number of cell phones in use increased by almost 500%.[1] Based on studies performed by (or in conjunction with) the Department of Transportation, cell phone use behind the wheel in 2008 was estimated at 1 in 16 drivers at any given moment based on observation of handheld cell phone use.[2] [5] As can be seen in Figure 1 however, there has not been a rise in carnage on the roadways attendant on this increase in driver cell phone use. In fact, the *accident* rate (a statistic largely independent of any engineering safety/protective measures that have been incorporated into vehicles in recent years) continues to drop. Obviously, driver distraction as a function of cell phone use does not appear to represent a major new source of additional danger to the driving public in and of itself.[3] Indeed, the fact that there are higher numbers of *reported* driver distraction type accidents every year is, more likely than not, a simple function of the fact that in most

1 According to the FHWA, in 2009, there were 210 million licensed drivers in the U.S. In 1997, there were 183 million licensed drivers.

2 In reality, given the prevalence of hands-free kits, the actual percentage is likely to be considerably higher.

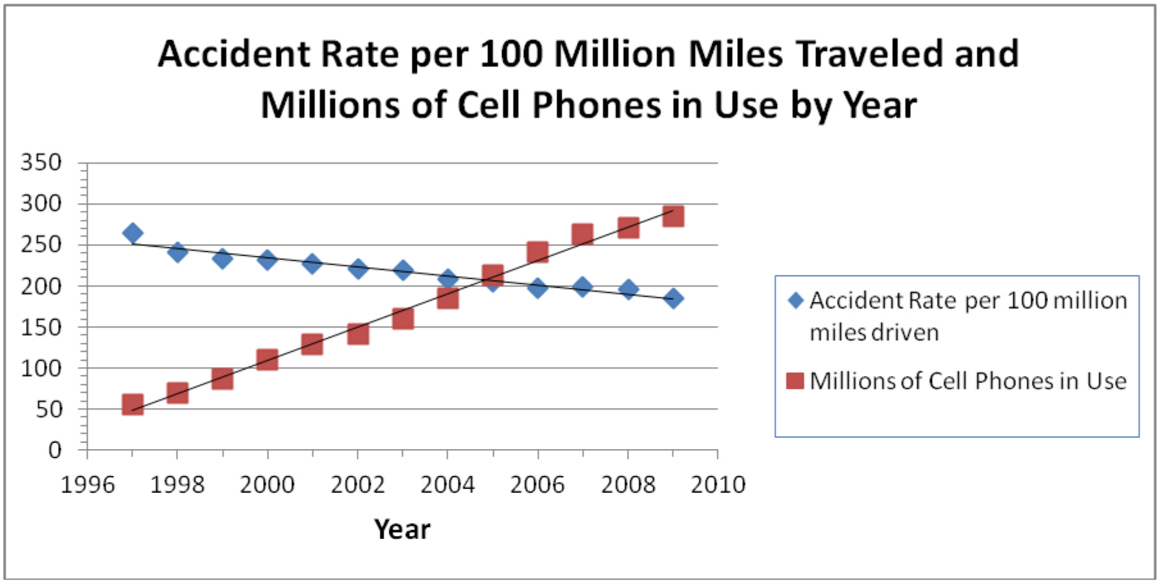

Figure 1. Accident Rate versus Cell Phone Use [34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44]

states accidents were neither tracked nor categorized as such until relatively recent years.[4] Further, due to the improvements in vehicle and roadway reliability and safety, the percentage of accidents stemming from distraction goes up proportionally as the number from all other causes goes down.

In point of fact, driver distraction itself has been an issue of interest since long before the introduction of cell phones, navigation systems, MP3 players, or any other type of modern device. When car radios were first introduced into vehicles in the 1930's there was concern that this would result in chaos on the roadways as vehicle operators became more engrossed in what they were listening to than on the roadways in front of them [14, 15]. Today, it is difficult to find a manufacturer selling an over-the-road vehicle of any type that does not incorporate some type of entertainment system (e.g., radio, CD, MP3, etc.) There does not appear to have been any statistical increase in the number or frequency of accidents as a function of the use of such products, although they do require occasional driver interaction and accidents do occasionally occur during these interactions.

A complicating issue in any discussion of "driver distraction" is the lack of any commonly accepted definition of the term itself [16]. The International Standards Organization developed the following rudimentary definition-"*attention given to a non-driving-related activity, typically to the detriment of driving performance*" [17]. Unfortunately, this definition could be interpreted to include such necessary activities as navigation and way-finding by looking out the windows, mental route recall, or other tasks. Stutts et al [18] distinguished distraction from other forms of driver inattention by defining distraction as a form of inattention in which a driver "*…is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object, or person within or outside the vehicle compels or induces the driver's shifting attention away from the driving task.*" This definition is better than that produced by the ISO, but still lacking.

A group of experts at the International Conference on Distracted Driving in Canada in 2005 [19] proposed a similar definition: "*a diversion of attention from driving, because the driver is temporarily focusing on an object, person, task or event not related to driving, which reduces the driver's awareness, decision making ability and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes.*" Lee et al [20] proposed a somewhat similar definition: "*Driver distraction is the diversion of*

[3] Indeed, many recent real-world, on-road studies [6,7,8,9] have concluded that the risk of accident while talking on a cellular phone and driving does *not* differ significantly from that of driving alone. It appears that the earlier oft-reported "four-fold increase" in accident probability [10] was almost exclusively the function of the methodology used to analyze the data, rather than a valid result.

[4] As of 2001, only 12 states tracked the incidence of cell phone usage in relation to accident propensity. Of these, only Tennessee, Oklahoma, and Minnesota had done so long enough to prepare reports based on their findings [11]. Further, it should also be borne in mind that even if 10% of all accidents were to occur while operators were actively using cell phones, this would not necessarily imply any type of *causal* link between the two activities. If 10% of the driving public was on the phone at any given time while driving, then random chance alone would suggest that such should occur. The same type of assertion could be made regarding the wearing of blue jeans or any other correlatable variable. Indeed, numerous studies have shown significant *improvements* in such driver performance variables as lane tracking while drivers were engaged in cell phone conversations. It is noteworthy that NHTSA currently estimates that 18-22% of all roadway crashes are associated with what they consider to be distracting activities [12], while other naturalistic studies indicate that such distracting activities are engaged in up to 34% of the time drivers are behind the wheel [13]. This would seem to indicate that the likelihood of having an accident is somehow *lower* while engaged in distracting activities than otherwise.

attention away from activities critical for safe driving toward a competing activity." Pettit [21] divides the phenomenon into multiple contributing factors:

• *Delay by the driver in the recognition of information necessary to safely maintain the lateral and longitudinal control of the vehicle (the driving task)*

• *Due to some event, activity, object or person, within or outside the vehicle*

• *That compels or tends to induce the driver's shifting attention away from fundamental driving tasks*

• *By compromising the driver's auditory, biomechanical, cognitive or visual faculties, or combinations thereof."*

Regan at al [22] note that most of the existing definitions of driver distraction focus on several common elements:

• the diversion of attention away from driving, or safe driving;

• attention diverted toward a competing activity, inside or outside the vehicle, which may or may not be driving-related;

• the competing activity may compel or induce the driver to divert attention toward it; and

• there is an implicit, or explicit, assumption that safe driving is adversely effected.

They further point driver distraction is not necessarily coequal to driver inattention which they define as "*insufficient, or no attention, to activities critical for safe driving."* They then propose a taxonomy of five categories of driver inattention:

• Driver Restricted Attention (DRA)-*Insufficient or no attention to activities critical for safe driving brought about by something that physically prevents (due to biological factors) the driver from detecting (and hence from attending to) information critical for safe driving.*

• Driver Misprioritised Attention (DMPA)-*Insufficient or no attention to activities critical for safe driving brought about by the driver focusing attention on one aspect of driving to the exclusion of another, which is more critical for safe driving.*

• Driver Neglected Attention (DNA)-*Insufficient or no attention to activities critical for safe driving brought about by the driver neglecting to attend to activities critical for safe driving.*

• Driver Cursory Attention (DCA)-*Insufficient or no attention to activities critical for safe driving brought about by the driver giving cursory or hurried attention to activities critical for safe driving.*

• Driver Diverted Attention (DDA)-*The diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving.* This category of inattention is equivalent to the more traditional definitions of "driver distraction".

The authors further divide Driver Diverted Attention into two subcategories:

• DDA driving-related (DDA-DR; between driving-related tasks) *is the diversion of attention away from activities critical for safe driving toward a competing driving-related activity.*

• DDA non-driving-related (DDA-NDR; between driving and nondriving - related tasks) - *is the diversion of attention away from activities critical for safe driving toward a competing nondriving-related activity.*

Regan et al [22] correctly note that when a driver elects to divert attention to a competing activity they (in most cases) have some latitude to self-regulate their driving behavior to either compensate for the anticipated impact of this diversion on their driving performance or to choose when to undertake such an activity. Either course allows them to maintain their situation awareness. The operator generally chooses when and if to divert attention to a secondary task based on the driving conditions prevalent at the time. They also note that task unrelated thoughts (e.g., performance of non-driving related activities) may interfere with performance of task-related activities (e.g., driving), and that the number of task-unrelated thoughts are related to task complexity and demands and stimulus rates. What this means is that essentially "the easier the task, the more the mind wanders." [23, 24]

This brings up a critical point that many researchers and the population in general appear to miss. "Driver distraction" may not simply be the result of alternative potential sources of interest competing for a limited volume of fixed attention on the part of the vehicle operator. Almost everyone recognizes that as workload increases beyond a certain level, performance begins to degrade. What is less well-recognized is that the reverse is also true-as workload decreases beyond a certain level, performance also begins to degrade as the operator shifts attention to other activities or thoughts. In short, there is an *optimal* level of arousal, and movement in either direction from this optimum results in performance degradation. This relationship is illustrated by the curve shown in Figure 2.

Due to the nature of the engineering design and refinement process, equipment designers tend to focus almost exclusively on the right side of this curve (i.e., the side where performance begins to drop due to operator overload.) Their goal is to prevent workload from exceeding a level that might result in reduced performance. Unfortunately, due to the variability of performance across the population, this almost always requires that the refinement of a design be in the

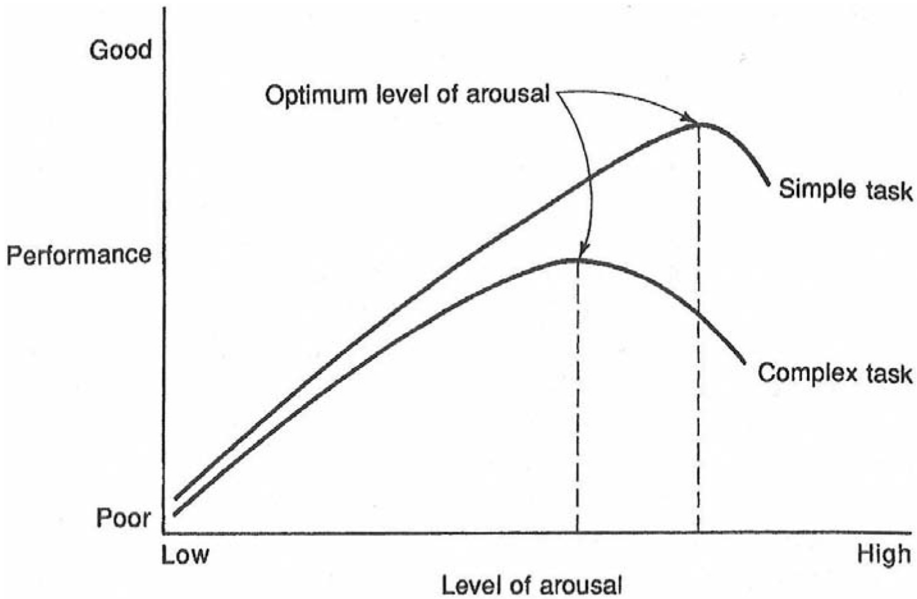

Figure 2. Yerkes-Dodson Law [45]

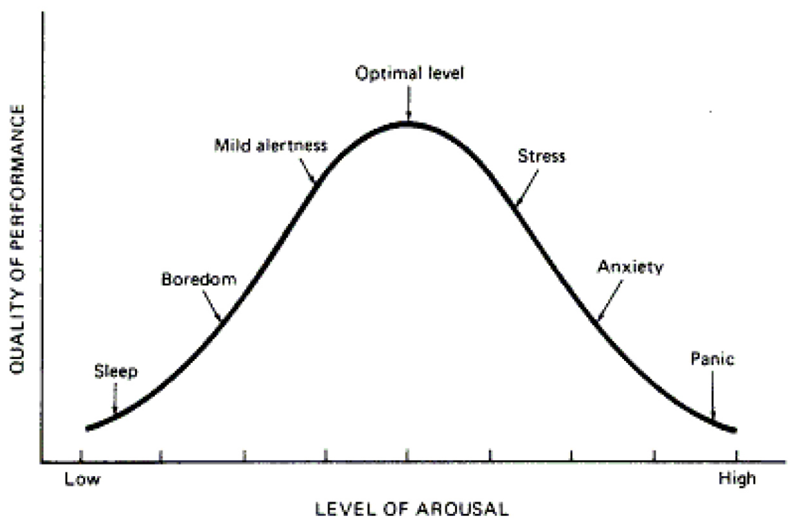

Figure 3. Alternative Presentation of Yerkes-Dodson Curve for Difficult Tasks

direction of accommodating the "lowest common denominator" (i.e., engineers are forced to design for the individual with the lowest level of capacity, rather than the average or highly-skilled user.) Reducing workload as well as the potential for human error through design is largely accomplished by reducing the level of human involvement in device control. This approach, while conservative in nature, may have inherent problems of its own. Figure 3 presents an alternative representation of the "difficult task" portion of the Yerkes-Dodson curve, which explicitly recognizes the fact that performance degrades on the *left* side of the curve as well as on the right.

In 1955, Hebb [25] proposed a relationship between arousal and performance which could be represented as a similar bell curve. As illustrated above, arousal is necessary for functioning in a fight or flight scenario. Hebb suggested that arousal is necessary for behavioral efficiency in everyday life as well and hypothesized that low arousal levels would produce negative behavioral responses. Support was found for this in a study by Heron [26], in which he paid college students to simply lie on a bed for as many days as they could endure while measures were taken to produce a highly stimulation-free environment. After approximately one day, subjects indicated that they were having trouble thinking clearly. After two days of limited stimulation, the majority of the participants were unable to complete simple mathematical computations, hallucinations became common, and concentration was low.

Heron's work obviously employs an extreme case, but anyone who has ever been engaged in a boring task and had to struggle to keep their attention focused upon it has experienced similar phenomenon. Vigilance researchers have studied this problem for decades in conjunction with such tasks as maintaining radar watches or monitoring automated systems. TSA baggage scanner operators at airports experience similar difficulties. The reduction in performance in such activities is typically addressed by switching operators on a frequent basis (i.e., 10-15 minute shifts), a process not typically viable in the automotive environment. This type of problem (dissociation of the operator) is endemic to any system which either requires minimal human input (e.g., monitoring capable semi-autonomous systems) or has been so largely "automated" by either the human operator developing more or less rote responses to routine situations (e.g., driving to/from home to work each day along a familiar route), or by engineers focused on "improving" the system through minimizing operator workload (e.g., aircraft cockpit automation systems[5]). In all these cases, the primary task requires that the operator employ only a fraction of their available cognitive resources during normal activities (i.e., a low arousal level). The operator in such cases normally attempts to "optimize" the employment of their available attentional resources in a parsimonious fashion. They devote just enough attention to the primary task to adequately perform it under normal or anticipated circumstances, and devote the bulk of their remaining capacity to other pursuits. The problem is that accidents, by definition, do not usually occur during "normal" or "anticipated" situations, and their antecedent conditions frequently go unnoticed by the operator under such conditions.

It is almost impossible to monitor a system which requires little or no operator input with one's full attention for more than a very short period of time. As an exercise, the reader is invited to attempt to focus their entire attention on watching the sweep of the second hand on a clock. In only a few seconds, the mind begins to wander off to other topics. This is much akin to the task facing an experienced driver-one who has established a set of expectations with regard to what events will likely occur in the near future, and who is mentally prepared to execute the responses required by those events. Until something unusual occurs, the operator "samples" the driving environment on a more or less frequent basis to insure that no unexpected events have arisen. This leaves a large percentage of his/her cognitive resources unused, a state that is difficult to maintain. To reach an optimal or near-optimal arousal state, these cognitive resources have to be devoted to *something*. Performance-wise, there appears to be little difference between a driver that is engrossed in a cell phone conversation and one that is mentally engrossed in many other activities employing those same mental resources. [29, 30] Their innate desire may be simply to return themselves to a near-optimal overall state of arousal, whether the additional task is planning a vacation, checking out the scenery outside the windows, or focusing on a problem from work. The operator would be considered "distracted" in all of these cases. In reality, it may be that the cognitive resources are simply underutilized by the driving task itself, and the driver is seeking to find other avenues towards which to direct them. Given this perspective, in-vehicle cell phone use (or most other distracting activities performed by drivers) should be viewed as merely a *symptom* of a more complex problem, not the problem itself.

If one examines the nature of the driving task as recently as 30 years ago (circa 1980 or earlier), it is likely that overall operator mental workload differed significantly from that experienced by the operator of a current generation automobile (particularly when one considers the number of still older vehicles on the road at that time.) A number of refinements to the automobile have increased driver satisfaction and comfort, while reducing workload and likely increasing driver dissociation from the vehicle-operation task itself. Some of these refinements and their effects on driver workload are listed in Table 1.

This list is obviously not exhaustive. Numerous other workload-reducing systems are currently or soon will be coming online as well (e.g., obstacle detection/avoidance, lane departure warnings, and blind spot information systems.) It is unlikely that the driving public would willingly forego many (if not most) of the vehicle refinements that have resulted in reduced driver workload in recent years. Given equivalent traffic conditions, driving is less stressful and more comfortable than it was even 20 years ago. Long driving trips were unquestionably more fatiguing for the operator in years past, potentially resulting in increased fatigue-related and decision-related errors. The reduction in accidents related to such factors must be weighed against any potential increase in reduced-workload/driver distraction accidents. There is no predetermined "optimal" workload level in such cases, since oftentimes operators choose to drive vehicles until they reach a subjectively determined personal maximum level of fatigue on long trips. If the driving workload goes down, likely the driving hours would simply be increased in a compensatory fashion until the same subjective level of fatigue is reached.

WHAT DOES THIS MEAN AND WHERE DO WE GO FROM HERE?

We do not argue that the simultaneous performance of multiple tasks does not normally impose additional workload on the individual over and above that of performing any of

[5] The aviation and railroad human factors communities have been highly concerned regarding the level of operator dissociation from the primary task due to workload-reducing-automation in advanced aircraft and locomotives for at least the past 25 years [27, 28]. The problem may be more acute in the automotive environment due to the greater chance of negative interaction with other vehicles and the need for control input/decision-making on a more continuous basis.

Table 1. New or More Prevalent Workload-Reducing Technologies Since 1980s

Vehicle Technology	Effect on Driver Workload/Arousal
Traditional Cruise Control	Reduction: Drivers no longer required to modulate throttle in response to changes in roadway conditions or road slope
Adaptive Cruise Control	Reduction: Drivers no longer required to modulate throttle position in response to changes in roadway conditions, road slope, or movement of surrounding traffic
Radial Tires	Reduction: Steering input less frequent due to reduced vehicle "wander" due to road imperfections
Automatic Transmissions	Reduction: Drivers no longer have to upshift/downshift to maintain vehicle within optimal power regime; braking effort/coordination reduced when stopping or slowing substantially
Improved Road Surface	Reduction: Less attention has to be paid to roadway surface while driving to avoid potential loss of control due to such hazards such as potholes, seams, or other surface irregularities
Reduction in In-Vehicle Noise/	Reduction: The effort of filtering out such vehicle-related interferences with concentration substantially increased overall driver workload.
GPS	Reduction: Operator focus on roadway configuration and recognition of landmarks in near vicinity to the vehicle is now substantially reduced. Use of GPS when traveling *to* destination now frequently results in an inability to successfully navigate during return *without* use of GPS since the details of the route are not recalled
On-dash warning lights	Reduction: Introduction of monitoring features reduces operator effort formerly spent in monitoring gauges and comparing current to optimal values
Improved Braking	Reduction: Reduced stopping distance results in reduced area ahead that must be actively monitored by vehicle operator.
Seatbelts/Airbags	Reduction: Decreased potential likelihood of personal injury in event of accident may result in reduced perceived criticality in avoiding them (e.g., a shift from "absolutely" to "greatly to be desired"—a mental perception of "no harm, no foul")
Improved steering	Reduction: Decreased "play" in steering results in decreased need for driver steering input
Radar Detectors	Reduction: Increased awareness of potential police presence results in reduced need to actively scan area for them on a continuing basis
Rear Seat Entertainment Systems	Reduction: Prior mental effort expended in "tuning out" children in rear seat is no longer required since they are quietly absorbed and entertained

these tasks in isolation. Nothing in the paragraphs above should be taken to suggest otherwise; indeed, the fact that additional mental effort is required to perform multiple tasks is central to the thesis that multitasking drivers may simply be attempting to raise themselves to an optimal level of mental arousal. Those same paragraphs, however, also support the hypothesis that "driver distraction" is not simply a function of multiple attractive competing alternatives for driver attention, but rather is symptomatic of a more global problem, that of lack of optimal demand by the driving task itself. As mentioned earlier, there is considerable existing empirical support for this position from other research communities (e.g., aviation.) The original research supporting the relationship between demand (arousal level) and performance expressed by the Yerkes-Dodson Law was performed in 1908, and the law itself was first proposed in the 1950's.[31] It has been repeatedly demonstrated to be true by more recent empirical research. No matter which hypothesis is true, however, the primary questions of interest are the same in either case: 1) How can the problem of driver distraction be solved? and 2) Can or should the problem be addressed at the *engineering* level at all?

The fact that the target of engineering development/ refinement is not *optimal*, but rather *reduced*, workload cannot be taken as an indictment of the auto manufacturers or their engineering staff. Such a goal is the straightforward result of mutually exclusive design criteria. Engineers are trained that the most effective means of reducing the potential for accident is to redesign the product so as to reduce potential risk. Human error is a major contributing factor in many types of accidents. Accident frequency has unquestionably decreased over the years by simplification of the driving task and reduction in the potential for operator error through reduction in operator decision-making and input. Further, if the potential for all drivers to become overloaded is to be reduced, this necessarily requires that the average overall workload of the task must decrease, so that even the least skilled operator is not overtasked in the event of an unexpected condition or event. Since human capabilities are not uniformly distributed (i.e., all drivers are not equally capable) and since automobiles are not uniquely designed to match the individual skills or capabilities of their operators, insuring that *over*tasking does not occur for the least skilled drivers necessarily results in those with greater capabilities being routinely being *under*tasked, particularly during routine operations (i.e., a less than optimal arousal level.) A return to a higher average operator workload during normal operation (thus approaching optimal loading levels for the average driver) would necessarily result in a greater potential for operators with less capability to be overloaded under more robust driving conditions or maneuvers, as well as a greater potential for operator error.

One can largely look at the issue as a problem in decision analysis where one type of error (not overloading marginally competent drivers) must be traded off against another (not *under*loading more competent/skilled drivers). The first type of error almost certainly *will* result in negative outcomes, while the second only has the *potential* to result in negative outcomes (and likely fewer of them based on accident frequency statistics.) Given this, designers/engineers must opt in favor of the greater expected benefit (i.e., reducing Type I errors). Engineering efforts to compensate for distracted driving (e.g., lane departure warning systems) will likely only compound the problem by further reducing overall operator workload and thus further reducing the arousal level of the majority of drivers. Short of completely automating the driving task, engineering fixes are unlikely to be a viable strategy for reducing driver distraction. Further, it is likely that even a fully-automated vehicle would require at least *some* degree of driver oversight. This produces a classic "Catch-22" type of situation in which the increased automation level would almost undoubtedly decrease the driver's attention on the monitoring task, making them even less likely to be able to detect unusual/dangerous situations in time to react to them.

Equally clearly, the answer is not simply admonishing the driving public to be more attentive when behind the wheel. Except in the extreme short-run, individuals are simply not capable of devoting more attention to a task than it appears to merit based on both their expectations and past experience. We parsimoniously allocate our limited supply of attention. This is not a strictly volitional choice on the part of the individual and exhortations by all the authorities in the world cannot alter such behavior except in the extreme short-run. Legislatively restricting particular mechanisms of distraction (e.g., banning cell phones or texting in automobiles) cannot and will not force attentional resources to be devoted to a driving task that routinely require them. More likely than not, such legislation will either be ignored or simply result in the driver finding some alternative non-driving-related employment for those attentional resources. No matter whether this outlet is thinking about unrelated subjects, focusing on the scenery outside the windows, or conjuring up appropriate mental imagery from an audiobook or play-by-play sporting events, such cannot and will not substantially reduce the potential for "driver distraction" types of accidents. It must be remembered that even prior to the advent of cell phones, anecdotal evidence from insurance companies revealed that it was common for drivers to be performing tasks such as shaving or reading newspapers/books while behind the wheel. Even today, most studies find that the commonest sources of driver distraction are "objects outside the vehicle", *not* cellular phones or entertainment systems. [32]

The question thus is not, "*How* do we reduce driver distraction?", but rather "*Can* we reduce driver distraction?" while attempting to simultaneously satisfy other mutually exclusive criteria. If it is desired that greater attention be focused on the driving task, then what may be required is that the driving task itself again become more attention-demanding (e.g., either a step backward in terms of the operator workload reducing advances of past years, or some other artificial means of increasing driver workload such as a decreasing lane width or reverting to manual transmissions[6]). If it is desired that both the mental workload of operating a motor vehicle (i.e., the operator's arousal level) and the potential consequences of driver error continue to be reduced, then the only viable alternative may be to somehow remove the operator from the process completely (i.e., automate the vehicle.) Based upon the authors' understanding of the current state of the art and the potential liability issues involved in such automated vehicles as Google's automated car or the National Automated Highway System vehicles demonstrated in the late 1990's, the latter alternative may not be viable at this time (for liability reasons if no other). Further, even if driving operations were to be totally automated in future vehicles, it is likely that having both automated and non-automated vehicles attempting to share the same roadspace would raise, not lower, accident rates in at least the short run, since it is unlikely that automated vehicles could in all cases successfully predict the actions of the human-controlled vehicles around them.

In short, given the considerations detailed above, it is likely that the "problem" of driver distraction is one that is unsolvable without a basic paradigm shift, and thus will be with us for years to come. What may be needed is to take an alternative perspective with regard to the entire issue of driver distraction and driver workload. Rather than simply attempting to minimize driver workload by further engineering improvements to the vehicle (and thus potentially producing even an greater likelihood that drivers to turn to secondary tasks to increase their arousal level), it may be necessary to focus instead on *optimizing* the level of driver workload to increase the involvement in the driving task itself.

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