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The Driving Question

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Goodman, Tijerina, Bents, and Wierwille (1999) present an excellent analysis regarding the safety of cellular telephones while driving and raise many important issues for current operation and future acceptance. However, we remain skeptical of their fundamental conclusion, specifically that the available evidence is adequate to support the conclusion that cellular telephone use while driving increases crash risk. This is not to say that such a relationship does not exist but that sufficient evidence has not yet been provided to meet the burden of proof. We suspect that Goodman et al. are sensitive to this need because they carefully present their conclusions with qualifications such as "at least in isolated cases" and "reasonably plausible," while clearly distinguishing between crashes caused by cellular phone use (which they repeatedly admit are a small number) and the *risk* of crashes among cellular phone users. There are two important facts upon which our objection is founded. First, the crash data simply do not exist to a reasonable and representative extent, at this time, to support definitive conclusions. Second, the type of statistical extrapolation at the heart of their presented predictive analyses requires that future technical implementations are simple and direct extrapolations of current technology. We consider the latter an unlikely development. In what follows we offer specific comments on the article by Goodman et al. with some general comments on "the driving question."

THE SAFETY OF DRIVING WHILE USING CELLULAR TELEPHONES

> . . . skepticism is a method, not a position. Ideally, skeptics do not go into an investigation closed to the possibility that a phenomenon might be real or that a claim might be true. When we say we are "skeptical," we mean that we must see compelling evidence before we believe.
>
> Michael Shermer, Editor-in-Chief, *Skeptic Magazine*

The Nature of the Question

If we combine an overlearned but crucial skill (such as driving) with a common and growing technology (such as telephones), an obvious safety question arises: Does cellular phone use cause vehicle crashes? This is the question that agencies like the National Highway Traffic

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Safety Administration (NHTSA), in response to public concerns, are mandated to answer. Unfortunately, currently available data do not address this question satisfactorily and, despite their carefully worded conclusions, we suspect that the study by Goodman et al. will be misrepresented by groups and individuals who, for different reasons, blur or misunderstand the distinction between "crashes" and "risk of crashes."

It is crucial to distinguish between the questions we can pose and the questions we can answer. When we diffuse a causal relationship to proportion of risk, we are in danger of wrongfully placing the human at the center of all error, because risk taking is a characteristic of behavior. This leaves the insidious possibility that poor design is forgiven because driver error caused the problem. Manufacturers will insulate themselves from responsibility by warning that drivers are ultimately responsible for the operation of the vehicle. Driver error will become the panacea for automobile crashes, just as pilot error has for aircraft crashes. Deciding whether cellular phones cause crashes therefore poses considerable and unsuspected challenges, despite the apparent simplicity of the question.

The Proportion of Baseline Problem

What if Goodman et al. (1999) had performed the same analyses but looked at drinking beverages as a factor in crashes? We suspect that the conclusions would be remarkably similar. Consider the following:

- Industry patterns would indicate that the presence of beverage holders in vehicles had shown a substantial growth in the last decade. Almost every make and model of vehicle has these devices, some even advertised as a feature.
- Patterns of use would indicate that beverage consumption, especially coffee drinking, has risen considerably in the last decade. Consumption of beverages in vehicles has similarly risen. This behavioral pattern has extensive and pervasive industry support (e.g., drive-through coffee huts, coffee-to-go chains, portable drink containers).
- Driver opinion would identify drinking beverages as a possible distracter (see Goodman et al., Table 1).
- Crash data would support the conclusion that drinking beverages has *directly* contributed to crashes.
- Crash data would support the conclusion that drinking beverages contributes to driver inattention and distraction, related to activities such as reaching, looking, dropping, and operating (e.g., opening containers) and poor driver strategies such as driving with one hand on the wheel (see Violanti & Marshall, 1996).
- Conclusions would indicate that drinking beverages while driving increases the risk of crashing.

What would we make of this study? The perception might be that drinking a beverage could not be a crucial factor in crashes because it appears to be such a simple and innocuous task. But is drinking any less difficult than conversing? The data from North Carolina and the National Automotive Sampling System–Crashworthiness Data System case studies suggest that conversation itself is the most prevalent single behavior associated with cellular-telephone-related crashes in the United States. Apparent simplicity is replaced by real complexity when we begin to examine the interaction between driving and any putative competing task.

When addressing the question of the *magnitude* of the risk from the use of cellular phones, Goodman et al. (1999) call the data "inconclusive." Yet this is the heart of the problem. Even if we acknowledge that cellular phone use increases the risk of a crash, we cannot quantify such a relationship. Is this risk differential any greater than that for the myriad of other tasks one could engage in while driving? Is the increase in risk significantly different from the risk inherent in the driving task alone? Such questions are not answered by Goodman et al. or our current knowledge.

The Data Problem

A fundamental problem faced by Goodman et al. (1999) and other researchers examining safety implications of in-vehicle technologies is the sparse data related to the role that such technologies play in crashes. To date, only the states of Oklahoma and Minnesota track cellular phone use as a potential contributory factor. Clearly, improved data collection and reporting is necessary, and state agencies should be encouraged to provide detailed information.

Tables 1 and 2 show the Minnesota motor-vehicle crash facts for 1996 and 1997 (Minnesota Department of Public Safety, 1996, 1997). How convincing an argument can be formulated from these data? Despite Minnesota's efforts to identify and systematically record cellular phone use as a factor in crashes, the data remains difficult to interpret. From the presented data, one could argue the following:

- Cellular phone use, specifically, contributes to very few accidents and ranks among the least-identified contributing factors in Minnesota crashes.
- Cellular phone use generally contributes to driver inattention/distraction, which ranks as the largest contributing factor in Minnesota crashes.
- Cellular phone use contributed to 57 injuries and 1 fatality in 1996 and 56 injuries and no fatalities in 1997. Some would regard this as reason enough to warrant safety studies.

Despite the asserted global increase in cellular telephone usage, we can see no comparable trend for an increasing crash rate across the two years. Thus, our conclusion can only be "not proven" at the present time.

The rate at which driver inattention/distraction is reported is also cause for concern. Clearly, inattention/distraction is an appropriately descriptive label for a real and important behavioral phenomenon. The danger comes if we think of inattention/distraction as an objective cause. Problems with this particular argument for causation were presented by Flach (1995) in addressing situational awareness. He cautioned against interpreting phenomenon descriptors as causal agents as a potential form of circular reasoning. How do we know that attention was lost? Because the driver crashed. Why did the driver crash? Because attention was lost. Although the identification of attention as a general concern helps us bound the problem, the use of such a general term may mask the salient behavior of concern and become an obstacle to research.

The "Auto-PC" and the Role of Human Factors

With the proliferation of Intelligent Transportation System (ITS) technologies, it is highly probable that in-vehicle systems will further intrude on the driving task. Wireless communications, Global Positioning System data links, collision-avoidance systems, and vision enhance-

TABLE 1
Contributing Factors in 1996 Crashes

Contributing Factors	Percentage of Factors Cited in Crashes by Severity of Crash: Fatal Crashes	Injury Crashes	Property Damage Crashes	Number of Crashes in Which the Factor Was Cited: Fatal Crashes	Injury Crashes	Property Damage Crashes	Number of People Affected: Killed	Injured
Human factors								
Driver inattention/distraction	12.1	22.5	19.8	103	10,718	15,430	115	16,226
Failure to yield right of way	12.8	15.4	14	113	7,617	11,307	126	12,065
Illegal/unsafe speed	17.8	12.8	13.1	138	6,195	10,409	164	9,481
Following too closely	1.0	6.3	6.3	8	2,910	4,756	15	4,298
Improper/unsafe lane use	4.3	3.2	5.3	36	1,594	4,308	39	2,365
Disregard traf contr device	3.6	5.0	2.8	32	2,503	2,257	38	4,191
Physical impairment	13.6	5.3	2.4	115	2,635	1,988	126	3,909
Driver inexperience	2.3	3.4	3.0	20	1,693	2,474	24	2,665
Vision obscured	2.2	2.8	3.0	18	1,336	2,221	19	1,809
Improper turn	0.7	1.7	2.6	6	862	2,167	8	1,397
Improper passing/overtaking	1.4	1.0	1.9	11	512	1,522	12	756
Unsafe backing	0.1	0.5	1.9	1	226	1,521	1	287
Improper parking/starting/ stopping	0.8	1.1	1.4	7	535	1,120	8	799
Driving left of center (not passing)	6.7	1.3	1.1	58	628	860	82	1,156
Pedestrian violation or error	2.2	1.0	0.0	19	505	0	19	524
Improper or no signal	0.1	0.3	0.4	1.	131	316	1	189
Impeding traffic	0.0	0.2	0.3	0.	74	198	0	138
Failure to use lights	0.3	0.2	0.1	3.	90	91	3	130
Driver on CB radio/cellular phone	0.1	0.1	0.1	1.	39	50	1	57
Other human factors	1.3	1.2	0.9	10	577	715	11	801
Vehicular factors								
Skidding	3.8	4.8	6.6	31	2,247	5,028	39	3,255
Defective equipment	0.5	0.9	0.8	4	448	676	7	647
Other vehicular factor	0.3	0.5	0.7	3	247	580	5	363
Miscellaneous factors								
Weather	6.4	6.1	8.1	30	2,476	5,656	37	3,541
Other	5.7	2.9	3.5	46	1,246	2,393	52	1,758
Total percentage	100%	100%	100%					
Total contributing factors	880	50,968	83,115					
Vehicles where there was "no clear contributing factor"	302	25,027	48,523					
Total number of vehicles	902	63,449	131,501					

Note. Zero, one, or two contributing factors may be associated with each vehicle. This causes the number of factors cited to be different from the number of vehicles, the number of crashes, and the number of people affected by the factors. Percentages are based on all factors cited; they do not sum to 100% due to rounding. Bicyclists and pedestrians are considered as vehicles in this table, and factors associated with them are included. Contributing factors with a frequency of less than one tenth of 1 percent are merged into the category "other human factors."

TABLE 2
Contributing Factors in 1997 Crashes

Contributing Factors	*Percentage of Factors Cited in Crashes by Severity of Crash* Fatal Crashes	Injury Crashes	Property Damage Crashes	*Number of Crashes in Which the Factor Was Cited* Fatal Crashes	Injury Crashes	Property Damage Crashes	*Number of People Affected* Killed	Injured
Human factors								
Driver inattention/distraction	14.6	23.1	21.3	122	10,419	15,308	140	15,753
Failure to yield right of way	14.1	16.1	14.6	124	7,445	10,824	142	11,823
Illegal/unsafe speed	13.6	12.1	11.8	119	5,504	8,604	143	8,931
Following too closely	0.6	5.9	6.7	5	2,509	4,663	8	3,609
Improper/unsafe lane use	3.7	3.2	5.4	32	1,504	4,026	35	2,198
Disregard traf contr device	5.5	5.0	2.9	49	2,365	2,163	60	3,989
Physical impairment	10.1	5.3	2.5	89	2,488	1,877	101	3,670
Driver inexperience	3.2	3.2	3.0	27	1,504	2,218	31	2,425
Vision obscured	2.8	3.2	3.6	13	1,379	2,345	13	2,030
Improper turn	1.1	1.8	2.6	10	837	1,991	10	1,304
Improper passing/overtaking	1.0	1.0	1.8	9	461	1,378	9	716
Unsafe backing	0.0	0.4	2.0	0	197	1,512	0	241
Improper parking/starting/ stopping	1.1	1.1	1.5	9	518	1,113	10	745
Driving left of center (not passing)	5.3	1.3	1.0	46	591	720	56	1,059
Pedestrian violation or error	2.7	1.0	0.0	24	456	0	25	479
Improper or no signal	0.0	0.2	0.4	0	111	271	0	159
Impeding traffic	0.3	0.2	0.2	2	99	165	2	155
Failure to use lights	0.5	0.2	0.1	4	88	79	5	140
Driver on CB radio/cellular phone	0.0	0.1	0.1	0	43	68	0	56
Other human factors	1.7	1.3	1.0	15	619	699	20	872
Vehicular factors								
Skidding	5.7	4.2	5.4	48	1,890	3,818	50	2,680
Defective equipment	0.9	0.8	0.9	5	392	700	5	583
Other vehicular factor	0.5	0.5	0.8	4	213	563	7	300
Miscellaneous factors								
Weather	6.8	5.6	7.0	40	2,172	4,448	50	3,157
Other	5.3	3.1	3.6	42	1,191	2,244	44	1,737
Total percentage	100%	100%	100%					
Total contributing factors	884	47,603	76,179					
Vehicles where there was "no clear contributing factor"	319	23,044	43,933					
Total number of vehicles	939	59,478	122,557					

Note. Zero, one, or two contributing factors may be associated with each vehicle. This causes the number of factors cited to be different from the number of vehicles, the number of crashes, and the number of people affected by the factors. Percentages are based on all factors cited; they do not sum to 100% due to rounding. Bicyclists and pedestrians are considered as vehicles in this table, and factors associated with them are included. Contributing factors with a frequency of less than one tenth of 1 percent are merged into the category "other human factors."

ment systems have already found their way into the vehicle. Agencies such as ITS America and government-sponsored programs such as the Intelligent Vehicle Initiative evaluate computer and communication technologies in response to safety, productivity, and mobility challenges. How can we influence this proliferation of technologies?

We raise this issue in response to Goodman et al.'s (1999) statements regarding the future role of human factors. They state that "the role of human factors should be on research directed toward cellular telephone designs that *minimize intrusion* on the driving task" (italics added). Elsewhere they state that "research is necessary to help ensure that designs and implementation strategies are *optimized to minimize* driver workload and distraction" (italics added). If indeed, the auto-PC is inevitable, there must be concerns about our ability to continue to protect the driver. At what point do we decide what is safe enough? In this effort, we should not be reactive but proactive. We can spend many years optimizing design and minimizing intrusion during implementation, but we do so at the risk of taking a step backward, where human factors moves away from user-centered design toward evaluating user adaptation. The goal of the human factors specialist is to find system design that supports the user's needs rather than fabricating technologies to which users must adapt (Wickens, Gordon, & Liu, 1998). We applaud Goodman et al. (1999) for advocating safety as a major issue, but we are concerned that vital questions such as Does this technology actually belong in the car? will be overshadowed by the desire to demonstrate that we can engineer technology that could be used by drivers.

THE DRIVING QUESTION

Goodman et al. (1999) effectively outline many reasons that examining driver behavior can be difficult, including the absence of data, limiting methodology, poor communication, and difficulties in reporting (e.g., drivers' unwillingness to report, lack of enforcement and legislation). We also regard these factors as major constraints to the development of improved driving research. However, we submit that there are difficulties in conducting research in the area of surface transportation that extend beyond the intricacies of individual studies and specific technologies, which are more to do with the inherent difficulties of understanding human behavior. We suggest some general limitations that make driving a difficult behavior to understand.

Why is it that driving appears so easy to accomplish but so hard to understand? After many decades of research, we still do not have a satisfactory model of driving behavior upon which we can agree and base our subsequent investigative work. Although we do have some descriptive insights into the driving task from the important work of McKnight and Hundt (1971), we still do not possess even a globally predictive construct. Why is this?

Driving is a paradox. It is a skill that is relatively easy to master—many millions of individuals drive successfully each day—yet it demands the synthesis of many complex abilities. As Groeger (1999) pointed out, it is a "new" skill, not one that evolution has sculpted us for, yet it is such a familiar, daily, and overlearned capability that those who have mastered driving rarely think about it at all. It is one of the most overlearned of all our skills because it is one of the few behaviors that humans engage in on almost a daily basis throughout their adult lives. Indeed, loss of driving privileges is a specter that haunts the older members of the population. Yet with the exception of early driver training, rarely does anyone treat driving as a skill and practice it as such (although programs such as Fifty-Five Alive are growing in popularity). Finally, driving failure can be deadly. We have no need to regale this audience with the figures for death and injury, but the fact that in the United States it remains the major cause of accidental death up to the age of 78 attests to its importance in terms of societal cost. Given these observations, why is it we do not know how people drive? We offer three answers.

The Driver Model

To argue that we do not understand driving is a little disingenuous, because we do not have a satisfactory model of human performance in general. To argue that we do not understand such behavior in one context is more than harsh on those whose business is entrenched in that context. Why do we not have a good model of human behavior? The answer is startlingly simple: We are not yet sophisticated enough to understand ourselves. Because behavior is situated or context dependent, successful models of behavior have to involve context. Unfortunately, the dominant information-processing models largely fail to do this. We might be able to tell what a driver might do generally, but we cannot predict response with confidence in any particular situation. Thus, when individuals study behavior in specific contexts—such as the operation of a mobile phone while driving—they have to refer vaguely to constructs such as visual attention, workload, and the like, which are generally relevant but specifically impotent. We argue that the greatest leaps in understanding the impact of in-vehicle technology will likely come concurrently with deeper and more detailed understanding of the driving context. The situation may improve when we understand more about contextual interactions. Such an effort has been initiated by ecological psychology, but the large-scale impact of this view and its integration with still dominant information-based approaches has yet to be achieved (see Flach, Hancock, Caird, & Vicente, 1995; Hancock, Flach, Caird, & Vicente, 1995).

Satisficing Versus Optimizing

Drivers drive well enough. That is, they drive sufficiently well to achieve the goal of the task. After Simon (1969), we refer to this behavior as *satisficing*. An example might be lanekeeping. Drivers probably do not care specifically where in the lane they are and are happy with keeping generally within one specific lane. Where they are in the lane is not an explicit goal of performance. However, when we come to measure performance, the investigator acts under the compulsion of optimization. That is, measures are taken that represent deviations from some investigator-specified optimal goal. In the case of lanekeeping, we see measures such as deviations around a center line, and we freely admit that we ourselves have often taken such values. What other specific momentary measures are available? Investigators then draw conclusions concerning performance variation and the influence of some particular manipulation (such as the difference between hands-on and hands-off phone operation while driving) and provide results and recommendations accordingly. Unfortunately, the investigational conclusions may be totally divorced from actual on-road behavior because the goals and measures derive from satisficing and optimizing, respectively. Lest anyone see an immediate solution for the specific example of lanekeeping (e.g., lane excursions), it has to be emphasized that excursions per se are not always "poor" or "bad" behavior but are crucially dependent upon the context in which that crossing occurs (e.g., overt overtaking vs. driver sleep onset). However, there is a strong expectation that those individuals with high variability in their vehicle control (as becomes evident with multiple lane excursions) will be those who pose an increased safety risk. Thus, in order to obtain a full portraiture of performance, we have to consider the driver and the vehicle in the specific context of concern.

Researchers often have difficulty grasping the concept of satisficing, and research methodology is rarely designed to look for good or satisfactory performance instead of an optimal one. As Simon (1969) noted, that is not the way the problem usually poses itself in design and research situations. We should note, however, that satisficing is even engrained in the way that we educate and train drivers. To get a permit, a young driver doesn't have to know all the rules of the road, just most of them. In a driving test, a young driver doesn't have to execute all the required driving maneuvers, just a component sample of them. How many licensed drivers still cannot or will not parallel park? As we seek to understand more of driver behavior, it is crucial that our dependent measures are directly related to actual driver goals and not just to convenient assessment metrics.

The Predictability of Crashes

There is, of course, the perennial problem of using crashes as a criterion. We claim that crashes are highly unusual, nonlinear events that result from a sequence of linked precursors. In particular, we wish to draw attention to the fact that they are not mere outliers drawn from distributions of normal driving. We cannot neglect to note that some (if not many) crashes are unavoidable because of the restricted space and time available for driver response. For example, if a vehicle or pedestrian appears in the driver's path with less than a reaction time to avoid collision, the crash can become inevitable. What we have never successfully faced—what is difficult to face—is that at least some crashes are the price society has to pay for ground transportation that exceeds the velocity of unaided human locomotion (Gibson & Crooks, 1938).

Our final point is a crucial if salutory one. Will the collective research efforts reported here have any effect on phone use in vehicles other than through post hoc litigation? In reality, are we trying to answer questions about a technology when, in effect, the horse has already left the barn? Perhaps. There is no doubt that litigation can have a palliative effect on poor design, but litigation is about restitution in specific cases, not design improvements per se. Even if we in human factors protested that in-vehicle phones were intolerably unsafe, would manufacturers listen? Because phones represent the door through which much more in-vehicle technology will enter, what can we do to limit, control, or modify implementation? The contribution of Goodman et al. (1999) is a very valuable one, yet there is still much to do. We have to ask hard questions such as, are there enough time and human factors professionals to investigate the avalanche of in-vehicle technologies? Rather than post-hoc investigation, we advocate legislative action that places the burden of proof on those who wish to put new technologies in vehicles. Cellular phones and similar in-vehicle implementations are to be considered potentially unsafe until demonstrated otherwise. Thus, like other governmental regulatory agencies such as the Food and Drug Administration and the Federal Aviation Administration, the NHTSA can act as the gatekeeper where the manufacturer proposes and the agency disposes.

In closing, we are aware of the ambivalence in several of the statements we made. On one hand, we remain skeptical that current knowledge supports the conclusion that cellular phones are causal agents of vehicle crashes. On the other hand, we caution against any intrusions on the driving task and therefore have considerable sympathy toward the general concerns expressed by Goodman et al. (1999). Despite the numerous points we raised, our central theme is simple. We assert that safe vehicle operation requires attentive, alert, and well-trained drivers. Therefore, the burden of proof of safety must be placed squarely on those who propose additions to the driving environment.

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