TRANSPORTATION HUMAN FACTORS, *1*(4), 313–316

RESPONSE

Reply to Comments on "The Effects of In-Vehicle Distraction on Driver Response During a Crucial Driving Maneuver"

P. A. Hancock
University of Minnesota

T. Ranney
Liberty Mutual Research Center for Safety and Health, Hopkinton, MA

DETERMINING SAFETY IN DRIVING

Rem Acu Tetegisti

In the commentary on our work (Hancock, Simmons, Hashemi, Howarth, & Ranney, 1999), Tijerina (1999) exhibits a characteristic acumen through his identification of the two most controversial aspects of our argument, and it is to these observations we wish briefly to respond. However, in passing, he refers to our choice of tasks and this is worth at least some response. As we all, collectively, struggle to evaluate the impact of innovative in-vehicle technologies on driver performance, we are faced with the common problem of a moving target. What is cutting edge technology one month is passé the next. In our work, we chose tasks that held at least a surface similarity to issues of particular present concern, that is, in-vehicle cellular phone operation (see Goodman, Tijerina, Bents, & Wierwille, 1999), but also selected tasks with an eye to the underlying processing demands that are likely to be required of the future driver. We agree with Kantowitz (1989) that a good theory may be the researcher's best tool and thus, although our choice of tasks may not have the highest contemporary face validity, they do relate to underlying psychological theory. Consequently, we are hopeful that the data will prove more generally useful in the longer run. However, the choice of specific tasks is a minor concern in comparison to the major issues to which we now turn.

How Safe Is Safe?

Tijerina (1999) goes directly to the heart of the matter when he questions our basis and rationale for deriving a safety limit. He points out, correctly, that many research groups and individ-

Requests for reprints should be sent to P. A. Hancock, Human Factors Research Laboratory, 141 Mariucci Arena, 1901 Fourth Street, SE, University of Minnesota, Minneapolis, MN 55455.

uals are grappling with just this issue which, at some juncture, is a sociopolitical decision, hopefully informed by the best level of scientific understanding available. In our work, we have chosen to relate driving safety to an earlier theory of stress and performance (Hancock & Warm, 1989) and clearly, there are a number of issues and concerns yet to resolve before such a conception is accepted as a basis for human-centered systems safety. Whether one believes systems exhibit gradual or catastrophic degradation, one has to decide at which point on a breakdown curve that a crucial threshold has been passed. In terms of human performance degradation, this curve is most frequently represented by an exponential decrease in capacity from a nominal or stable state to a terminal or failed state of performance. This is most frequently envisaged as the descending arms of the traditional inverted U relation between stress and performance (i.e., Yerkes & Dodson, 1908; see also Hancock, 1987). Tijerina emphasizes the complexity of this issue by pointing to the vast number of interactive sources of influence on safety and performance and in this, he is assuredly correct. The Hancock and Warm (1989) model seeks to embrace this complexity through synthesis of influential factors related to spatial and temporal features of the task and environment that are given as information rate and information structure. Superimposed on this Cartesian base are the resident adaptive capabilities of the exposed individual that vary with such characteristics as age, experience, and more contentiously, fatigue (Hancock & Verwey, 1997). The fact that the Hancock and Warm (1989) model has met with general approbation and has been applied successfully to the driving task by others (e.g., Desmond & Matthews, 1997) is encouraging. However, the attempt to reduce tasks and environmental displays to "information" values to be entered into information processing models has been one of the great frustrations of psychology of the late 20th century, and Tijerina is right to emphasize intrinsically this general failure when pointing to our own proposition. What we can assert is this: In order to provide data about incipient failure that many Intelligent Transportation Systems technologies, for example, collision-avoidance systems, require to generate protective action, we need to emphasize early indications of driver decrement and deal with the false alarm problem as best we may (see Parasuraman & Hancock, 1999; Parasuraman, Hancock, & Olofinboba, 1997). Thus our recommendation was to use driver transition from a stable to a transient state. The model by Hancock and Warm (1989) indicates that this occurs for behavioral capability in the fracture of a comfort envelope. We are acutely aware of the problem of cross-validating insufficiently defined concepts such as comfort and safety.[1] Thus, a fundamental problem is how to use multiple response measures, many recommended by Tijerina (1999) to provide a dynamic assessment of driver comfort and workload level, and this continues apace. Therefore, our theoretical stance endeavors to grapple with perhaps the central problem of transportation safety, which is that crashes and incidents are a concatenation of multiple, nonlinear influences that conspire momentarily to produce unusual and destructive circumstances. In seeking to protect against these exceptionally rare events we must pay the defensive cost of Type II error.

Tijerina (1999) asks, "Does the 24% decrease in stopping safety margin when pursuing the distracter task mean nothing? If not, what does it mean?" (p. 312). In our case, we interpret this decrease in terms of "spare" capacity. Thus, drivers were able to respond successfully, although the coincident occurrence of a light change and an in-vehicle distracter acted to reduce spare capacity. The question remains whether spare capacity as a psychological construct from attention can be matched directly to a safety "margin" as reflected in actual on-road performance outcome. Clearly, we believe there is such a relation as presented in our model, but the full expression of all impinging factors in a real-world context has yet to be accomplished. Although this obviously remains the significant challenge, we suggest that the Hancock and Warm (1989) model can provide at least a general framework and an early road map for progress.

How Many In-Vehicle Displays?

Tijerina (1999) notes that our recommendation of no more than two additional displays in the vehicle is a non sequitur. At least to some extent, he is correct. To derive our recommendation, we took the observed 24% decrement, and using the curves in the Hancock and Warm (1989) model, asked what decrement an additional competing display would induce if activated at the same time. Our conclusion being that this would bring the driver close to the point of transition from the stable to the transient state, and so our recommendation is inferential rather than observational. However, our general motivation for advancing the suggestion of no more than two additional displays was somewhat more polemic.

In the United States, drugs cannot legally enter the marketplace until extensive evaluation and approval by the Federal Drug Administration. The onus is on the manufacturer to establish that the product is safe and effective. This process also occurs in other agencies such as the Federal Aviation Administration. It can certainly be a cumbersome and frustrating process; we defend the strategy, not the bureaucracy. At present, there are few, if any, barriers to the introduction of in-vehicle devices, and although law enforcement and litigation may later prove palliatives, they are corrective, not proactive, strategies. It is our contention that devices need to establish both their safety and effectivity in the manner of a "driving impact statement." On the adoption of this general approach, we would soon see a wealth of implementation research. This might help address Tijerina's (1999) questions to us, many of which remain unanswered today—a century after the introduction of automobility. Indeed, what does constitute a "display," especially in electronic systems? With different depths of menu screens, each individual one putatively a display, are we better off thinking in terms of the type and number of additional driver tasks we are imposing with the inclusion of new technologies? Can we act to regulate task load and driver workload rather than the specific composition of the vehicle's displays and controls? Thus, reading a newspaper while driving may very well be more impactful on safety and performance than the addition of any individual, discrete electronic screen, and therefore, what the driver is doing may be more relevant for safety evaluation than what they are surrounded by. Indeed, one can ask whether any permanent displays are needed for driving anyway. Perhaps one reason we do not know these answers is that our research community has failed to adopt this proactive stance about in-vehicle devices. Thus, a fundamental stimulus for our suggestion was to advance this perspective in which arguments are framed in the proactive and positive mode rather than the reactive and negative mode. Certainly, we do not anticipate that our initial recommendation will provide any closure to this issue. Such was not the purpose. Rather, it was to stimulate response and discussion, and thus, we thank Tijerina for his insightful reply.

ACKNOWLEDGMENTS

Preparation of this response was supported by Grant HFRL-99-01 from the Intelligent Transportation Systems Institute of the Center for Transportation Studies, University of Minnesota. The opinions expressed herein are those of the authors and do not necessarily represent those of any named agency.

NOTE

1 At the International Congress on Applied Psychology in Kyoto, Japan, July 1990, Welford indicated that one could cross-validate graphology with astrology. The result, of course, need not have anything to do with reality. Thus, fur-

ther definitions of safety, safety margins, and safety decrements, alongside comparable developments looking at the relation of comfort to workload and workload margins, is an important next step.

REFERENCES

Desmond, P. A., & Matthews, G. (1997). Implications of task-induced fatigue effects for in-vehicle countermeasures to driver fatigue. *Accident Analysis and Prevention, 29,* 515–523.

Goodman, M. J., Tijerina, L., Bents, F. D., & Wierwille, W. W. (1999). Using cellular telephones in vehicles: Safe or unsafe? *Transportation Human Factors, 1,* 3–42.

Hancock, P. A. (1987). Arousal theory, stress and performance: Problems of incorporating energetic aspects of behavior into human-machine systems function. In L. S. Mark, J. S. Warm, & R. L. Huston (Eds.), *Ergonomics and human factors: Recent research* (pp. 170–179). New York: Springer-Verlag.

Hancock, P. A., Simmons, L., Hashemi, L., Howarth, H., & Ranney, T. (1999/this issue). The effects of in-vehicle distraction on driver response during a crucial driving maneuver. *Transportation Human Factors, 1,* 295–309.

Hancock, P. A., & Verwey, W. B. (1997). Fatigue, workload and adaptive driver systems. *Accident Analysis and Prevention, 29,* 495–506.

Hancock, P. A., & Warm, J. S. (1989). A dynamic model of stress and sustained attention. *Human Factors, 31,* 519–537.

Kantowitz, B. H. (1989). The role of human information processing models in system development. *Proceedings of the Human Factors Society, 33,* 1059–1063.

Parasuraman, R., & Hancock, P. A. (1999). Using signal detection theory and Bayesian analysis to design parameters for automated warning systems. In M. Scerbo & M. Mouloua (Eds.), *Automation, technology, and human performance: Current research and trends* (pp. 63–67). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Parasuraman, R., Hancock, P. A., & Olofinboba, O. (1997). Alarm effectiveness in driver-centered collision-warning systems. *Ergonomics, 40,* 390–399.

Tijerina, L. (1999/this issue). Commentary on Hancock, Simmons, Hashemi, Howarth, and Ranney, "Effects of in-vehicle distraction on driver response during a crucial driving maneuver." *Transportation Human Factors, 1,* 311–312.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurological Psychology, 18,* 459–482.