PERGAMON

Transportation Research Part F 2 (1999) 197–199

TRANSPORTATION RESEARCH PART F

www.elsevier.com/locate/trf

Is car following the real question – are equations the answer?

P.A. Hancock

Human Factors Research Laboratory, University of Minnesota, 141 Mariucci Arena, 1901 Fourth Street, SE, Minneapolis, MN 55455, USA

Abstract

Within the constraints that they set themselves, Brackstone, M. and McDonald, M. (*Transportation Research*: *Part F* (2000)), do a good job in elucidating the current state-of-the-art concerning car following models. Further, their protestation concerning the importance of such models in the light of growing intelligent transportation systems (ITS) technology and potential application in collision-warning and collision-avoidance systems is also undoubtedly correct. Also, as a member of the human factors expert panel cited (Intelligent Transportation Society of America. (1997). In *Proceedings of the Intelligent Vehicle Initiative Human Factors Workshop*. Washington DC: ITS America) it can be confirmed that normative models of driving remain a crucial unsolved issue. Thus, for these reasons their present review is both helpful and timely and deserves wide circulation. The points of contention do not concern their specific observations but rather the intrinsic assumptions upon which they are based. In particular, the question asked is, is car following the real question and equations the answer?

1. The engineer and the psychologist

Car following is a seductive phenomenon for engineers and physicists. Surely, if drivers are limited to a single lane, there is a vehicle in front of them and the physical properties of each are known, then some form of descriptive equation should capture the behavior observed. Having presented the case for one pair, surely we can generalize to multiple pairs. Such models should then aid our understanding of one predominant form of traffic accident – the rear-end collision. If such a model were successful, we would then have a basis for expansion into the less straightforward types of maneuver like over-taking or turning across traffic. Soon, we would be able to model all traffic flow and significant benefits could be reaped for all of traffic safety. Clearly, this is a worth while and laudable goal. The only problem is reality.

Real world effects impact the model process at several levels but for the sake of brevity the focus is here on two central, related issues. The first concerns the goal of driving and the goal of car following models. It is safe to assert, that driving is, with few exceptions, a satisficing task (see

1369-8478/00/$ - see front matter
PII: S1369-8478(00)00006-1

Hancock & Scallen, 1999; Simon, 1969). The term *satisficing* is used in the sense that it has been used previously. That is, drivers drive well enough to accomplish their task, but by and large they do not seek continual improvement in driving skill towards some nominal 'optimal' level. In any given situation, they do not seek to optimize their performance (although some circumstances such as race-car driving represent exceptions). The problem with a number of existing models is that they frame the question of behavior around the idea of optimal performance. Admittedly, some models introduce factors such as 'noise' to help explain performance variation and sub-maximal achievement but they are founded on a flawed assumption. This often leads to a confused and confusing search for the equivalence between a physical characterization such as closing velocity and a psychological phenomenon such as the onset of avoidance action.

While it is true that the domain of psychophysics has, for over a century, sought relations between physical intensities and psychological response, it is fair now to question this way of thinking. We have always considered physics as reality and the psychological response as a deviation from that reality. However, we have, in actuality, mixed up our independent and dependent variables, a mistake that is only now being rectified (see Flach, 1999). Thus deriving equations from physical descriptions of motion and subsequently trying to fit these to data derived from behavioral response both literally and figuratively, puts the cart before the horse. This is no fault to be laid at the door of Brackstone and McDonald (2000), after all they are commentators on the information they can find. However, it is a historical result of the fact that most early modelers were trained in physics and grounded in engineering. As a result, the present conclusion that such models have proved largely disappointing is not surprising although it should be noted that this is certainly no necessary reason to dismiss modeling as a useful strategy.

What we find in reality is that the pluralistic motivations of different drivers and the dominance of satisficing behavior in driving mean that such models are unlikely to render the 'grail' of a simple formula. Indeed, it is clear from their commentary that Brackstone and McDonald (1999), are aware of the problem, noting that differing contextual factors add layers of complexity to modeling as such factors are introduced (cf. Ceder & May, 1976). These efforts can rapidly devolve to curve-fitting exercises in which additional degrees of freedom are added to formulations, as more contextual elements are included. What such models eventually represent, in driving terms, only their advocates can explain. Thus, the manuscript is replete with mathematical formulations, which are confounded because 'subjects may have been given instructions, which biased their driving behavior'

2. What of psychological models?

Eventually, car following models developed which sought to include such psychological variables as 'threshold detection' 'tau' and its derivatives (see Groeger & Brady, 1999) which purports to 'directly' communicate time-to-contact with another vehicle or object. Fundamentally, these models rely upon a perceptual signal to trigger avoidance behavior. However, much of the research supporting such threshold notions have occurred in static, non-reactive, laboratory conditions, not out on the road, demanding actual decisions and responses. Thus, most so-called 'psychological' models are hybrids, using a single perceptual parameter as a start signal to 'run' a classic mathematical description. Whether fuzzy-set models are an answer or an escape, the present author, being deeply engaged in this issue, is unwilling to say. In other contexts, fuzzy modeling is found helpful in crossing the divide between the psychological and the physical perspective, whether this is another case remains *sub judice*. At the end, Brackstone and McDonald turn the tables by asking the psychologist how notions such as motivation and attitude can be incorporated into dynamic models. Their lament is surely justified. However, the trick here is to understand that putatively more obvious human capacities such as vision are equally as difficult as driver attitude to fit into equations and that the apparent simplicity that chronological measures impart is just that, apparent rather than real.

In the end, the efforts of conscientious traffic engineers in respect of a particular model type cannot be dismissed, without offering at least some ideas as to potential replacements. While this is so on a purely academic level, it is much more so on the level of producing technologies which can certainly impact transportation safety and thus reduce loss of life on the roadway. Hence, avoidance systems should be based upon an architecture that replicates the human behavioral response to threat (Hancock, 1993, see also Gibson & Crooks, 1938). Such a system would provide an 'envelope' of protection, which has been shown both technically feasible and practically successful (Schiller & Donath, 1997). This conception does not take particular maneuvers (such as car following) and attempt to provide a single complementary system. Rather it provides a surround that protects from all directions. Ironically, this system is found upon a 'mass-spring' model, which has been successful in human motor control simulation and does not differ in radical ways from the mathematical models surveyed by Brackstone and McDonald (2000).

The larger question remains. Will the physicist and the psychologist ever meet? Someday they must. Yet clearly much remains to be achieved if those of a mathematical persuasion are to change their fundamental perspective to a psychological focus while many in psychology learn to use the austere scalpel of numbers in their descriptions of behavior. Hopefully, such a union will be of great value in transportation and many worlds beyond.

References

Brackstone, M., & McDonald, M. (2000). Car following: a historical review. *Transportation Research: Traffic Psychology and Behaviour: Part F 1, 2*, 181–196.

Ceder, A., & May, A. D. (1976). Further evaluation of single and two regime traffic flow models. *Transportation Research Record, 567*, 1–30.

Flach, J.M. (1999). Beyond error: The language of coordination and stability. In P.A. Hancock, *Human performance and ergonomics* (pp. 109–128). San Diego: Academic Press.

Gibson, J. J., & Crooks, L. E. (1938). A theoretical field-analysis of automobile driving. *American Journal of Psychology, 51*, 453–471.

Groeger, J.A. & Brady, S.J. (1999). Tau dot or not? *Paper given at the Eighth International Conference on Vision in Vehicles*, Boston, MA, August.

Hancock, P.A. (1993). Evaluating in-vehicle collision avoidance warning systems for IVHS. In E.J. Haug, *Concurrent engineering: tools and technologies for mechanical system design* (pp. 947–958), Berlin: Springer.

Hancock, P. A., & Scallen, S. F. (1999). The driving question. *Transportation Human Factors, 1*, 47–55.

Schiller, W., & Donath, M. (1997). The virtual bumper: A control based collision avoidance system for highway vehicles. Minnesota Department of Transportation (MN/DOT) Report No. 1998–30, St. Paul, MN.

Simon, H. A. (1969). *Sciences of the artificial.* Cambridge, MA: MIT Press.