Behavioral applications of vehicle-dynamics simulation*

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The behavioral applications of vehicle-dynamics simulation are described. Modeling the dynamic properties and characteristics of the automobile and driving are emphasized.

As psychologists interested in the problems of highway safety, we view driving performance as a function of driver skills and capabilities and the dynamic characteristics of the vehicle itself. Although accident researchers sometimes tend to attribute accidents either to human error or vehicle failure, this two-state classification is a gross oversimplification. For example, in emergency situations, accidents may occur because the driver is ignorant of the dynamic characteristics of his vehicle or because his experience or training is inadequate relative to the vicissitudes of vehicle handling. Optimally, vehicle design and driver training should be compatible in order to minimize the incidence of traffic accidents. But optimization is difficult, in part because of substantial individual differences between Ss, in part because of the complexity of vehicle design and dynamics and variability of car-road interface, and in part because of the huge expenses involved in creating a suitable variety of test vehicles and test sites.

Many of these optimization problems, we believe, can be attacked with driving simulators relying on on-line computer control. Many simulators, especially those used in driver education programs, cannot provide realistic feedback, either visual or kinesthetic, because they rely on noninteractive displays (such as movies) and kinesthetic feedback modes (typically provided by spring-loaded steering wheels and pedals). A crucial feature of simulators, we feel, should be the ability to represent faithfully the dynamic characteristics of different vehicles. Thus, the simulation system should be capable of representing a wide range of the possible dynamic characteristics of vehicles, as determined by a large number of combinations of continuous parameters, road conditions, and driving scenarios. Usually, these requirements can be met only with driving simulators controlled on-line by computers, programmed to model vehicle dynamics.

DESCRIPTION

These simulators need not be either elaborate or (if the computer is owned or can be borrowed) budget wreckers—at least compared to some varieties of simulators. The Engineering Psychology Laboratory's simulator uses an AD-4 owned by the Highway Safety Research Institute. The essential feature of our system is a fairly sophisticated program modeling the dynamic properties and characteristics of car and various driving scenarios. A number of people have been involved in the development of this simulation system; for at least the last year, however, we have relied on the programming talent of Charles MacAdam of HSRI. The vehicle-dynamics model we use is one developed by Dugoff, Fancher, and Segel (1970) and modified to our needs. It allows great flexibility in changing parameters to simulate various driving environments and vehicle handling characteristics. For instance, the road surface can be modeled by changing the coefficient of friction. Thus, we can train and test Ss' performance on a variety of driving surfaces from pavement to glare ice.

Changing handling characteristics allows us to model various types of cars. The parameters such as wheel base, effective wheel radius, car mass, center of gravity, and steering ratio, which affect the handling characteristics, can be changed to study driving performance changes from car to car.

Because of the flexibility of the system, we can also model emergency situations such as tire blowout, power steering loss, or extreme steering maneuvers. Driving in such situations is quite different from normal driving. It may require not only an extension of normal responses, but also responses which are not normally in the driver's response set. For instance, tire forces or irregular power steering assist may make it difficult to straighten the path of a car after a hard turn, and responses may vary if these problems occur.

Physically, our simulator includes a driving station which has the conventional control devices and a CRT mounted at eye level. The display on the CRT and the vehicle simulation are both controlled by the AD-4 and provide stimulation and feedback to the S. The system is a closed loop, so the display provides the input to the vehicle simulation through the S and the simulation output provides the input to the display. The visual display is not "rich" and is not in color, but it does present a "driver's-eye" perspective, which captures the essential features and geometry of the S's view in a real vehicle. For example, the road converges in the distance, on-coming "cars" get larger and appear to speed up as they approach, and the entire location and orientation of the display changes as the S provides inputs to the system such as steering, braking, or accelerating.

The nonvisual feedback is provided through the steering wheel, accelerator and brake pedals, and a generator of road noise. The steering feedback is the most essential and is supplied by a computer-controlled

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torque motor attached to the steering column. Two separate forces are involved: one is a spring force proportional to the angle of the front wheels, and the other is a damping force proportional to the rate of change of the angle of the front wheels.

APPLICATIONS

We see at least three promising applications for vehicle-dynamics simulation. First, such simulation can be used for basic research into the human components of driving, particularly psychomotor skills involved in vehicle control. Second, they have promise as training aids in driver education courses, permitting training of students in rare emergency situations. Third, information from simulators could suggest redesign of vehicles, eliminating handling characteristics that are not ideally compatible with the skills and limitations of average drivers.

Currently, we are using our simulator for basic research that complements and extends research completed last summer. That study involved a standard American sedan—not a simulator—and was conducted on a closed driving course. Ss in this experiment were extensively trained in making an avoidance maneuver, varying in difficulty from trivial to nearly impossible emergency maneuvers. We obtained several performance measures from Ss, both before and after the consumption of alcohol, including recording of steering inputs. These same Ss are now being run on our simulator, under conditions as similar as possible. We plan to compare performance on the test track directly with performance on our driving simulator. Comparison data is very incomplete, but what we do have looks promising.

Using the simulator, we plan to extend the test track research, testing for the effects of alcohol on decision processes and psychomotor performance under different levels of motivation. We also hope to use the simulator to study the effects of other impairers, including other drugs and fatigue, on judgmental and psychomotor aspects of driving.

Second, both track and simulator results indicate that Ss quickly improve in their ability to execute extreme maneuvers. Training is an important issue primarily because the familiar family car handles much differently during extreme maneuvers than in routine driving situations. One advantage of vehicle-dynamics simulation techniques over conventional trainers is the ability to train Ss to cope with forces encountered in unfamiliar or emergency situations.

For example, we found in the test track work that Ss initially had difficulty in steering on occasions when tire forces caused difficulty in straightening the car's path after a hard turn. However, they rapidly learned to cope with this problem. Training in such situations can be accomplished with this type of interactive simulation.

Vehicle failure raises similar training issues, perhaps best illustrated by tire blowouts. It is common knowledge that you should not hit the brakes if a tire blows, but most drivers have never actually experienced tire blowout. Most drivers would probably have difficulty instinctively recognizing a blowout and inhibiting the natural braking response, especially at highway speeds. By making an abrupt change in the parameters of the tire model and the coefficient of friction, our simulator can provide experience in this situation.

Obviously, computer-controlled simulators are preferable for many training purposes to conventional simulators, which are noninteractive and cannot represent the dynamic characteristics of vehicles. Our experience indicates that Ss can be trained on a variety of tasks, including those that involve extreme maneuvers. This type of on-line system could be a valuable addition to many driver training programs.

A third topic is the application of vehicle-dynamics simulation to vehicle design. One demanding but interesting task would be the determination of typical driver control functions. As we understand, much of the formal work on vehicle dynamics is based on assumptions about highly idealized control inputs, perhaps those of professional drivers or those that are mathematically convenient. Yet, research with simulators could suggest vehicle designs that could permit the driver to naturally extrapolate responses from normal to emergency situations, perhaps eliminating the need for special training on the most extreme maneuvers.

SOME SPECULATION

A related issue concerns what happens when vehicles are designed so that they have different dynamic characteristics. The crucial behavioral issues are the specificity of psychomotor skills and how they transfer to vehicles with different dynamic characteristics. Changing from vehicles with three-speed manual transmissions to those with four speeds is likely to result in some grinding of gears, but little real damage. Transfer effects in changing from vehicles with full-power, for example, to those with nonpower steering and brakes could be fairly persistent. Although we do not know of any relevant accident statistics, the magnitude of negative transfer effects could be estimated using simulation techniques. Ss could be trained on a system using one combination of vehicle parameters and then transferred to a system using a different combination of parameters. This type of research might suggest that all vehicles be designed so that they have about the same characteristics or that they have "parameters" that are adjustable to suit individual drivers. More speculatively, drivers could be trained on vehicles comparable to those they normally use and perhaps be retrained on simulators when they change to vehicles with substantially different handling characteristics.

Finally, we would like to reiterate the importance of flexibility, provided by computerized systems, in vehicle simulation. We realize that simulation techniques, even those far more sophisticated than ours, have major disadvantages compared to the use of real cars and real driving tasks. But the applications we are concerned with, for the most part, are not feasible except by simulation; the cost of real cars is prohibitive, and data collection and training of large numbers of Ss is agonizingly slow and therefore an expensive process in itself. Yet, we feel that the potential basic research, training, and design applications are important and that pragmatic considerations necessitate the flexibility of on-line computer simulations in at least some of these applications; with some imagination, others could probably be identified.

REFERENCES

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