Customer Needs, New Technology, Human Factors, and Driver Science Research for Future Automobiles

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INTRODUCTION

Abstract

Human factors engineering/ergonomics is one of the most important disciplines contributing to customer-oriented vehicle design. This discipline is of great interest to mechanical engineers, since safety and ease of use are critical product attributes. This paper identifies some of the vehicle attributes important to the customer and the associated human factors issues. As an illustration, this paper describes the information required to design a navigation interface. In addition to application-specific data, basic human factors research is needed to provide a foundation for vehicle engineering and evaluation, in particular, research on replicable protocols for measuring how people drive (both normally and prior to crashes).

Background

Automobile manufacturers and suppliers want to develop vehicles and vehicle components that customers want, that are safe and easy to use, and that can be sold at a profit. In the past, mechanical and electrical engineering enhancements led to more features. Now, the critical difference between products is the number of usable features provided, not the total number of features. By a commonly accepted definition of quality, a product that is difficult to use is a poor quality product (Roy, 1990). The VCR display in many American homes always flashes at 12:00 AM because consumers find setting the clock too difficult, and for the same reason, never program or adjust their VCR. For automobiles, customers complain about not understanding how to use the radio presets, difficulty in getting in and out of the back seat, and not being able to see the instrument panel. Incorporating usability in cars has become critical, and human factors engineering/ergonomics has become a highly visible aspect of automotive design.

In American automotive design, a popular approach is the "House of Quality," an approach which originated at Mitsubishi Kobe shipyard (Hauser and Clausing, 1988). As part of a Quality Function Deployment program, this approach entails several steps: (1) listing and weighing the customer attributes, (2) identifying the engineering characteristics, (3) determining the linkage between customer attributes and engineering characteristics, (4) collecting objective data for each engineering characteristic and identifying links between them, (5) setting performance targets, and (6) determining the process to achieve the targets. This paper identifies customer attributes and engineering characteristics from a human factors perspective, along with the data necessary to satisfy them.

WHAT VEHICLE ATTRIBUTES ARE IMPORTANT TO THE CUSTOMER?

The first step in designing a vehicle that customers will buy is to identify the relevant vehicle attributes. This step, along with identification of the users and their tasks, forms the first phase in a typical human factors design effort.

As summarized in Table 1, attributes can be grouped into categories associated with impact, vehicle movement, exterior and interior design, and access and repair. For each category there are several subcategories, and for each subcategory, many attributes. For example, attributes for seat belts include the protection provided, the comfort to the wearer, and the ease of retrieving, fastening and unfastening the belts. Human factors engineers can help identify customer attributes and convert them from the vocabulary of the customer into measurable engineering characteristics. For example, "a seat belt should not chafe the neck of the wearer" might become "after a 30-minute drive while wearing a bathing suit, no more than two drivers in an anthropometrically diverse sample of 20 rate the seat belt as uncomfortably irritating their neck." To satisfy that requirement, mechanical engineers would consider the location of the seat belt anchor points, the tensioning mechanism, and many other factors.

Table 1. Selected attributes of importance to the customer.

Category	Subcategories
Occupant protection	seat belts; air bags; interior geometry, components, & structure; fire, electrical, & chemical hazards
Vehicle movement & control	steering; braking; guidance; ride quality; seat comfort
Exterior design	field of view, glazing; headlights, taillights; mirrors; conspicuity
Interior design	controls; displays; thermal comfort; air quality; sound environment
Access, maintenance, & repair	ingress, egress; trunk & underhood; maintenance & repair; documentation & manuals

While the vehicle attributes important to the customer are well known (at least within the car manufacturers and suppliers), there is limited information for new technology. In part, this is because customers cannot say how useful a feature will be if they have not had experience with it. The most recent Delphi study (Office for the Study of Automotive Transportation, 1994) indicates safety will be the most important factor to buyers of intermediate cars; suggesting that engineers should emphasize the safety attributes of new technology.

WHAT TECHNOLOGIES ARE LIKELY TO APPEAR IN CARS OF THE FUTURE?

To satisfy customers, engineers must be aware of the features afforded by new technology. In the last few years, there have been great strides made in incorporating computer and communications technology into new vehicles. Shown in Table 2 are estimates of when several new technologies will achieve 5% market penetration in the U.S. (Underwood, 1992). Traffic and navigation systems are likely to appear first, collision avoidance systems second, enhanced vision third, and finally, advanced control systems. Electronic systems (e.g., electronic traction control, TV) generally have appeared earlier in Japan than elsewhere, because of customer demands, more permissive liability laws, and in the case of navigation, greater road network complexity.

Table 2. Expected Implementation Time Frames of New Technology

Function	5% Market Share	50% Market Share
Real-time traffic information	1996	2007
Mayday (emergency call)	1998	2010
Yellow pages, etc.	2000	2012
Traffic-adaptive route guidance	2000	2020
Autonomous navigation	2000	2012
Frontal collision warning	2002	2013
Back-up, blind spot detection	2002	2015
Adaptive (intelligent) cruise*	2004	2015
Automatic braking	2008	2020
Rollover warning (for trucks)	2010	never
Night/Fog vision	2010	never
Automatic lane keeping	2011	2032
Automated platooning	2035	never
Automated driving	2040	never

Note: Intelligent cruise control systems (which sense surrounding vehicles and adjust speed based on traffic) are likely to achieve commercial success in the U.S. because expressway speeds vary with congestion. With added functionality (automatic braking, automated lane keeping, etc.), this feature will evolve into an automated driving system.

WHAT SPECIFIC HUMAN FACTORS DATA IS NEEDED TO DESIGN VEHICLE COMPONENTS?

It is the responsibility of human factors engineers to help implement new features by disseminating driver-related design data. This may include data on driver size, the legibility of text, and the organization of complex displays. Unlike seat belts, brakes, mirrors, and other common vehicle components, much less is known about how new systems should be implemented to satisfy customers. To provide that information, a comprehensive human factors research program is needed to support new vehicle technology. (See Green and Bagian, 1995 for an overview.) If initial implementations of new features are unsafe or difficult to use, customers may be unreceptive to improved designs (as has been the case in the U.S. for speech interfaces).

Consider the human factors data needs for a navigation system as an illustration. Suppose a group of businessmen is driving a car to a golf course in an area they have never been to before. After entering the destination (and there is considerable interest in how), an electronic map (to be read while driving) might appear showing the route. If maps are too complex and take a long time to read, distracted drivers might collide with vehicles ahead. The tradeoff between map complexity and reading time is a human factors matter. At some point, drivers will need to decide to turn. What information should a turn display include (geometry of the next turn, heading, etc.)? Is a turn display necessary, or can drivers navigate effectively when given only destination distance and heading?

Without answers to these questions, systems designed by engineers for future vehicles will be of inferior quality. The research program required will not be cheap or completed quickly. Given the level of effort required for navigation, the aggregate human factors effort required for all automotive applications (in Table 1) is considerable.

WHAT ARE THE BASIC (DRIVER SCIENCE) RESEARCH NEEDS FOR NEW SYSTEMS?

Application-specific data must be supplemented with basic research. To provide data necessary to design and evaluate the safety and usability of existing and new vehicle systems, information is needed on how people drive now (both normally and before crashes). This information should be organized as models of driving behavior, which engineers can then apply.

1. Measure how people normally drive

Baseline data are needed examining how people drive now to determine if new systems make driving safer and easier. Data should be collected using instrumented cars on how normal, nonintoxicated drivers perform when they drive to work or go shopping. Of interest are driver age and sex, the type of car, the type of road, traffic, and in particular, regional differences in aggressiveness (Boston vs. the midwest U.S., Italy vs. Germany, Osaka vs. Kyushu). The results from this research could be used to develop standards of normal driving. (For example, "On average, an electronic map should require no more fixations than a paper map [a presently unknown value].")

To conduct normative driving studies (and certify products), an agreed upon set of measures is needed (both of driver output and vehicle output). Also needed is evidence linking those measures to driving difficulty. Without agreement, engineers cannot verify claims that a particular design is safer or easier to use than another. A system that draws visual attention away from the road should add to the risk of driving, but the specific limits are unknown. If a vehicle wanders from its lane, a collision is more likely, but the desired measure (e.g., number of lane excursions, the standard deviation of lane position) is uncertain.

A fundamental tenet of science is that measurements should be replicable, and that replication is essential to establish "the truth." On-the-road human factors tests are conducted all over the world, using different types of roads, drivers, and vehicles. Measurements are also obtained from driving simulators. However, comparisons of on-road tests with each other are rare, and even rarer are comparisons of simulators with on-the-road tests, or simulators with each other. Research examining these three comparisons is needed to determine the accuracy and reliability of driving data.

2. Formulate models of driving

Just as physics is applied to develop engineering models, psychology should be used to develop models of driving. A model can be a verbal description how of a system works, a flow chart, a set of equations that provide engineering estimates, or an exact quantitative description of a system. A useful model of driving should accept road geometry, traffic, vehicle description, and driver behavior files, from which the model should generate predictions of driver behavior (e.g., glance durations and frequencies), performance (speed, and lateral position), and workload over time. Using data describing typical drivers and trips, estimates of driver performance and workload for proposed interface designs (varying in the types of controls and displays used, etc.) could be computed. Just as finite element models are used to evaluate alternative chassis designs, so should mental models be used to evaluate driver interfaces.

3. What happens prior to real crashes?

Accident reconstruction (using skid marks and vehicle damage) is a well accepted engineering practice. Detailed data is available from flight and voice recorders for virtually every major air transport accident, but not for automobile accidents. Knowing where drivers were looking, what were other vehicles doing, etc., prior to crashes could be valuable in identifying the causes of accidents. Engineers will find the data on what is distracting very useful for designing safer vehicles.

A fleet of vehicles should be instrumented to record driver and vehicle performance parameters during normal driving on public roads. This idea has not been pursued due to the cost of the recording equipment.

WHAT SHOULD ENGINEERS GAIN FROM THIS PAPER?

1. Human factors engineering, mechanical engineering, and electrical engineering should be given equal emphasis during vehicle design. To the customer, products that fall apart or are confusing to operate are all judged of poor quality.

2. Human factors engineers can help convert customer attributes into engineering characteristics.

3. Specific human factors data and engineering models of driver performance should be used o design products. Research is needed to fill application-specific knowledge gaps (e.g., for navigation).

4. Human factors engineers can assist in certification of product safety and usability. For that to occur, research is needed on the sensitivity and reliability of alternative measures and methods.

In summary, while vehicle design is cost and technology driven, customers will not buy vehicles that are not safe and easy to use. Engineers must develop behavioral specifications for safety and usability, observe real drivers in simulators and real vehicles, and based on feedback, modify and retest systems and features. Engineers must understand the importance of human factors engineering, apply the principles and design data, and promote research to eliminate knowledge gaps.

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