INTEGRATION OF DRIVER IN-VEHICLE ITS INFORMATION

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ABSTRACT

In order to remain competitive in the marketplace, manufacturers are including more and more infotronic systems in vehicles. These next-generation interactive systems must function without decreasing the safety and ease of operation of vehicles. From a human factors perspective, these goals cannot be accomplished without integration of in-vehicle information. Integration in a human factors context refers to the needs of the driver, rather than characteristics of hardware, software and infrastructure. There is a strong need to integrate three classes of driver information inside the vehicle: (1) safety and collision avoidance, (2) advanced traveler information systems, and (3) convenience and entertainment systems. As more information is added inside the vehicle, cars and trucks start to take on some of the interface characteristics of airplanes. Fortunately, there are many human factors lessons that have been learned in the aviation domain that can be applied to the integration of in-vehicle information. These include research on operator workload and allocation of function. Human factors research needs for next-generation vehicles are articulated.

INTRODUCTION

In a speech before Convergence '98, Richard Parry-Jones, group vice-president for Product Development, Ford Motor Company, made the following points:

- Analysts predict global sales of 50 million units at $30 billion in the year 2011 for the total Intelligent Transportation Market.
- Infotronic systems will allow automakers to differentiate their product from the competition.
- While reliability is the greatest challenge to infotronics development, the man-machine interface is a close second.
- Infotronic technology must be intuitive and easy-to-learn.
- Next-generation interactive systems must blend information, communication, and entertainment technologies into the everyday driving experience without complicating the basics of operating vehicles.

This goal of combining varied sources of in-vehicle information is a worthy challenge that can be achieved by applying state-of-the-art human factors principles. But the research required to accomplish this cannot wait until 2011; we must start now. How well in-vehicle information is integrated will affect not only the market share of individual automakers, but also the safety of every driver on the road once these advanced systems are widely deployed (1). In our opinion, integration of in-vehicle Intelligent Transportation Systems (ITS) information is the primary human factors conundrum facing the ground transportation industry. Indeed, in a speech given to the Minnesota ITS Forum (Minneapolis, September 16, 1998), the first author of this paper argued that information integration guidelines should be the highest priority for ITS human factors research.

VARIETIES OF IN-VEHICLE INFORMATION

In this paper, integration applies to the in-vehicle information used by the driver. This differs from other ITS uses of the term "integration" which can also refer to hardware, software and infrastructure. Our use of the term "integration" is limited to a human-centered approach that is concerned only with in-vehicle information that is perceived directly by the driver. Thus, issues regarding data formats on a vehicle bus are beyond the scope of this paper because the driver cannot perceive data formats directly. Our concern is only with those tangible aspects of the driver-machine interface (i.e., displays and controls) that are perceived and manipulated directly by the driver.

This approach is not intended to diminish the importance of system architecture, since there is no driver-vehicle interface (DVI) without an underlying set of sub-systems that communicate with each other and ultimately with the driver. However, our approach implies that *from the driver's perspective*, these crucial underpinnings are invisible, and thus, important only to the extent that they place constraints on what the driver perceives and controls. A perfect hidden system architecture, from a human-centered perspective, will place no limitations on the driver's ability to obtain desired information while preventing too much information from creating stress and detracting from the general driving experience. Of course, if carried to its logical extreme, this design philosophy suggests that the driver-interface should be designed first, while the rest of the system architecture (including the vehicle) exists only to support an interface that makes driving safe and enjoyable. We doubt that many vehicles have been designed from this perspective.

Just as Caesar's Gaul was in ancient times in three parts divided, so too can we categorize in-vehicle information into three parts:

1. Safety and collision avoidance.
2. Advanced Traveler Information Systems (ATIS).
3. Convenience and entertainment.

For ancient Roman chariots, this information was limited to the direct sensing capabilities of the driver with perhaps an assist from a passenger who whispered salient information in the driver's ear. In the modern road vehicle, sophisticated sensors and on-board computers extend the range of the driver's sensibilities far beyond what the ancient charioteer could perceive with his own unaided senses. This can be a mixed blessing because it offers the potential to present far more information per unit time than the modern driver can process. Advances in vehicle technology have not been accompanied by similar biological improvements in the human operators who remain at the same functional level as the Roman charioteer. Hence, great care must be exercised to combine these sources of in-vehicle information in a manner that drivers find pleasant rather than stressful, and that makes driving safe rather than dangerous.

Table 1 lists some representative safety and collision avoidance systems (CAS) that are either available now in vehicles or under development by automakers and their suppliers. Table 2 lists available ATIS. Table 3 lists convenience and entertainment systems. The total amount of information available from these systems far exceeds driver information processing abilities. While designers are increasing use of speech as both input (command) and output (display) in hopes of decreasing perceptual overload by not presenting non-roadway visual information, this by itself will not solve the overload problem. Understanding auditory information still requires cognitive processing and generating speech commands also places a mental load on driver motor programming capabilities. Hence, human factors research is needed to determine satisfactory methods for combining and integrating these diverse information sources and the response commands associated with them.

Table 1. Potential ITS in-vehicle information for safety and CAS.

• Road Departure
• Rear End
• Lane Change/Merge
• Intersection
• Railroad Crossing
• Drowsy Driver
• Automatic Cruise Control
• Yaw Control
• Roadside and Emergency Services
• Vehicle Location and Voice Availability
• Stolen Vehicle Location System
• Theft Detection

Table 2. Potential ITS in-vehicle information for ATIS.

• Trip Planning
• Route Guidance
• Route Selection
• Multi-Modal Coordination
• Route Navigation
• Yellow Pages
• Automated Tolls
• Motorist Services
• Vehicle Status
• Regulatory Information
• Travel Advisories
• Road Condition
• GPS

Table 3. Potential ITS in-vehicle information for convenience and entertainment systems.

• Telefax
• Pager
• Radio- and CD-based Audio Systems
• Cellular Phone
• Television
• Mobile PC
• Retrievable Settings for Seats and Mirrors
• Personal Messages (e-mail)

Lessons From Aviation

As more and more information sources are added to the vehicle, cars and trucks start to take on some of the characteristics of airplanes. The human factors profession has considerable experience in organizing the information perceived by pilots in the cockpit and several lessons from aviation can be applied to regulating driver workload (2). The general name for this approach is human-centered automation (3). The basic idea is that the needs of the human operator are the driving force behind system design. Since technology is capable of presenting information in almost unlimited formats, it is better to choose a format that is safe, convenient, and pleasant for the driver, rather than a format that is convenient for the vehicle system designer.

Although the designer is most often human, human-centered design does not imply that the system designer is a satisfactory surrogate for the end user. Information that the designer finds useful and interesting may not matter to the driver, and so should not be presented. For example, some early in-vehicle navigation systems displayed the number of satellites currently being received by the vehicle GPS. While a system engineer might find this datum useful, or at least entertaining, the average driver has no interest in the implications for GPS accuracy that this datum might convey and so is better off without it. Similarly, an advanced vehicle yaw control that indicates it is operating by displaying a light and an auditory tone is telling the driver more than she wants to know. In aviation, a principle called the “dark and silent cockpit” has been quite successfully used by Boeing for many years. Information the pilot does not need is not displayed. For example, if all engines are operating normally, details of this operation are not presented. If an aircraft sub-system is not within normal operating parameters, then various warning messages are displayed. Furthermore, the pilot has the option of calling up information he wants if it is not currently displayed. But, most of the time, many displays are quiet.

Allocation of function is the term used by human factors specialists when deciding what tasks need be performed by the machine part of a system and what tasks by the human part (4). While many allocation of function decisions are fixed (e.g., the driver does not provide motive power to the vehicle), others can vary dynamically. For example, when a driver elects to enable cruise control, he is allocating the function of maintaining constant vehicle speed to the machine. In most systems, dynamic allocation of function decisions are made by the operator. But intelligent machines can also make these decisions. A crash avoidance system may decide there is insufficient time to alert the driver and may decide, on its own, to apply braking force to prevent or minimize a collision. This raises the issue of intelligent interfaces (5). One way to solve the problem of too much in-vehicle driver information is to remove the driver from the loop when this is appropriate. Since people tend to prefer to be in control of their machines, rather than vice versa, this is a delicate area. In aviation, fly-by-wire systems have different modes of operation wherein certain pilot control actions are prohibited. Sometimes mode confusion has lead to serious accidents. But as vehicles become more like airplanes, the need for intelligent interfaces increases. This is another challenge for infotronic systems where aviation experience may prove helpful.

HUMAN FACTORS RESEARCH NEEDS

It is vital to appreciate that integration of in-vehicle information is defined by the intersection of system characteristics and their effects on the driver. System characteristics considered alone are not sufficient. For example, a design engineer working on a particular system listed in tables 1-3 might be very concerned about defining message sets, message priorities, and message density. These features would determine how the system and its driver interface should function. But since the engineer has not considered the human side of the equation, it is likely that the final system will not meet good human factors practices. To accomplish this goal, the engineer need also explicitly consider human-centered effects, such as the compatibility of the message set and its relation to other in-vehicle message sets, the workload imposed on the driver which is a function of driver age and experience, and the mental model used by the driver to interpret system messages. The same system will be treated otherwise by different drivers.

The ultimate solution to the problem of diverse driver mental models and capabilities might be to have a smart chip embedded in the ignition key. This chip would contain information necessary to tailor system responses to the capabilities and desires of each individual driver. Default preferences, that the driver could change for any trip, would automatically be used. The technology to build such smart ignition keys is already here. Many luxury cars on the road today can remember physical preferences of the driver, such as seat position and mirror angles. The critical human factors research need is to determine what information should be entered on the smart key and how each system should use this information, taking into account the set of all in-vehicle systems.

A recent Transportation Research Board (TRB) Workshop on Research Directions on In-Vehicle Computing (Long Beach, CA, August 25-26, 1998) had a break-out session on human factors research needs which the first author was privileged to lead. By design, most of the participants were not human factors specialists, yet they had little trouble articulating research needs. Two high-priority human factors and safety issues were identified:

- Integrate warning systems.
- Integrate all In-Vehicle Information Systems (IVIS).

While the first topic is a sub-set of the second topic, it was decided that the urgent need for rapid progress in this area dictated an immediate start on the less inclusive initial topic. This should be followed rapidly by research on the second topic.

Particular issues within these topics were driver overload (develop metrics and redlines), message prioritization and overlap (resolving conflicts), false alarms (thresholds for driver tolerance), display modality (codify existing research), voice activation (a key subset of modality), and timely generation of guidelines and standards to make this information available to designers in a helpful format.

Another human factors study recently was conducted in support of the U.S. Department of Transportation's Intelligent Vehicle Initiative (IVI) (6). The objective of the study was to identify human factors research needs that could help to ensure a safe and well engineered Generation I vehicle and to provide a technical basis for the development of Generation II and III vehicles. The identified human factors research needs encompass a wide variety of user services including navigation, roadway conditions, automated vehicle query, and driver information systems. Driver assistance will span from autonomous cruise control to vehicle control, combining both lateral and longitudinal elements of the driving task, elevating the driver to the role of systems manager rather than being a manual controller.

Potential IVI technologies and the related human factors issues were identified and discussed at a workshop comprised of IVI program stakeholders held in December, 1997. Among the study conclusions was an overall need to integrate and manage information being presented to the driver as well as an understanding of the effects of integrating information into multi-function displays.

One of the primary concerns was the need to develop an understanding of how best to present collision avoidance information to the driver. To optimize Collision Avoidance System (CAS) presentation, research should provide designers with guidance on the optimal use of vision, audition and tactile information displays to elicit from the driver the response desired to prevent the impending situation. As CAS sensors expand from surveying the area in front of the vehicle to include a series of sensor packages that provides for 360 degrees of coverage of the vehicle, guidelines will be needed to integrate these various sensors into a total picture to be presented to the driver.

CAS information must be combined with other forms of ITS information such as routing and navigation of driver information. How will these additional information displays impact the CAS message? As part of a multifunction display, CAS information will have to compete for the driver's attention. This study noted that both driver acceptance and driver workload issues regarding the combining of displays should be researched. Should CAS displays be designed separately from other information displays or do drivers respond appropriately to integrated displays? Do drivers prefer separate displays? Integrated displays should be designed based upon guidelines generated from research on the relevant perceptual and cognitive issues that bear on human-centered automation.

Additional human factors research issues described the needs of commercial trucking and transit operators. Currently, heavy trucks already have more specialized displays than are found in a regular private vehicle, providing the truck driver with information on vehicle or cargo status, trip requirements, and the desires of the company dispatcher. Both regular auto displays and the additional heavy truck displays will soon be joined by the array of displays being developed for future heavy vehicles. These future displays can include more specialized information that pertains to a particular phase of the trip such as collision avoidance, vehicle stability, driver status, cargo identification and automated transactions. Again, research is needed to develop empirically-based guidelines to support the integration of these displays within the vehicle cab that will best support the operations of the driver. Issues that should be addressed include the determination of when information should be combined into multifunction displays or remain as separate displays and controls. What are commercial operator information needs and how do they change within different phases of the trip? What is the workload capacity of the vehicle operators and in what order should the information be presented to the operators?

CONCLUSIONS

The good news is that, as a discipline, human factors has the tools to answer these questions. For example, recent guidelines for ATIS/CVO (7) have been placed on the Internet by the Federal Highway Administration (8). Much effort was devoted to making these guidelines helpful for designers, many of whom lack formal training in human factors. Similar guidelines are needed for human-centered integration. It is important to realize that such guidelines are more than compilations of existing human factors practices extracted from older guidelines related to other domains, such as defense or human-computer interaction. The unique requirements of in-vehicle ITS information demand dedicated empirical research to ensure that ITS workload does not interfere with safe and convenient vehicle operation (9). While simulators are useful for studying driver response to advanced in-vehicle systems (10), there are also abundant opportunities for on-road research. The human factors profession has evolved many techniques for collecting valid driver data.

The bad news is that the will to build such integration guidelines has not yet been translated into action. This reminds us of an advertisement for a popular brand of oil filter: you can pay a little now or a lot later. We have confidence that the requisite human factors knowledge for human-centered integration will be developed sooner or later. Members of this audience will help make the decision about the timing of this knowledge — will it be soon so that the ITS community can benefit from human-centered integration, or will it occur later, after consumers have rejected early systems because they add more stress, decreasing the pleasures of driving, and because insurance rates have gone up for vehicles that have this advanced technology on board?

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ENDNOTES

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