Haptic feedback research explores driver cognition issues

Only a few decades ago, catastrophic failure of critical components was a common cause of automobile crashes. Broken tierods sent cars hurtling into ditches; brake systems failed suddenly under the strain of mountain driving. Today, improvements in automotive engineering have greatly reduced the number of crashes caused by mechanical failure while driving. So why are so many people still losing their lives every year in automobile crashes?

Statistics show that more than 40,000 Americans die every year on the road—that adds up to more than 650,000 deaths since 1990. And if current trends continue, driving-related incidents will become the third leading cause of death in this country by 2020, up from ninth in 1990.

“These numbers are simply staggering,” says human factors researcher Michael Manser of the ITS Institute’s HumanFIRST Program.

One explanation for this apparent paradox is that while engineers have been very successful in making vehicles safer, drivers remain largely unchanged. Today, driver error may be as significant as mechanical failures. And with the myriad electronic controls and options present in today’s high-tech vehicles, not to mention cellular phones and other personal communication devices that demand drivers’ attention, the potential impediments to good driving performance may be increasing.

All drivers, no matter how experienced, are subject to natural limits of human behavior, cognition, and perception. But just as technology can help overcome physical limitations, it can also help address the perceptual and cognitive biases that often lead to less than optimal driving performance. The potential solution, says Manser, is using technologies that support—rather than impede—good driving practices.

Manser, who is currently interim director of the HumanFIRST Program, has been involved in a range of research projects focused on issues of driver performance since joining the University of Minnesota in 2002. For the past four years, he has been one of the primary researchers in a collaborative effort with Nissan Motor Company of Japan aimed at evaluating a new driver-assistive system that helps improve driver perception of lead vehicle status changes.

The Nissan system uses a haptic (touch-based) feedback mechanism attached to the accelerator pedal to provide variable resistance depending on how close the driver’s vehicle is to a lead vehicle. The closer the vehicle gets to the lead vehicle, the more the pedal pushes back against the driver’s foot. Forward-looking range sensors are able to sense changes in distance much more accurately and quickly than the human eye, and relay these changes instantly even if the driver’s attention is elsewhere.

Although humans are endowed with highly evolved senses of hearing and touch, we rely almost exclusively on vision when we get behind the wheel. In this context, says Manser, haptic feedback systems are interesting because they exploit a relatively underused information channel that may not compete with the many visual cues that drivers already have to process.

ITS Institute researchers have experiment ed with a number of other haptic feedback applications in the past, including the use of variable steering wheel resistance to signal bus operators that they are departing from a designated bus lane.

Unintended consequences

Today, a number of in-vehicle technologies already exist that address drivers’ perceptual and physical limitations. One example is electronic stability control, which improves vehicle controllability by allowing an onboard computer to control the braking of individual wheels and, in some cases, adjust engine power during sudden maneuvers. Onboard GPS systems that re duce the cognitive demands of navigation are proving to be popular optional equipment. New technologies, such as adaptive cruise control systems that automatically maintain a safe headway between vehicles on the highway are now entering the consumer market, while even more advanced vehicle systems incorporating vision enhancement and obstacle detection are

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Car following tests of the haptic feedback system were carried out on the MnROAD test track.

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University team takes second at annual Intelligent Ground Vehicles Competition

A year’s worth of hard work paid off for a team of University students at the 15th annual Intelligent Ground Vehicles Competition in Rochester, Michigan. Mechanical engineer ing master’s students Eddie Arpin and Rich Hoglund, along with computer science doctoral student Seth Berrier, took second and fourth place in two of the June competition’s three cat egories with their robot vehicle, AWESOM-O. There were 36 other teams in this year’s competition. Arpin and Hoglund became involved with the project when they were students of Institute director Max Donath, who told his class about the competition. The two contacted Berrier and began planning their robot in June 2006. With funding from the ITS Institute, the team worked to design a robot that would meet the contest’s criteria. There were two primary challenges. The autonomous challenge, in which the team placed second, required the vehicle to move around an outdoor obstacle course under a prescribed time limit while traveling no faster than 5 mph and avoiding obstacles on the track. Judges ranked the vehicles based on the adjusted time each one took to complete the course. The navigation challenge, in which the team placed fourth, required the robot to travel from a starting point to a number of target destinations and return to home

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In September, the ITS Institute’s rural intersection safety research capped several years of work in the laboratory and on the roads of rural Minnesota with the publication of three new research reports, completing a series that documents the development of an innovative crash reduction system.

Crashes at unsignalized rural high way intersections “are a major cause of death and serious injury in Minnesota, and we find the same pattern all across the United States,” said Intelligent Vehicles Lab director Craig Shankwitz, one of the leaders of the research effort. Between 1998 and 2000, he said, 62% of all intersection-related fatal crashes in Minnesota occurred at rural through- stop intersections where high-speed rural expressways intersect low-speed, low-volume rural roads.

Such statistics motivated the American Association of State Highway and Transportation Officials to officially recognize the importance of rural intersection safety in its Strategic Highway Safety Plan, in which it identified the development and deployment of new technologies as a key safety initiative to address the issue.

“These new reports represent the fruit of several years of innovative, cutting-edge work by all the members of the rural intersection decision support research team,” said ITS Institute director Max Donath.

The new publications bring the Developing Intersection Support Solutions series to a total of five reports. Among the project tasks described are:

- An analysis of rural expressway intersection crashes in Minnesota, including the development of a technique to identify intersections having crash rates higher than expected;
- A statistical model that can be used to estimate or project the societal benefits of deploying a rural stop sign assistant at rural intersections;
- The design, development, and implementation of a rural intersection surveillance and data acquisition system. (Gap acceptance behavior of drivers at several intersections has been quantified, and more than ten crashes have been captured.); and
- A task analysis, design study, and simulator-based evaluation of innovative Driver-Infrastructure Interface (DII) concepts for communicating to the stopped driver, leading to an understanding of the timing and content of information needed for an effective, acceptable DII. The research undertaken in the Rural IDS research program laid the foundation for Minnesota’s participation in the Cooperative Intersection Collision Avoidance Systems (CICAS) research initiative, which brings together federal agencies, automobile manufacturers, and university transportation centers with the goal of developing new technologies to prevent collisions. Minnesota’s CICAS research, expected to last five years, will focus on infrastructure-based solutions and include four main components:
  1. Measurement of driver gap acceptance at an instrumented intersection
  2. Alert and warning algorithms to be used to appropriately inform drivers of dangerous conditions using new changeable graphic signs only visible to stopped drivers
  3. A deployable sensor system used both to compute the dynamic “state” of the intersection and to feed the alert and warning algorithms necessary data
  4. A field validation and subsequent field operational test to quantify the performance and safety benefits of such systems

The reports are available on the Institute’s Web site at www.its.umn.edu/publications/ResearchReports.

### Rural intersection safety reports published

The Fall 2007 Advanced Transportation Technologies Seminar Series featured University of Minnesota faculty and visiting researchers presenting their recent ITS-related work on a variety of transportation topics.

The burgeoning popularity of cellular phones, PDAs, and other mobile electronic devices has sparked heated debate about the potential for increased crash risk due to driver distraction. Louis Tijerina, a human factors researcher and driver distraction expert with the Ford Motor Company, presented an overview of recent research on this important safety question and on the more general issue of interface design for driving safety at a November 13 seminar.

Determining what aspect of cell phone use—dialing, conversation, or other factors—produce this elevated risk is an important step toward designing better interfaces, said Tijerina. According to the data Tijerina reviewed, the act of looking away from the road to dial a number appeared to be much more risky than actually holding a typi- cal conversation; looking away from the road is also a risky behavior when it comes to adjusting the stereo system or other in-vehicle controls. This is one of the motivations for the voice interface feature of Ford's Sync system, he said.

Peeta, director of the NEXTTRANS Center at Purdue University, presented a December 4 seminar on methods for modeling the complex interdependencies among civil infrastructure systems. The rapid growth of large urban centers, coupled with the expansion of networks providing transportation, energy, and communications, presents enormous new challenges to infrastructure managers, Peeta said. Recently, natural and man-made disasters have led to cascading system failures in many areas, highlighting the need to understand how multiple interdependent systems interact with each other.

Peeta proposed a “System of Systems” approach to modeling these interactions in which the various infrastructure systems are modeled as components of a multilayer infrastructure network connected through physical, functional, budgetary, informational, and market interdependency factors. This modeling approach, Peeta asserted, will give researchers and infrastructure managers a clearer perspective on complex problems, enabling them to better manage both normal operations and crisis situations.

The Advanced Transportation Technologies Seminar Series will resume in Fall 2008. All seminars are free and open to the public. More information is available on the ITS Institute’s Web site at www.its.umn.edu/Events/SeminarSeries/.

### Seminars bring transportation experts from industry, academia to Minnesota
Students visiting the MTO.

Because these systems make driving physically and cognitively easier, Manser says, they all have the potential to improve driver performance by freeing the driver’s resources to focus on primary driving tasks. However, he cautions, technologies can have unintended consequences when they are used in ways their designers never intended. For example, instead of concentrating on driving, people may choose to use their extra cognitive resources to fine-tune the stereo system or chat on their cell phones.

Manser first set out to determine whether drivers could effectively process information presented to them through this novel non-visual channel. The HumanFIRST Program’s immersive driving simulator provided an ideal environment for initial testing, allowing the research team to monitor driver reactions and control the parameters of driving situations in which the haptic feedback system would be activated.

Reaction time data from initial tests revealed that the drivers responded to the sudden slowdown by a lead vehicle by moving their feet off the accelerator pedal more quickly when using the haptic feedback system, and that this benefit was present in both high-complexity and low-complexity secondary task scenarios.

A second finding from this test highlights some of the hidden complexity of driver response. The data reveal that the initial reaction times of drivers using the haptic feedback system are better (i.e., lower), but that the drivers then take slightly longer to transition from the accelerator pedal to the brake pedal. Manser believes this slight delay may be the result of drivers performing a visual double-check on the lead vehicle to make sure it is actually slowing.

This extended transition time is more than offset by the reduced reaction time, making total response time significantly better with haptic feedback than without.

These results substantiate the hypothesis that the use of a haptic feedback system can result in a significant improvement in driver performance, and that this is the result of the system freeing cognitive resources that are then directed to the primary task of driving. However, an unintended consequence is that drivers could use the cognitive resources it frees up to perform other secondary tasks.

The HumanFIRST researchers devised a second test to investigate this possibility. Like the first test, it involved performing a secondary task while following a lead vehicle, but this time the task required drivers to interact with a touch-screen display rather than adjusting a stereo system. This task was designed to be more demanding perceptually, cognitively, and physically in order to approximate the normal demands of an in-vehicle secondary task (i.e., cellular phone) of real-world situations. Drivers were instructed to complete the task as many times as they could within a two-minute period.

In the second set of tests, the researchers found that using the haptic feedback system improved vehicle controllability (the primary task), but also improved drivers’ performance on the secondary task. These findings suggest that drivers are taking advantage of the newly freed resources from the haptic system to improve driving performance and to improve secondary task productivity. In 2006, HumanFIRST received follow-on funding from Nissan to continue researching the implications of the haptic pedal system.

The future of feedback

Haptic feedback is one example of how technology can be used to support and enhance the abilities of drivers. As researchers and automotive manufacturers continue to work together to develop new driver support systems, the future may see further improvements in driving performance.

“Today, we are beginning to develop technologies that address human performance limitations in completely new ways. These tools have the potential to improve performance and make driving easier and more comfortable—but, we need to understand first and foremost how human beings interact with new technologies.”

— Peter Park Nelson

Undergraduate students get perspective on traffic research

Two groups of undergraduate students visited the Minnesota Traffic Observatory during the Fall 2007 semester to get acquainted with the types of research carried out in an advanced transportation research laboratory.

In August, a group of prospective Institute of Technology students were given a tour of the lab’s facilities as part of their visit to the University of Minnesota campus. The group, whose members were interested in pursuing science and engineering education at the university, heard from senior educational systems developer Chen-Fu Liao and MTO Lab Manager Ted Morris about the lab’s data gathering, simulation, and visualization capabilities.

Center for Transportation Studies director Robert Johns welcomed a class of first-year engineering students to the MTO in October. The class, which focuses on writing and communication skills for science and engineering, heard about the importance of communicating research results to foster successful implementation.
base, given only the coordinates of the targets in latitude and longitude. Finally, the vehicles were judged in a design competition based on a written report, oral presentation, and examination of the vehicle.

The team outfitted the 220-pound vehicle with several features. A camera served as the robot’s “eyes,” enabling it to see objects and lines painted on the track. Since that provided only 2-D vision, AWESOM-O was also outfitted with a laser measurement system that allowed the vehicle to know what objects were around it and how close they were. In addition, the robot also used GPS and a digital compass for location and vehicle heading information.

The team’s placement this year is significantly higher than that of the last team that represented the University in 2005, which placed 8th in the autonomous challenge and 11th in the navigation challenge.

“We were happy with the quality of our robot compared with the other teams,” Arpin said. “I think it went as well as it could, since it was our first year in the contest.” Donath, who served as the team’s adviser, was pleased with the team’s performance.

“They worked very well as a team. I’ve really never seen three people work so well together.”

Arpin said the team is considering entering the competition again next year, but would need to recruit a few more team members, as the project would be too big for the three of them to undertake again.