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Transportation Safety in the Digital Age

Automation and the Human: Intended and Unintended Consequences

APRIL 13, 2012

CAMBRIDGE, MASSACHUSETTS

THERE ARE CLEARLY UNINTENDED CONSEQUENCES of introducing automation into transportation communications, navigation and control systems. This roundtable deepened our understanding of human-machine interactions in transportation system design and operation and raised several key points:

-  The human is seen as an essential element in the system for monitoring the automation, to act as a supervisory controller over the automation, and to be able to step in when the automation fails.
-  While there are new paradigms for human-automation, human-agent, and human-robot interaction, we are still very far from automation being a true teammate.
-  Automation policy to guide design, operation and management of highly automated systems needs to be developed.
-  There is a need to further advance our knowledge of attention and interruption management in human-machine teams.

INCREASINGLY HUMANS ARE BEING ASKED TO INTERACT WITH AUTOMATION in complex transportation system management and control functions ranging from air traffic management to unmanned aviation systems, positive train control systems, motor vehicle dashboards, and ship control systems.

Recent reports suggest that non-standard automation of motor vehicle control functions may make transportation vehicles too complicated to drive without a much greater emphasis on operator training. Changes in the roles and responsibilities of the human operator introduce difficult and error-prone tasks to system designers, human operators and automation supervisors, and technicians, especially in the context of unforeseen or atypical events.

Transportation Challenges and Opportunities: A Colloquia Series





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Intended and Unintended Consequences

“Transportation over the centuries has advanced by technology. In recent years we find more and more IT systems, electronic systems, driving transportation and doing things for the operator. Today we want to hear about not only what those technologies are, and not only what their intended consequences are, but especially their unintended consequences.”

– **Robert Johns, Associate Administrator and Director**
Volpe National Transportation Systems Center

The Program

Welcome and Introductions

Keynote Remarks

What Transportation Accidents Reveal About Automation

Is “Team” a Good Metaphor for a Human-Automation System?

Attention and Interruption Management in Human-Machine Teams

Authority, Responsibility, Adaptivity and Cooperation in Human-Automation Interaction

Question and Answer Session

The Expert Panel

Robert C. Johns, Associate Administrator and Director of the Volpe Center

Gregory D. Winfree, JD, Acting Administrator and Deputy Administrator, Research and Innovative Technology Administration

The Honorable Robert L. Sumwalt, Member, National Transportation Safety Board

Daniel Serfaty, Chairman and CEO, Aptima, Inc.

Nadine B. Sarter, Professor; Ph.D., Industrial and Systems Engineering, University of Michigan

Thomas B. Sheridan, Ph.D., Emeritus, Professor of Engineering & Applied Psychology (Mechanical Engineering), Professor Aeronautics & Astronautics, Massachusetts Institute of Technology

Stephen M. Popkin, Ph.D., Director, Center for Human Factor Research and System Applications at the Volpe Center

Please note: The views of non-DOT participants do not necessarily reflect the views of the U.S. Department of Transportation.

COORDINATION AND COLLABORATION are central challenges in fusing human and automated control systems. The relationship is evolving from master/slave to the notion of two agents collaborating. True teamwork between humans and automations must await a day when computers will be able to recognize and react to human signals and thereby judge the appropriate time to interrupt a human engaged in performing a task.

The Opportunity of “New and Better”

“In just over a decade, the script for how we live and do business has been almost completely rewritten ... We have a wonderful opportunity to harness the tide of change, rather than being caught in its wake.”

– **Gregory D. Winfree, JD**

Research and Innovative Technology Administration

- Industry practices, rules, regulations, and statutes need to be reevaluated and updated to reflect the sea change in how operators, managers, vehicles, and infrastructure interface with automation technology.
- What was once considered science fiction is now very much a possibility. The future of surface transportation could very well be defined by driverless vehicles.
- Our challenge is to engage in R&D that is inclusive and cross-modal, focusing on vehicles but also pedestrians and wildlife and planning for all types of community—urban, rural, and in between.
- We need new and better ways to work together, coordinating research and improving communication among government, industry, and the academic community.



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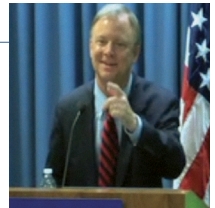
What Transportation Accidents Reveal About Automation

“Humans are not good monitors of highly automated systems ... Automation needs to support the human, and not the other way around.”

– **The Honorable Robert L. Sumwalt,**

National Transportation Safety Board

- The advantage of human-centered automation is that the operator is actively engaged in controlling the vehicle as long as certain parameters are not exceeded. The system intervenes only if the operator attempts to take the vehicle “outside the box” of accepted maneuvers.
- The disadvantage of non human-centered automation is that the operator is removed from the control loop—the operator is limited to just monitoring the system. The hazard is that the operator is not fully engaged—or not engaged at all. Recent train and plane crashes happened when automation failed and human operators waited too long to recognize the failure and react.
- Human operators need to be actively engaged in the control loop and kept from over-reliance on the automation.



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Is “Team” a Good Metaphor for a Human-Automation System?



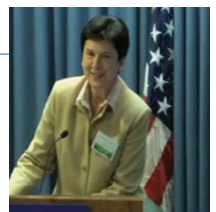
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“So what kind of signals do I send to the automation? In addition to cognitive signals, am I sending emotional signals? And are those signals interpreted?”

– **Daniel Serfaty**
Aptima, Inc.

- Teams are very complex—key competencies are initiative/leadership, monitoring and feedback, compensatory behavior (jumping in to help), and adaptability. These must be considered, in constructing human-automation “teams.”
- The new science of teams has developed quantitative measures which have promise for understanding complex teams of humans and automation. The measures are energy (how team members contribute to the team as a whole), engagement (how team members communicate with each other), and exploration (how different teams communicate with one another).
- “Congruence” is a concept of fit, that may provide a way to introduce automation and anticipate the kinds of shift in roles and functions that will result in the human side of the equation. It may require redesigning the human team in order to integrate the automation optimally.
- We are still very far from automation being a true teammate.

Attention and Interruption Management in Human-Machine Terms



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“A lot of interruptions serve a good purpose ... but if they’re untimely or poorly designed we know that they will lead to errors, to reduced productivity, and of course to people being annoyed by technologies interrupting them when it shouldn’t.”

– **Nadine B. Sarter, PhD,**
University of Michigan

- Many current technologies are unable either to recognize or to judge context in order to determine whether a human should be interrupted at a given moment. Even two humans, if separated physically, lack the relevant cues to make a judgment. The performance costs of interruptions range from inappropriately missing or ignoring a signal to inappropriately stopping the ongoing task to switch to the interrupting task.

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Master caution in the cockpit of a commercial aircraft. © iStockPhoto/Nasowas

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- “Pre-attentive reference” signals may help an operator determine whether to engage an interruption, without taking focal attention off the ongoing task. Examples include changing wallpaper color, emitting different scents (e.g., lemon smell or rose smell), or a buzzing sensation in the hands.
- “Graded feedback” reflects the urgency of the interruption, by providing a signal that varies over time in frequency and/or intensity to reflect the urgency of a situation. For example, the frequency of a buzzing signal or the intensity of a color might be increased to reflect greater urgency.
- Although research focuses on sharing two tasks, most workplaces now bombard the operator with 3, 4, or more tasks simultaneously. Research needs to focus on helping humans notice signals and make good judgment calls, as it will be many years before automation learns to make judgment calls.

Authority, Responsibility, Adaptivity and Cooperation in Human-Automation Interaction



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“It’s hard enough to have the human understand what the computer’s doing, but having the computer understand what the human’s doing and intending is even a bigger challenge—we’re a long way from that.”

– **Thomas B. Sheridan, PhD,**
Massachusetts Institute of Technology

- Humans shouldn’t always be in charge—for example, not when there’s no time for a human to respond and not when the human doesn’t have the knowledge to manage responsibly. People are slow, compared to automation—there is a limit on how fast humans can absorb information and decide what is relevant—and some humans are much slower than others.
- There are degrees of automation, all the way from automated suggestions or recommendations to the automation choosing and implementing an action without any reference to the human. Sometimes the human monitors or supervises the automation, and sometimes the automation needs to monitor the human—for example, wake the human up.
- There are significant challenges to getting humans and computers to cooperate. If their goals are different, or if they cannot stay synchronized, there will be conflict. It’s a big challenge to measure and model humans’ intentions and adaptive behavior so that a computer can “understand.”

The Expert Panel



Speakers and moderators for the “Roundtable on Automation and the Human: Intended and Unintended Consequences,” at the Volpe National Transportation Systems Center, April 13, 2012. From left: The Honorable Robert L. Sumwalt; Daniel Serfaty; Thomas B. Sheridan, PhD; Nadine B. Sarter, PhD; Gregory D. Winfree, JD; Robert Johns; Stephen M. Popkin, Ph.D.

Meet Volpe

Volpe has been helping the transportation community navigate the most challenging problems for more than 40 years. As the National Transportation Systems Center, our mission is to improve transportation by anticipating and addressing emerging issues and advancing technical, operational, and institutional innovations across all modes. Part of the U.S. Department of Transportation’s Research and Innovative Technology Administration, Volpe is a unique Federal agency that is 100 percent funded by sponsor projects.

Home to renowned multidisciplinary expertise in all modes of transportation, Volpe serves its sponsor agencies with advanced technologies, research, and programs to ensure a fast, safe, efficient, accessible, and convenient transportation system that meets vital national and international interests and enhances the quality of life for the traveling public, today and into the future.

About the Colloquia Series

Volpe, The National Transportation Systems Center, is pleased to present a new Colloquia Series on Transportation Challenges and Opportunities. The series, which brings together industry experts from government, academia, and the private sectors, continues Volpe’s long tradition of facilitating knowledge exchange across the transportation community and takes a fresh approach in addressing today’s transportation challenges and issues. The series is available via webinar and members of the transportation community are encouraged to participate in question and answer periods.

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