Human Autonomous Vehicles Interactions: An Interdisciplinary Approach

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Abstract
This paper describes an interdisciplinary approach we adopted at the University of Michigan to investigate how humans interact with autonomous vehicles. We present four projects that the Michigan Autonomous Vehicle Research Intergroup Collaboration (MAVRIC) is working on, leveraging expertise from human–computer interaction, industrial engineering, mechanical engineering, information systems, and information and computer science.

Author Keywords
Trust; situation awareness; takeover transitions; autonomous vehicles, self-driving cars

ACM Classification Keywords
H.1.2 User/Machine Systems: Human factors; H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; I.2.9 Robotics: Autonomous vehicles.

Introduction
Automated driving is becoming an engineering reality, with increasing levels of automation being introduced and built into autonomous vehicles. According to the Society of Automotive Engineers (SAE), driving automation can be categorized into six levels, with level

0 being no automation and level 5 being fully automated [1]. Level 2 and near level 3 automation have been gradually implemented in vehicles (e.g., Volvo XC90, all Tesla models, Mercedes S class), and clear roadmaps toward level 4 automation have been announced by major car manufacturers. Although there is still speculation of when full automation will be realized, vehicles of level 5 automation have been on the road for testing.

Automated driving introduces new research questions on how drivers, passengers, and other road users will interact with autonomous vehicles. For instance, will drivers and other road users trust and accept autonomous vehicles? How will highly automated driving change drivers' cognitive workload, attention allocation, and situation awareness (SA)? Will drivers be able to take over the driving task when automation fails unexpectedly?

To answer such questions, we adopted an interdisciplinary approach leveraging expertise from human–computer interaction, human factors, mechanical and industrial engineering, and information and computer science. In this paper we describe four projects the team is working on.

Project 1: AV and Pedestrian Interaction

In Project 1 the team is investigating how autonomous vehicles interact with pedestrians [2]. Autonomous vehicles (AVs) have the potential to improve road safety. Trust in AVs, especially among pedestrians, is vital to alleviate public skepticism. Yet much of the research has focused on trust between the AV and its driver/passengers [3]. To address this shortcoming, the team employed communication theory to examine the interactions between AVs and pedestrians. We conducted a human-in-the-loop experiment with 30 participants in an immersive virtual reality environment. The study manipulated two factors: AV driving behavior (defensive, normal and aggressive) and the traffic situation (signalized and unsignalized road crossings).

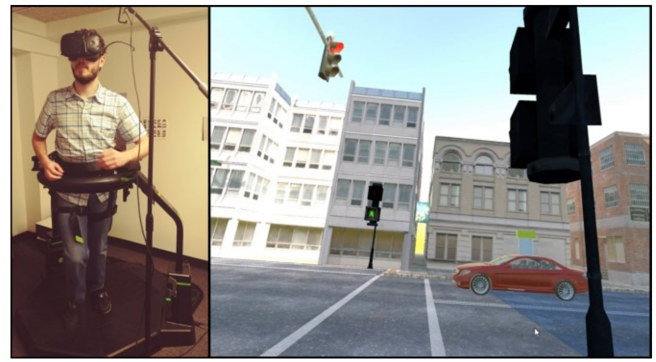

Figure 1: Virtual Reality Setup in Project 1

Our preliminary results reveal that (1) aggressive driving decreases trust in the AV; (2) signalized crosswalks increase trust in the AV; (3) the impact of aggressive driving on trust depends on the type of crosswalk — specifically, the detrimental effects of aggressive driving are alleviated at a signalized crosswalk; and (4) increasing trust in AV is significantly related to reduced distance between the AV and the pedestrian and increases in jaywalking.

Project 2: AV Trust via Situational Awareness

In Project 2 the team investigated the relationship between trust and situation awareness [4]. Vehicle autonomy in the form of driver assistance systems (DAS) allows drivers to immerse themselves in a non-driving-related task. Unfortunately, drivers might not trust the DAS and thus underuse or even discard it. In this project, we employed research from the human factors literature on situation awareness (SA). In this study we sought ways to enhance drivers' trust in autonomous vehicles by augmenting drivers' SA.

Figure 2: Driving Simulator used in Project 2

To examine this, we conducted a human-in-the-loop study with 30 participants. The study manipulated SA embedded in a DAS and assigned the participant a secondary task. In the study, the control condition provided no information to the driver. The low SA condition provided a status update, whereas the high SA condition provided a status update and suggested a course of action. Data collected included measures of trust, trust behavior, and task performance in the form of survey, eye-tracking, and heart rate data. Results show that SA both promoted and moderated the impact of AV trust, leading to better secondary task performance.

Project 3: AVs Explaining Themselves

Project 3 is to investigate the effects of explanations in passengers' trust in AV [5]. Expectations and explanations are essential in establishing a trust relationship. Humans have difficulty trusting an agent that behaves unpredictably and unexpectedly. Research has shown that an AV can potentially mitigate this negative effect by providing an explanation about why it has taken specific actions [6].

Figure 3: Driving Simulator used in Project 3

In this project, we employed research from the human–computer interaction literature on feedback and feedforward. In doing so, we examined the effects of explanations in promoting trust in AVs. The study employed a within-subjects design with four driving conditions: DC1 - the AV provides no explanation about its actions; DC2 - explanations are presented 7 seconds prior to the AV actions; DC3 - explanations are presented within 1 second after actions have been taken by the AV; and DC4 - explanations are presented 7 seconds before the AV takes action and the driver is asked to approve or disapprove the AV's action.

Table 1: Preliminary results on trust, anxiety, preference and cognitive load

	Trust	R.O. Trust	Anxiety	Prefer.	Cog.Load
DC1	5.6	3.3	3.1	5.2	20.3
DC2	5.9	1.7	2.9	5.5	16.6
DC3	5.6	2.7	2.8	5.4	19.3
DC4	5.6	2.3	2.6	5.2	25.6

DC = Driving Conditions; R.O. = Rank Order
Prefer. = Driver Preference; Cog. Load = Cognitive Load

The preliminary results suggest that explanations provided before the AV takes actions promote more trust than explanations provided afterward.

Project 4: Drivers' Readiness to Take Over

Through Project 4 we aim to design adaptive in-vehicle alerts in response to drivers' takeover readiness. Despite the promising safety benefits of highly automated driving, the concern from a human factors perspective is that drivers become increasingly out-of-the-loop when they start to engage in non-driving-related tasks. Drivers who are decoupled from the operational level of control have difficulty taking over in any situation, and particularly in situations that the automation cannot handle. To tackle this problem, we drew from the engineering and computer science literature on computational modeling. In this project we propose to design an adaptive in-vehicle alert system in response to drivers' takeover readiness. We aim to develop computational models capable of predicting driver takeover readiness by analyzing both the driver's physiological data and data from the current driving scenario in real time, and design and evaluate an adaptive in-vehicle alert system.

Interdisciplinary approach

The team adopted an interdisciplinary approach to study how autonomous vehicles interact with drivers, passengers and other road users. Specifically, building the simulators/testbeds and instrumenting various types of physiological sensors often involves expertise from computer science and mechanical engineering. Designing appropriate interaction scenarios requires knowledge from many domains. Analyzing the data obtained from physiological sensors and eye-tracking devices requires techniques in machine learning. Taken together, MAVRIC and its members represent a unique opportunity to leverage an interdisciplinary approach to study human interaction with AVs.

Short biography

The motivation of the team for attending the workshop is to engage with an interested audience on the topic of interaction with autonomous vehicles.

X. Jessie Yang is an assistant professor in the Industrial and Operations Engineering department at the University of Michigan. Her research interests include human factors and HRI. Of particular relevance to the workshop is her research on trust in automation.

Dawn Tilbury is a professor in the Mechanical Engineering department at the University of Michigan with a courtesy appointment in the EECS department. Her research interests include control theory and applications in many different domains. Of particular relevance to the workshop is her research in shared control of unmanned vehicles. She is currently serving as the assistant director of the Engineering Directorate at the National Science Foundation.

Lionel P. Robert Jr. is an associate professor in the School of Information at the University of Michigan and the director of the Michigan Autonomous Vehicle Research Intergroup Collaboration (MAVRIC). His research in the area of AVs focuses on exploring questions related to human interactions with AVs.

Anuj K. Pradhan is an assistant research scientist at the University of Michigan Transportation Institute's Human Factors Group. He is interested in the etiology of injuries and fatalities caused by motor vehicle crashes, from a human factors and behavioral standpoint. In the domain of AVs his focus is on driver behavior & individual characteristics, and on driving simulation.

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