Interacting with Autonomous Vehicles: What Can We Learn from Cognitive Science?

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Abstract
This position paper argues that the field of cognitive science can make valuable contributions to understand human interaction with autonomous vehicles. Specifically, cognitive science can provide: (1) tools and methods, (2) theoretical frameworks, (3) simulations and models. I will illustrate each of these aspects with examples of my own recent research.

Author Keywords
Autonomous driving; Automated vehicles; Cognitive Science; Interruptions; Theory; Cognitive Modeling; Simulation; Transition of Control.

ACM Classification Keywords
H.1.2 [User/Machine Systems]: Human information processing; H.5.2 [User Interfaces]: Benchmarking; I.2.9 [Robotics]: Autonomous vehicles.

Introduction
The CHI 2018 workshop on Autonomous vehicles focuses on what researchers and practitioners in the field of autonomous vehicles can learn from other domains. In this position paper, I argue that these people can also learn more from disciplines that are already involved in the design and evaluation of

autonomous systems. Specifically, I illustrate how the field of cognitive science can help in three ways, by providing: (1) tools and methods, (2) theoretical frameworks, (3) simulations and models. Each of these three aspects will be illustrated with examples from my own recent research.

Tools and Methods

The fields of cognitive science and psychology provide a wide set of tools and methods for experimentally testing hypotheses and designs. The methods range from neuroscientific methods such as EEG-ERP [7] to behavioral methods such as reaction times [6]. Importantly, the field of cognitive science has extensive experience in creating paradigms that systematically control for confounding (or nuisance) factors, such that more confidence can be gained regarding the causality of effects in a user test or experiment. Systematic control is important in the design and evaluation of autonomous systems, as it allows systematic testing of theory and intuition. It complements other approaches, such as observational and ethnographic approaches, in that the experimental methods typically are aimed at deriving general principles that generalize beyond a specific context.

Theoretical Frameworks

The application of tools and methods in various settings and domains has helped the development of larger theoretical frameworks about human behavior and thought. The deployment of autonomous vehicles on the road is still in relative early stages. Although there are theoretical frameworks that are specifically aimed at autonomous vehicles, these are few in number and not yet widely tested. Therefore, the field benefits from applying other, earlier developed frameworks from for example the field of cognitive science to autonomous driving scenarios.

In my own research, I have recently investigated how the paradigm of interruption research can be applied to understand the transition of control in autonomous vehicles in a more systematic way. There exist many detailed frameworks for understanding interruptions in other settings, such as desk-top computing (e.g., [1]). Such frameworks consider the switching of tasks – for example, being interrupted by an in-car alert to take over the wheel – as going through a series of explicit stages. For each stage, there is a wealth of experimental data and theoretical predictions available.

The stages of an interruption, as specified in theoretical frameworks, can be quite easily adapted for an autonomous driving scenario [5]. The adaptation highlights that a transition of control scenario also goes through a series of stages. For each of these stages, predictions about behavior are available – for example, what factors make it relatively easier or harder to switch to another task such as driving. The theoretical predictions help in the systematic study and design of human behavior in autonomous vehicles. Moreover, the theory allows identification of gaps in our understanding that require further research from our community.

Simulations and Models

Theoretical frameworks can be taken one step further by specifying them as computer simulations. Formalizing theory in computational frameworks has a long standing tradition in HCI [3], and has also been applied to study regular driving and driver distraction

[2]. Simulations and models can be used for different purposes. I will discuss three purposes.

A first purpose is to use them as a formalization of theory and as a general framework for describing and predicting human behavior. For example, in my recent work I have used the framework of Hidden Markov Models to describe human mode errors in a systematic way [4].

A second purpose for the use of models is to translate findings from a controlled (lab) setting to a more realistic (on-the-road) setting. For example, in recent work we measured human lane change reaction time to a visual warning in a simulated driving setting [6]. Our setting was kept simple by design, to allow for measurement of small effects in lane change reaction time. However, in the lane change task we did not include additional factors that we expect to affect reaction time, such as effects of glancing in a mirror or due to driving on busy roads. As these factors have been measured before, we could use those measures (i.e., the expected distribution of reaction times) to compare how our results might transfer to on-road conditions. In this process we simulated what reaction times would emerge when our measured times were combined with the predicted effect of the other factors. The results showed that the late reaction times that we measured in the lab might have an even stronger impact in on-the-road situations.

A third purpose for the use of models is in studying, through simulation, how factors that are not directly observable (for example: mental distraction, priorities) affect human behavior. In a simulation model, one can specify how the unobservable factors influence human thought. After this specification, one can measure how these factors affect output measures of the model, such as predicted reaction time or standard deviation of lane keeping performance. These measures can then be compared to human behavior (e.g., experimental results), to give further insight on how these hidden, or latent, variables affect behavior. For multiple examples, see [2].

General Discussion

In this position paper, I have illustrated how we can learn even more from disciplines that are already involved in the design and evaluation of autonomous systems. Of course, the design and evaluation of autonomous systems requires an interdisciplinary approach. Therefore, all of the work discussed above is not solely informed by Cognitive Science research. In fact, some of the broader theoretical work that I described [4,5] has benefitted tremendously from researching it together with researchers from other fields of study.

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