Trust and Control in Autonomous Vehicle Interactions

Chandler Creech, Suresh Kumaar Jayaraman, Lionel Robert, Dawn Tilbury, Xi Jessie Yang, Anuj Pradhan and Katherine M. Tsui

I. Introduction

Autonomous vehicles have the potential to reduce traffic accidents and improve road safety. Ironically, public skepticism due to the risk and safety considerations remains one of the major barriers to the widespread adoption of autonomous vehicles. Therefore, trust is vital to the promotion of the acceptance of this new technology.

This abstract summarizes some recent research on trust in autonomous vehicles and our proposal to promote trust between autonomous vehicles and pedestrians. We aim to develop a trust framework based on expectations, behaviors and communication between the pedestrian and the autonomous vehicle. We describe a user study that is designed to determine the effects of driving behavior and situational characteristics on a pedestrian's trust in autonomous vehicles.

II. Trust in Autonomous Vehicles

A. Related Studies

The problem of trust in autonomous vehicles is not a completely new topic. Current research has primarily focused on the problem of ensuring that the driver trusts the autonomous vehicle [1], [2]. These studies demonstrated that communicating the intent of the vehicle to the driver was an effective method for improving the driver's trust in the autonomous vehicle. However, autonomous vehicles will also have to interact with other road users such as pedestrians, cyclists, other vehicles, etc. Despite this, we know very little regarding issues of trust between autonomous vehicles and these humans outside of the autonomous vehicles who also share the road.

Even though some recent research focusses on developing explicit communication interfaces such as LED message boards, LED lights, speakers, etc., for conveying the vehicle's intent to the surrounding road users [3], [4], the effects of this intent communication on road users' trust is not studied. Also, there is currently no research exploring road users' trust based on the autonomous vehicle's implicit intent communication (such as vehicle driving behavior).

B. Research Objectives

This research work aims to understand how to promote trust between autonomous vehicles and pedestrians (Figure 1), who are the most vulnerable road users. To accomplish this, we aim to develop a framework using trust models to control the vehicle characteristics (which includes driving behavior, explicit intent communication, etc.) to promote trust between autonomous vehicles and pedestrians. The framework will be based on the expectations, behaviors and communication between the pedestrian and the autonomous vehicle [5].

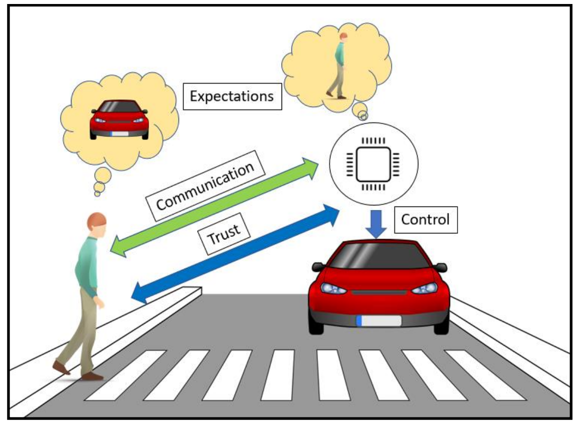

Figure 1. Trust Interaction between an autonomous vehicle and a pedestrian

A user study will be conducted to identify factors which can promote trust. The user study will focus on determining the impact of driving behavior and situational characteristics on a pedestrian's trust in autonomous vehicles. Details of the user study will be explained in the following section.

III. User Study

In this user study, we consider the interaction between a pedestrian and autonomous vehicles at a midblock crossing. In addition to vehicle driving behavior (defensive, normal or aggressive), the study also aims to analyze the effect of crossing type (signalized or unsignalized) on the trust of pedestrians.

The hypothesis of this study is that pedestrians will exhibit more trust towards autonomous vehicles at signalized crossings when the vehicle exhibits more defensive driving behavior.

A. Method

This study will employ an experimental design using virtual reality. Participants will act as pedestrians tasked with getting across a mid-block crossing with several autonomous vehicles approaching. There will be six conditions (2 x 3) represented by the type of autonomous driving behavior (defensive, normal, aggressive) and the type of crossing (signalized, unsignalized). Autonomous driving behavior will be manipulated by the vehicle acceleration and jerk profiles.

B. *Experimental setup*

The participants will be placed in an immersive virtual reality environment utilizing an omnidirectional treadmill [6] and a virtual reality headset to act as a pedestrian in a simulated urban environment as shown in Figure 2.

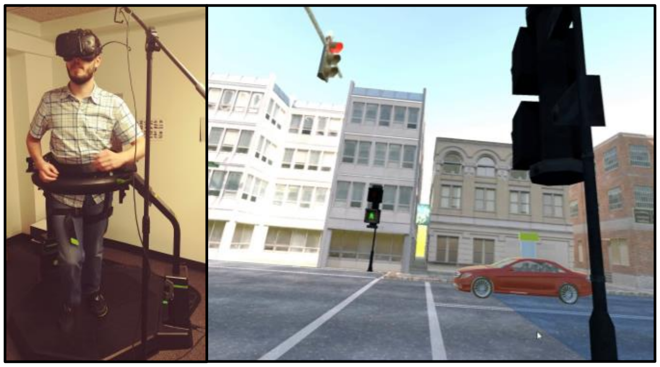

Figure 2. Virtual Reality setup for user study

C. *Measurements*

The study will collect attitudinal, behavioral and physiological measures. The attitudinal measures include trust [7], [8], mood [9], propensity to trust, simulation sickness [10] and task load [11], which are measured through surveys. The behavioral measures include waiting time, crossing time, walking speed of the participants, etc., which will be collected from the simulation. The physiological measurements of heart rate variability and eye tracking will be taken during the experiment.

IV. FUTURE WORK

The user study is expected to support the notion that vehicle driving behavior and situational characteristics are important factors in promoting pedestrian trust. The study can be extended to evaluate the effects of driving behavior on different categories of pedestrians (age, physically disabled, blind, etc.) or groups of pedestrians. Similar user studies can be conducted to evaluate effects of other vehicle characteristics such as explicit intent communication, pedestrian recognition, etc.

The most significant pedestrian trust factors would be revealed by these user studies, which could be used to model pedestrian's trust in autonomous vehicles. The same trust modelling framework can be later extended to include other road users such as cyclists, other drivers, etc.

ACKNOWLEDGMENT

This research is partly funded by Toyota Research Institute, North America.

REFERENCES

[1] Verberne, F.M., Ham, J. and Midden, C.J., 2012. Trust in smart systems sharing driving goals and giving information to increase trustworthiness and acceptability of smart systems in cars. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *54*(5), pp.799-810.

[2] Rezvani, T., Driggs-Campbell, K., Sadigh, D., Sastry, S.S., Seshia, S.A. and Bajcsy, R., 2016, November. Towards trustworthy automation: User interfaces that convey internal and external awareness. In Intelligent Transportation Systems (ITSC), 2016 IEEE 19th International Conference on (pp. 682-688). IEEE.

[3] Florentine, E., Ang, M.A., Pendleton, S.D., Andersen, H. and Ang Jr, M.H., 2016, October. Pedestrian Notification Methods in Autonomous Vehicles for Multi-Class Mobility-on-Demand Service. In *Proceedings of the Fourth International Conference on Human Agent Interaction* (pp. 387-392).

[4] Lagstrom, T. and Lundgren, V.M., 2015. *AVIP-Autonomous vehicles interaction with pedestrians* (Doctoral dissertation, Thesis).

[5] Hoff, K.A. and Bashir, M., 2015. Trust in automation integrating empirical evidence on factors that influence trust. Human Factors: The Journal of the Human Factors and Ergonomics Society, 57(3), pp.407-434.

[6] Virtuix Omni : http://www.virtuix.com/

[7] Muir, B.M., 1987. Trust between humans and machines, and the design of decision aids. *International Journal of Man-Machine Studies*, *27*(5-6), pp.527-539.

[8] Jian, J., Bisantz, A. M., & Drury, C. G. (2000). Foundations for an empirically determined scale of trust in autonomous systems. International Journal of Cognitive Ergonomics, 4, 53–71.

[9] Bradley, M.M. and Lang, P.J., 1994. Measuring emotion: the self-assessment manikin and the semantic differential. Journal of behavior therapy and experimental psychiatry, 25(1), pp.49-59.

[10] Kennedy, R.S., Lane, N.E., Berbaum, K.S. and Lilienthal, M.G., 1993. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. The international journal of aviation psychology, 3(3), pp.203-220.

[11] Hart, S.G. and Staveland, L.E., 1988. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. Advances in psychology, 52, pp.139-183.