

An investigation into human-autonomous vs. human-human vehicle interaction in time-critical situations

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ABSTRACT

We performed a driving simulator study to investigate merging decisions with respect to an interaction partner in time-critical situations. The experimental paradigm was a two-alternative forced choice, where the subjects could choose to merge before human vehicles or highly automated vehicles (HAV). Under time pressure, subjects showed a significantly higher gap acceptance during merging situations when interacting with HAV. This confirmed our original hypothesis that when interacting with HAV, drivers would exploit the HAV's technological advantages and defensive programming in time-critical situations.

CCS CONCEPTS

- Human computer interaction (HCI)

KEYWORDS

Human-machine interaction, trust in automation, autonomous vehicles, cyber-physical systems

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1 Introduction

In a few years, traffic participants will share roads with highly automated vehicles (HAV). Therefore, it is important to investigate how humans would behave in complicated traffic situations in the presence of HAV. [1] investigated the interaction between HAV and pedestrians crossing a road within a game theoretic chicken game model. The main assumptions of the authors were that HAV would act more cautiously and are more law abiding than human drivers. These assumptions are based on the experiences described in [2]. This makes HAV incapable to act risk averse in a chicken game, giving the humans an advantage during the interaction, thus leading to the assumption that humans may utilize the HAV's defensive programming to gain a temporal advantage.

The main objective of this study is to investigate potential behavioral differences concerning human-human and human-HAV interactions in complex merging situations. We want to investigate if humans will take advantage of the alleged technological advantages of HAV as described in [1] to gain a temporal advantage in the experiment. For this purpose, we conducted a driving simulator study in combination with a questionnaire survey.

2 Methods & Materials

The study was conducted with 17 subjects (7 males, 10 females, mean age = 26.0y, SD age = 9.3y, mean driving experience = 8.6y) in a full-scale fixed-base driving simulator which offered a field of view of 150 degree.

During one block of the experiment, each subject encountered 10 intersections. At each intersection, the subjects had to stop because of a stop sign and the arriving traffic. The cars in the traffic drove 50 km/h and, except for one wider gap, kept a time headway that made merging impossible. The subjects could choose to either merge into the gap or wait until all the traffic passed. Since the

subjects are waiting at a stop sign and the gap size was relatively small, merging would force the car after the gap to brake.

In five of the intersections, a HAV followed the gap, and in the other five intersections, a normal human-driven car drove after the gap. The subjects were told beforehand that the HAV were defensively programmed to avoid collisions [1], although all cars followed the same driving behavior during the simulation.

The experiment consisted of three blocks: the first block was a training session, where the subjects familiarized themselves with the experimental setup and the driving simulator dynamics. The subjects were asked to complete the course under a given time limit during the second or third block to get an additional monetary reward, whereas the order of the blocks was altered to avoid a learning effect. The experiment would have been stopped in case of an accident, which did not occur during the study.

The subjects filled out a questionnaire after the experiment. It included self-assessment items about driving experience and trust in HAV. Subjects were asked to rate all items on a six-point scale with six being maximum agreement on the item.

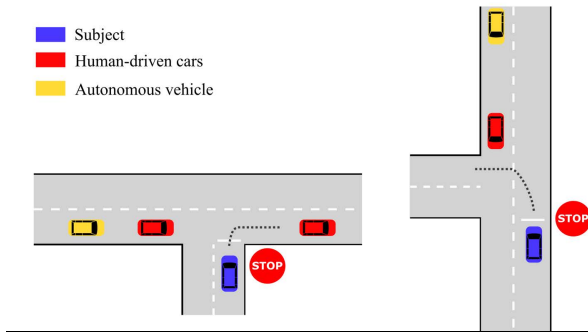


Figure 1: Sketch of a right and left turn at an intersection through oncoming traffic: The subject is waiting at a stop sign. The arriving traffic includes human driven cars (red) and an autonomous vehicle (yellow). The subject has the option to merge into the gap or wait for the traffic to pass.

3 Results & Discussion

From the behavioral data, the percentages of accepted gaps given the type of interaction partner were determined. If a subject decided to merge in four out of the five intersections with a HAV after the gap, the gap acceptance probability with respect to HAV would be 80%. Accordingly, the subject then decided to wait for all the cars to pass in one out of the five intersections. The percentages of accepted gaps were averaged over all subjects. Additionally, the means and standard deviations for the quantitative items of the questionnaire were calculated.

A total number (N) of 168 and 170 merging situations were analyzed for the experiments with and without a time limit respectively. During the block without a time limit, the subjects merged in 27.1% of the intersections if the car after the gap was a HAV [s. Table 1]. Accordingly, in 72.9% of the intersections, the subjects waited and let all cars pass. In the intersections with just human cars present, they merged in 34.1% of the cases. During the

blocks with time limit, the number of accepted gaps increased significantly. Subjects merged before a HAV in 89.0% of the intersections and in 69.4% of the cases before a human driver after the gap. The difference between these two conditions was significant with $p = 0.002$ given a chi-square test.

These results are also consistent with the results of the questionnaire. The mean score for questions related to trust in HAV is 3.90 ± 1.44 , which shows an above average agreement with the given items. Overall, the results suggest that human drivers are more likely to merge before a HAV than human drivers in a time-critical setting.

Table 1. Percentages of accepted gaps

	Without time limit (N = 170)	With time limit (N = 168) $p = 0.002^{**}$
Human (%)	34.1	69.4
HAV (%)	27.1	89.0

The subjects came from a relatively young (mean age = 26y) and heterogeneous demographic with academic background, thus having potentially high trust in technology [3]. Subjects with more conservative views on the reliability of technology may act more cautiously during the interaction with HAV.

The results of this study are based on the assumptions that the subjects recognize HAV and know about their technological advantages and defensive programming. These assumptions follow the argumentation given in [1] and mirror the promises given by current research in the field of HAV both from a research and industry perspective.

4 Conclusion

We presented a study concerned with the investigation of human-HAV interaction. It could be shown that the subjects merged more frequently in front of a HAV, thus taking advantage of the law-abiding and cautious driving strategy of HAV. The subjects overestimated the behaviour and driving performance based on the unjustified information about the defensive programming of the HAV. This automation complacency may lead to dangerous traffic situations or even accidents in case of excessive overestimation of the reaction times of the HAV or sensor failure [4].

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