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Sense of Safety for Pedestrians and Autonomous Vehicles

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ABSTRACT

As the electric vehicle industry continues to progress, vehicles equipped with active driving capabilities are becoming increasingly prevalent on the road. The widespread commercialization of advanced autonomous vehicles necessitates the resolution of their capacity to interact with other road users in a safe, precise, and efficient manner. In the daily accident the mortality rate among pedestrians and cyclists constitutes 26% of all accidents, which is a significant statistic that most previous studies have focused on, particularly on the interaction between autonomous vehicles and vehicle occupants. However, research into how autonomous vehicles interact with pedestrians outside the vehicle is comparatively scarce. The academic community, primarily focused on the vehicle kinematics of eHMI and the characteristics of unmanned automobile traffic environments, has conducted extensive research and analysis. This article aims to utilize the richness of survey data to provide insight into the intuitive feelings of pedestrians when interacting with unmanned vehicles in the absence of traffic infrastructure. This article aims to provide insight into pedestrian feelings when interacting with unmanned vehicles and proposes a model for safe interactions in the absence of traffic infrastructure.

Keywords: Autonomous car, Pedestrian, Sense of safety

INTRODUCTION

As the electric vehicle industry continues to progress, vehicles equipped with active driving capabilities are becoming increasingly prevalent on the road. By 2030, the number of global L4 and L5 grade autonomous cars is expected to exceed 8 million. The widespread commercialization of advanced unmanned vehicles necessitates the resolution of their capacity to interact with other road users in a safe, precise, and efficient manner.

Every day, the roads are plagued by a multitude of collisions. According to the World Health Organization's "Global Road Safety Status Report 2018," the mortality rate among pedestrians and cyclists constitutes 26% of all accidents, which is a significant statistic that most previous studies have focused on, particularly on the interaction between autonomous vehicles and vehicle occupants. However, research into how autonomous vehicles interact with pedestrians outside the vehicle is comparatively scarce. The academic community, primarily focused on the vehicle kinematics of eHMI and the characteristics of unmanned automobile traffic environments, has conducted extensive research and analysis.

The studies towards autonomous vehicles mainly focus on the interaction of passengers in the vehicle, with relatively low attention to the interaction with pedestrians outside the vehicle. Currently, research on the interaction between autonomous vehicles and pedestrians mainly focuses on eHMI, vehicle kinematics characteristics, traffic environment characteristics, and pedestrian characteristics.

In previous studies, the mainstream research direction of pedestrian interaction with autonomous vehicles is on eHMI. Many scholars take eHMI as the main research direction. Canadian scholars Mahadevan and Karthik used vehicle behind-the-scenes simulation and remote control two-wheeled balance car to simulate the interaction between pedestrians and autonomous vehicles. Through testing four different interaction scenarios, it was concluded that autonomous vehicles need to provide clear cues for interacting with pedestrians (Mahadevan et al., 2018).

Regarding the interaction between pedestrians and autonomous vehicles, in addition to the eHMI fixed on the vehicle, there are also devices fixed on the road infrastructure, as well as devices carried by pedestrians, such as mobile phones. China has a huge network of surveillance cameras and a relatively advanced 5G IoT system, so the focus of this study is on the application on road infrastructure.

Automobile manufacturers of different brands have already applied eHMI technology to their latest models, such as Mercedes-Benz, Jaguar, SMART, and other brands. However, eHMI has certain limitations: eHMI of different brands have completely different ways of expression, which creates a learning curve for pedestrians; on the other hand, it is difficult for the government to establish unified standards for the eHMI of multiple brands.

Subsequent studies have also been conducted by scholars on the factors influencing eHMI such as position and colour. In 2022, German scholars Janina and Ingo (Bindschädel et al., 2022) collaborated with Porsche to conduct a “two-step” human-vehicle communication test. The first step involved achieving a forward-leaning effect on the vehicle body by adding a mechanical structure, providing pedestrians with an ambiguous interaction cue at a greater distance; the second step involved providing pedestrians with a clear interaction cue at close range through the eHMI device installed on the vehicle body. Additionally, in their study, they pointed out that when pedestrians interact with autonomous vehicles, the sequence of visual attention is from the grille - hood - windshield - roof, from bottom to top.

In a paper at Chongqing University of Technology, the concept of “pedestrian visions” was proposed. The author recorded 17 videos of pedestrians interacting with vehicles at an intersection using a drone, and analysed the angle of pedestrians’ field of vision frame by frame. The pedestrians were divided into three categories: conservative, cautious, and adventurous.

We divide the interaction between autonomous vehicles and humans into three categories. The first category is the interaction between autonomous vehicles and occupants inside the vehicle, including drivers with control takeover capability and passengers; the second category is people outside the vehicle, such as pedestrians, cyclists, who are more vulnerable to injuries in daily traffic accidents compared to occupants inside the vehicle, and may have weaker sense of security towards autonomous vehicles; the third category includes people outside the vehicle who do not have direct interaction with autonomous vehicles, mainly distant pedestrians or relatives of pedestrians in the interaction scene.

Compared to the other two types of human-vehicle interaction modes, the interaction safety between the occupants and autonomous vehicles is the strongest. However, if we calculate it as 100 units, the interaction safety between the occupants and autonomous vehicles still cannot reach its peak.

Due to pedestrians being a relatively vulnerable group in the interaction between humans and vehicles, pedestrians have a relatively weak sense of safety in the interaction process with autonomous vehicles. With the introduction of autonomous vehicle concepts, pedestrians' sense of safety may decrease to some extent, but as the capabilities of autonomous driving improve, pedestrians will eventually have full confidence in autonomous vehicles.

We define relatives and friends who interact with the surrounding interactive scenes and interact with people and vehicles as associates who interact with autonomous vehicles. In many traffic accidents, many people who do not have direct interaction with vehicles are also affected, such as the families of injured pedestrians.

SURVERY SETUP

The purpose of this study is to investigate the effects of interaction between pedestrians and autonomous vehicles on pedestrians' perceptions of safety. We make the server into three parts, first we collected the basic information of our participants, the sample we collected are all from Jiangsu and Shanghai province, which is one of the most developed areas in China.

In the second part, we investigate the attitude pedestrian towards autonomous vehicles. In the questionnaire, we let participants to rank the daily transportation method they used, then the acceptance of autonomous vehicle. After that we conducted several scene tests, assuming three scenarios as a pedestrian crossing a crossway without traffic light. In the first scene there will be a human driven vehicle riding from aside, in the second scene there will be an autonomous vehicle riding from aside, and in the third scene, there will be a autonomous vehicle with LED light on the windshield, which tells the pedestrians the autonomous vehicle stop or not, riding from aside. After that, we use NPS (Net Promoter Score) to define the acceptance of the participants.

In the third part, we set a open question for the participants to propose the communication method they believe can provide the best sense of safety for human-vehicle communication.

PRELIMINARY RESULTS

At the point of writing this article, the data-collection process is still not complete yet, and we have already collected 55 participants. Although the quantity of the sample at this point is inadequate enough, we still have found something from the data.

All the participants are from Jiangsu and Shanghai province, ageing from 18 to over 60, most of the participants are in 31~40, which are mainly corporation employees. 72% of the participants own a bachelor's degree and 15% own a master's degree. When we talk about the most frequent transportation method the participants use, according to the Table 1 below, 64.7% choose motor vehicles as the most frequent transportation method, while walking be the least. However, in this survey, 70% of the participants have never drive or ride in an autonomous vehicle. We could say the popularity of autonomous vehicle in China is not so widespread at this moment.

Table 1. Rank of daily transportation method.

Option	Mark	1st	2nd	3rd	4th
Motor vehicle	4.07	33(64.7%)	9(17.7%)	5(9.8%)	4(7.8%)
Rail transits	3.44	8(15.4%)	24(46.15%)	13(25%)	7(13.5%)
Electric bicycle	3.27	9(17.7%)	15(29.4%)	21(41.2%)	6(11.8%)
Walking	2.58	5(9.6)	5(9.6%)	13(25%)	29(55.8%)

In the second part of the survey, the participants are told to assume that they are pedestrians intended to cross a road without traffic light, there will be three scenarios being tested in this part. According to the result, the average point of scene one is 5.51, 13 participants chose 8 (nearly extremely likely to cross the road). In the scene two, the average point is 4.85, in which there are 13% participants think they are impossible to cross the road when a autonomous vehicle approaching. However, the average point come to 6.02 when we add a LED light on the autonomous vehicle, it shows that communication between pedestrian and autonomous vehicle is quite essential. The NPS value of three scene are −45.46% for human driven vehicle, −58.18% for autonomous vehicle, and −38.18% for autonomous vehicle with LED light.

In the third part, half of the participants think that autonomous vehicle should equip an artificial intelligence prediction model, and 38% think visual senser is necessary for autonomous vehicle. In the open question, some participant emphasis that visual senser could give them some sense of safety, other else hold the view that if autonomous vehicle could stop at 2 meters away from the crossway would be comfortable for them. A little participant does not believe the present technology, they hope with the advanced artificial intelligence prediction model they may have enough sense of safety to cross the road without a traffic light, when an autonomous vehicle passing by.

CONCLUSION AND FUTURE WORK

To conclude, from the survey we conducted we could see that in Shanghai and Jiangsu province, China, although we could find plenty of news about autonomous vehicles road test, the autonomous vehicle is still not popular among majority of the citizen. According to the three scenario we find out that people still do not have trust towards autonomous vehicles, but it shows the importance of autonomous vehicle – pedestrian communication. Collectively, the findings in this research could contributes to the community that presently autonomous vehicles are not such popular in China, furthermore, the pedestrians are more unconfident with autonomous vehicles, but we could see the importance of pedestrian and autonomous vehicles communication.

The main shortcomings of this study is the lack of real testing scenarios for interactions between autonomous vehicles and pedestrians, and the subjectivity of the questionnaire survey content; at the same time, due to the small sample size of the test, there is a certain bias in the data, especially the lack of testing samples from people who have never met autonomous vehicles before. In the future, this group of people can be included in the testing. The sample we collected from this questionnaire are all from Jiangsu and Shanghai province, there still be some undeveloped areas in China, who have never met autonomous vehicles. Furthermore, the different road culture will also affect the sense of safety, in Zhejiang province there is a legal provision states that all the motor vehicles must stop when pedestrians are crossing the road, or you will be fined. On my point of view, his legal provision may helpful for autonomous vehicle development.

APPENDIX

Study on the Interaction Safety Perception Between Autonomous Vehicles and Pedestrians

Traffic accidents occur worldwide every day, with pedestrians often suffering more injuries. With the rapid development of autonomous vehicles, much attention has been focused on the interaction between occupants and autonomous vehicles, while overlooking the interaction with pedestrians. We plan to conduct a comprehensive questionnaire survey to test the safety perception of pedestrians when interacting with autonomous vehicles in the presence or absence of traffic facilities, and to provide some suggestions for the future development of autonomous vehicles.

1. **Gender:**

   Male Female

2. **Age Group:**

   Under 18 18–25 26–30 31–40 41–50 51–60 Over 60

3. **Occupation:**

   Student Employee Teacher Other (please specify) ______

4. **Education Level:**

   Middle school or below High school/vocational school

College (associate's degree) University (bachelor's degree)
Graduate school or above

5. **Daily Travel Habits (Please rank from top to bottom):**

[ ] Walking [ ] Car [ ] Rail transportation [ ] Bicycle/Electric scooter/Motorcycle [ ] Other

6. **Have you ever ridden or driven an autonomous vehicle?**

Yes No

7. **How likely are you to accept autonomous vehicles? Please choose a number from the following options:**

Impossible ◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10 Extremely likely

8. **When crossing a pedestrian crosswalk without traffic light, how likely are you to pass when a human-driven car approaches from the side?**

Impossible ◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10 Extremely likely

9. **When crossing a pedestrian crosswalk without traffic light, how likely are you to pass when an autonomous vehicle approaches from the side?**

Impossible ◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10 Extremely likely

10. **In order to enhance the interaction between autonomous vehicles and pedestrians, we installed a LED light on the windshield of the autonomous vehicle. When the LED light is yellow, it means the autonomous vehicle has detected pedestrians. When crossing a pedestrian crosswalk without traffic light, how likely are you to pass when a LED-equipped autonomous vehicle approaches from the side?**

Impossible ◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10 Extremely likely

11. **What safety measures do you think autonomous vehicles should have?**

Visual sensors High-precision maps
Artificial intelligence prediction models
Relevant road Internet of Things (IoT) facilities
Other (please specify) ________________

12. **As a pedestrian, what measures do you think autonomous vehicles can take to make you feel safe when crossing intersections without traffic lights?**
13. **What safety regulations do you think the government should strengthen when promoting autonomous vehicles?**

Enact stricter regulatory standards
Strengthen scrutiny of autonomous vehicle technology

Increase penalties for violations
Other (please specify) _________________

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