Passenger Expectation to Autonomous Bus HMI in Different Scenarios: A Field Study

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Abstract. The rapid development of autonomous driving technology made it possible to implement autonomous buses (ABs) for public passenger transport. Previous work has shown that for passengers, different autonomous driving scenarios will produce different information expectations. Passengers will have more information needs for unexpected autonomous driving scenarios. And the provision of relevant information can mitigate these negative effects of unexpected behavior. Nevertheless, it remains unclear in which conditions are unexpected scenarios for passengers of ABs, and what information expectations are for different scenarios. Through a semi-structured field qualitative study of 10 passengers, we have obtained seven factors that affect the HMI experience of ABs. Three unexpected scenarios and four reasons why the unexpected scenarios affect the passenger experience are identified. And passengers' expectations of different HMI information for normal and unexpected autonomous driving scenarios. Based on the above results, we proposed HMI information design recommendations for ABs.

Keywords: Autonomous bus · Automated driving · Human-machine interface · Passenger information

1 Introduction

With the rise of autonomous vehicles, efforts to automate are gradually focused on public transportation. For developing countries, public transportation can best solve this increasing demand for mobility. And it has a positive impact on people's health, transportation, environment, and economic growth [1, 2]. In previous work, there have been many studies on the HMI of autonomous vehicles, but Millonig and Fröhlich [3] identified a number of challenges regarding passenger interaction in automated public transport. They concluded that in the research of automobile user interface, the discoveries of private cars cannot be simply transferable to autonomous buses, but the needs of passengers need to be understood in a specific public transportation environment. They also highlight a need for transparency and efficiency in the communication with not only the road environment but passengers as well.

Autonomous buses and autonomous private cars also have obvious differences in how passengers use them. When people experience unexpected and unpredictable vehicle behavior. This can lead to anxiety and lack of trust, and unacceptance of autonomous vehicles [4]. It has been shown that providing explanations to drivers can alleviate these

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negative effects [5]. Current studies have identified unexpected scenarios for drivers of autonomous private cars. In addition to the sudden behavior of some vehicles, it also contains some takeover scenarios [6]. On the bus, passengers are not expected to be ready for takeover. Therefore, autonomous driving may have different unexpected scenarios for private car drivers and bus passengers. There are also differences between private car drivers and bus passengers in terms of information expectations in different scenarios. Information is generally regarded as an integral component for comfort when using public transportation [7]. Private cars need to provide a variety of information to maintain the driver's situational awareness to ensure the correctness and high efficiency of the takeover [8]. At present, there have been a few studies on the HMI information of autonomous buses. Mirnig et al. [9] have explored three different HMI displays that communicating information related to the upcoming stops and timely stop requests to the buses to passengers. Fröhlich et al. [10] studied how to convey the awareness and intend of the vehicle to passengers, and the usefulness of this information communication. Lundquist [11] studied the multi-device information prompts from getting on to getting off the car to improve the user experience. However, the scenarios of these studies are not systematically defined and differentiated.

Our work investigates passengers' perceptions of autonomous bus HMI and unexpected scenarios, intends to provide assistance to designers so that passengers can obtain the more needed information in different scenarios and enhance the ride experience. In this article, we use a semi-structured qualitative study of 10 people:

(1) Describe the reasons why the existing HMI cannot satisfy passengers;

(2) Explain the unexpected scenarios in the minds of autonomous bus passengers and the reasons why these scenarios affect the experience;

(3) Discuss the HMI information expectations of autonomous bus passengers in different scenarios; and.

(4) Think about how we can design better HMIs to enhance the ride experience.

2 Method

2.1 Participant

We recruited 10 participants from design majors to ride on autonomous buses. Seven passengers were female and three passengers were male. Nine participants belonged to the age group of 18-to-25-year-olds, one belonged to the age group of 26-to-30-year-olds. They have the need to travel by bus in daily life, and nearly a third of them (30%, n = 3) take the bus five times a week or more. One in five people (20%, n = 2) had already experienced autonomous vehicles, and only one person had been riding in an autonomous bus before. None of the participants were familiar with the test road.

2.2 Setup in the Autonomous Bus

Participants took the autonomous bus and participated in a 20 (10 * 2) minute trip. The bus was 11 m long and had 20 seats. The bus operated primarily on SAE Level 4, and it drove with a speed between 10 and 30 km/h - faster on the straight segments and slower during turns. The autonomous bus traveled along a predetermined circular route in a closed test area. The bus encountered multiple traffic lights and turned along the route, and was operated by a safety officer trained to monitor the bus during all rides. The bus had two indoor screens for passengers. One screen provided a map that showed the bus position and the surrounding area, and basic information about the bus and road conditions (speed, station information, automatic/manual driving mode (see Fig. 1 left) The other screen showed a Real-time return video in front of the bus (see Fig. 1 right). Since this research only focuses on the visual information of the HMI, the bus has no voice message.

Fig. 1. Map and basic information display screen (left), Real-time return video display screen (right).

2.3 Procedure

The study procedure on-site was as follows:

(1) Participants were welcomed at the reception desk. They were introduced to the study procedure to understand the basic information of autonomous buses, and filled in the informed consent and an initial questionnaire, which included demographic information, the frequency of daily bus use, and earlier experiences with autonomous vehicles.

(2) Afterwards, they were guided to the bus. They were introduced to the operator and researchers (two persons) and were told to not interact with either of them. They are also required to take the autonomous bus as they do on daily buses (e.g., they can choose their seats at will), but to avoid distractions, they cannot use mobile phones. In addition, participants were free to talk to each other freely during the ride. They were then briefed on the actual task.

(3) Then, the participants boarded the bus to ride. The bus drove on the road in the circular test area, each ride took 10 min, and there were two rides in total. The safety officer does not operate during the driving process, and only took over and stopped when the bus arrived at the terminal.

(4) After the ride, the participants were guided back to the reception desk for a 30-min interview.

The semi-structured interview procedure was as follows:

(1) First, we asked participants to describe their experience of riding an autonomous bus, including the difference between riding an ordinary bus, and their experience of existing HMI information in the bus.

(2) Second, we asked participants to told us which behaviors of the autonomous bus were unexpected to them. And why did these behaviors surprise them?

(3) We were also interested in information expectations in different scenarios. Therefore, we ask participants to told us what information they want to see under normal and unexpected scenarios. After that, all interviews were transcribed.

3 Result and Discussion

We applied inductive qualitative content analysis based on journaling. In inductive content analysis, the categories are not predefined. Therefore, this method enables the researcher to describe the meaning of qualitative data systematically and increase the understanding of phenomena [12, 13].

Factors Affecting the HMI Experience of Autonomous Buses. We were curious about passengers' opinions on the existing HMI of autonomous buses, so we asked participants whether the existing HMI can meet their riding needs. 90% (N = 9) of the participants felt that their requirements could not be satisfied, and described the impact reason of HMI experience. Excluding one person who felt that the existing HMI can meet the needs, the following valid answers were 9 people (see Table 1).

Table 1. Categories of factors affecting the HMI experience of autonomous buses formed by inductive content analysis

Generic categories	Description	Subcategories
Invalid information	Existing interface information which does not work	– Unconcerned
Unclear visual information	Visual information which is difficult to see	– Small font size – Low contrast – Short stay speed
Incomprehensible visual information	Unintelligible visual information	– Confusing icon
Unsuitable screen layout	Screen location is not convenient for viewing	– Easily obscured – Too far for the rear passengers
Insufficient information	Less than expected information	– Not enough
Preference	Existing display methods are different from people's preferences	– Unsuitable layout – Unsightly
Technical factors	Technical error	– Inaccurate positioning

Two-thirds (N = 6) of the participants mentioned unclear visual information, incomprehensible visual information, and insufficient information. Unclear visual information specifically includes the information font size was too small (N = 2), the stay speed was too short (N = 2), the interface color contrast was not obvious (N = 2). Incomprehensible visual information includes unintuitive icons (N = 3) and digital display without the unit (N = 4). Nearly half of the participants (N = 4) mentioned invalid information (e.g., P1 mentioned she was not interested in the current zoomed-in speed information. P5, P6, and P8 mentioned "the map information was too crude to be effective".). Followed by is the unsuitable screen layout (N = 3), the information design is not in line with preference (N = 2). And one participant (N = 1) mentioned technical factors such as inaccurate positioning.

According to the analysis, because the bus is a moving space, attention should be paid to the font size and interface contrast of the text information, and the display icons should be intuitive and easy to understand to reduce the learning load. And pay attention to the validity of the information. The reasonable layout and technical factors of the screens in autonomous buses are still to be studied, but they are not the focus of this research.

Unexpected Scenarios and Causes of Impact. We found that three unexpected scenarios affect the experience which is mainly focused on the two situations of avoidance (N = 6) and speed change (N = 10), and the impact of turning (N = 4) is less. The specific behaviors of avoidance include being forced to stop by sudden obstacles (N = 5) and long-term parking caused by carefully avoiding pedestrians under too complicated road conditions (N = 1). Speed change mainly includes sudden acceleration and deceleration caused by sudden braking (see Table 2).

Table 2. Categories of unexpected scenarios formed by inductive content analysis.

Generic categories	Description	Subcategories
Turning	Steering operation while driving the vehicle	– Turn left – Turn right
Avoidance	Operation when the vehicle encounters an obstacle	– Vehicle stopped – Long-term parking
Speed change	Changes in speed when the vehicle is moving	– Acceleration – Deceleration

The main factors affecting the experience are divided into four categories: distrust of intelligent systems (N = 4); insufficient information (N = 3); sudden behavior (N = 3); and influence (N = 1) (see Table 3).

It can be seen that distrust of intelligent systems (specifically including doubts about safety, and doubts that buses are not as good as human drivers in complex traffic) are the main factors, followed by is insufficient information provision and the impact of sudden behavior. Because the ride experience is affected by insufficient information and sudden behavior, design can be used to enrich the information prompts. Bad experience which from sudden behavior can be avoided by effectively convey the intention of the bus.

Information Expectations for Different Scenarios. Normal scenarios: Road conditions are what most people want to see in normal scenarios, and more than two-thirds (N

Table 3. Categories of causes of impact formed by inductive content analysis.

Generic categories	Description	Subcategories
Distrust intelligent systems	Autonomous driving system cannot react like a human driver	– Not safe – Can't cope with complicated road conditions
Insufficient information	Less than expected information	– No prompt
Sudden behavior	Inconsistent with expected vehicle behavior	– Emergency braking – Not smooth speed change

= 7) of the participants choose it. It includes road congestion, road conditions ahead, and nearby conditions. 60% of the participants (N = 6) want to see vehicle movement information (e.g., acceleration, deceleration, turning, braking) and time planning information (e.g., estimated arrival time), and 50% of the participants (N = 5) want to see itinerary management information (e.g., transfer information). Other participants mentioned personnel information about people (e.g., human traffic, safety officer) and temperature information (e.g., weather, indoor and outdoor temperature) (see Table 4).

Table 4. Categories of normal scenarios information expectations formed by inductive content analysis.

Generic categories	Description	Subcategories
Time planning	Smart traffic time information which can be planned and calculated	– Arrival time
Vehicle movement	Inherent attributes of the vehicle	– Turning – Acceleration – Deceleration
Road conditions	Unplanned information in a small area outside the vehicle	– Congestion – Conditions ahead – Nearby conditions
Temperature	Temperature information	– Weather – Indoor and outdoor temperature
Personnel	Information about people	– Human traffic – Safety officer
Itinerary management	Line information which can be planned and calculated	– Transfer station

Unexpected scenarios: In unexpected scenarios, information expectation is concentrated in the underlying explanations and real-time information. All participants mentioned the underlying explanation which is the action taken by the vehicle (e.g., "obstacles detected"). Secondly, 90% of the participants (N = 9) mentioned real-time information (e.g., congestion, traffic light, crowd, turning, etc.). A small number of participants (N = 3) mentioned giving handling measures which mentions how to deal with the unexpected situation. One participant mentioned explaining accident degree (e.g., recovery time, emergency level) (see Table 5).

Table 5. Categories of unexpected scenarios information expectations formed by inductive content analysis.

Generic categories	Description	Subcategories
Through real-time information	Reflect the current traffic and vehicle situation	– Congestion – Traffic light – Crowd – Turning – Acceleration – Deceleration – Braking
Through the underlying explanation	Action taken by the vehicle	– Obstacles detected
Explaining accident degree	Degree of response to emergencies	– Recovery time – Emergency level
Giving handling measures	How to deal with the situation	– Manual driving

Overall, we found that whether in normal or unexpected scenarios, basic and objective real-time road information is what passengers want to see. The information needs of normal scenarios are more experience-oriented, and high-quality service information is more emphasized. In unexpected scenes, it is more desirable for vehicles to convey their intentions through underlying explanations, and to compare the bus judgment with the objective situation to enhance trust.

4 Conclusion

In this article, we investigated passengers' perceptions of unexpected scenarios, and their information expectations of HMI in autonomous buses. To this end, we presented the results of a semi-structured qualitative study, conducted with a field autonomous bus at the test park. We found that in addition to basic and objective real-time road information, there should be a focus on providing relevant information to passengers in different scenarios. The main reason is that passengers have different needs for different scenarios. For normal scenarios, passengers prefer to see diversified information that improves the ride experience. For unexpected scenarios, such as avoidance, speed change, and turning, passengers prefer the bus to explain the potential behavior to convey the intention. Second, the usability of the HMI, such as whether the font size is appropriate, whether the icons are easy to understand, and whether the interface contrast is clear, should also be considered. Our results provide guidance on how to better design HMI information and which further research directions to pursue.

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