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The Public Requirements on Interior Facilities of Highly Automated Vehicles in China

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ABSTRACT

Under highly automated driving, it is possible for drivers to work, entertain and relax in the vehicles. These non-driving related activities bring new challenges in designing interior facilities of highly automated vehicles. It is promising to improve highly automated vehicles' acceptance and user experience by developing interior facilities based on drivers' needs. This study adopted an online questionnaire to explore the public requirements on interior facilities of highly automated vehicles in China. Moreover, the needs of different groups were analyzed and compared for a detailed understanding of the effects of various individual characteristics. The results indicated that people expected to communicate with the automated driving systems and were unwilling to lose their right to control the vehicle completely. In addition, individual characteristics significantly affected the requirements. This study contributes to understanding the public requirements on interior facilities and improving the acceptance of highly automated vehicles.

Keywords: Highly automated vehicles, User requirement, Interior facilities, Individual characteristics

INTRODUCTION

Automated vehicles have received increasing attention, as they are expected to enormously reduce the driving workload and improve traffic safety (Li et al., 2021a). However, fully automated driving has not been realized yet due to the limitation of relevant technologies, suggesting that a human driver is still required for the present automated vehicles (Zeeb et al., 2015). Under highly automated driving, human drivers are not instructed to monitor surrounding traffic continuously but still need to take over the vehicle if there is a take-over request issued by the systems (Schinkel et al., 2019; Li et al., 2021b). Hence, it signifies that human drivers change from active operators to passive observers during automated driving, compared with manual

driving vehicles (Aria et al., 2016). The changing of the roles makes it possible for human drivers to work, entertain and relax continuously during automated driving (Jorlöv et al., 2017; Pudāne et al., 2021). Thus, driver's activities in automated vehicles will be significantly different from those in conventional cars.

Several previous studies have investigated the expected naturalistic non-driving related activities under automated driving, such as watching movies and sleeping, by online surveys and driving simulation experiments (Hecht et al., 2019). These non-driving related activities for drivers under highly automated driving, seldom being considered for designing the vehicle interiors of conventional vehicles, bring new challenges and requirements for developing highly automated vehicles' interior facilities (Mathis et al., 2021). Therefore, it is promising to improve the acceptance of highly automated vehicles by developing interior facilities based on drivers' needs.

Numerous existing studies have investigated the seating configuration and position preferences, including reclined seats, rotated swivel seats, and the combinations of backrest and seat pan angle (Bohman et al., 2020; Stanglmeier et al., 2020). These studies contributed to a better understanding of drivers' general requirements on the seating configuration and position of automated vehicles. However, the seating preference is only one aspect of the interior facilities of highly automated vehicles, indicating that only focusing on the seating preference is not adequate to systematically understand drivers' needs and improve the acceptance of highly automated vehicles. Therefore, it is necessary to investigate drivers' requirements on various interior facilities of highly automated vehicles.

However, there is still a lack of such researches, impeding the development of interior facilities that meet the needs of the drivers. Hence, this study adopted an online questionnaire to explore drivers' requirements on interior facilities of highly automated vehicles in China. Moreover, the needs of different groups of drivers were analyzed and compared for a detailed understanding of the effects of various individual characteristics on the requirements on interior facilities of highly automated vehicles.

SURVEY DESIGN

The survey consists of two parts, including fifteen questions and one multidimensional Likert scale. Participants' individual characteristics, including gender, age, residence, income, occupation, education, carsickness experience, accident experience, driving experience, knowledge of the automation, attitude to automation, and experience of using automated driving systems were collected in the first part. The second part obtained their requirements on interior facilities of highly automated vehicles as the drivers through a multidimensional five-point Likert scale.

Respondents were instructed to rate the nine interior facilities, including voice assistants, seats with tables, cancellation of operating devices (e.g., steering wheel and pedals), partitions that separate each seat, entertainment and office equipment connected to personal smartphones, a monitor displaying real-time operation information of the vehicle, a large-scale touch screen,

reclining seats for lying comfortably, and devices to ease motion sickness on a bipolar Likert scale: strongly agree (5), agree (4), neither agree nor disagree (3), disagree (2), strongly disagree (1). Note that highly automated driving was explained as not equal to fully automated driving. To ensure that the description in the survey is not ambiguous or misleading, the survey was improved in two pretest rounds, including a total of 110 respondents.

PARTICIPANTS AND DATA ANALYSIS

Participants were recruited via a Chinese online survey platform named WJX and received monetary compensation for their participation. In total, responses from 367 subjects from different cities in China were collected in September 2021. To ensure the validity and quality of the data, we incorporated quality control procedures. This study was approved by the Institution Review Board of Tsinghua University. The detailed demographic characteristics are stated in the following section.

The validity check was conducted to remove invalid samples prior to the data analysis. Descriptive statistics on overall respondents were collected for drivers' requirements on interior facilities of highly automated vehicles. The Mann-Whitney U test and Spearman correlation analysis were adopted to analyze and compare the requirements on interior facilities for different groups of drivers. The statistical significance level was set at $\alpha = 0.05$ in the present study.

DEMOGRAPHIC STATISTICS

In total, responses from 367 subjects were collected, and the data of 214 respondents were adopted for the analysis after conducting the validity check, suggesting the valid response rate was 58.31%. The mean age of the 214 respondents was 30.13 years (Min = 18, Max = 61, SD = 6.28) and their genders were basically balanced with 113 males (52.8%) and 101 females (47.2%). The respondents were from 28 provincial-level administrative regions of China. Moreover, the respondents included students, officers, workers, engineers, teachers, salespeople, managers, accountants, doctors, etc.

As self-reported, 87.9% of respondents had a valid driving license, and 46.7% have ever driven automated vehicles. In addition, 42.9% of respondents hold a positive attitude towards automated vehicles, whereas 14.2% of respondents were neutral about it, and 42.9% of respondents hold a negative attitude. The education of the respondents was 11.8% below undergraduate, 79.9% with a bachelor's degree, 7.8% with a master's degree and 0.5% with a Ph.D. degree. According to participants' self-report, 42.6% were never involved in carsickness, whereas 52.5% sometimes and 4.9% were always involved in carsickness. In addition, 26.5% of the respondents have ever experienced traffic accidents, among which 9.3% were hurt in the accidents.

DRIVERS' GENERAL REQUIREMENTS ON INTERIOR FACILITIES

As shown in Figure 1, the drivers' general requirements on the nine interior facilities of highly automated vehicles were obtained based on the average

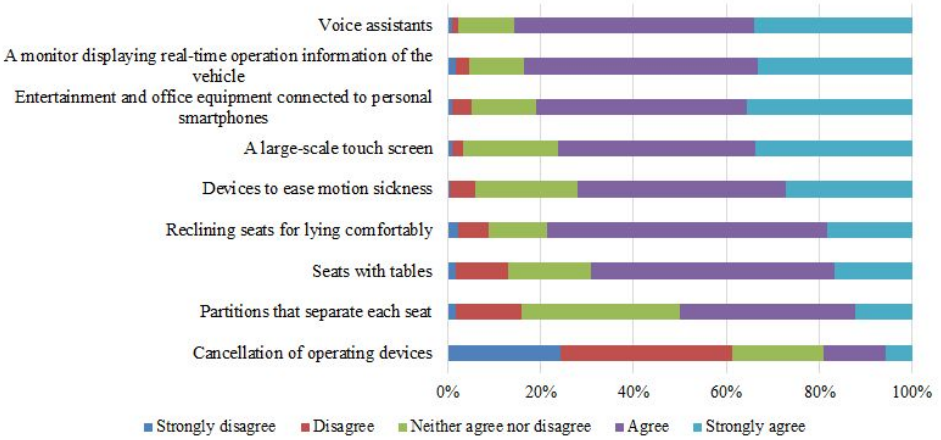

Figure 1: Drivers' general requirements on interior facilities of highly automated vehicles.

of all the respondents' ratings. The most required interior facility were voice assistants, followed by a monitor displaying real-time operation information of the vehicle and entertainment and office equipment connected to personal smartphones, which shared the same importance. A large-scale touch screen, devices to ease motion sickness, and reclining seats for lying comfortably were interior facilities in high demand. However, seats with tables, partitions that separate each seat, and cancellation of operating devices (e.g., steering wheel and pedals) were below the average, indicating fewer drivers' general requirements for highly automated vehicles. It is worth noting that the cancellation of operating devices (e.g., steering wheel and pedals) were the least required interior facility and significantly different from the others.

The results indicated that as the driver of highly automated driving vehicles, people expected to communicate with the automated driving systems and were unwilling to lose their rights to control the vehicle completely.

CARSICKNESS AND REQUIREMENTS ON INTERIOR FACILITIES

According to the previous studies, carsickness was considered one of the critical problems for highly automated vehicles due to the absence of vehicle control during automated driving (Wada, 2016). In addition, carsickness was proven to significantly affect drivers' activities during automated driving. Thus, it is necessary to investigate its impact on requirements on interior facilities of highly automated vehicles. Considering the distribution of the samples, we divided the respondents into two groups, which were respondents ever involved in carsickness and never involved in carsickness. Then, the present study compared the requirements on interior facilities of highly automated vehicles between the two groups.

The Mann-Whitney U test was adopted to compare the requirements on interior facilities between respondents ever involved in carsickness and never involved in carsickness. The results showed that there were significant differences between the two groups of respondents in terms of their requirements for

interior facilities, including devices to ease motion sickness ($p = 0.001$), voice assistants ($p = 0.004$), a large-scale touch screen ($p = 0.016$), and entertainment and office equipment connected to personal smartphones ($p = 0.022$). Specifically, people ever involved in carsickness prefer devices to ease motion sickness and voice assistants but are even less likely to need a large-scale touch screen and entertainment and office equipment connected to personal smartphones. In addition, it is worth noting that the cancellation of operating devices was the least required interior facility for both groups of respondents.

The results indicated that the carsickness significantly affected drivers' requirements on certain interior facilities of highly automated vehicles, especially for facilities to ease or aggravate carsickness. Moreover, drivers were unwilling to lose the rights to control the vehicle entirely for both respondents ever involved in carsickness and never involved in carsickness.

DRIVING EXPERIENCES AND REQUIREMENTS ON INTERIOR FACILITIES

The driving experiences of the respondents were collected, including driving years, driving frequency and experience of using automated driving systems. The Mann-Whitney U test was adopted to assess the effect of the experience of using automated driving systems on the requirements on interior facilities of highly automated vehicles, whereas the Spearman correlation analysis was adopted to assess the effect of driving experiences on the requirements on interior facilities of highly automated vehicles.

The results indicated a significant effect of the experience of using automated driving systems on the requirements on entertainment and office equipment connected to personal smartphones ($p = 0.005$), a large-scale touch screen ($p = 0.023$), seats with tables ($p = 0.026$), and a monitor displaying real-time operation information of the vehicle ($p = 0.033$). Specifically, people with the experience of using automated driving systems prefer entertainment and office equipment connected to personal smartphones, a large-scale touch screen and a monitor displaying real-time operation information of the vehicle, whereas they showed less interest in seats with tables. Moreover, the driving years were found to significantly impact the requirements on a large-scale touch screen (ρ=0.203, $p = 0.003$) and devices to ease motion sickness (ρ=-0.180, $p = 0.008$). In addition, there was a significant effect of driving frequency on the requirements on entertainment and office equipment connected to personal smartphones (ρ=0.172, $p = 0.012$) and a monitor displaying real-time operation information of the vehicle (ρ=0.154, $p = 0.024$).

CONCLUSION

This study adopted an online questionnaire to explore the public requirements on interior facilities of highly automated vehicles in China. In addition, the needs of groups with different individual characteristics were analyzed and compared for a detailed understanding. The results indicated that people expected to communicate with the automated driving systems and were

unwilling to lose their right to control the vehicle completely. In addition, carsickness and driving experiences significantly affected the requirements. However, there was no significant effect of gender and education.

This study contributes to understanding the public requirements on interior facilities in China, comprehending the effects of individual characteristics on the requirements and improving the acceptance of highly automated vehicles. However, it is an inevitable problem in online surveys that the sample bias affects the analysis and comparison. In addition, the effect of the experience of different levels of automated vehicles was not distinguished due to the survey design. Moreover, this study investigated the requirement of highly automated vehicles. However, for the three levels of automation in highly automated vehicles (L3, L4 and L5), drivers' tasks and responsibilities are different, indicating that it is necessary to investigate the requirement, especially for cancellation of operating devices, under the three different levels.

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