

ISASE 2020

Take-Over Request in Highly Automated Driving: A Survey on Driving Experience and Emergency Operation Accuracy

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Abstract: An essential question in highly automated is how to aid drivers to make safe transitions between manual and automated control. We surveyed 1122 people about the driving experience and public opinions of a highly automated vehicle. Determined whether driving state and frequency would provide a significant difference in the accuracy of TOR, investigated the effects of different secondary tasks in driving on driver's takeover control performance in HAV. The survey showed that there is no correlation between the state of driving and the probability of making mistakes in an emergency. Besides, we need to take into account the instant communication between the driver and the system because the leading cause of stress in driving is anxiety about traffic accidents and concerns about insufficient traffic information.

Keywords: *Take-over request, Driving experience, Driving mistake, Highly automated vehicle*

1. INTRODUCTION

With the rise of advanced driving assistant systems, highly automated driving has become more feasible. However, one of the most pressing research questions in highly automated driving is how to aid drivers to make safe transitions between manual and automated control [1]. Drivers of automatic cars may occasionally need to switch from their secondary task to the driving task when urgency situation happens [2]. During this switch, they have to shift their attention from one task to the other, which requires perceiving the state of the driving environment, make decisions, and act accordingly [3]. Being engaged in secondary tasks can cause drivers to be vulnerable to delays or errors when getting back to the driving task due to not having a chance to attend to it and not being in the loop [4]. This can lead to hazardous situations if the driver has to take over a vehicle's control due to automation shortcomings. Therefore, appropriate user interface designs for Take-over Requests (TOR) are required to ensure a smooth transition from secondary to the hands-on driving task [5]. In this case, a safe transition from highly automated to manual driving has to be ensured. Precisely, suitable ways to prepare the driver to take back the vehicle control, for example, by displaying that he/she

needs to take back his/her hands on the steering wheel, have to be identified.

Studies have examined the design, effectiveness and timings of TORs. However, the current work has focused on the efficacy of TORs in isolation and without considering the multi-tasked context of driving and the actual situation of drivers in driverless cars [6]. A futuristic in-vehicle environment that relies heavily on control of automation raises a vital question: How can we support a driver's ability to seamlessly switch from engaging with a non-vehicle-handling task to monitor and resume the several complex maneuvers that constitute effective vehicle handling?

The first problem we need to solve is to understand the actual state of the driver in the highly automated vehicles (HAV). Driver preference of secondary task, the driver's state while driving, and mistake categories in an emergency condition. In order to gain a better understanding of those issues and general acceptance by target user groups around the world, this survey was designed to expand upon the existing survey data to include a broader examination of driving state and public opinion about HAV.

The research purpose was to determine whether driving state and frequency would provide a significant difference

in the accuracy of TOR, investigating the effects of different secondary tasks in driving on driver's takeover control performance in HAV.

2. METHODS

2.1 Survey instrument

An online survey was conducted using Google Form (docs.google.com/forms), a survey administration app. A questionnaire was developed to examine several critical topics related to HAV. The main topics addressed were the following:

- Basic information: nationality, age, gender, occupation.
- Driving experience: driving frequency, the state during driving, types of operating errors in emergencies.
- Public opinions of HAV: expected benefits of HAV, concerns about using HAV, preference of secondary task.

2.2 Respondents

In the innovation diffusion theory proposed by Everett Rogers (see Figure 1), the adoption life cycle of emerging technologies is described as a bell-shaped curve, showing the five periods of users' adoption of emerging technologies, and the users are divided into the time sequence of adopting emerging technologies. Five groups of people, including innovators, early adopters, early majority, late majority, and laggards [7].

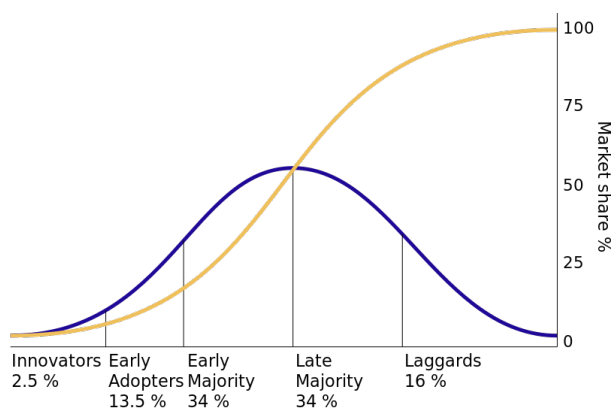


Figure 1: Innovation diffusion theory model

In the hybrid mode period, which is the early stage of the introduction of HAV, innovators, early adopters, and the early majority will be user groups of HAV. But the proportion of innovators is small, and they are secondary users. Although early adopters are also a minority of consumers, they are mostly promoters of new technologies, which have a more significant impact on

subsequent adopters and have a decisive effect on the diffusion of new technologies. Therefore, early adopters and the early majority are both the primary users of HAV in the hybrid mode period, and they are also the target users of this survey. The characteristics of these users are shown in Table 1 [8].

Table 1: Definitions of early adopters and majority

Adopter Category	Definition
Early Adopters	Have a relatively strong desire to consume new products and have a strong acceptance of emerging things.
Early Majority	They are more discreet in adoption choices than early adopters.

The target user groups of this study can be summarized by combining the definition of two adopter groups and the research goals mentioned above. The key characteristics are shown in Table 2.

Table 2: Target user characteristics

Age	20 ~ 50
Driving experience	More than 1 year
Characteristics	a) Have a certain level of understanding of HAV; b) Secure acceptance of emerging technologies;

The audience tool was used to target and recruit individuals 20 years and older from Google form's respondent databases. The 1122 respondents of the online survey were gathered from the 14th of September 2017 at 09:00 until the 30th of September at 21:00 (JST). The respondents took an average of 5.4 minutes (SD = 4.9) to complete the survey. All of the respondents had a driving experience for more than one year.

2.3 Chi-squared test

The Chi-Square statistic is most commonly used to evaluate Tests of Independence when using a cross-tabulation [9]. Cross tabulation presents the distributions of two categorical variables simultaneously, with the intersections of the categories of the variables appearing in the cells of the table. The Test of Independence assesses whether an association exists between the two variables by comparing the observed pattern of responses in the cells to the pattern that would be expected if the variables were truly independent of each other [9].

Base on the chi-square test to determine whether driving state and frequency would provide a significant difference in the accuracy of TOR, investigating the

effects of different secondary tasks in driving on driver’s takeover control performance in HAV. Under the significant level of 0.05, if the statistic corresponding probability p-value is less than 0.05, it is considered a cross-sectional table between variables that are not independent, has a particular dependency [9].

3. RESULTS

3.1 Driving frequency & driving state

Table 3 shows the driving frequency of the female group was an association with the driving state (The probability p-value corresponding to the chi-square statistic is 0.008, which is far less than 0.05). However, the male group was no correlation between the driving frequency and state (The probability p-value corresponding to the chi-square statistic is higher than 0.05).

For the female group, the leading cause of stress is the anxiety about traffic accidents. The secondary reason is drowsiness and fatigue (and women who drive more often have more drowsiness and fatigue). Drivers who were driving four times per week are not only more prone to anxiety than other drivers but also the state of discomfort is lower than that of other groups. For male groups, stress mainly comes from restless fatigue from traffic accidents.

Table 3: Driving frequency & driving state cross tabulation

Gender		Value	df	Asymptotic Significance (2-sided)
Female	Pearson Chi-Square	43.976 ^b	24	0.008
	Likelihood Ratio(L)	45.362	24	0.005
	Linear-by-Linear Association	0.754	1	0.385
	N of Valid Cases	634		
Male	Pearson Chi-Square	22.844 ^c	24	0.529
	Likelihood Ratio(L)	23.335	24	0.500
	Linear-by-Linear Association	0.385	1	0.535
	N of Valid Cases	488		

3.2 Driving mistakes in emergency situations & driving state

According to the chi-square test (see table 4), the chi-square statistic p-value of both the female group and the male group is higher than 0.05, which indicates that there is no correlation between driving state and make a mistake in an emergency. Also, most people will make mistakes in emergency times. The sense of stress during driving comes from the uneasiness of traffic accidents and fatigued driving.

Table 4: Driving mistakes in emergency situations & driving state cross tabulation

Gender		Value	df	Asymptotic Significance (2-sided)
Female	Pearson Chi-Square	9.170 ^b	6	0.164
	Likelihood Ratio(L)	8.954	6	0.176
	Linear-by-Linear Association	.005	1	0.942
	N of Valid Cases	634		
Male	Pearson Chi-Square	12.533 ^c	6	0.051
	Likelihood Ratio(L)	12.832	6	0.046
	Linear-by-Linear Association	3.095	1	0.079
	N of Valid Cases	488		

3.3 Types of operating errors in emergency situations

Respondents were asked: “What kind of mistake do you make while driving in a dangerous situation?” They were asked to select the following options:

- Make the mistake of accelerator for the brake
- Make a mistake on the left or right blinkers
- Forgot to turn off the blinker
- Signal disregard
- Make a mistake to correct direction of the steering wheel
- Others

Figure 2 shows 25.84% of respondents made a mistake on the left and right blinkers, while 24.51% of respondents got the wrong direction of the steering wheel. Also, there had 14.92% of respondents admitted making the mistake

of accelerator for the brake while driving in a dangerous situation.

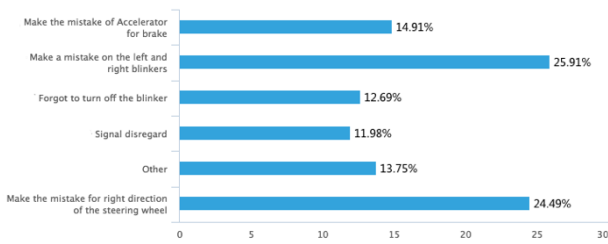


Figure 2: Percentage of respondents made mistake in emergency situations

3.4 Secondary tasks in HAV

Respondents were asked: “What would you like to do in a highly automated vehicle?” They were informed that multiple choices could be made for the secondary task. Figure 3 presents the percentage of respondent’s preference for secondary tasks in HAV. The most frequent response was “listen to music,” “to take asleep,” “play smartphone,” and “to play a game.”

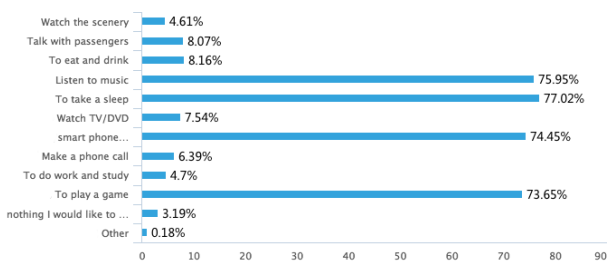


Figure 3: Percentage of respondent’s preference of secondary tasks

Besides, according to cross statistics, automated driving does not alleviate the pressure sensation generated during driving. The pressure sensation caused during driving mainly comes from the anxiety from traffic accidents and insufficient traffic information.

4. CONCLUSION

The survey examined driving experience and state regarding HAV technology and yielded useable responses from 1122 persons 20 years and older. The main finding was as follows:

- Most people make mistakes during emergency times, but there is no correlation between the state of driving and the probability of making mistakes in an emergency. In future experiments of the take-over system research, the state of the experimenter in the car is not a factor that can affect the final result.
- “Make the mistake to the wrong direction of the steering wheel” was the most frequent misbehavior in a dangerous situation. The level of urgency of the situation with which the automation cannot cope is a critical parameter of the take-over procedure. Several scenarios are imaginable, such as an accident that has

just happened right in front of the vehicle. Under such circumstances, taking over the vehicle with the wrong direction will have unpredictable consequences. Design an efficient multimedia display that can convey complex messages and provide context to improve a driver’s ability (i.e., shorter reaction times) to switch from no-driving task to resume the driving task on different situations.

- Regardless of gender, the leading cause of stress in driving is anxiety about traffic accidents and concerns about insufficient traffic information. When designing the take-over system, we need to take into account the instant communication between the driver and the system to reduce user distrust.

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