Psychological evaluation experiment of driver in self-driving car

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ABSTRACT

The automobile is an extremely convenient form of transport and has contributed significantly to the advancement of society, but the spread of cars has also brought social problems such as reduced safety (traffic accidents), traffic congestion, and increased fuel consumption. In recent years, there have been expectations that self-driving technology can resolve these issues, and not only automotive manufacturers but also various IT firms in the US and Europe such as Google and Apple are racing ahead with their initiatives. However, little research has been conducted on how passengers feel about this kind of automated control.

In the experiment reported in this paper, three scenarios were selected from a collection named “Scenarios that make drivers feel anxious,” which had been extracted from a questionnaire with a large number of respondents. The three scenarios were “A. Merging traffic,” “B. Vehicle ahead braking suddenly,” and “C. Curves.” Two of the components (“Distance to other vehicles” and “Speed of vehicle”) were used as variables in a driving test performed using an autonomous vehicle simulator. The level of anxiety and whether or not it was acceptable were recorded for each variable using a questionnaire. A model was created for the relationship between the aforementioned variables and the sense of anxiety felt by individuals, and an “acceptable value” was computed in the form of “A distance (speed) of up to X is acceptable.”

1. Introduction

Due to progress in self-driving technology it is expected that highly precise driving operations will become possible, such as maintaining a stable vehicle speed, which is difficult for the typical driver, maintaining short distances between vehicles, and reacting very quickly to changing conditions. However, little research has been conducted on how passengers feel about this kind of automated control. For example, it is not understood what level of anxiety will be felt by passengers when the vehicle parks next to the neighboring vehicle with only a few centimeters to spare, or drives at a speed that results in uncomfortable sensations. In a self-driving system that aims to provide not only "safety" but also "reassurance," it is vital to consider the human factor [1].

In this research, for driving scenarios that could cause anxiety we derived a relationship between the anxiety of the driver on the one hand and the distance to other vehicles or speed of the vehicle on the other hand. To achieve this we used distance to other vehicles and vehicle speed as variables and actually had the participants ride in an imitation self-driving vehicle, following which we used a questionnaire to obtain responses. In addition, by obtaining the acceptable threshold values in the scenario, we demonstrated how policies for self-driving vehicle control standards may be derived.

2. Method

2.1 Experiment participants

The experiment participants comprised 12 men and 12 women, with eight people from each of three age ranges (20s and 30s, 40s and 50s, and 60s and up), for a total of 24 people (Table 1). During the screening process we asked candidates about such factors as their tendency to become car sick, driving frequency, and awareness and behavior patterns during driving in order to achieve a nonbiased selection of experiment participants.

2.2 Driving conditions targeted by the survey

From the results of a previously conducted questionnaire called “Scenarios that make drivers feel
anxious," we extracted scenarios that could also occur in a self-driving context, selecting the three scenarios that the majority of respondents indicated generated most anxiety. The three scenarios were as follows.

A. Merging traffic
B. Vehicle ahead braking suddenly
C. Curves

2.3 Experiment conditions (Figure 1)

For each driving situation, we established three conditions using Distance to other vehicles or Vehicle speed as variables.

(1) Task A Merging traffic

After starting, the self-driving vehicle drives behind and to the left of an ordinary vehicle (in the lane to the left). The task starts with both vehicles driving at a speed of 40 km/h (overtakes → merges with traffic before the ordinary vehicle). The inter-vehicle distance, defined as the distance between the right-hand side of the self-driving vehicle and the left-hand side of the ordinary vehicle, was set as the driving condition. The three driving conditions were A2 (d=2 m), A5 (d=5 m), and A8 (d=8 m).

(2) Task B Braking

After starting, the self-driving vehicle follows the ordinary vehicle at a set speed (distance to other vehicle 13 m, speed 50 km/h). The distance to other vehicle d at the point at which the self-driving vehicle began to apply the brakes, after the brake lights of the ordinary vehicle came on, was set as the driving condition (this was explained to the test subject as the timing at which the self-driving vehicle braked). The three driving conditions were B6 (d=6 m), B9 (d=9 m), and B12 (d=12 m).

(3) Task C Curves

After starting, the vehicle accelerates to the specified speed in the driving condition (= the driving condition) and performs laps of the course. The vehicle enters the curve at the specified speed without decelerating. The vehicle decelerates so that the speed at the exit of the curve is 40 km/h (no deceleration in the case of C40). The three driving conditions were C40 (40 km/h), C50 (50 km/h), and C60 (60 km/h).

2.4 Overview of the imitation self-driving vehicle

Vehicle used: Mercedes-Benz E240

We constructed an imitation of the driver's seat of a right-hand-drive vehicle in the passenger seat of this left-hand-drive vehicle, by setting up a dummy steering wheel connected to the actual steering wheel, dummy pedals and an instrument panel (Fig. 4 bottom left: imitation driver’s seat; bottom right: primary driver’s seat). Experiment participants sat in the right-hand seat, and participated in the test as the driver of the self-driving vehicle. The actual driving of the vehicle was conducted by an experienced driver seated in the left-hand seat. The hands of the driver were concealed from the experiment participants sitting in the right-hand seat so that they were unable to see the driver manipulating the controls.

2.5 Questions

After each driving task, the participants were asked the following three questions.

① How much anxiety did you feel? (Six levels)
② How did you feel about this from the perspective of not causing anxiety to the driver? (Seven levels)
③ How acceptable was this experience? (Four levels)

Table 1. Attributes of the experiment participants

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Figure 1. Experiment conditions

Table 1. Attributes of the experiment participants
3. Results

3.1 Relationship between anxiety, distance to other vehicle and vehicle speed, and acceptable values

We created a predictive formula using logarithmic regression based on the average evaluation values for each of the "distance to other vehicle" conditions.

(1) Task A Merging traffic (Figure 3)
A regression formula of $R^2 = 0.98828$ was obtained from the logarithmic regression. The relation model is $Y=2.1781\ln(X)+0.7213$. Obtaining the corresponding value for distance to other vehicle from the evaluation points based on the logarithmic regression equation, the distance to other vehicle for "3 Somewhat acceptable" was 4.6 m.

(2) Task B Braking (Figure 4)
A regression formula of $R^2 = 0.99929$ was obtained from the logarithmic regression. The relation model is $Y=55.3361\ln(X)-7.8762$. Obtaining the corresponding value for distance to other vehicle from the evaluation points based on the linear regression equation, the distance to other vehicle for "3 Somewhat acceptable" was 9.4 m.

(3) Task C Curves (Figure 5)
A regression formula of $R^2 = 0.99309$ was obtained from the logarithmic regression. The relation model is $Y=-7.125\ln(X)+31.263$. Obtaining the corresponding value for entry speed from the evaluation points based on the linear regression equation, the entry speed for "3 Somewhat acceptable" was 45.6 km/h.

3.2 Variance by driver attribute

A two-way analysis of variance was performed using the two factors of sex and driving conditions for each item evaluated.

For "1. Anxiety" there was a significant interaction ($P = 0.0381$). The result of the simple main effects test was that, for A2 and A8, there was a significant difference between men and women (A2: $P = 0.003$, A8: $P = 0.04$).

For "3. Level of acceptability" there was a significant interaction ($P = 0.047$); Figure 10. The result of the simple main effects test was that, for A2, there was a significant difference between men and women ($P=0.009$).
3.3 Comments from experiment participants
Representative comments from experiment participants follow
(1) Task A Merging traffic
"In each of the three conditions I felt that the vehicles were closer than it would be if I were driving. I would have gone further forward, and slowed down after merging. More than the speed and the distance to the other vehicle, the fact that I didn’t know the timing of the merging might be what made me anxious”
→ The comments received generally supported the evaluation results, with the distance in condition A2 being close enough to cause participants to feel fear.
(2) Task B Braking
"I became anxious when the self-driving vehicle did not brake as soon as the brake lights of the vehicle ahead came on. Rather than the sense of distance, speed or timing, I might have been reassured if the brake pedal had moved together (even if it had just dropped down that would have been okay)”
→ The comments received showed details and tendencies similar to the results of the questionnaire. With regard to the distance (13 m) to other vehicle when following the ordinary vehicle, this was interpreted as both long and short, and this perception seems to differ according to the individual.
(3) Task C Curves
- "I couldn’t feel the vehicle slowing before we entered the curve, and although I assumed that it was safe because it was a self-driving vehicle, I did feel anxious about the speed”
→ There were many comments showing that the failure of the self-driving vehicle to decelerate when entering the curve led to anxiety. This suggests that the level of anxiety varies not only with the absolute level of speed when entering a curve, but also with the way the speed itself changes. This requires further investigation and verification.

4. Conclusion
In this experiment, we made clear the relationship between anxiety, distance to other vehicle and speed under various driving scenarios in a self-driving vehicle. In addition, we obtained results that may lead to policies to determine acceptable levels for self-driving vehicle control.

It was also demonstrated that the above relationship and acceptable values varied by sex. In these tasks we learned that, in merging situations, men feel anxiety more strongly even at the same distance to other vehicles and that, depending on the driving scenario, control methods may need to be changed.

5. Future Tasks
On this occasion we measured the level of anxiety using distance to the vehicle as a variable under situations involving merging traffic and the vehicle ahead braking. However, as it is predicted that the results will vary when the speed changes, it appears likely that more experiments must be performed with a greater number of conditions. In order to perform the experiments with a greater number of conditions, an experimental method that is simpler and imposes less of a burden on the experiment participants and the experimenters is desirable.

Many of the comments from the experiment participants mention that their inability to predict the behavior of the vehicle led to anxiety. This suggests that, because in Level 3 self-driving vehicles the driver is not completely freed from the demands of driving and is required to monitor the situation ahead, some kind of information display indicating the vehicle’s next action may be required going forward. As the level of anxiety felt is likely to vary depending on the presence or absence of such information displays, this suggests the need for experiments that use as their variables the presence or absence of the information display, the method of display, and the design[2].

References