Effect of Visual Distraction on Response time for Lane Change with Partially Automated Vehicle

Toru Hagiwara, Kazuyoshi Shimizu, Yutaro Suzuki,
Tasuya Iwasa, Haruko Okuyama
hagiwara@eng.hokudai.ac.jp

1* Faculty of Engineering, Hokkaido University, Japan
2* Honda R&D Co., Ltd. Automobile R&D Center, Japan

Backgrounds

- The drivers might concentrate on secondary tasks excessively while driving the partially automated vehicle. It is found the driver's response to any sudden event under a visual distraction to be much later in partially automated driving than in manual driving.

- However, not many papers have investigated how the driver reacts when needing to take control in such a situation.

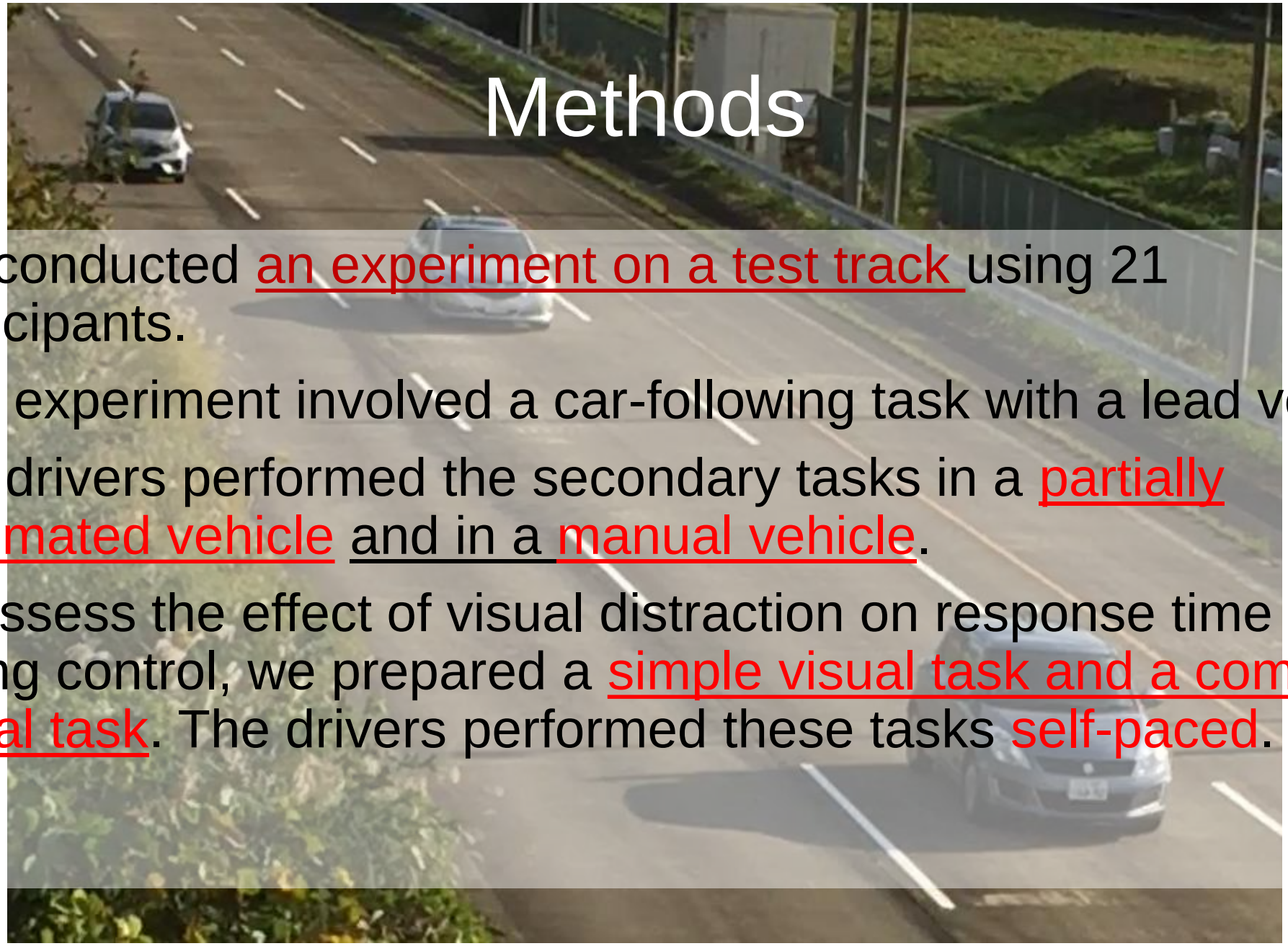
- Fundamental approaches are required to reveal how visual distractions affect the driver's resumption of control.

Objectives

- The 1st objective is to clarify how visual distraction under partially automated driving affects the driver's subjective assessment.

- The 2nd objective is to clarify how visual distraction under partially automated driving affects the driver's response time in a lane change task when the driver needs to take control.

Methods



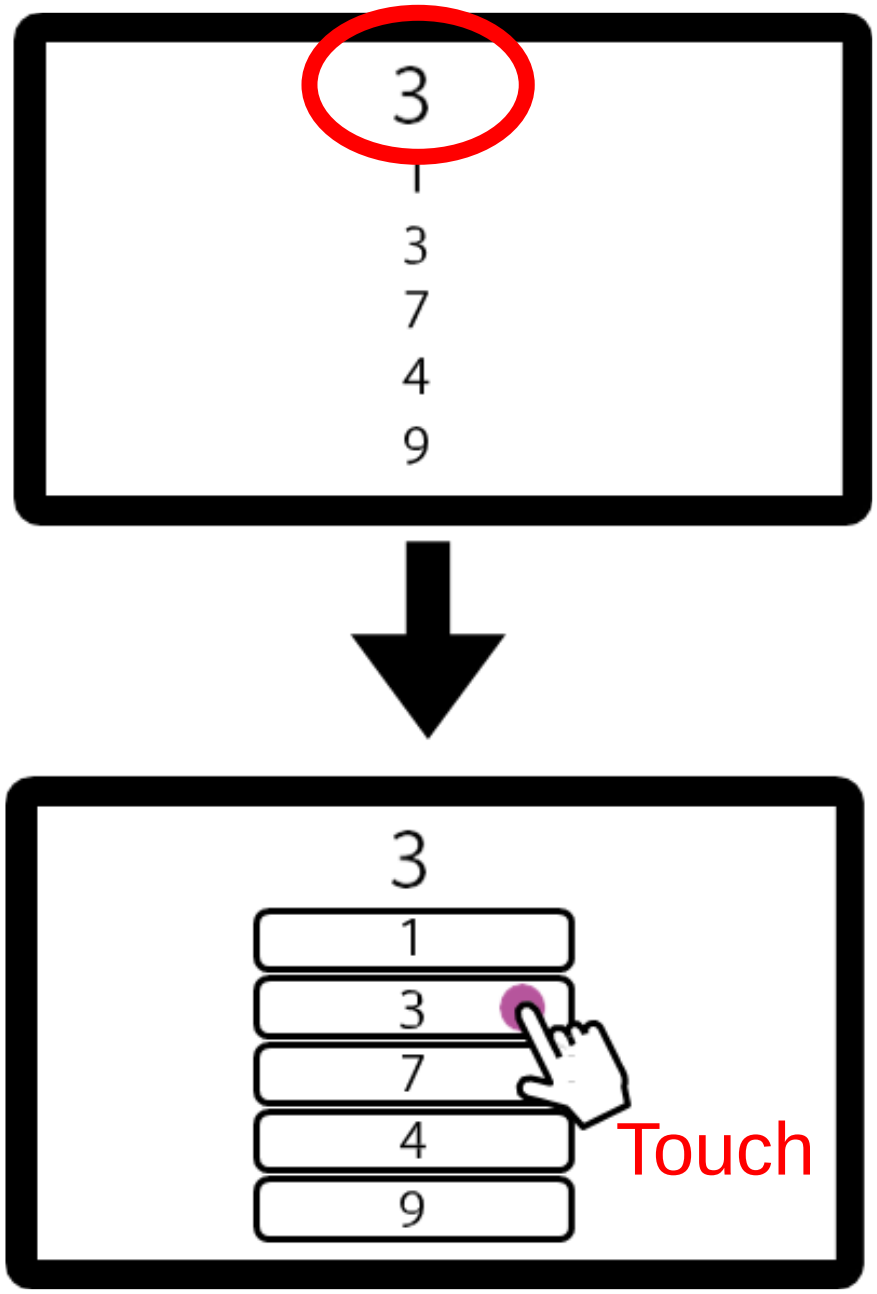
- We conducted an experiment on a test track using 21 participants.
- This experiment involved a car-following task with a lead vehicle.
- The drivers performed the secondary tasks in a partially automated vehicle and in a manual vehicle.
- To assess the effect of visual distraction on response time in taking control, we prepared a simple visual task and a complex visual task. The drivers performed these tasks self-paced.

Partially Automated Vehicle

- Adaptive Cruise Control (ACC) and Lane Keeping Assist System (LKAS) were installed in the partially automated vehicle.
- The LKAS applies torque to the steering to keep the vehicle between the left-lane line and the right-lane line. The applied torque increases as the vehicle approaches either of the lane lines. However, the driver needs to hold the steering control in this system.

Secondary Tasks
Simple Visual Task

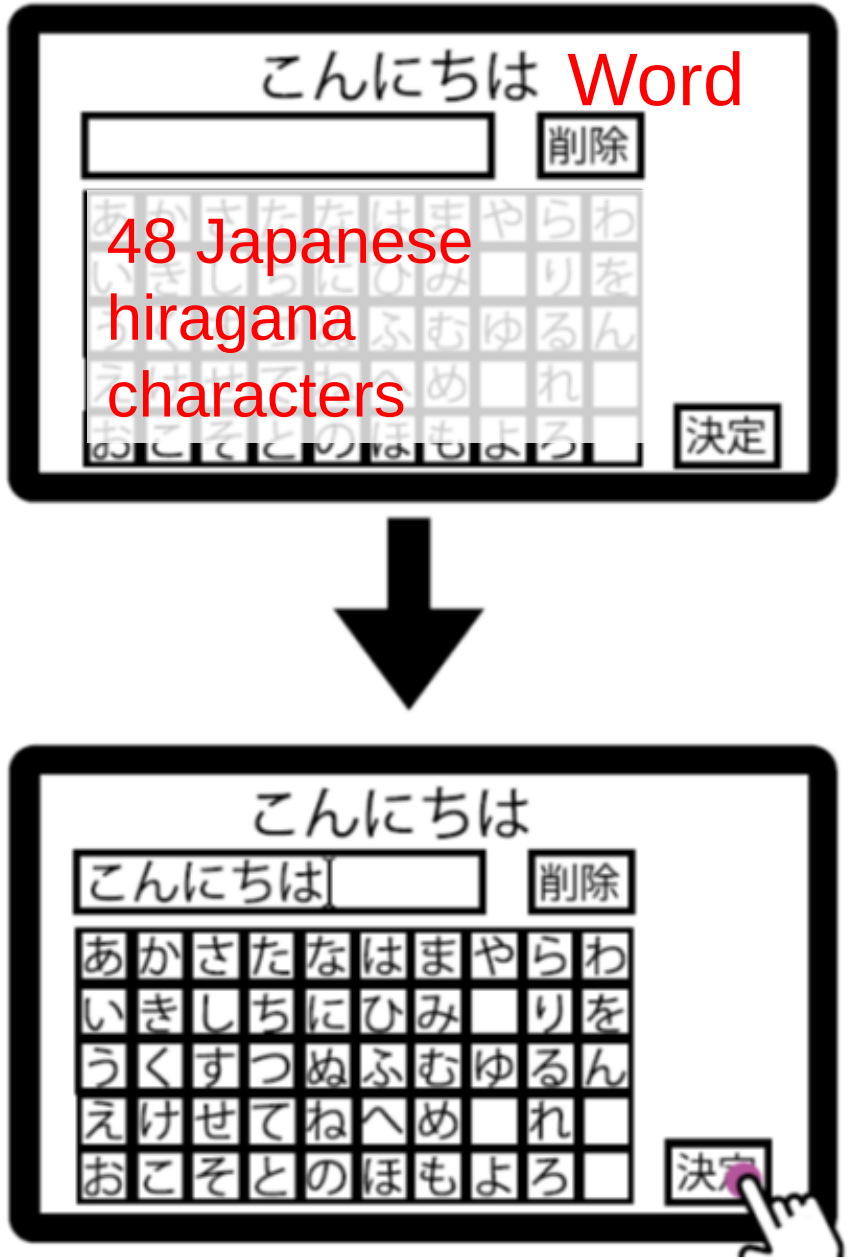
- The participants were required to view a single-digit numeral on the in-car display.
- While viewing it, the participants were to touch the same single-digit numeral from the five other numerals shown on the in-car display.



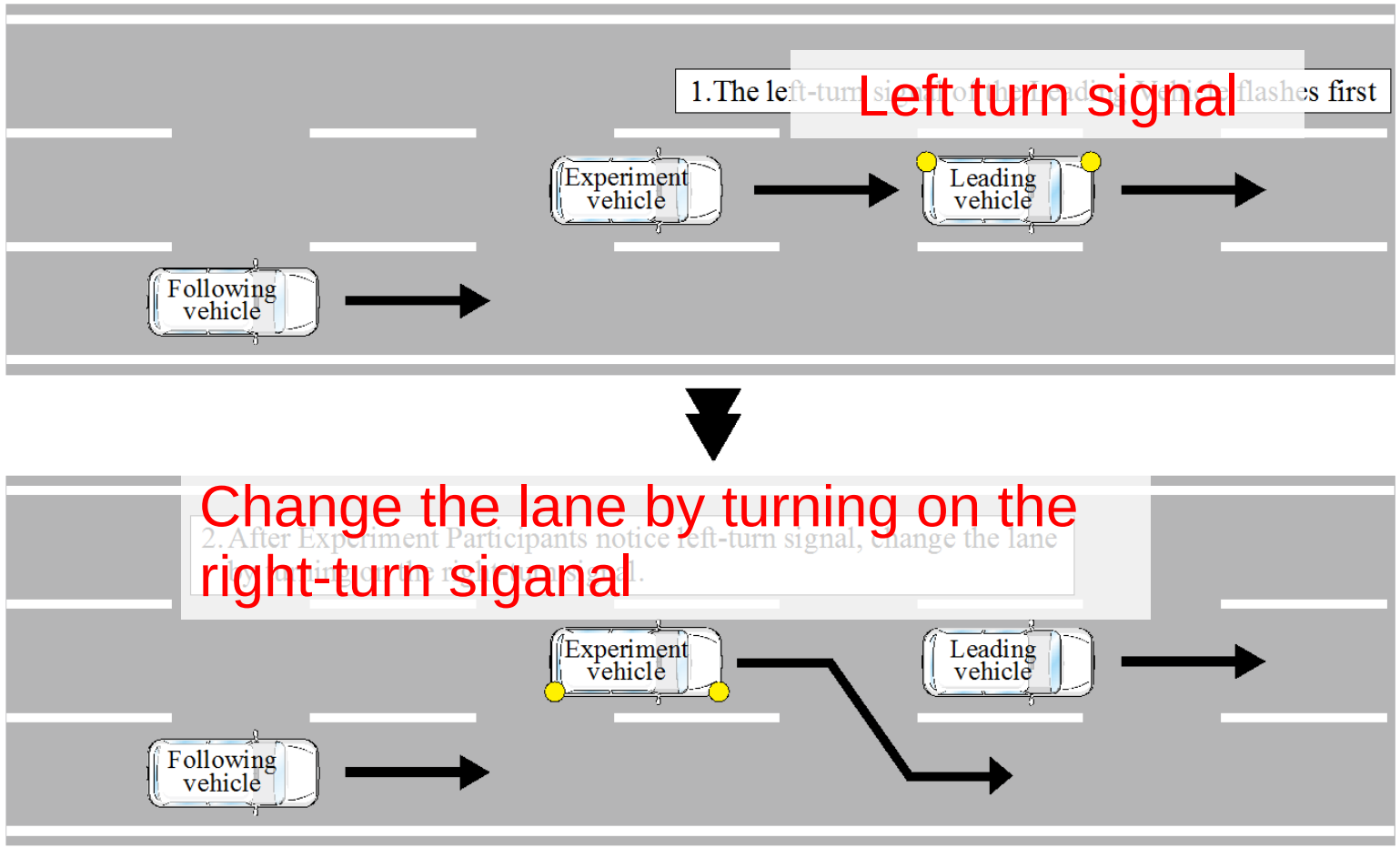
Secondary Tasks, cont.

Complex Visual Task:

- The participants were required to view one short word on the in-car display. The word was of five, six or seven Japanese hiragana characters.
- While viewing that word, the participants were to tap all the characters of the presented word with their index finger on the in-car display.
- The participants had to select the correct characters from among the 48 Japanese hiragana characters, which places a complex visual load on the participants rather than the simple visual task.



Lane Change Task



- While performing the primary task and the secondary tasks, the drivers were suddenly required to change lanes as soon as possible after noticing the left-turn signal of the lead vehicle.
- The left-turn signal of the lead vehicle was intended to simulate the sudden situation.
- The experimental vehicle has to change lanes to avoid the lead vehicle by turning on the right-turn signal.

Five Subjective Assessment Items

Q1: While you driving the test section, how easy was it to perform the simple visual task?

While you were driving the test section, how easy was it to perform the complex visual task?

Q2: While you were driving the test section, how comfort was it to perform the simple visual task?

While you were driving the test section, how comfort was it to perform the complex visual task?

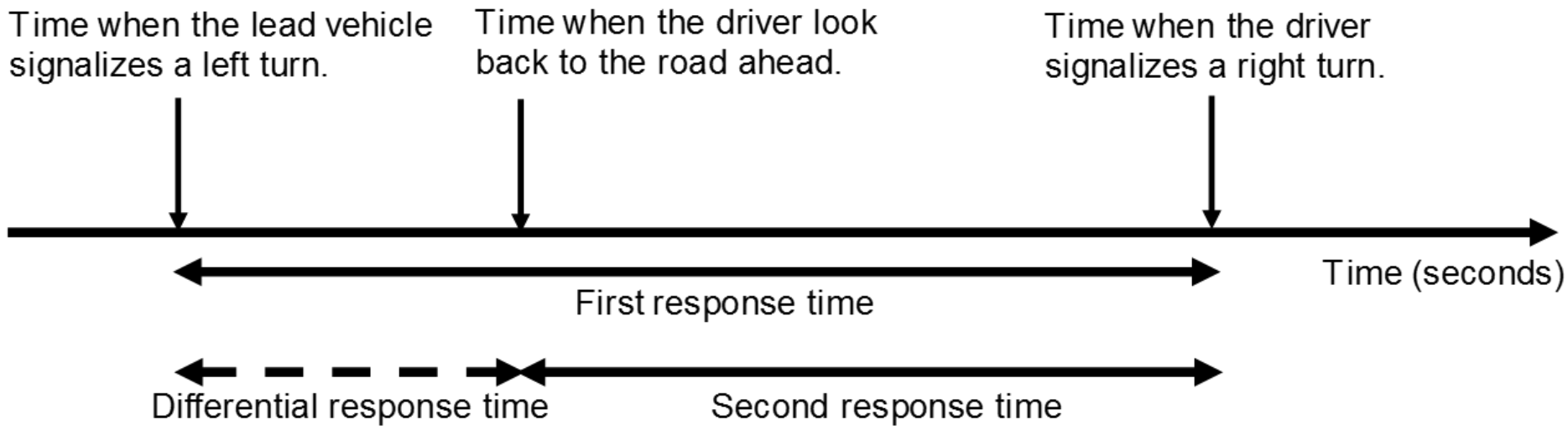
Q3: While you were driving the test section, how heavily did you depend on the ACC?

Q4: While you were driving the test section, how heavily did you depend on the LKAS?

Q5: How comfort was it to drive the test section using the advanced driver assistance systems?

Measuring the Response Time

- We used the following two response times.
  - The differential response time refers to the lag between when the lead vehicle signalized a left turn until the participants looked back to the road ahead.
  - The second response time refers to the lag between when the participants looked from the secondary task in-car display back to the road ahead until the participants signalized a right turn.



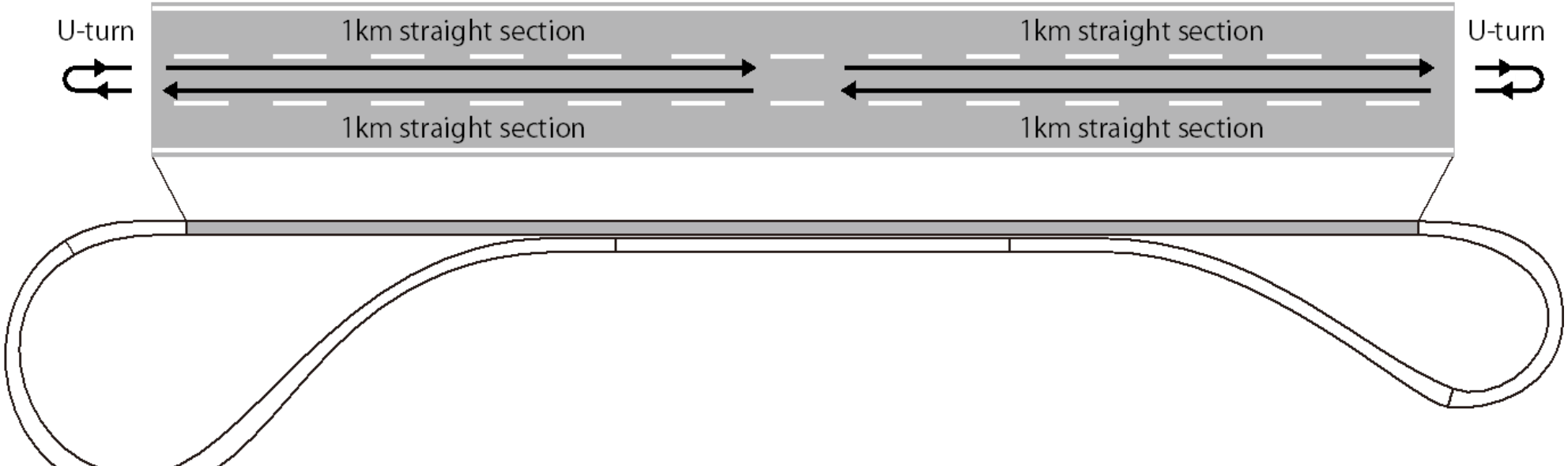
Experimental Design

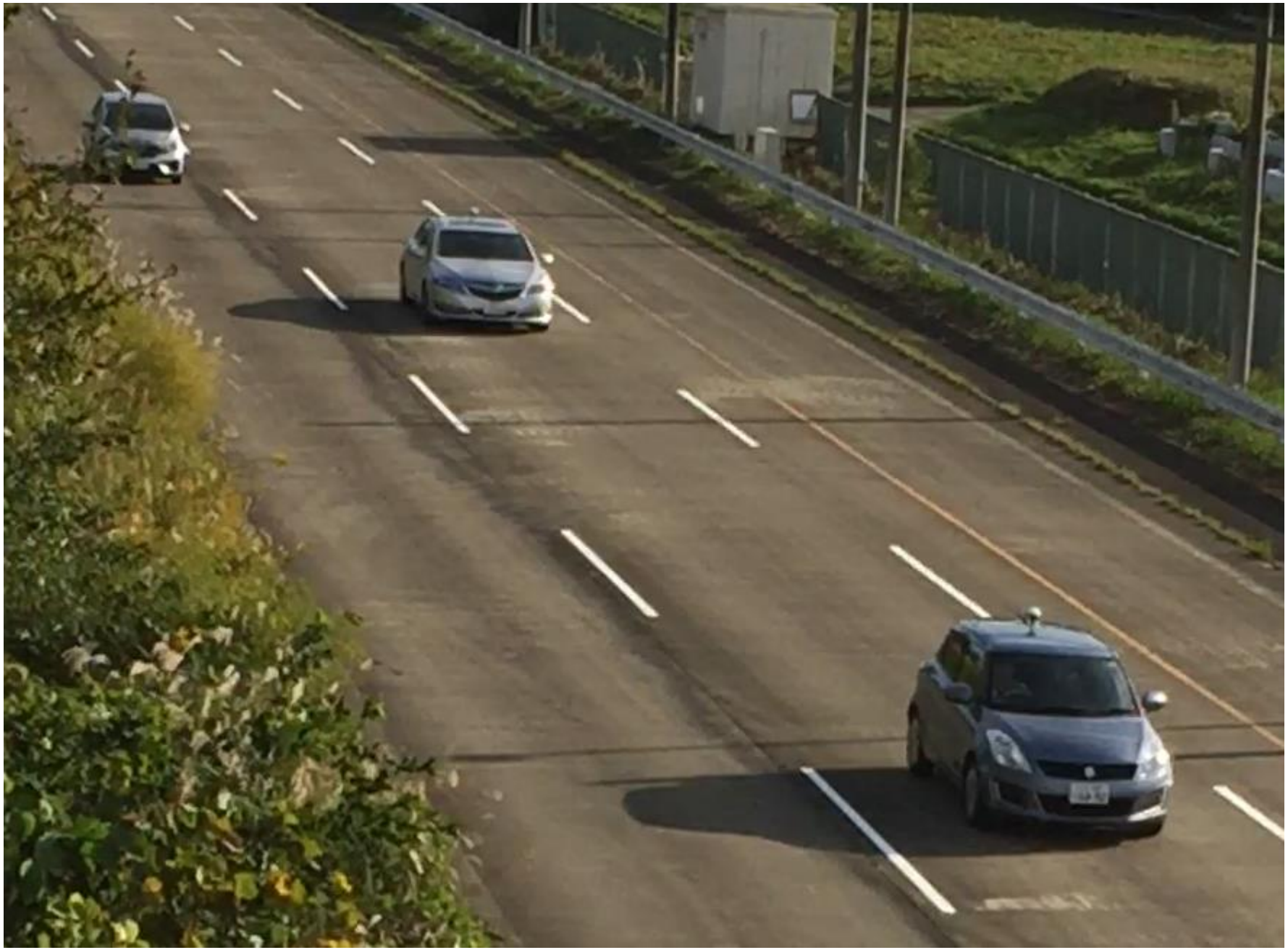
- There were two independent variables: the vehicle type (manual vehicle and partially automated vehicle), and the secondary task condition (the simple visual task and the complex visual task). The participants were self-paced in performing each of the two visual tasks during each run.

- Each participant used the manual vehicle for the first session and the partially automated vehicle for the second session. It was thought that the participants become easy to familiar with the operation of the ACC and the LKAS after they drove the test vehicle under manual condition.

Experimental Design, cont.

- The participants went around the 4km-course nine times in the manual vehicle and the partially automated vehicle.
- We divided the 4km course into four 1km straight sections.
- This gave us 36 1km sections in all. Each participant performed the lane change task four time. The secondary task conditions and the lane change task were randomly and independently assigned to each of the 36 1km straight sections.

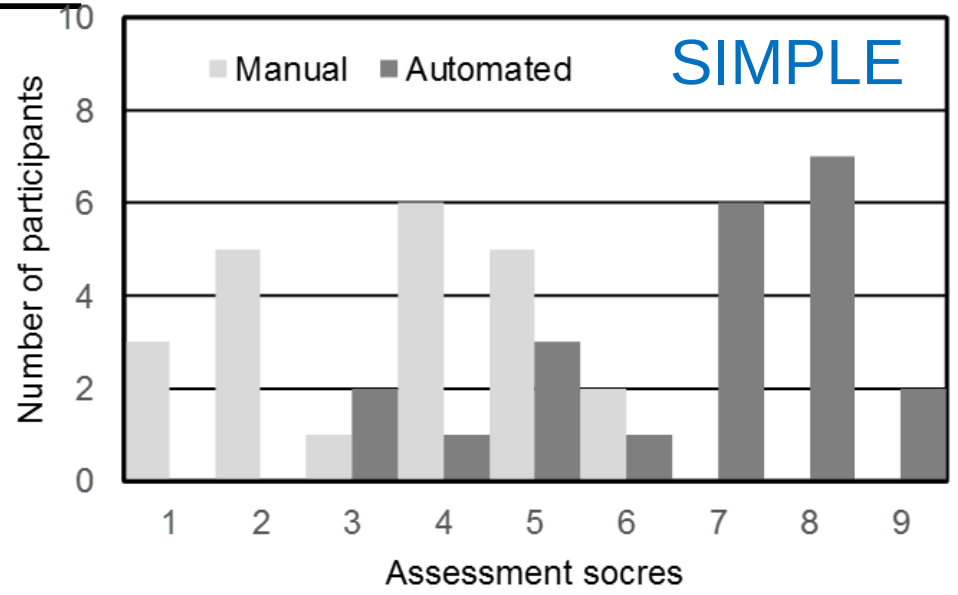


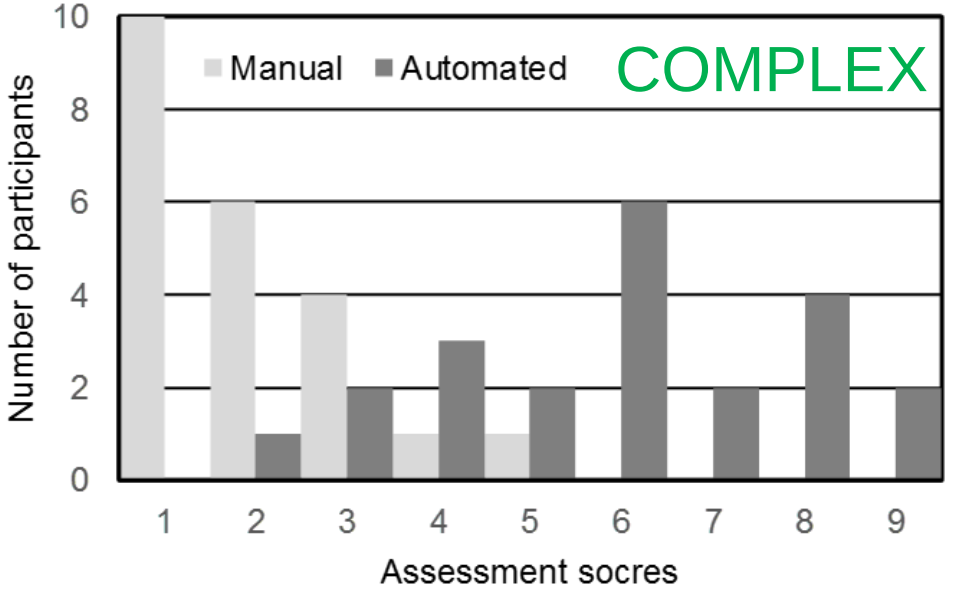


Results:

Subjective assessments of how easy it was to perform the simple and the complex visual tasks.

- There was no interaction effect between the secondary tasks and the vehicle.
- Vehicle type (F(1,79)=99.8, p<0.01) and secondary task (F(1,79)=10.5, p<0.01) had a significant effect on mean subjective assessment score for comfort.
- The operation of the secondary task under partially automated vehicle was significantly easy rather than that under manual vehicle. Also, the operation of the simple visual task was significantly more easy than that of the complex visual task.

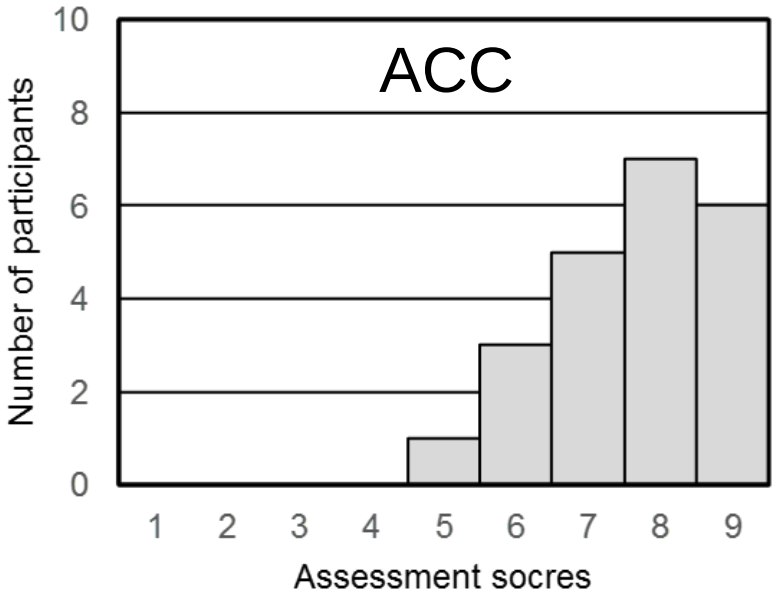


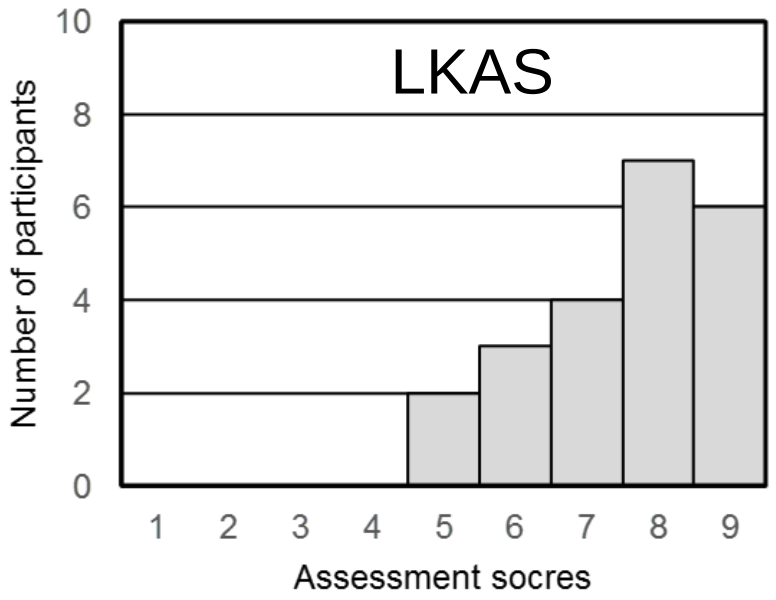


Results:

Subjective assessments of dependence on ACC and LKAS.

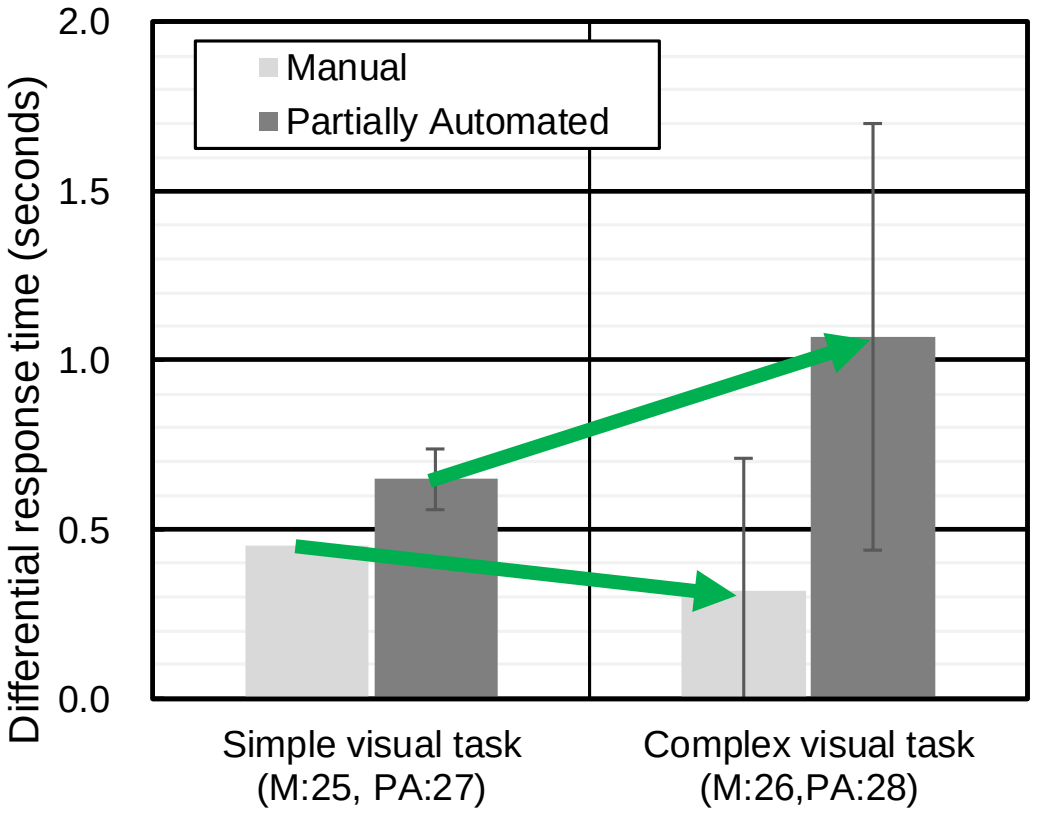
- The large value of the horizontal score means that the drivers depended on the ACC and LKAS.
- The most number of drivers selected high evaluation scores, and this means the most drivers depended on these systems.





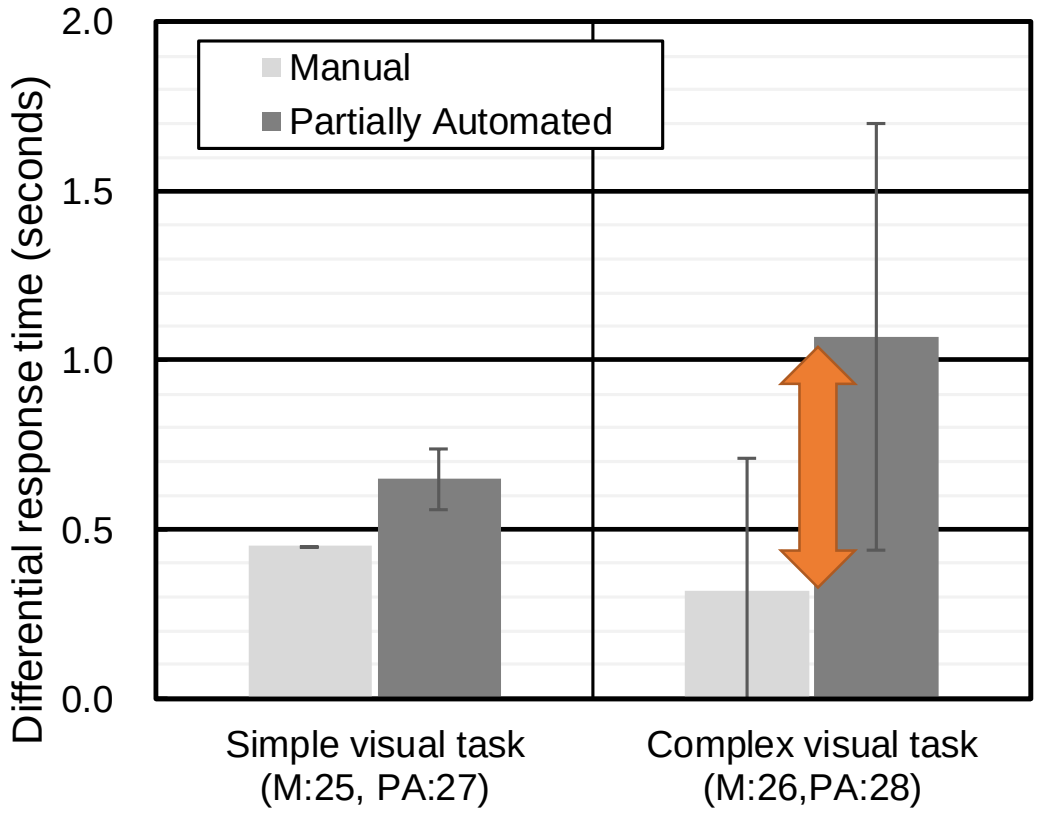
Differential response time

- The interaction between the secondary task and the vehicle type ($F(1, 89)=4.61$, $p<0.05$) was found to have a significant effect.
- Under the complex visual task, the mean differential response time for the manual vehicle became shorter than that under the simple visual task. However, this tendency was opposite for the partially automated vehicle.



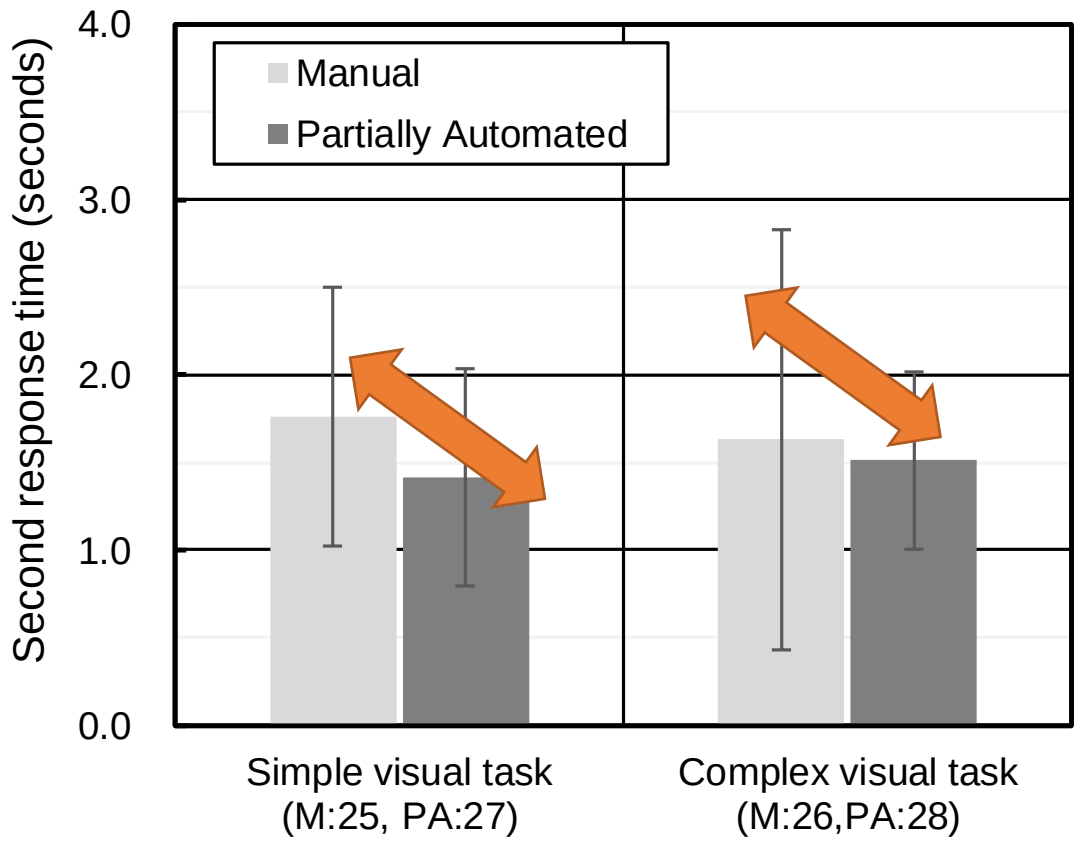
Differential response time, cont.

- Thus, we examined the mean differential response time among the two secondary task conditions for each of the two vehicles.
- There was significant difference in the mean differential response time among the two vehicles in case of the complex visual task.



Second Response Time

- There was no interaction effect between the secondary tasks and the vehicle.
- Vehicle type ($F(1,139)=5.64$, $p<0.05$) had a significant effect on the mean of the second response time.
- The second response time for the partially automated vehicle was significantly shorter than that for the manual vehicle.



Conclusions

- The differential response time for the complex visual task in the partially automated vehicle was significantly greater than that in the manual vehicle.
- It is supposed that the drivers might have chosen to focus excessively on the complex visual task because of relying heavily on partially automated driving.
- Then, it might be required to install the human machine interface to decrease the differential response time under the partially automated driving condition.

Conclusions, cont.

- Also, the second response time for the partially automated vehicle was significantly shorter than that for the manual vehicle.
- Then, it might be required to install the human machine interface to increase the driver's trust for automated vehicle.

- These results reveal that early second response can cover delay of differential response time under the simple tested driving conditions.
- However, we need to confirm these results under more complex driving situations with the partially automated vehicle.

Thank you for your kind attention

Participants

- Twenty-one drivers (aged 21 to 63 years, mean of 41.5 years, 11 females and 10 males) participated. They were recruited through local advertisements and were screened to ensure that they were active drivers with a valid Japanese driver's license.
- At the beginning of the session, the experimenters spent 30 minutes explaining contents of the experimental.
- When the explanation was complete, the participants gave written informed consent of participation. No individual declined to participate.
- The research methodology was approved by Ethical Review Committee for Research with Human Subjects in Engineering Course of Hokkaido University, Japan.

Primary Driving Task

- In case of the manual driving, participants were required to follow a lead vehicle whose speed changed.

- The lead vehicle slowed to 65 km/h and sped up to 70 km/h.
- Also, participants were required to maintain about 40m of headway (approximately 2 seconds) while following the leading vehicle.

Discussions about the response times

- The differential response time for the complex visual task in the partially automated vehicle was significantly greater than that in the manual vehicle.
- It is supposed that the drivers might have chosen to focus excessively on the complex visual task because of relying heavily on partially automated driving.
- In contrast, the second response time for the partially automated vehicle was significantly shorter than that for the manual vehicle. The partially automated vehicle might accelerate driver's situation awareness due to leave the vehicle operation to the ACC and the LKAS.