SIP-adus Human Factor / Experimental Demonstration / HMI

FY2018 Report

Overview

AIST
DENSO
Tokyoto Business Services
University of Tsukuba
Keio University

Task A : To investigate effects of system information on drivers' behavior

FY2018 Implementation Content

- Survey A-4 : Survey on understanding on “Automatic driving technology" (Questionnaire Survey)
- Experiment A-5 : Study on minimum item of knowledge’s system state (Test Course)
- Experiment A-6 : Further examination on acquiring knowledge about system state (Driving Simulator)
- Experiment A-7 : Verification of mode awareness in dynamic transition of the level of driving automation (Driving Simulator)
- Experiment A-8-1 : Verification of the effect of shared HMI for improving driver’s situation awareness to a hazard oversight (Driving Simulator)
- Experiment A-8-2 : Effectiveness’ verification of the information of the certainty for improving driver’s situation awareness to a hazard oversight (Driving Simulator)
- Survey A-9 : Survey on learning style (Questionnaire Survey)
- A- ⅰ : Driver's knowledge’s items on system functions and guidelines for expressions (Test Course)

Survey A-4: Survey on understanding on “Automatic driving technology"

【*Purpose*】

- Survey on the understanding of the general public about the terms related to "automatic driving technology".

【*Method*】

- It was conducted as a questionnaire survey using the Web. We will confirm the trend by respondent's attributes.

【*Evaluation item*】

- Questions are set about "① degree of interest in news on purpose, function and limit of automatic traveling system", "② understanding of" purpose "," function "," limit "" of automatic travel system.
- Evaluate from two series "Cause: How aggressively are you trying to obtain information" and "Result: Know how recent cases are".

【*Summary*】

- About news on automatic driving, 40% said they have heard it. The proportion increased as the age increased. (Those who answered "I have heard" at over 61 years of age are over half)
- Regarding the understanding of the level of automatic driving, 60% understood about LV 1 and LV 3 (as understood by LV 2, it is below 50%).
- When understanding the level is divided into "operation" and "RtI", the understanding of "operation" is high (70%), but the understanding of "RtI" was about 50%.

Experiment A-5-1 : Study on the minimum items of the knowledge on the system state. (Test Course)

【*Purpose*】
- Verify the hypothesis about the minimum items of the knowledge on the system state.

【*Hypothesis*】
- It is useful to properly intervene into the car's control by instructing the knowledge about the necessity of driver's intervention, the meaning of an RtI, and typical scenes to intervene when the RtI is issued.

Depends on construction site lane reduction scene

【*Participants*】
- 32 people (average 37 years old, 16 males and 16 females)

【*Method*】
- Running on the test course (outer circumference road) of Japan Automobile Research Institute (JARI) and the actual car was equipped with the level 3 of driving automation.
- SuRT implemented as subtask.

Event	Condition a	Condition b
Construction	2/16 (0.13) [1:1]	12/16 (0.75) [6:6]
Broken vehicle	1/16 (0.06) [0:1]	5/16 (0.31) [0:5]

【*Independent Variable*】: Prior knowledge (inter-subject factor)
- Condition a (FY16 Experiment 1 Condition 2 presence intervention scene)
- Condition b (FY16 Experiment 1 Condition 4 example of intervention screen)

【*Evaluation items and results*】
- Ration of the number of the cases in which drivers avoided obstacles. (The result is shown on the right)
- It was shown that the driver responded the RTI in a proper way under Condition b.

Experiment A-5-2 ：Study on minimum knowledge item of system state (Test Course)

【*Purpose*】

– The result of Experiment A-5-1 is verified on elderly drivers.

【*Hypothesis*】

– It is useful to properly intervene into the car's control by instructing the knowledge about the necessity of driver's intervention, the meaning of an RtI, and typical scenes to intervene when the RtI is issued.

Depends on construction site lane reduction scene

【*Participants*】

– 24 people (average 71 years old, 12 males and 12 females)

【*Method*】

– Running on the test course (outer circumference road) of Japan Automobile Research Institute (JARI) and the actual car was equipped with the level 3 of driving automation.

– SuRT implemented as subtask.

Event	Condition a	Condition b
Construction	0/12 (0.00) [0:0]	6/12 (0.50) [2:4]
Broken vehicle	2/12 (0.17) [0:2]	5/12 (0.42) [3:2]

【*Independent variable*】: Prior knowledge (inter-subject factor)

– Condition a (FY16 Experiment 1 Condition 2 presence of intervention scene)
– Condition b (FY16 Experiment 1 Condition 4 Example of intervention screen)

【*Evaluation items and results*】

– Ration of the number of the cases in which drivers avoided obstacles. (The result is shown on the right)

– By condition b, it was shown that the driver responded the RTI in a proper way.

Experiment A-6 Detailed examination on acquiring knowledge about system state (Driving Simulator)

【*Purpose*】Based on the Experiment-1's outcome of FY2016, A-3 aims to set up and verify the hypotheses via investigating the effects of knowledge acquisition and the experience about system failure.

(Driving Automation Level3 / non-driving task / hand-off)

【*Hypothesis*】-1st phase: the HMI's knowledge serves driver take-over behavior to an RTI and system failure

-2nd phase: training and the experience for the failure are effective for a long-term period

DS used for 1st phase

【*Participant*】72 (1st) / 72 (who participated in 1st) + 18 (only 2nd)

【*Apparatus*】DSs shown in the two pictures

DS used for 2nd phase

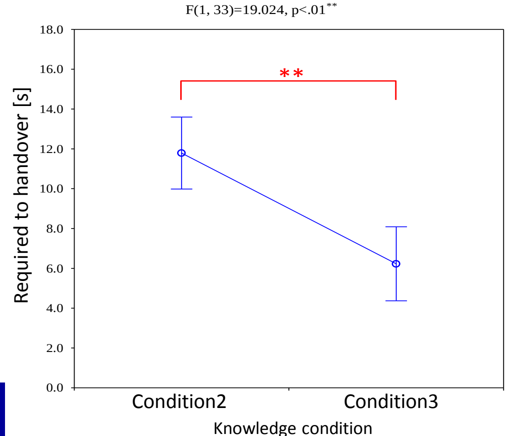
【*Experimental design*】

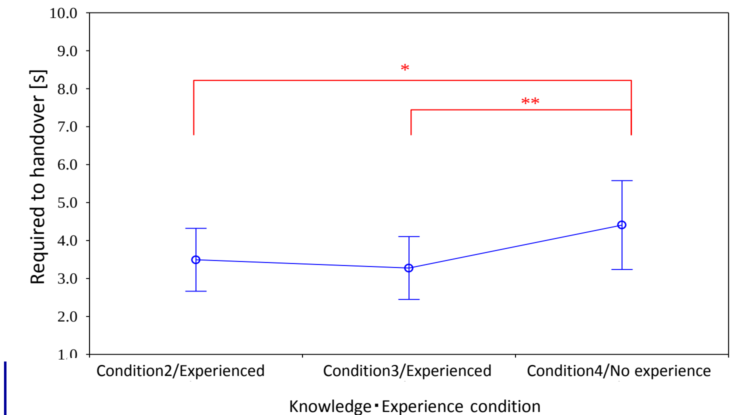
-1st one knowledge-factor (2) between subjective

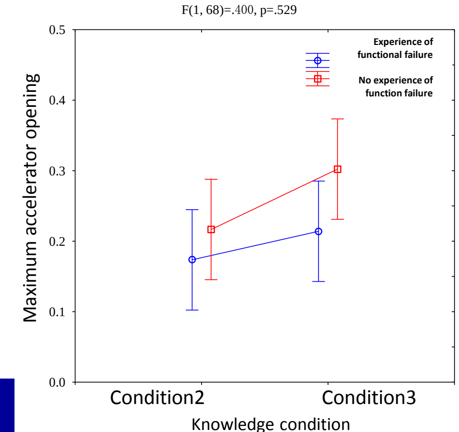
-2nd (1) one training-factor (3) between subjective

(2) two factors (knowledge(2) × experience(2)) between subjective

【*Results*】The HMI's knowledge is useful to driver take-over behavior to an RTI and the system failure. The training and the experience of the system failure were effective for a long-term period.







Experiment A-7: Verification of mode awareness in dynamic transition of the level of driving automation (Driving Simulator)

【*Purpose*】
- It is to verify whether the level (mode) awareness could be maintained through the HMI via the dynamical mode transition according to traffic environment.

【*Hypothesis*】
- Mode confusion would not occur though the system shifts the mode dynamically.

【*Participants*】
- 60 people (average 40 years old, 30 males and 30 females)

【*Method*】
- Experiment is conducted in an environment where the automatic operation level is dynamically switched on the driving simulator.

【*Independent variable*】Inter-subject factor
- Messages at level transition (status, action to take)
- Level transition method (single, multiple)

【*Evaluation items and results*】
- Driver's response behavior is evaluated when the level of driving automation is transited. (right table)
- The message of action was easier for the driver to do the response to an RTI appropriately.

Message at level transition

Status	Mode presentation	Behavior presentation
To level 2	We will move on to Level 2	Please monitor the surrounding environment.
To level 1 (ACC release)	We will move on LKA only Level 1.	Please pedal operation.
To level 1 (LKA release)	We will move on ACC only Level 1.	Please handle operation.
To level 0	We will move on to Level 0	Please move to manual operation.
Level 3 automatic operation possible	We can use Level 3, automatic operation.	Automatic operation is available.

Example of results: when transitioning to level 2
Frequency of appropriate countermeasure action

Types of HMI	Appropriate number of actions
Mode presentation	39/60(0.65)
Behavior presentation	49/60(0.82)

Experiment A-8-1: Verification of the effect of shared HMI for improving driver's situation awareness to a hazard oversight (Driving Simulator)

【*Purpose*】

- It is to verify the effectiveness of shared HMI in which the control intention and the detected objects are shown for improving driver's situation awareness to a hazard oversight.

【*Hypothesis*】

- it is effective for drivers to respond a hazard by using the HMI presents the information about situation awareness though the system oversights the hazard.

【*Participants*】

- 40 people (average 35 years old, 20 males and 20 females)

【*Method*】

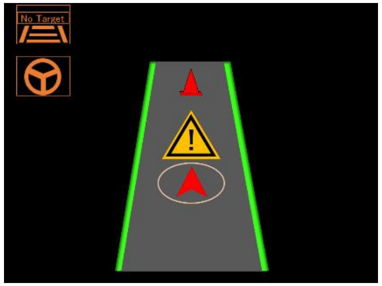
- Using the HMI that presents objects to be recognized by the Level 2 system and control intentions, an experiment including hazard overlooking scenes is conducted.

【*Independent variable*】

- Condition A: Simplified HMI
- Condition B: Control HMI (same HMI of FY17 A-3-1)

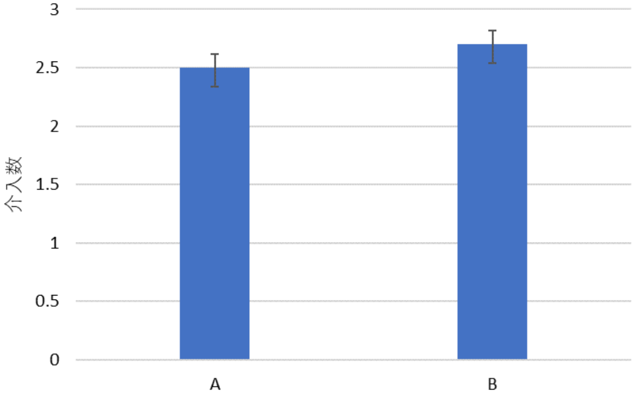
【*Evaluation items and results*】

- It is to evaluate whether the drivers operate the avoid operation correctly to the oversighted obstacle.
- Results showed that the driver responded appropriately when the system overlooked the hazard even with the simplified HMI.



Condition A: Simplified HMI

Condition B: Control HMI



Experiment A-8-2: Effectiveness' verification of the information of the certainty for improving driver's situation awareness to a hazard oversight (Driving Simulator)

【*Purpose*】

- t is to verify the effectiveness of the HMI that presents certainty information for the driver to properly deal with the situation when the driving automation overlooks the hazard .

【*Hypothesis*】

- Presenting the certainty information on situation awareness that enables the driver to properly detect the hazard oversight in the low confidence level situation.

【*Participants*】

- 60 people (average 42 years old, 30 male and 30 female)

【*Method*】

- Experiment is conducted to the scenes including a hazard overlooking scene by the system using HMI that presents the certainty information .

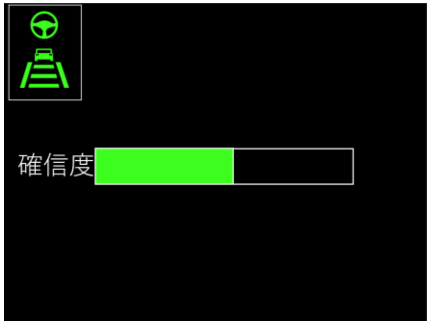
【*Independent variable*】

- Condition A: With certainty information and recognition information.
- Condition B: With certainty information and no recognition information.
- Condition C: Without certainty information and recognition information.

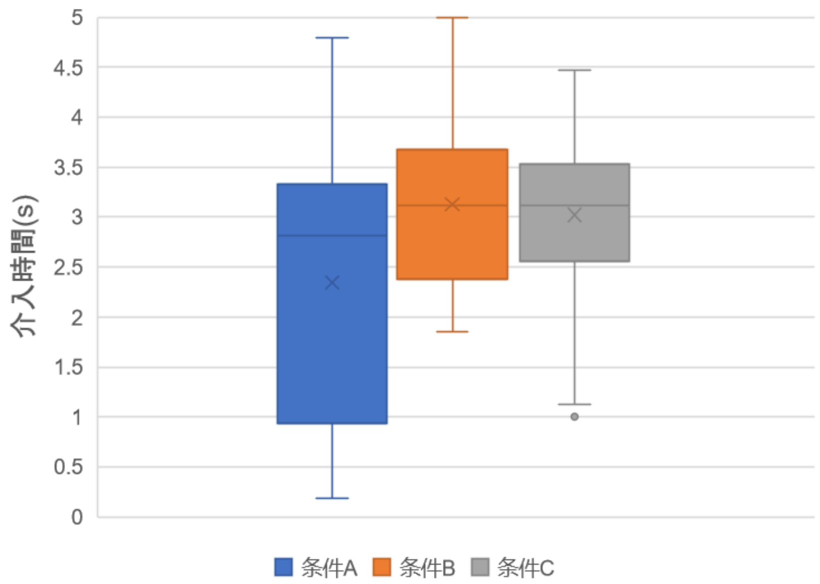
【*Evaluation items and results*】

- It is to investigate the response time of initiating the avoidance operation for the oversighted object by the system.
- Results showed that it was effective for the driver responded the oversighted obstacle appropriately in the scenario where the level of the certainty was declined .

With certainty information and recognition information



With certainty information and no recognition information



Survey A-9: Survey on learning style (Questionnaire survey)

【*Purpose*】

- It is to construct "Drafting guidelines on the items and expressions of the knowledge about driving automation", extensive survey (web survey, etc.) in order to investigate the guidelines based on the individual's learning style on instructing drivers and its reaction.

【*Hypothesis*】

- It is different that drivers effectively acquire the prior knowledge that the driver should have is different in dependence on the learning style of the driver.

【*Method*】

- Extensive survey is evaluated as the base of the response survey to the instruction according to the learning style / personality conducted in FY2017.

【*Evaluation item*】

- It is to investigate the driver's response before and after the instruction of the automated driving system's function in a questionnaire format by focusing on the learning style (Felder / Silverman model (the result is applied for the experiment design, such as A-5, A-6)

【*Summary*】

- As a teaching method, we found out that the degree of comprehension to "video teaching" is high.
- For video teaching, when examined by learning style, higher effect was seen in "Visual" and "Sequential".

A-i: Guidelines on driver's knowledge items and expressions on system functions (test course)

【*Purpose*】
- It is verified the result of the experiment of A-5 on the test course.

【*Hypothesis*】
- It is useful to properly intervene into the car's control by instructing the knowledge about the necessity of driver's intervention, the meaning of an RtI, and typical scenes to intervene when the RtI is issued.

【*Participating companies and method*】
- Upper right table

【*Independent variable*】: Prior knowledge (inter-subject factor)
- Condition a (FY16 Experiment 1 Condition 2 presence of intervention scene)
- Condition b (FY16 Experiment 1 Condition 4 Example of Intervention Screen)

【*Evaluation items and results*】
- Ration of the number of the cases in which drivers avoided obstacles. (The result is shown on the right)
- It was shown that the driver responded the RTI in a proper way under Condition b.

	Company A	Company B	Company C
Leading vehicle	One	None	One
Obstacle	LED warning light	Install "sign of lane decrease" and LED warning light on rubber mat	LED warning light on rubber mat
Automatic operation level	Level 3	Level 2	Level 3
Hands On / Off	Hands off	Hands on	Hands off
HMI (sound) at RtI occurrence	Warning tone (same as Experiment A-5)	Announcement of “Change driving"	Announcement of “Change driving"
Explanation of HMI in condition a	None	None	There
Presentation of HMI (voice)	Presented	Presented	None
SuRT	Continuous	1 time / 10 seconds	1 time / 10 seconds
System cancellation	Handle, accelerator, brake operation	The system is released with RtI	The system is released with RtI

Participants	Condition a	Condition b
Company A	1/10（0.10）	8/12（0.70）
Company B	1/9（0.11）	6/9（0.67）
Company C	2/13（0.15）	5/14（0.36）

In the experiment of company C, we did not announced "change of driving" as prior knowledge.
⇒ It is important to “Hearing the sound"

Task B : Evaluation of driver condition and the state of maintenance of the HMI

FY2018 Implementation Content

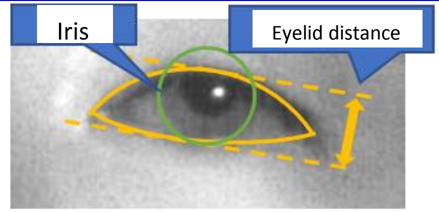
1. Examination of the evaluation index of driver condition during automatic driving and feasibility study of driver monitoring system (DMS)

2. Formulation of Basic HMI Requirements for Maintaining Driver Status: Evaluation of effect of awareness maintenance HMI

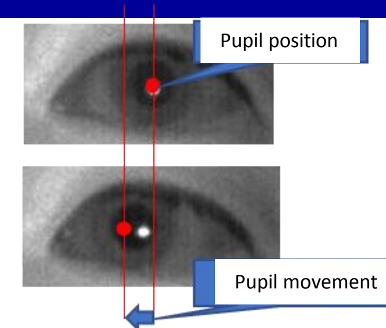
Investigation of DMS's feasibility

-Define the detection specifications based on data collected in driving simulator and test course.

-Feasibility study by evaluate and improve detection performance with data collected on public roads.



Eyelid degree= Eyelid distance / Iris diameter



Item	Index value	Detection specification	Specification for evaluation (FHD,120fps)	Specification for general-use camera (VGA,30fps)
Blink	**Frequency**: Number of last 2 min. (Times)	Calculate degree of lid opening by detecting upper and lower eyelids and iris. Blinking is judged from the amount of movement per unit time.	Evaluated with occurrence timing detection performance F value: 0.85	Evaluated with occurrence timing detection performance F value: 0.81
Eye closing	**PERCLOS**: % of eye closing time in the last min. (%)	Closed eye is judged from when the degree of open eyelids is 20% or less. PERCLOS is calculated from percentage of closed eye ≧ 500 msec. within the last min.	Mean of error: 0.61%	Mean of error: 0.62%
Saccades (Fast eye movement in a short time)	**Frequency**: Number of last 2 min. (Times) **Amplitude**: Amplitude of pupil movement (Angle)	Calculate the moving speed in the lateral direction of the pupil position and classify it from the movement amount (px) of the pupil to the amplitude (deg.) when the threshold value is exceeded. Small: 5〜8 degree Medium: 8〜16 degree Large: 16〜32 degree	Evaluated by occurrence timing detection performance for each amplitude Large F value: 0.77 Medium F value: 0.71 Small F value: 0.55	Evaluated by occurrence timing detection performance for each amplitude Large F value: 0.69 Medium F value: 0.65 Small F value: 0.47
Gaze	**Gaze duration**: Average duration at each place in the last min. (Min/Times) **Gaze ratio**: Gaze ratio to each place in the last min. (%)	Gaze target (Fr glass, Sub Disp.) is estimated from the angle of gaze. Calculate the average time and ratio of the unit time from the gaze which continue 2 seconds or longer.	Fr glass F value: 0.90 Sub Disp. F value: 0.92	Fr glass F value: 0.91 Sub Disp. F value: 0.90

1. Examination of the evaluation index of driver condition during automatic driving feasibility of driver monitoring system (DMS)

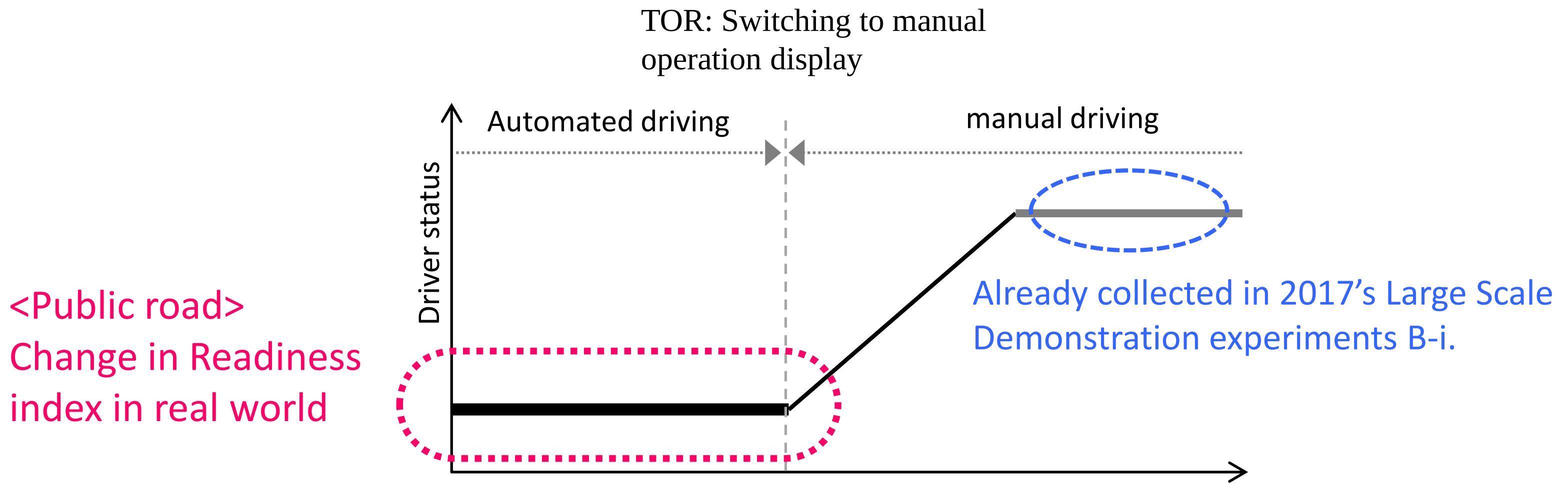
Public road experiment: Real world data acquisition of Readiness composition index

Purpose of experiment

Data acquisition of Readiness constitution indicator

In an actual environment, we will acquire data for a long time of about 3 hours, collect data on environmental changes and readiness composition indicators of various driver states.

Positioning of collected data



Experiment B-1-3: Real world data acquisition of Readiness composition index

Experiment Scale (1/2)

Participants: 40 people

Age : 20 to 50 year's old / male-female ratio is half (plan)

Conditions : - Those who regularly drive (approximately once or more per week)

- People who experienced driving highway once or more in month.
- Those who have never received a course aimed at improving driving skills, such as motor sports training and A license / B license training
- Those who do not wear glasses while driving (soft contact lenses are acceptable)

Experimental vehicle: Automatic driving level 2

(Tesla Model S, or Benz E Station Wagon)

<u>When switching from automatic to manual</u>

Automatic operation ON / OFF display + sound presentation

→Same design with 2017 test course experiment

Experiment B-1-3: Real world data acquisition of Readiness composition index

Experiment Scale (2/2)

Experimental period: 3 days per person (manual operation, automatic operation, automatic operation)
Driving time will be 3 hours 30 minutes

Automatic operation in use: Hands ON

Participant: Research staff

Teaching during automatic driving: Always keep track of the surrounding traffic conditions and monitor automatic operation so that there is no accident.
On the scenes where RtI presentation possibility exists, the situation and concrete points are clearly indicated on the map (task A result).

Experiment B-1-3: Real world data acquisition of Readiness composition index

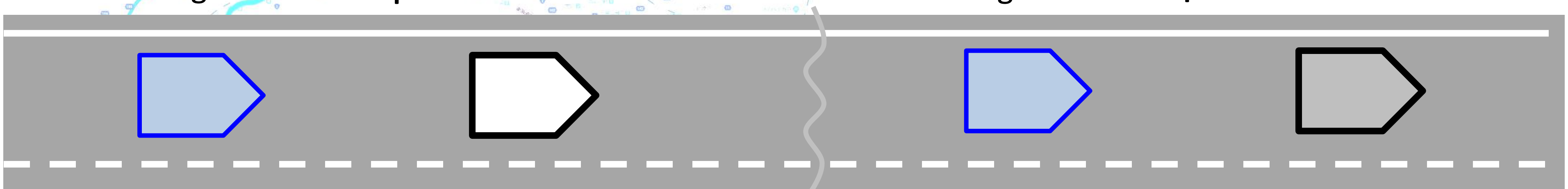
Traveling route

Suburban highway in Tokyo | Long distance highway

Outward trip : Yokosuka IC → Shin-hodogaya IC → Yokohama Machida IC → Gotemba JCT → Shinshimizu JCT

Return : Yokosuka IC ← Shin-hodogaya IC ← Yokohama Machida IC ← Gotemba JCT ← Shimizu JCT.

Following vehicle — Experimental vehicle: **Tesla S** — Following vehicle — Experimental vehicle: **Benz E**



One observer

Two participants
(Driver will change on outward and return)
1 measurer

One observer

Two participants
(Driver will change on outward and return)
1 measurer

Experiment B-1-3: Real world data acquisition of Readiness composition index

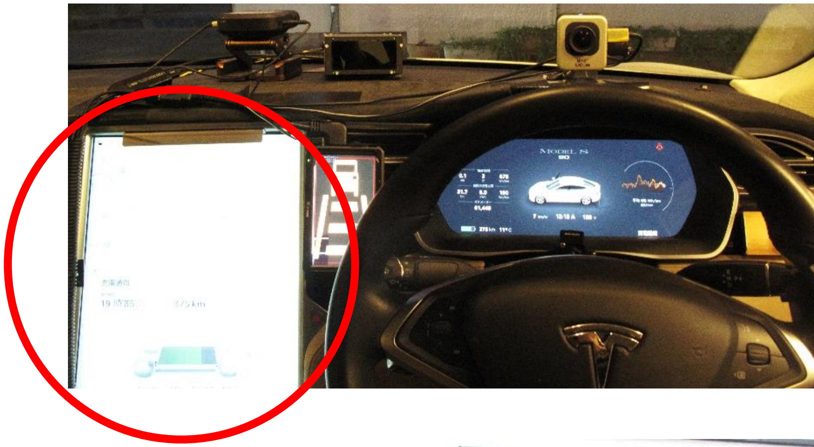
Measurement item

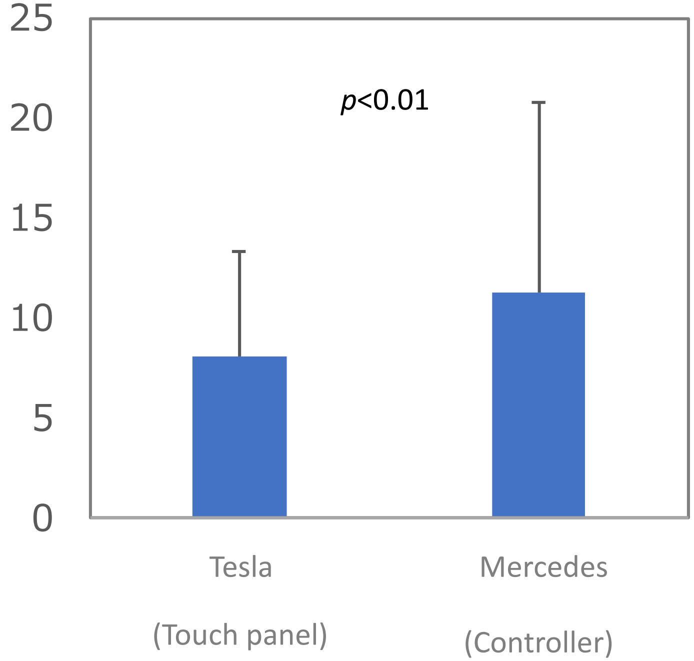
- ■ Driver, vehicle, traffic environment data
  - DMS gaze, eyelid degree, blink, saccade (instant eye movement)
  - Vehicle information (CAN information)
  - GPS information
  - Video surroundings of vehicle

- ■ Other measurement items
  - Hearing of driver status

    ※The staff regularly ask questions to the driver.
  - Observation records of the surrounding environment (weather, traffic congestion, interruptions, confluent vehicles, lane change etc.) by the staff and observation record of driver condition (execution of secondary task etc.)

Inattentiveness: Navitask (Change scale of map / Change direction of map)





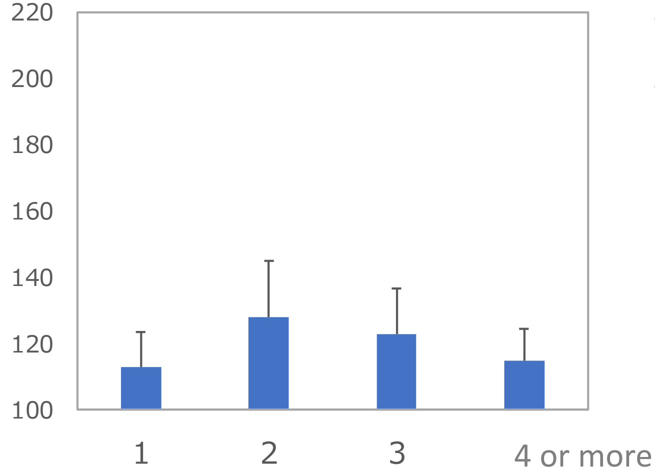
Display’s total viewing time (sec)

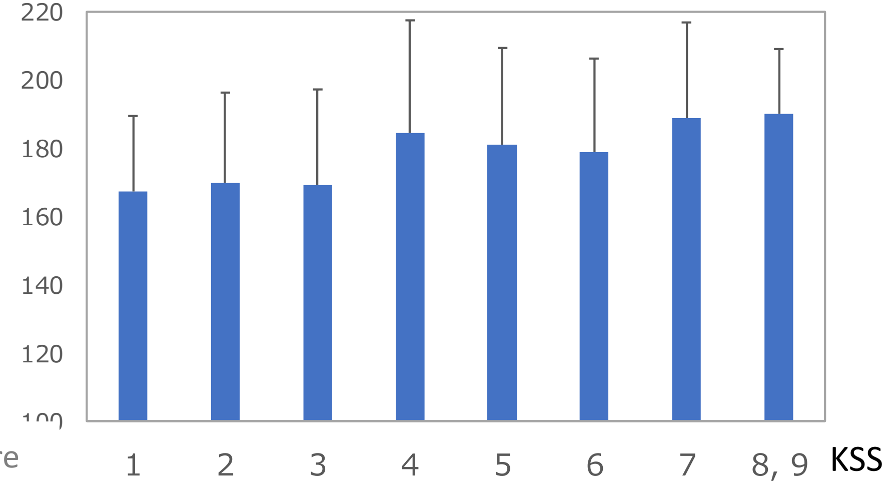
Total viewing time to Navi in 1 minute after the start of Navitask

Decline in drowsiness

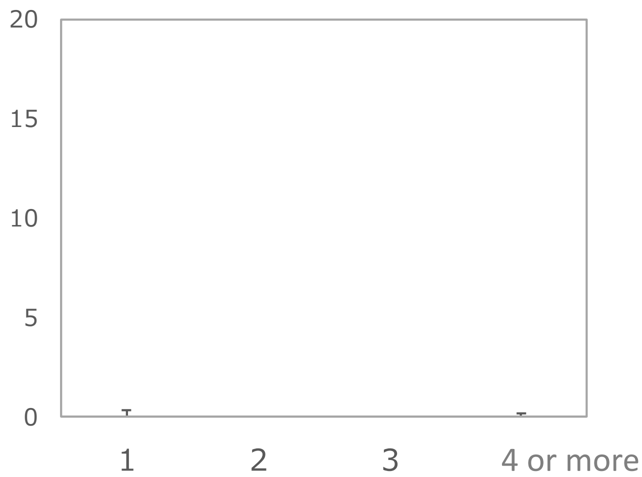
Manual driving
(FY 2017's OEM demonstration experiment)

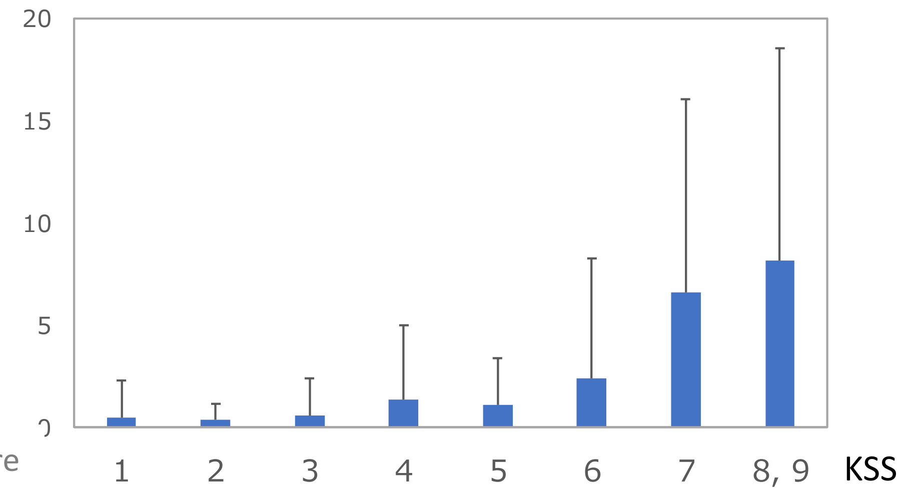
Automated driving
(Public road experiment)





Blink duration (sec)

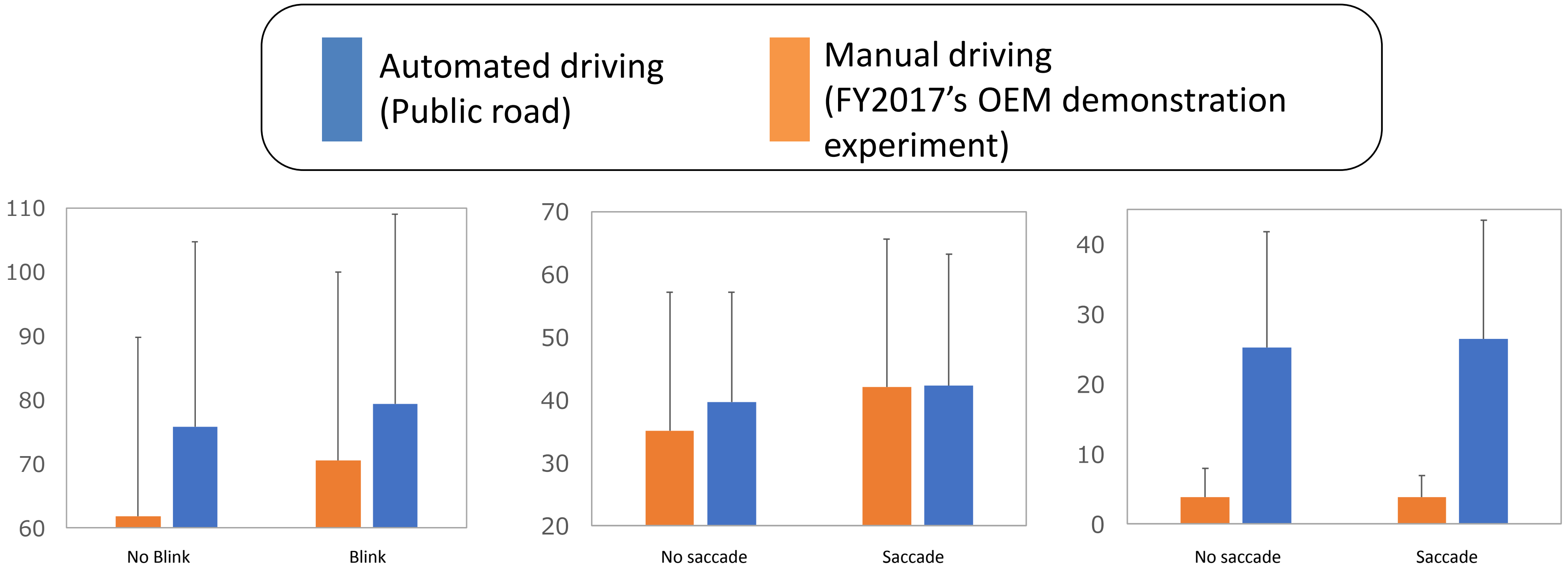




PERCLOS (%)

With or without thinking: Comparison with baseline (Manual operation)

Compared to manual operation, the number of blinks and the large saccade occurs more during automatic operation.



Number of blinks (times)

Small saccade occurrences (times)

Large saccade occurrences (times)

※ With the thinking, there are no consciousness as much as Nback which has been carried out so far.

2. Establishment of HMI Basic Requirements for Maintaining Driver Status: Effect of maintaining awareness Level of HMI

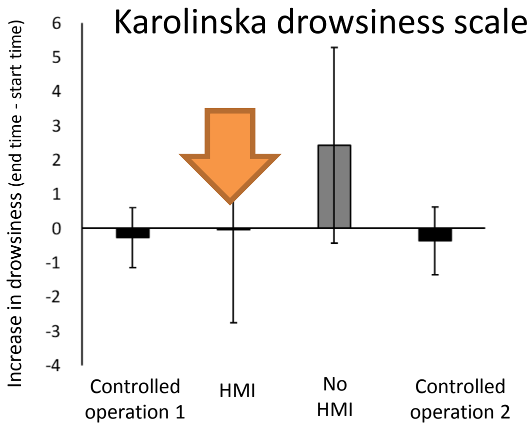
Experiment B-4-2: Consideration of cold wind and vibration's HMI

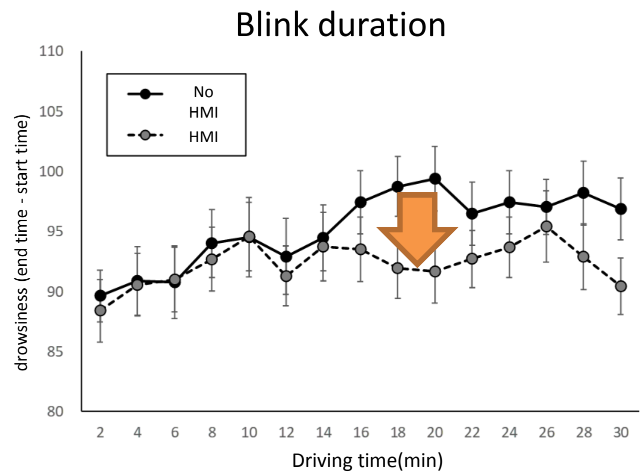
【Method】

- Maintenance · Recovery HMI · · · Presenting cool wind and vibration to the driver during automatic operation.
- Experimental environment ... AIST · North site test runway
- Driving environment · · · Automatic operation (following the leading vehicle) → RtI occurrence → Avoid the pylons with manual driving.
- Driving conditions ① Controlled operation 1 (3 minutes of automatic running)
  ② No HMI (30 minutes of automatic running)
  ③ With HMI (Stimulate presentation while 30 minutes of automatic running → Strong presentation 1 minutes before RtI)
  ④ Controlled operation 2 (3 minutes of automatic running)
- Participants · · · 36 people(18 males, 18 females), average age 45.4 years (21-75 years)
- Drowsily index ··· Subjective indicator: Japanese version's Karolinska drowsiness scale (difference before and after running)
  Objective indicator: Blink duration (average of two minutes immediately before RtI)
- Readiness index · · · Reaction time of steering operation
  Variation in steering operation

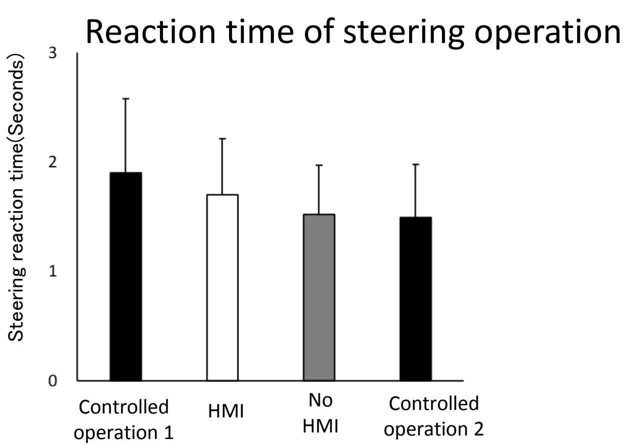
【Result】

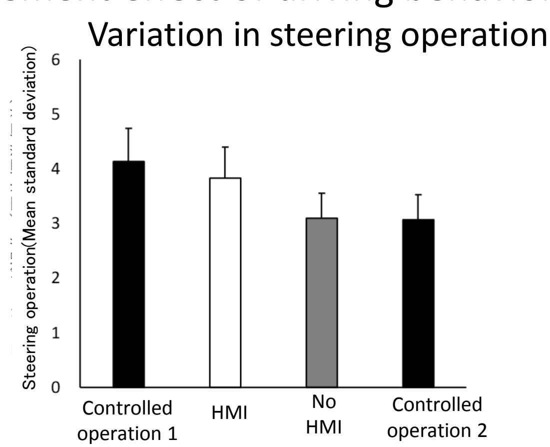
Drowsiness・・・The effect of suppressing the increase of drowsiness by HMI was confirmed





Readiness level・・・We could not confirm the improvement effect of driving behavior by HMI.





【Conclusion】 Cool air / vibration's HMI suppress the drowsiness but there were no effect of maintain and recover of Readiness level. There is a possibility that the lowering of the sensible temperature may have been influenced.

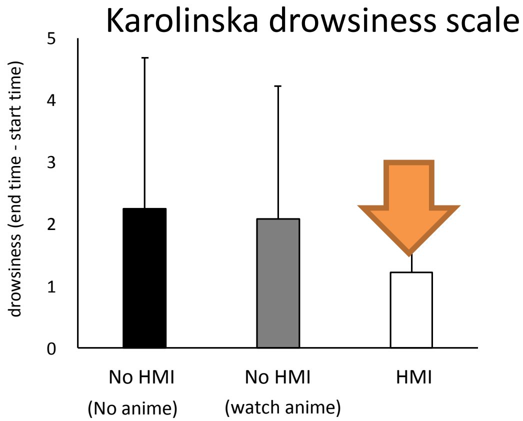
Experiment B-4-3-1: Active cognitive task (video game) HMI examination

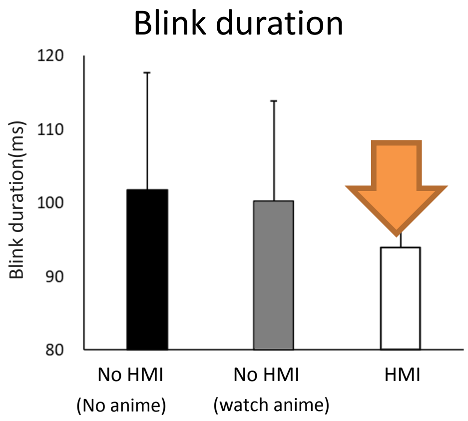
【Method】

- Maintenance / Recovery HMI･･･Playing video game(Tetris) for 10 minutes during automatic driving.
- Experiment environment･･･AIST · 6 axis motion type driving simulator
- Driving environment･･･30 minutes of automatic operation → RtI generation → Avoid the stopping vehicle by manual driving.
- Driving conditions ① No HMI (no animation viewing)
  ② No HMI (with animation viewing)
  ③ With HMI (10 minutes of animation viewing → 10minutes of playing video game→ 10 minutes of animation viewing)
- Participants･･･36 people(male 18, female 18), average age 44.3 years (19 to 74 years old)
- Drowsily index ･･･Subjective Indicator: Japanese Karolinska Sleepiness Scale (difference before and after driving)
  Objective indicator: Blink duration (average of two minutes immediately before RtI)
- Readiness index･･･Reaction time of steering operation
  Variation in steering operation

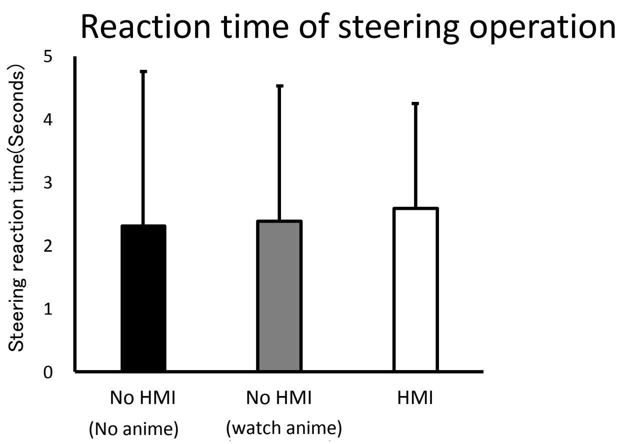
【Result】

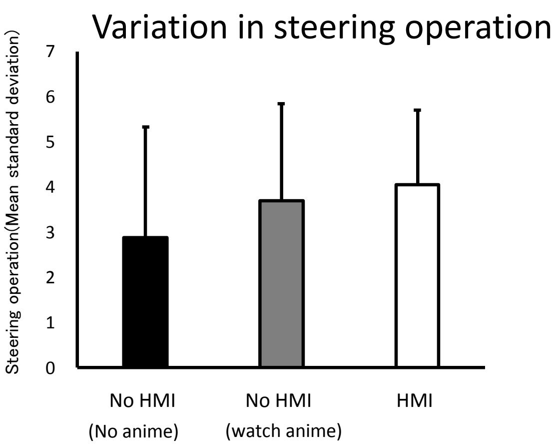
Drowsiness・・・The effect of suppressing the increase of drowsiness by HMI was confirmed





Readiness level・・・We could not confirm the improvement effect of driving behavior by HMI.





【Conclusion】

Active cognitive task HMI suppresses drowsiness 10 minutes after completion of the task, however maintaining / restoring effectiveness of Readiness level is not recognized.

Experiment B-4-3-2: Influence of automatic travel time on drowsiness and readiness

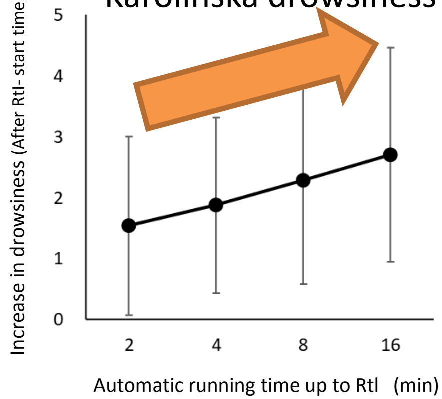
【Method】

- Experimental environment ... AIST · stationary driving simulator
- Driving environment · · · Automatic travel (following the leading vehicle) → RtI occurrence → Avoid the stopping vehicle by manual driving → Automatic driving restart → (×3 times)
- Driving conditions ① 2 minutes of automatic running
  ② 4 minutes of automatic running
  ③ 8 minutes of automatic running
  ④ 16 minutes of automatic running
- Participants ... 40 people(20 males, 20 females), average age 39.1 years (21 to 56 years old)
- Drowsily index ··· Subjective indicator: Japanese version’s Karolinska drowsiness scale (difference between before running and after RtI)
  Objective indicator: Drowsiness judgment by facial expression (within 1 minute immediately before RtI)
- Readiness index · · · Reaction time of steering operation
  Variation in steering operation

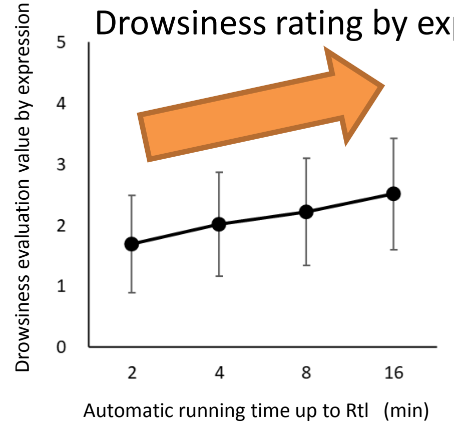
【Result】

Drowsiness・・・We confirmed drowsiness increase according to automatic traveling time

Karolinska drowsiness scale

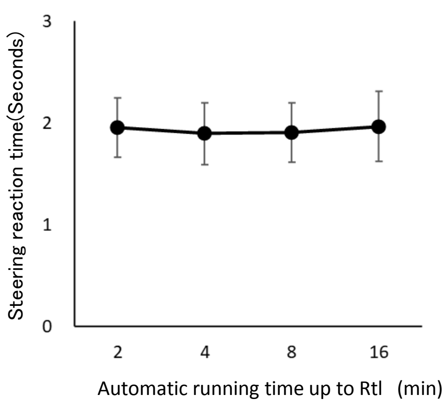


Drowsiness rating by expression

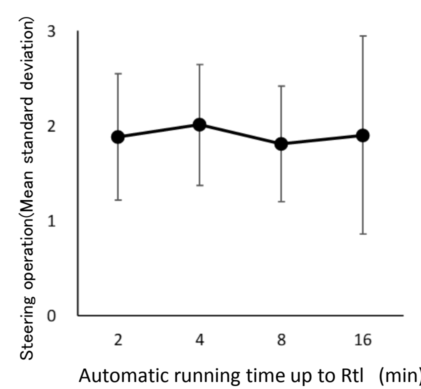


Readiness level・・・We could not confirm changes in driving behavior according to automatic driving time

Reaction time of steering operation



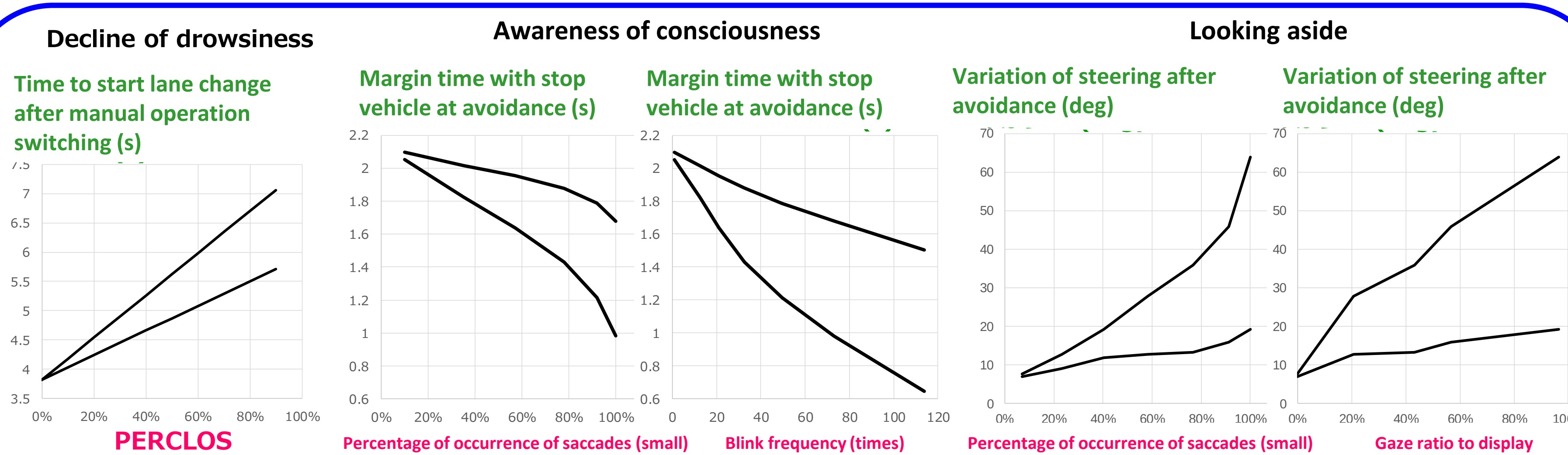
Variation in steering operation



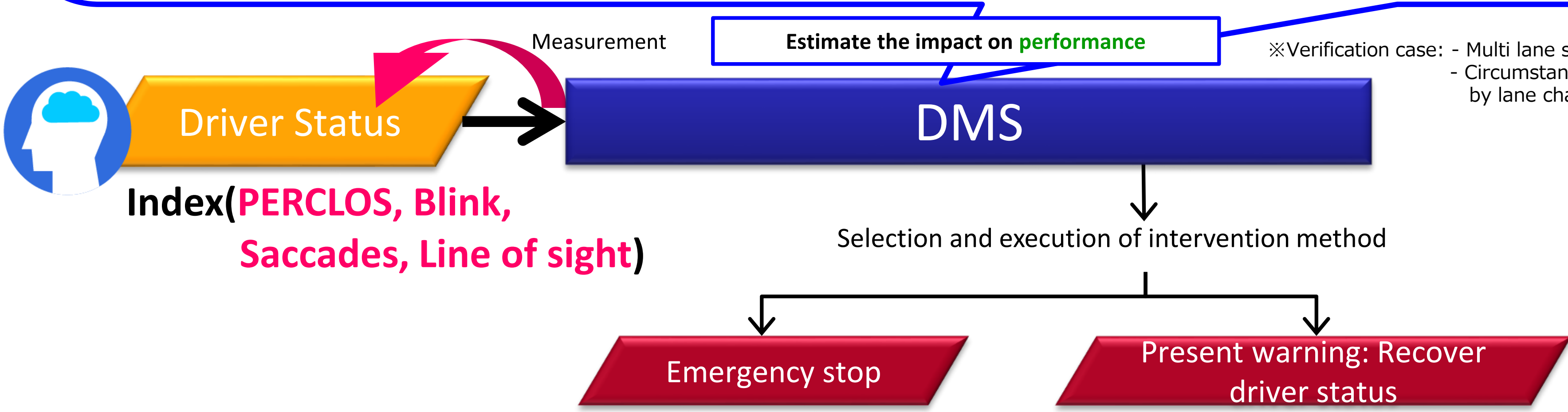
【Conclusion】 In automatic traveling within 16 minutes, drowsiness increases according to traveling time, however It does not necessarily directly lead to a decline in Readiness level.

Example of how to use Readiness index

Estimated the Readiness level based on the relationship between the driver status indicator obtained from the driver's state data during automatic operation and the driving behavior data after manual operation switching and the performance.



<Calculated from the linear regression coefficient of the driver‘s condition index and the driving behavior index and 95% confidence interval at each of awakening degree>



※Verification case: - Multi lane section
- Circumstances to avoid by lane change.

Achievement of 2018's

1. Examination of the evaluation index of driver condition during automatic driving feasibility of driver monitoring system (DMS)

   Confirmed that it is possible to measure the indicator of the driver's condition which is the result of FY2016 and FY2017 at the public road environment. (real world)

2. Establishment of HMI Basic Requirements for Maintaining Driver Status: Effect of maintaining awareness Level of HMI

   Confirmed that the effect of suppressing increase in drowsiness of the driver during the automatic traveling, however the effect of improving the performance after driving change was not effected.

Task C：To investigate effective communication method between AV and other traffic participants.

FY2018 Implementation Content

C-5. Requirements for communication between an automated driving vehicle and other traffic participants in low-speed conditions for general roads.

C-5-1. Examination of communication requirements by test track experiment
C-5-2. Consideration of communication requirements by simulator experiment
C-5-3. Examination of communication requirements by field experiment

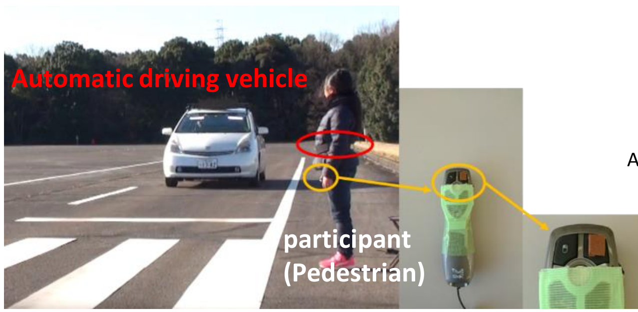
C-6. Proposal of investigation method on the influence of locality and traffic participant attributes in communication between an automated driving vehicle and other traffic participants.

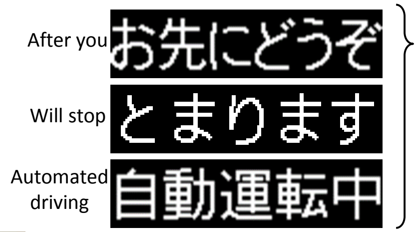
C-6-1. Investigation of survey method on the influence of locality and traffic participants' attributes · Comparison between Japan and the UK.
C-6-2. Investigation on the influence of regional characteristics and attributes on communication between automated driving vehicle and pedestrian at low speed.

C-5 Extraction of requirement on communication in low speed condition for general road

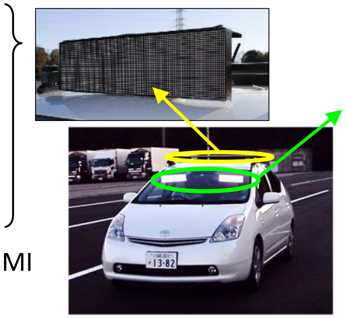
C-5-1 Extraction of basic requirement for automatic vehicle and pedestrian communication in low speed condition (test track)

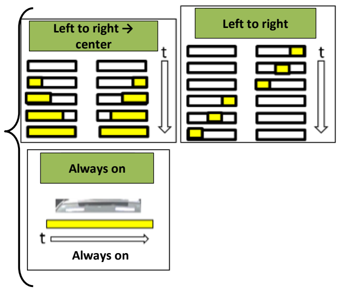
Purpose: Investigate pedestrian recognition and judgment on communication when communicating intention and state to other traffic participants using external HMI from an automated vehicle traveling in low speed condition and extract communication requirements





Intention / state by external HMI
Communication (text type)





Intention / state by outward HMI
Transmission (light type)

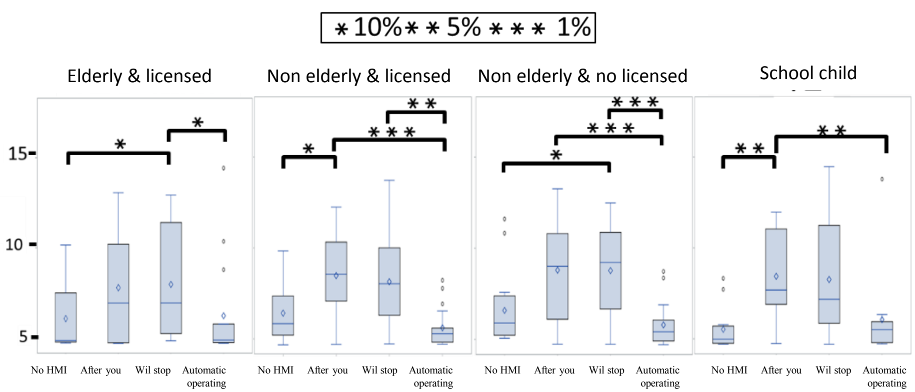
Participants: 79 people, non-elderly people [licensed], non-elderly people [no licensed], elderly people [licensed], school children

Experimental method: When the preceding vehicle and the automated vehicle approached the pedestrian crossing at a low speed of 15 km/h, when the subject judged that the crossing can be started safely by observing the vehicle condition of the automated vehicle (including the external HMI) Press the button.

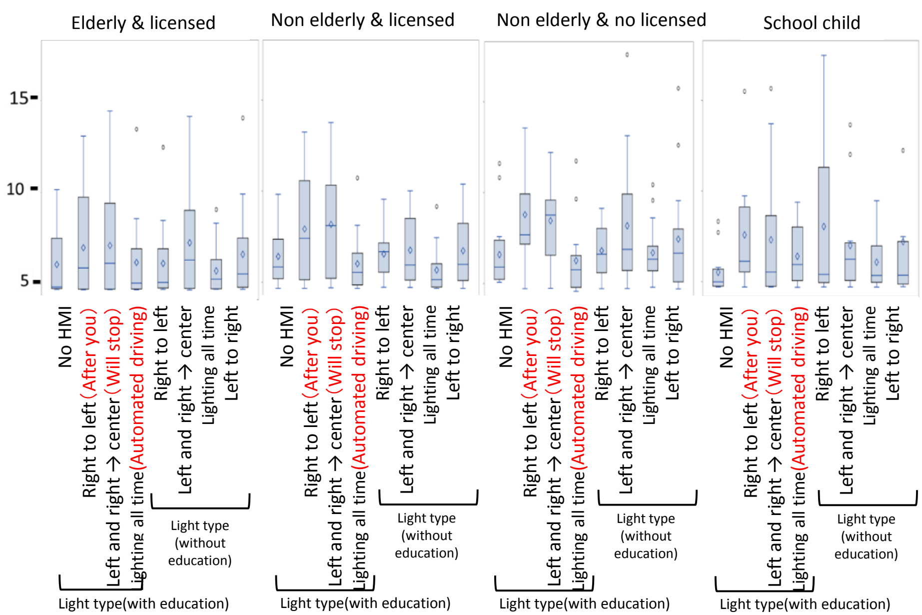
Experimental condition: Control condition (without external HMI), text type, light type (light meaning educated / no light meaning educated)

C-5 Extraction of requirement on communication in low speed condition for general road

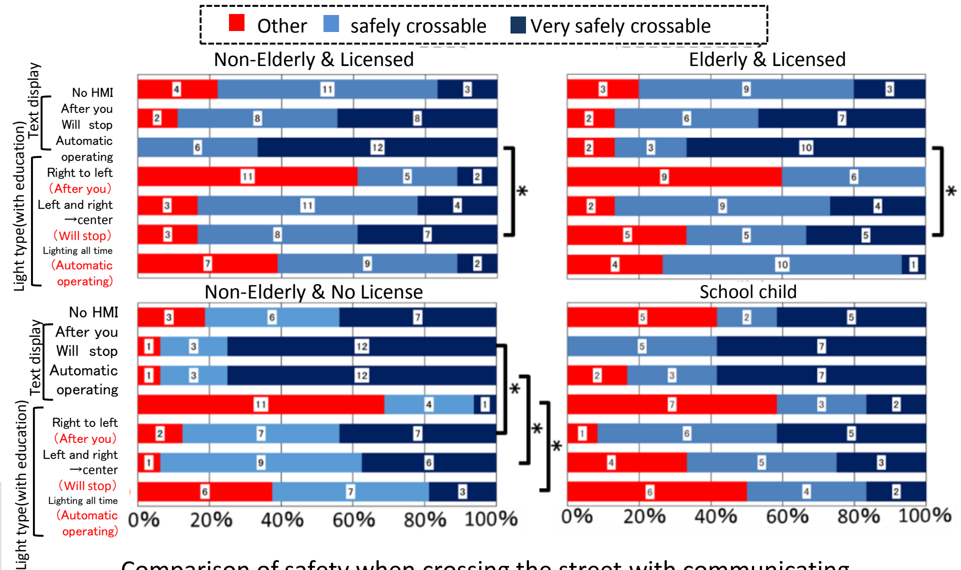
C-5-1 Extraction of basic requirement for automated vehicle and pedestrian communication in low speed condition (test track)



Text display type of external HMI



Light type of external HMI (without education · with education)



Comparison of safety when crossing the street with communicating vehicle which has external HMI.

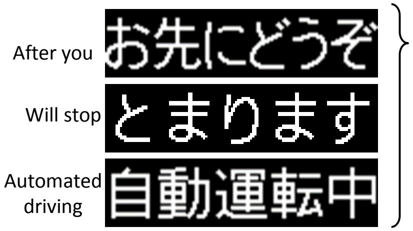
Result :

- People judge safer and earlier when transmitting intention in text form such as “After you", “Will stop" at low speed.
- Transmission of “Automated driving" delays judgment timing, reduces the sense of security at the time of judgment → consciousness of vigilance
- With the light type, the timing of judgment can be improved by education, education is necessary for the light type.

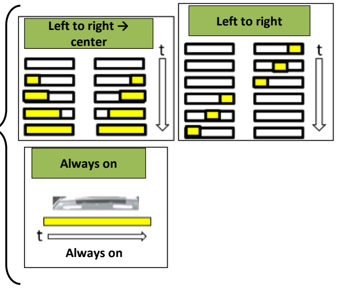
C-5 Extraction of requirement on communication in low speed region for general road

C-5-1 Extraction of basic requirement for communication between automated vehicles and non-priority side drivers in low speed condition (test track)

Purpose: Investigate the recognition and judgment of the non-priority side driver about the communication when communicating the intention and state from the automated vehicle traveling in the low speed condition to the non-priority side driver using the external HMI, extract the communication requirement.



Intention / state by external HMI Communication (text type)



Intention / state by external HMI Transmission (light type)

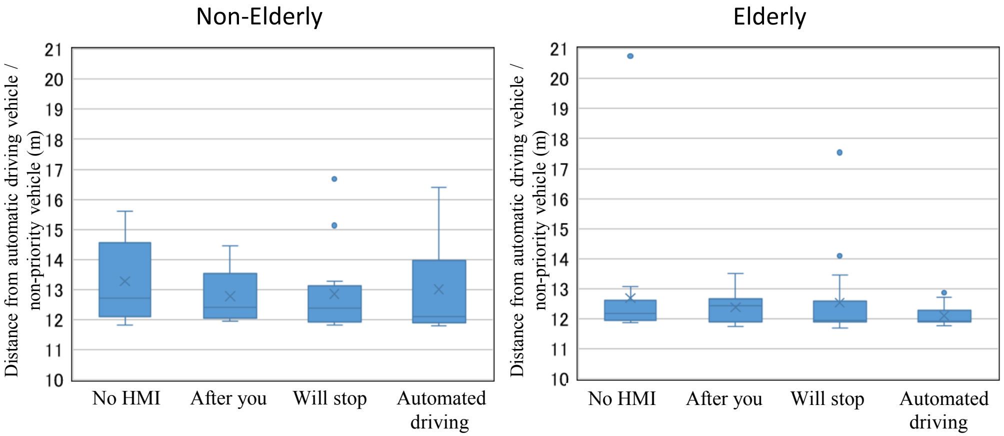
Participant : 40 people, non elderly, elderly

Experimental method : Forward cars and automatic driving vehicles approach the T-shaped intersection at a low speed of 15 km/h, participant can safely start progressing by observing the vehicle condition of the automatically driven vehicle (including the external HMI) (to the priority traffic side when it is judged that it can merge), press the button.

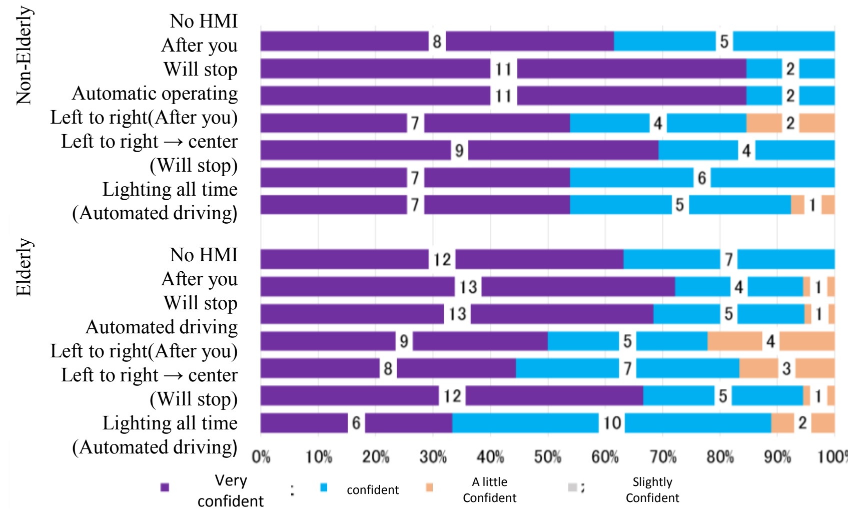
Experimental conditions : Control condition (without HMI), text type, light type (light meaning educated / no light meaning educated)

C-5 Extraction of requirement on communication in low speed condition for general road

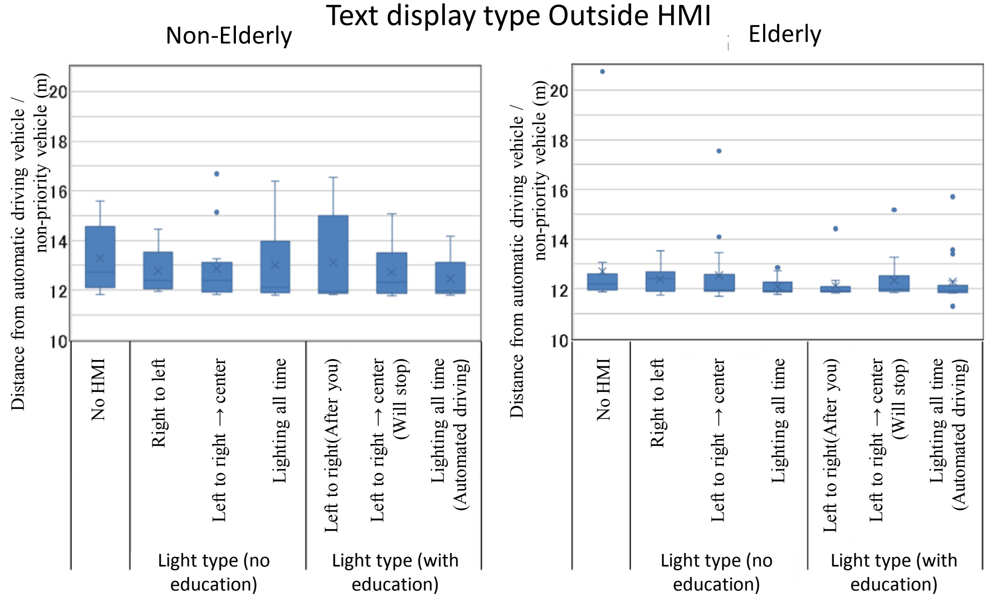
C-5-1 Extraction of basic requirement for communication between automated vehicles and non-priority side drivers in low speed condition (test track)



Text display type Outside HMI



Comparison of conviction at the time of judgment of progress when equipped with external HMI



Light type of external HMI (without education · with education)

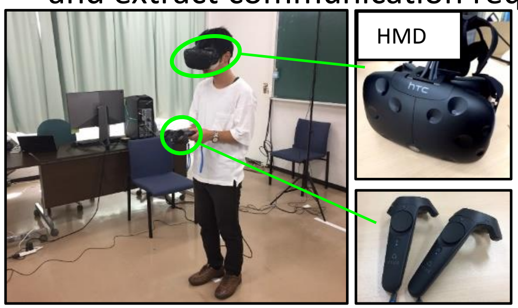
Result :

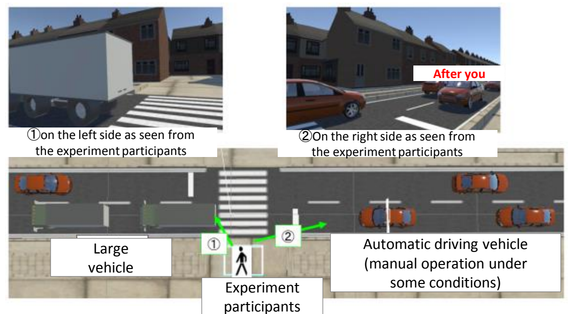
- In the low-speed driving when the intention and state in text form such as “After you“, “Will stop“ are transmitted from automated vehicle to non-priority side driver, the confidence will improved at the time of judgment, but judgment timing is the same as without the external HMI as well → In the low speed running, judgement is made in the state of the vehicle is near stoppage or when it reached.
- In light type, decision timing is improved by learning → Using light type need education.
- However, there is a possibility that the certainty at the time of judgment may be slightly reduced by learning → Influence of the number of lighting patterns to be learned.

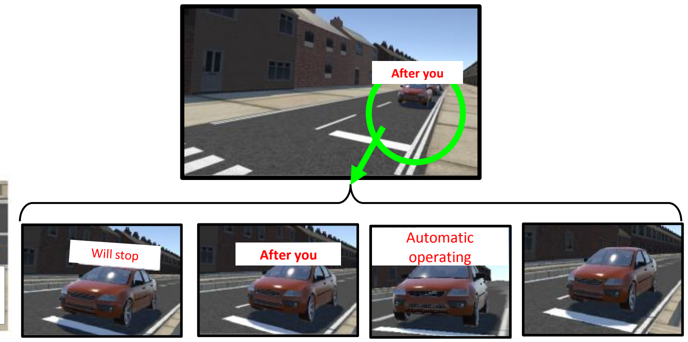
C-5 Extraction of requirement on communication in low speed condition for general road

C-5-2 Extraction of basic requirements for automated vehicle and pedestrian communication in low speed condition (VR experiment)

Purpose: Investigate pedestrian recognition, judgment and negative influence on communication when communicating intention and state from automated vehicle traveling in low speed condition to pedestrians using external HMI and extract communication requirements







Participant : 50 people, non-elderly (licensed)

Experimental method : Automated vehicle decelerates from 15 km/h to a low speed state and approaches the pedestrian crossing, participant can safely start crossing by observing the vehicle condition of the automated vehicle (including the external HMI). When the participant decides to do crossing action by operating the button. (including left and right check by using controller)

Experimental conditions : Control conditions (automated vehicle without external HMI, manual driving vehicle), text type

Result :

- “After you" “Will stop" confirming the possibility of affecting pedestrians' verification behavior to the left side by intention transmission → Pedestrians may rely on confirmation behavior for external HMI

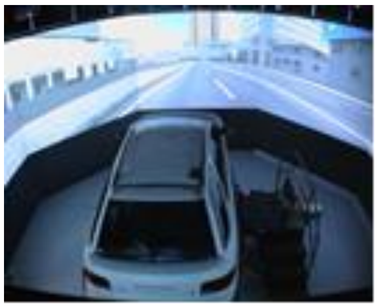
To suppress the negative effect, it is necessary to carefully examine the method of intention transmission by external HMI.

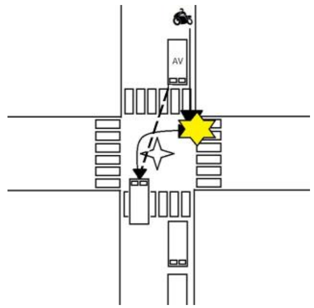
→ Control of transmission of external HMI according to road environment and traffic conditions.

C-5 Extraction of requirement on communication in low speed condition for general road

C-5-2 Extraction of basic requirement for communication between automated vehicle and non-priority side driver in low speed condition (DS experiment)

Purpose : Concerning communication when communicating intention and state from an automated vehicle traveling in a low speed condition to a non-priority side driver using an external HMI to examine the recognition and judgment of the non-priority side driver and the negative influence.





Subject : 40 people, both elderly and non elderly

Experimental method : Forward cars and automatic cars decelerate from 25 km/h, 15 km/h to a low speed state and approach the pedestrian crossing, participant can safely start right-turn by observing the state of the automobile (including the external HMI), perform right-turning action by usual driving task (operating the accelerator pedal and steering wheel. (including right and left confirmation)

Experimental conditions : Control conditions (automatic driving car without HMI, manual driving vehicle), text type

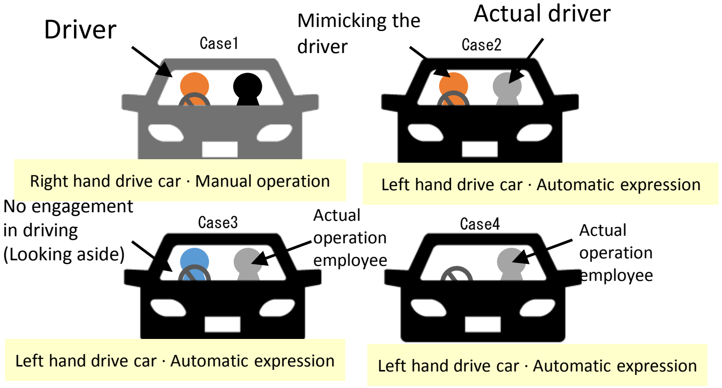
Result : (For automated vehicles at intersection when non-priority side drivers waiting for right turn) Condition of intention transmission such as “After you”, “Automated driving”, triggers inadequate confirmation action at non-priority side driver (Contact with two-wheeled vehicle that slips through the side of automated vehicle. “after you", "Automated driving" 3 people, 1 person under the condition without external HMI)

> To suppress the negative effect, it is necessary to carefully examine the method of intention transmission by external HMI.
>
> → Control of transmission of external HMI according to road environment and traffic conditions.

C-5 Extraction of requirement on communication in low speed condition for general road

C-5-3 Extraction of basic requirement for automated vehicle and pedestrian communication in low speed condition

Purpose: Representation of automated vehicle · Consider pedestrian recognition, judgment, and influence on psychological aspect for approaching vehicles with or without driver's eye contact when he/she tries to cross.



Participant : 152 people, Non Elderly (licensed / no licensed), Elderly (licensed / no licensed)

Experimental method : The preceding vehicle and the experimental vehicle approached a low speed state from about 20 km/h to 30 km/h, and the participant passed the crosswalk at the timing when the participant arrived at the crosswalk side, the experiment vehicle stopped before the crosswalk. The pedestrian crosses the pedestrian crossing at the ordinary procedure by looking at the state of the experimental vehicle etc.

Experimental conditions : Manual driving car, automated driving expression (driver is monitoring front), automated driving expression (driver is not looking front), automated driving expression (without driver)

Result :

- In a manually driven car, pedestrians judge whether or not to cross by not only vehicle behavior (stop / deceleration) but also the driver's eye contact and gesture, improving reliability and confidence at the time of judgment
- Automated driving expression vehicle, regardless of the state of the driver, the judgment of whether or not the vehicle is crossing with a clue as to the behavior of the vehicle (stop / deceleration), the feeling of anxiety at the time of crossing is slightly increased due to the automated driving expression (There were many pedestrian who does not notice the state of the driver.)

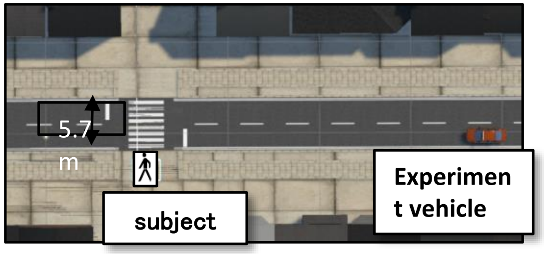
C-6 Proposal of investigation method on the influence of locality and traffic participant attributes in communication

C-6-1 Study on usefulness of survey method using HMD environment and comparison between Japan and the UK.

Purpose : Regarding recognition of pedestrian / non-priority side driver against intention transmission by external HMI, examine items that can be evaluated in HMD environment and extract recognition timing and effects on psychological aspect between Japan and the UK. Also, it examines the implementation and operation of external HMI between Japan and the UK.

Experiment in Japan

Experiment in the UK



Common Road Environment (VR) in Japan and the UK

Existence of external HMI and contents.

Participant : Japan 20 Non-Elderly (licensed) UK 20 Non-elderly (licensed)

Experimental method : Automated vehicle decelerated from 25 km/h to 15 km/h further to a low speed state and approached the pedestrian crossing or the intersection, participants observe the vehicle condition of the automated vehicle (including the external HMI) and judge that it can safely cross or start right-turning, then press the button and actual cross. (including checking left, d right, and front)

Experimental conditions : Deceleration behavior (25 km/h → 10 km/h, 25 km/h → 0 km/h), presence or absence of external HMI.

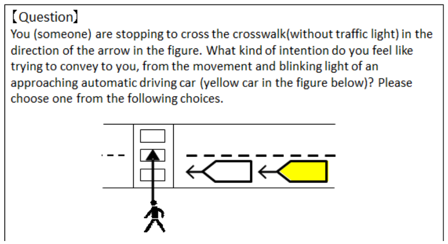
Result :

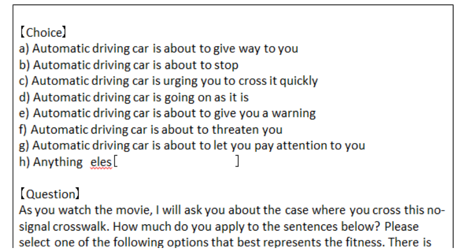
- Suggested possibility of nearly the same result in HMD (VR) environment and real world environment.
- Suggests the possibility of extracting regional differences in pedestrian and non-priority side driver subjective perception of intentional transmission with external HMI. (comparison between Japan and the UK for crossing judgment and right-turning judgement using external HMI)

C-6 Proposal of investigation method on the influence of locality and traffic participant attributes in communication

C-6-2 Investigation on the influence of locality and attributes on communication between pedestrian and automated driving vehicle at low speed

Purpose : Transmission of intention and state from the automated vehicle that runs at low speed and transmission of intention and state, and the state of the driver of the automated vehicle (forward monitoring, distracting (not looking front) will affect the pedestrian's recognition and judgment to the automated vehicle. It examines influence on the basis of locality and pedestrian attributes.


【Question】
You (someone) are stopping to cross the crosswalk(without traffic light) in the direction of the arrow in the figure. What kind of intention do you feel like trying to convey to you, from the movement and blinking light of an approaching automatic driving car (yellow car in the figure below)? Please choose one from the following choices.


【Choice】
a) Automatic driving car is about to give way to you
b) Automatic driving car is about to stop
c) Automatic driving car is urging you to cross it quickly
d) Automatic driving car is going on as it is
e) Automatic driving car is about to give you a warning
f) Automatic driving car is about to threaten you
g) Automatic driving car is about to let you pay attention to you
h) Anything eles[ ]

【Question】
As you watch the movie, I will ask you about the case where you cross this no-signal crosswalk. How much do you apply to the sentences below? Please select one of the following options that best represents the fitness. There is

Participant : 1380 people, Sapporo City (290 non-elderly people, 58 elderly people), 23 wards of Tokyo (312 non-elderly people, 64 elderly people), Osaka city (289 non-elderly people, 58 elderly people), Shikoku Four prefectures [excluding prefectural office location] (261 non-elderly people, 48 elderly people)

Experimental method : Observe the moving pictures approaching the pedestrian crossing while changing the indication of the external HMI at the low speed state of 15 km/h. Answer whether or not automated vehicle tries to yield the pedestrian, how he/she recognizes intention and state of the automated vehicle , how he/she recognizes such situation in terms of substitution of safety confirmation.

Experimental conditions : Lighting pattern of HMI, transmission of intention / state by text display type external HMI, forward monitoring of driver of automated vehicle / distracting

Result :

- Intention transmission by external HMI tends to enhance security feeling for pedestrians.
- There is a tendency that the interpretation for a specific lighting pattern is partially different depending on the area and attribute. → Consideration of locality and attributes
- Specific intention transmission by text type has a tendency to let the elderly dependence on ambient confirmation to automated vehicle. → Contents and operations that do not excessively depend on external HMI are required.

Recommendations for Communication Design between Automated Vehicle and Other Traffic Participants Based on the results of FY2018

- In order to allow the driver and pedestrians to recognize the intention to transfer from the automated vehicle that runs at low speed, the stop behavior is mainly used. However to convince drivers and pedestrians of the intention to transfer from an automated vehicle at an early timing and convince the behavior decision, it is effective to utilize the external HMI.
- Depending on the content of the external HMI, there may be a change in the confirmation behavior of traffic participants, a negative influence may be occurred.
- External HMI which transmits "automated driving" (including automatic driving) hinders the driver and pedestrian's recognition of the intention of the automated vehicle. Also, interpretation for automated vehicles varies depending on traffic participants, and education etc. is necessary to realize secure and smooth communication.
- In order to utilize the external HMI with lighting, standardization and education and learning for drivers and pedestrians are required. However, when learning a plurality of lighting patterns corresponding to the intention and state of the automated vehicle, there is a possibility of delaying the decision timing of traffic participants after learning.
- Proposal and recommendation of evaluation indicators such as safety of traffic behavior, security of the target person, facilitation of traffic, and the like, in order to evaluate communication between the automated vehicle and the pedestrian.
- Proposal of application of methodology (Web survey, HMD experiment, test track experiment etc.) according to analytical purpose for communication evaluation.

Task D：Proposal for guidelines and activities for ISO

- “TR21959 Road vehicles：Human Performance and State in the Context of Automated Driving: Part 1-Common Underling Concept”
  → Technical Report published by active works under Japan initiative

- “Prior Knowledge and Various System Information” of Task A, “Various Driver Status and Various Performance Indicators” of Task B were defined as terms on Common Underling Concepts.

- Start drafting works on “DTR21959 Part 2: Considerations in designing experiments to investigate transition processes”

Task E：Collaboration with participants and safety management in large-scale field operational test

Relationship between R & D subjects and large-scale FOT

Task A : To investigate effects of system information on driver behavior

i. **To investigate effects of static information of the system**
ii. To investigate effects of dynamic information of the system state on driver behavior
iii. To identify fundamental requirements of the HMI displaying the dynamic information of the system state (prototyping included)
iv. Formulation of knowledge to be provided based on understanding of the degree survey on automatic driving technology and guidelines for its expression

Task B : To investigate effects of driver state on his/her behavior in transition

i. To define driver readiness and identify fundamental requirements for the driver monitoring system
ii. **Evaluation of DMS**
iii. To define the transition time as function of readiness
iv. To identify the fundamental requirements of the HMIs for supporting the driver to stay with the appropriate readiness and to take-over the driving task smoothly

Task C : To investigate effective way to functionalize AV to be communicative

i. To study non-verbal communication between drivers and other road users
ii. To investigate the effect of external HMIs (message, lamp, etc.) and ID display (ex. In automated driving) on the behavior of surrounding road users
iii. To identify the fundamental requirements for external HMIs and ID display for sending message to surrounding road users (prototyping included)
iv. To investigate the effects of cultural differences on the communication using external HMI

Large-scale FOT of HMI

- FY2017 Experiments in which companies participate（Public road): Acquisition of baseline data by commercial vehicles equipped with Lv. 0 to 2
- FY2018 Experiments in which companies participate（test course): Enhancement of verification data using Lv. 2 and Lv. 3 (prototype car)

Outline of participatory verification experiment

※( ) : plan

Participating Companies	Total number of participants						Experimental period and place	実験車両等
	Task A	Task B				Gross total		
		inattentiveness state (Nback)	distraction state (SuRT)	Decline of drowsiness	Total			
Company A	34 (20)	18 (10)		16 (10)	34 (20)	68 (40)	[Period] 2018/11/5-12/11 [Place] Japan Safe Driving Center Central Training Academy at Ibaraki.	About LV3 (Hands OFF)
Company B	20 (20)	10 (10)	9 (10)		19 (20)	39 (40)	[Period] 2018/11/21-11/26 [Place] Japan Automobile Research Institute (JARI) at Ibaraki.	About LV2 (Hands ON)
Company C	24 (20)		13 (10)	12 (10)	25 (20)	49 (40)	[Period] 2018/10/1～11/14 [Place] Own test course	About LV3 (Hands OFF)
Gross total	78 (60)	28 (20)	22 (20)	28 (20)	78 (60)	156 (120)		

Purpose

Verify the relationship between teaching information and teaching method on the system function to the driver and the handover performance (driver behavior and vehicle behavior) in the vehicle equivalent to LV.2 and LV.3. Specifically, we verify the hypothesis that it is useful to know in advance as "knowledge of the necessity of driving handover, meaning of RtI indication, example of situation requiring intervention" for appropriate handover. (Based on results of DS experiment up to FY2017)

Scenario

- Separate participants into two groups (right table) with different prior knowledge levels.
- Subtask (SuRT) is performed on participants in the preliminary low speed region (approximately 30-50 km/h) and RtI is generated at the same event (avoidance of obstacles)(TTC: 6 seconds)

	Group with little prior knowledge (Condition 2)	Group with a lot of prior knowledge (Condition 4)
Common teaching	• Description of experiment contents • Explanation about automatic driving vehicle • Explanation of how to use the automatic driving vehicle system • Explanation of subtask during automatic operation	
Teaching of RtI	• Description of RtI	• Description of RtI • Explanation of display of RtI • Scenes where RtI occurs (3 scenes)

Result (Breaking news)

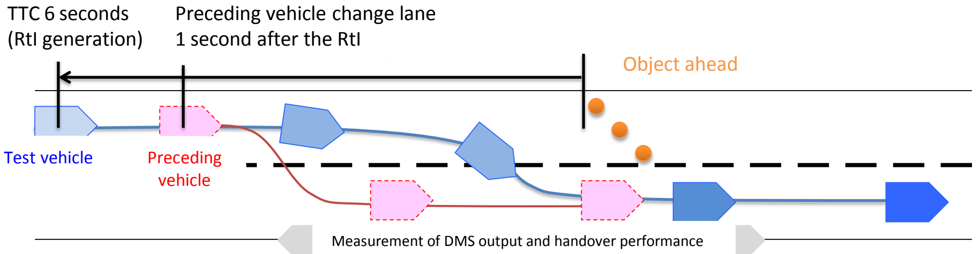
- Based on the result of three companies, the hypothesis that equivalent to LV.2 and LV.3 is necessary as prior knowledge until “the necessity of handover, the meaning or RtI indication, and scenes requiring intervention” are generally verified. (Compared to condition 2, the ratio of obstacle avoidance in condition 4 is higher.)

Purpose

Verify the relationship between the controlled driver condition and the DMS output value and the operation handover performance (driver behavior and vehicle behavior) in the vehicle equivalent to LV 2 / LV 3. In the controlled driver status, we examine three contents such as “exhibiting inattentiveness”, “distraction” and “Decline of drowsiness”.

Scenario

- Manual running, only automatic running, and automatic running + subtask’s three sessions will be carried out. (Under the decline of drowsiness, we will present two sessions which is manual running and only automatic running)
- Subtask will be “exhibiting inattentiveness : Nback (2 back)” and “distraction : SuRT (diffucult).



Description of RtI event

- Performing sub-task with automatic running (low speed) in the state where there is a preceding vehicle, and generating RtI as a forward obstacle avoidance event (TTC: 6 seconds). The preceding vehicle changes the lane one second after RtI occurs. (In the case of a decrease in drowsiness, RtI is generated at 25 minutes after the start of running (or when the passenger observes the subject and judges that the decline of drowsiness).

Result

- The DMS output value under the controlled driver condition and the relationship with the operation handover performance are utilized as validation data in the research and development of task B (derivation of Readiness index).