SIP-adus Human Factor / Experimental Demonstration / HMI

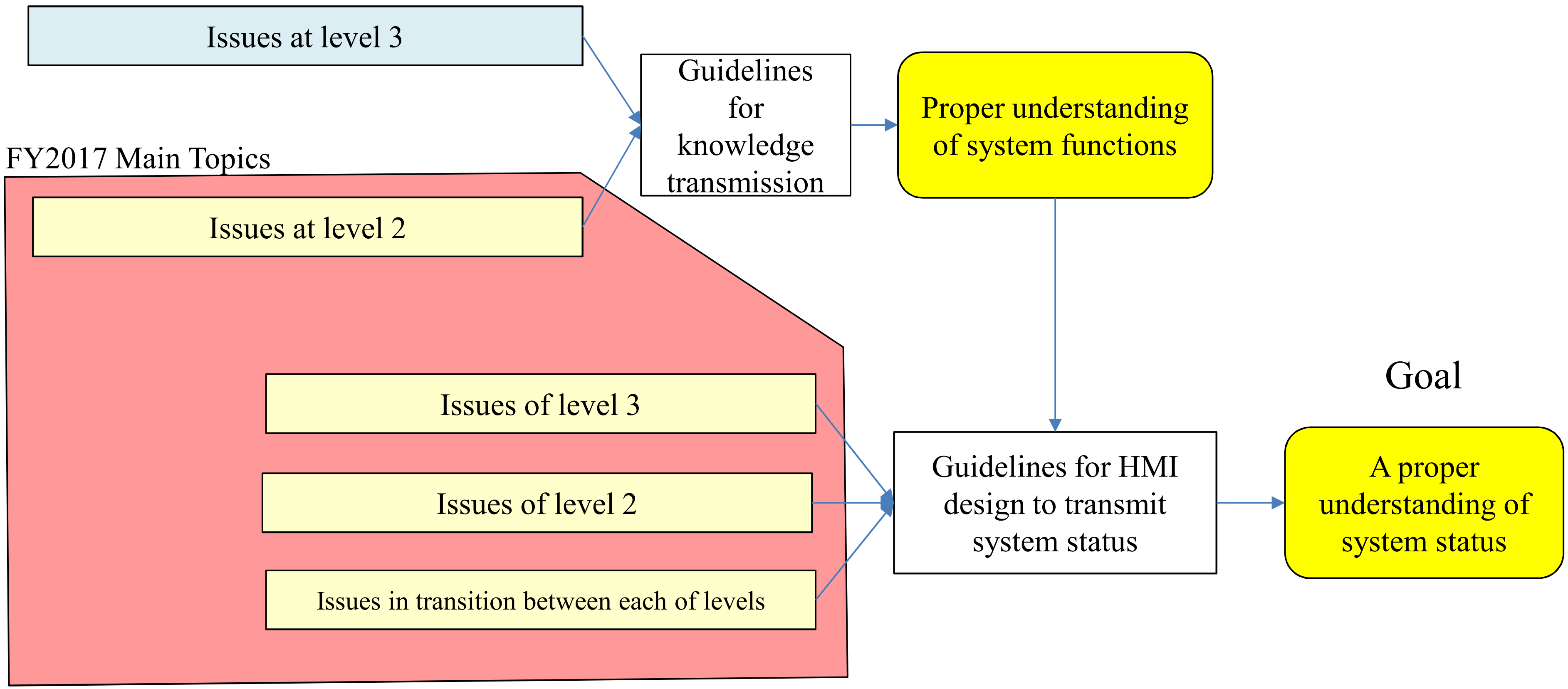
FY2017 Report

Overview

AIST
DENSO
Tokyoto Business Services
University of Tsukuba
Keio University

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

Overall Picture of Implementation contents in FY2017



Draft guidelines are summarized via conducting driving-simulator (DS) experiments.

Specific Implementation Items of Experiments in FY2017

Prior knowledge

Issues at level 2：Clarification of what kind of knowledge to convey

- A-1-2: Knowledge about possibility of system overlooking a hazard via DS Experiment

Issues at level 3： Clarification of transmitted knowledge and transmitting method

- A-1-1: Verification of minimum extent of knowledge about RtI via Test Course (TC) Experiment
- A-4: Investigation of understanding automated driving technology（web-based questionnaire research）

HMI

Issues at level 2： HMI for promptly detecting and understanding necessity of driver intervention

Related to the Obstacle avoidance

- A-3-1: Detection of system limitations (overlook) that system does not cognize via DS experiment
- A-2-2: Smooth understanding of system limitations that system cognizes via DS Experiment

Issues at level 3： HMI for supporting driver's decision making when an RtI is issued

- A-2-1: Support for driver's peripheral environment recognition when an RtI is issued via DS Experiment
- A-3-3: Suppression support for issues about "Where exactly am I?" via DS Experiment

Issues of transitions between each of levels

- A-3-2: HMI for supporting mode awareness, permissible level transitions via DS Experiment

A-1-2 : Knowledge about possibility of system overlooking a hazard via DS Experiment

(Purpose) Based on the outcome of FY2016, A-1-2 aims to investigate possibility of generalization of knowledge by describing concrete "scenes" about how to express knowledge involved system limitation of overlooking a hazard.

(Driving Automation Level) Level 2 equivalent (no subtask but hand-off)

(Method)

Participant: 30 elderly people with age of 60+ (Averaged of 68 years old)

Independent variable: Prior knowledge between subjects

- Group A: Be explained about the concrete "scenes" in which system overlooks a hazard….. 15 people
- Group B: Do not explain about the "scene" of hazard oversight ….. 15 people

Dependent variable：

- Accident rate, Time from RtI generation to steering operational intervention scene.

Working hypothesis：

When drivers are instructed example scenes,

- they can appropriately response to overlooked hazard, and
- they can also deal with an un-instructed scene.

Scenario：

- Pylon, Cardboard, stopped vehicle that system overlooks.

Equipment：

- Driving simulator in Univ. of Tsukuba as shown in Picture

A-1-2 Results

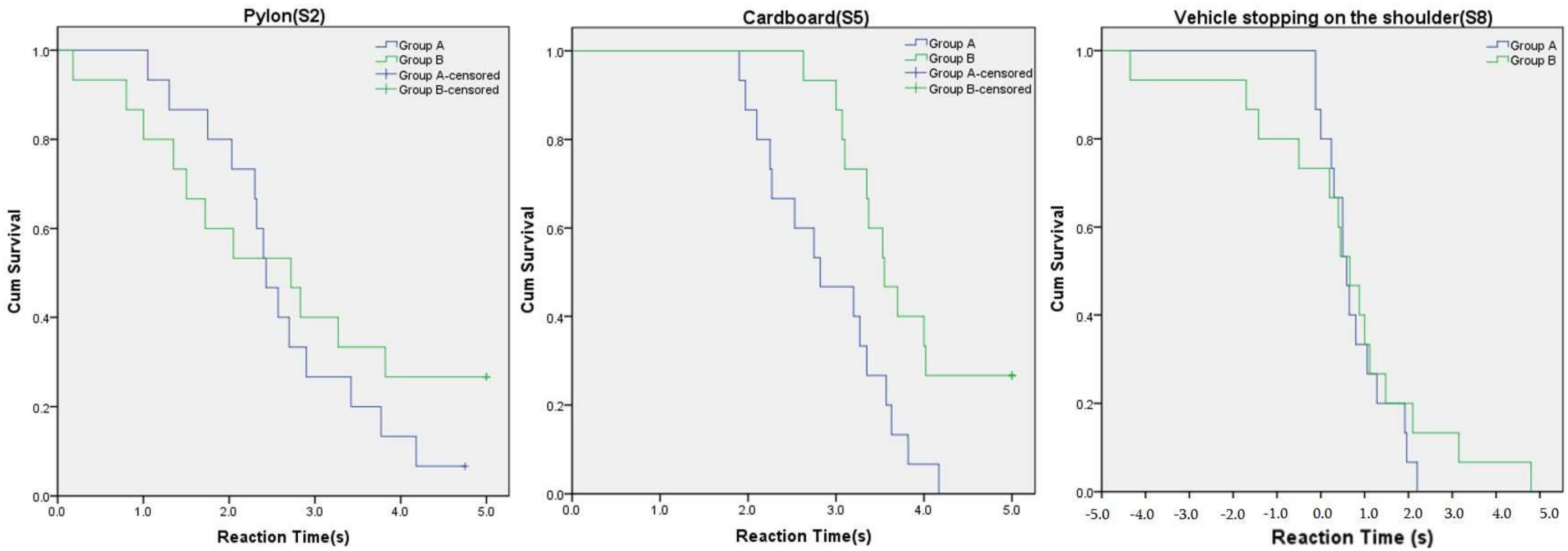
Accident rate

Significant difference

($\chi^2(1)=6.05$, $p=0.014$)

Scenario	Group A(15)	Group B(15)
Pylon(S2)	1/15	4/15
Cardboard(S5)	0/15	4/15
Standing vehicle(S8)	1/15	0/15
Total	1/60	8/60

Survival analysis of time required for intervention: Significant difference($\chi^2= 6.792$, df = 1, $p < 0.01$**)



A-1-2 Summary

- Possibility of system overlooking a hazard
  - Drivers were prone to delay their interventions, which was easy to lead to an accident if they were not instructed the possibility.
- Generalization of knowledge
  - In cases of an unknown overlook hazard, appropriate responses were more when they were taught some concrete scenes.
- Utilization of the outcomes
  - System could preliminarily specify such obstacles that are easy to be overlooked based on sensor's capacity.
  - It is important to inform users such obstacles in advance.

A-1-1 : Verification of minimum extent of knowledge about RtI (TC Experiment)

(Purpose) A-1-1 of TC experiment is conducted to verify the influence revealed by DS Experiment 1 in FY16, in which investigated an influence of knowledge about system function on transitions from automated control to manual operation and extracted minimum extent of necessary items of the knowledge items.

(Driving Automation Level) Level 2 equivalent (no subtask, hand-on)

* Originally level 3 was assumed, however Level 2 equivalent was set due to ethical restrictions

(Method)

Participant: 40 people whose ages are in a range of 20-60 years old

Independent variable : Prior knowledge (between-subjects factor)

- Condition A (FY2016 Experiment 1 Condition 3, only teaching the meanings of HMI)
- Condition B (FY2016 Experiment 1 Condition 4, sample scenes necessary to be intervened)

Dependent variable

- Time from RtI generation to steering operational intervention scene.

Working hypothesis :

- Drivers could rapidly intervene into car control as same as the findings in Experiment 1 in FY2016 under condition B.

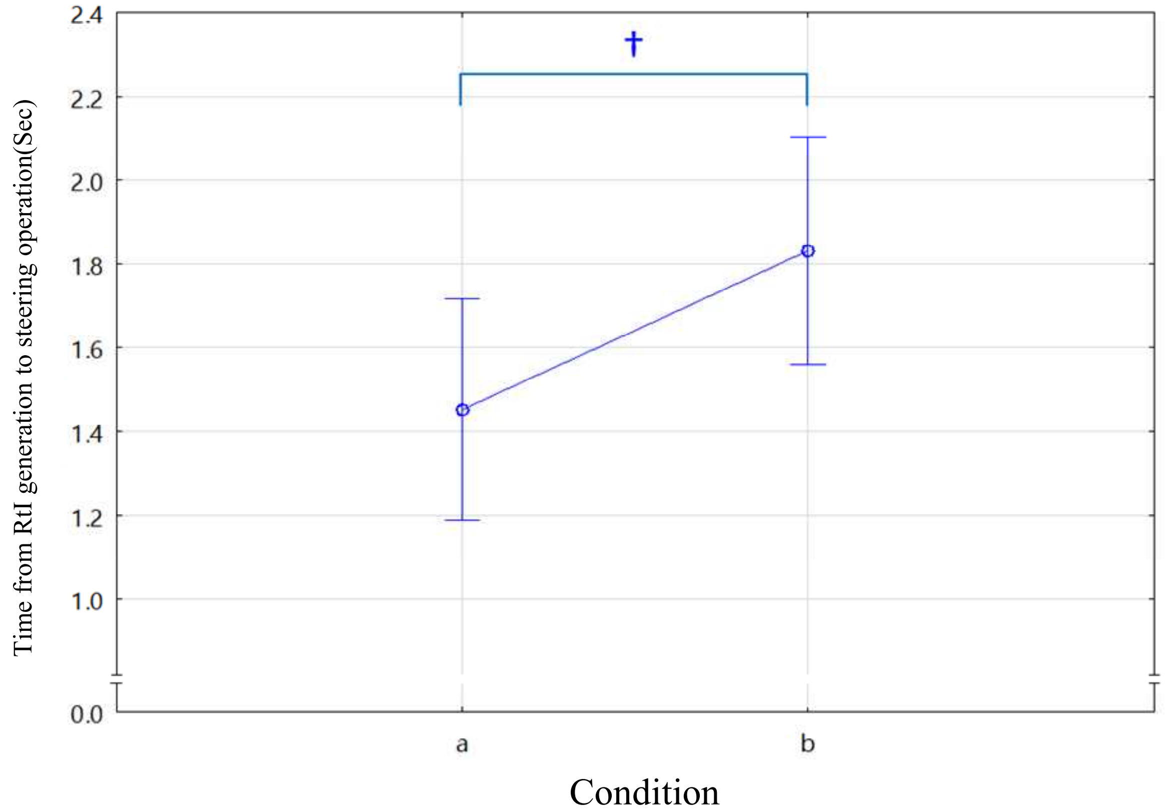
Scenario :

- First excise trial in Task B
- Voice of message “Change driving” issued by the system. There is no clue information about the situation in which an RtI is issued.

Equipment :

- TC in AIST and experimental Tesla. model S

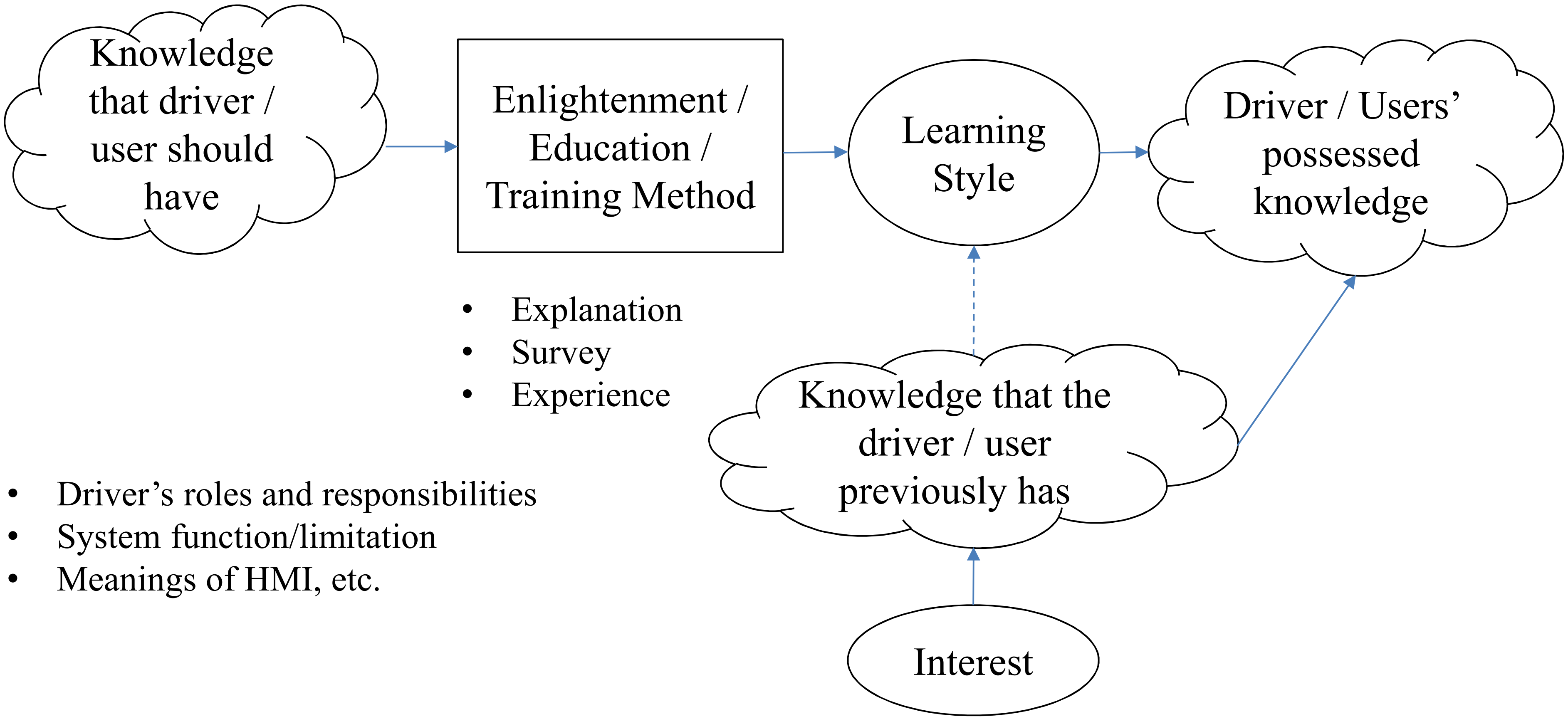
A−1−1：Result（time from RtI generation to steering operation）



- There is no cue information about surrounding environment. Therefore, drivers under condition b delayed to response an RtI because they might consider why the RtI was issued.
- Anyway, drivers under both of condition A and B could properly deal with an RtI.

A-4: Investigation of understanding the automated driving technology (web-based questionnaire research)

A-4 is to investigate driver's knowledge about automated driving and driving support as well as acquired process (learning style). Based on the result, it we can clarify the necessity of adjustment of knowledge provision method according to learning style.



A-4: Method

(Method)
Survey 1： Fixed point observation to understanding of current state on automated driving (Larger sample sizes of FY2016's survey result)

Survey 2:
Research Question 1: Is there any individual difference of how to understand automated driving? Is it enough just to compensate for the lack of knowledge?
Research Question 2: What is the learning style that should be distinguished with regard to functions/limitations of automatic driving, driver's roles, etc?
Research Question 3: What ars appropriate teaching/education methods for each of learning styles. Is it possible to response such issues in a greatest common denominator way?

Investigation items of Survey 2

1. Personality Big5
2. Learning Style（Index of Learning Style by Richard M. Felder and Barbara A. Solomon）

Survey 1： Fixed point observation to understanding of current state on automated driving (Larger sample sizes of FY2016’s survey result)

Example： there is almost no change from last year (no matter how the change is better or worse)
Most of people did not understand level of automated driving.
⇒ Explanation of “This system is level XXX so OOO” does not make sense .

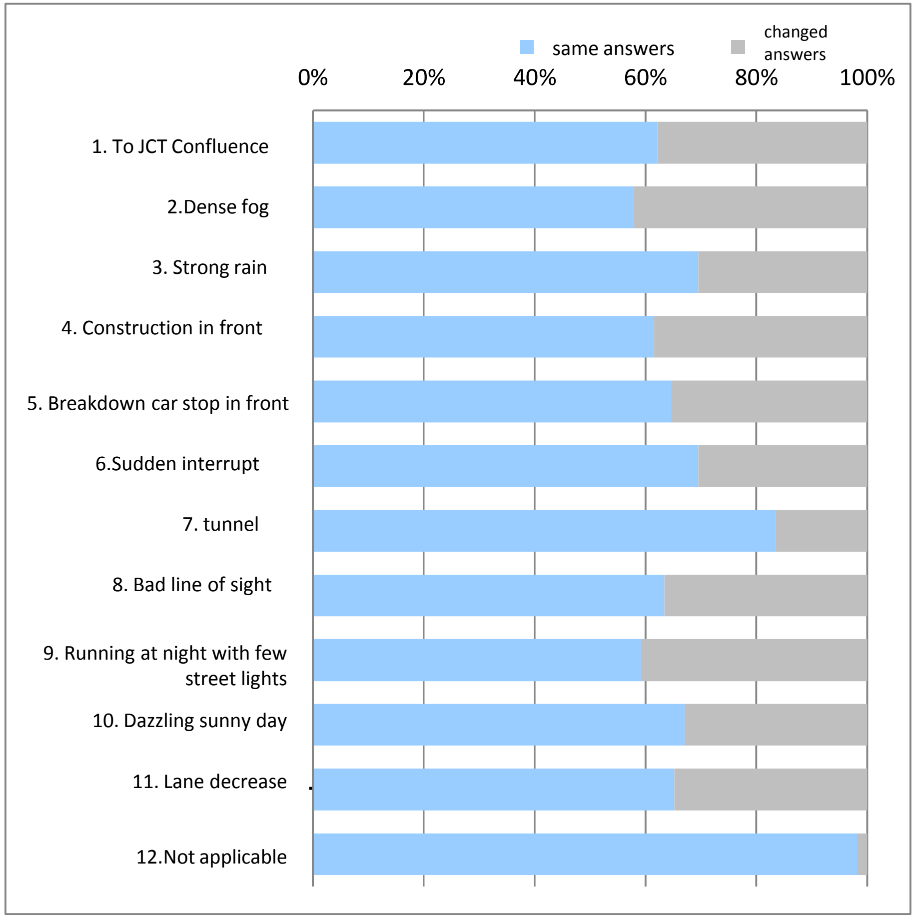
			1	2	3	4	5
	Please mark applicable terms related to automation functions	All	Understand correctly	Imagine from words	I saw the explanation, but I do not understand it	I have never seen an explanation, I do not understand it	Never heard of it
16	Level of Driving Automation	2084	105	651	179	211	938
		100.0	5.0	31.2	8.6	10.1	45.0

			1	2	3	4	5
17	Level of Driving Automation	1009	59	310	83	103	454
		100.0	5.8	30.7	8.2	10.2	45.0

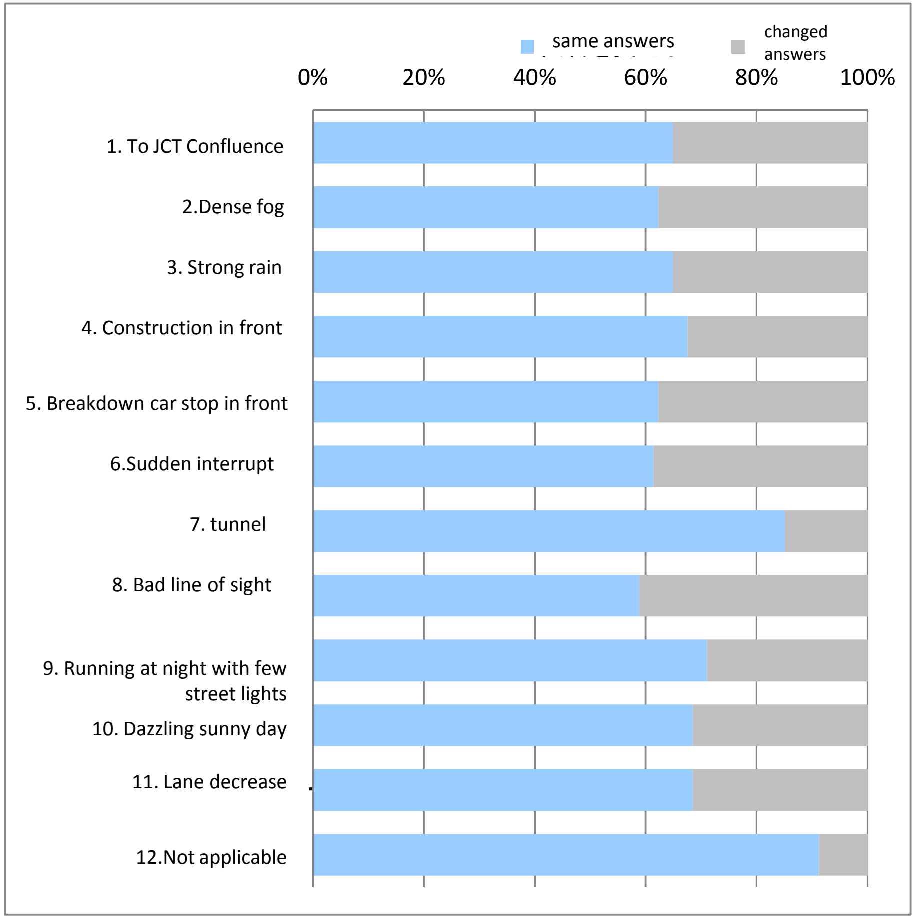
Example of Survey 2：Effect of teaching（Percentage of people who changed responses before and after instruction）

Examples of personality effects：【Extroversion】 Knowledge of "Automatic driving system" before/after（n=278）

Weak :n=164



Strong :n=114



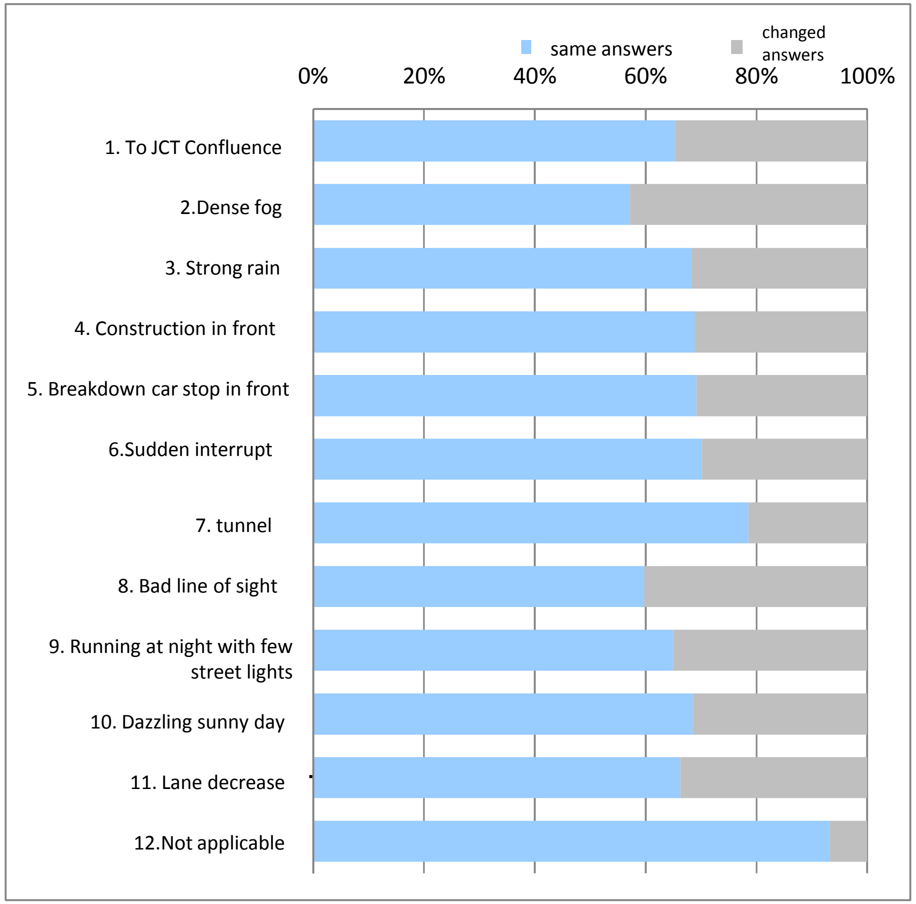
No effect of personality

cf.Oshio, A., Abe, S., & Cutrone, P. (2012). Development, reliability, and validity of the Japanese version of Ten Item Personality Inventory (TIPI-J). *The Japanese Journal of Personality*, **21**, 40-52.

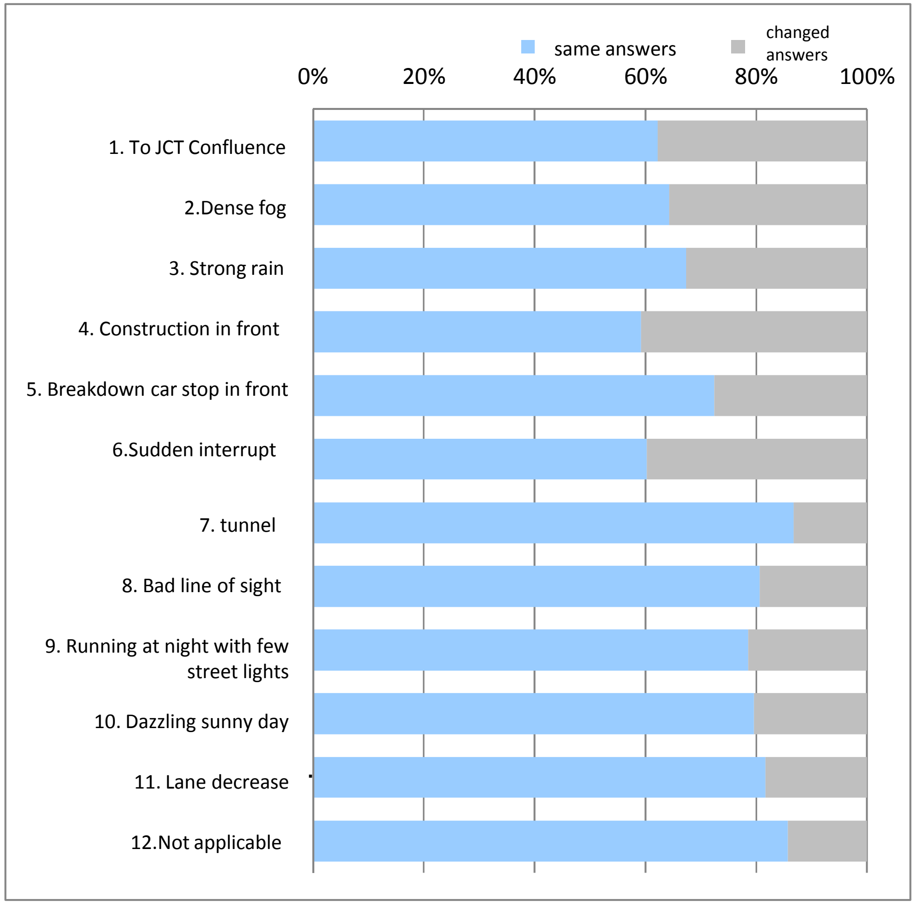
Example of Survey 2：Effect of teaching（Percentage of people who changed responses before and after instruction）

【Sequential/Global】 Knowledge of "Automatic driving system" before/after（n=406)

SEQ:n=308



GLO:n=98



Learning style may affect teaching effect

cf. Richard M. Felder, Barbara A. Soloman,LEARNING STYLES AND STRATEGIES

Summary of web-based survey and future issue

- Research Question 1: Is there any individual difference of how to understand automated driving? Is it enough just to compensate for the lack of knowledge?
  - Learning style may affect how to understand.
- Research Question 2: What is the learning style that should be distinguished with regard to functions/limitations of automatic driving, driver's roles, etc?
  - No conclusion has been reached at the present time.
  - It is needed to keep investigating the issue.
- Research Question 3: What are appropriate teaching/education methods for each of learning styles. Is it possible to response such issues in a greatest common denominator way?
  - Further discussion will be done based on RQ2's conclusions

A-3-1: Detection of system limitations (overlook) that system does not cognize via DS experiment

(Purpose) A-3-1 aims to clarify necessary elements in HMI that represents system status in preparation for overlooking a hazard at level 2 of driving automation.
(Operation level) Level 2 equivalent (no subtask, hand-off)
(Method)
Subjects: 60 elderly people with age of 60 or more.
Independent variable: Content to be instructed drivers through HMI (within-subject factor)

i. All objects that system cognizes.
ii. System intention
iii. Both i and ii
iv. Normal display neither i nor ii

Dependent variable:

- Number of interventions, Number of accidents, TTC to an obstacle at time point of intervention.

Working hypothesis:

- Drivers could properly deal with a hazard when they are presented as i.

The evaluation index in this experiment is as follows.

- Accident rate, Time from RtI generation to steering operation in intervention scene

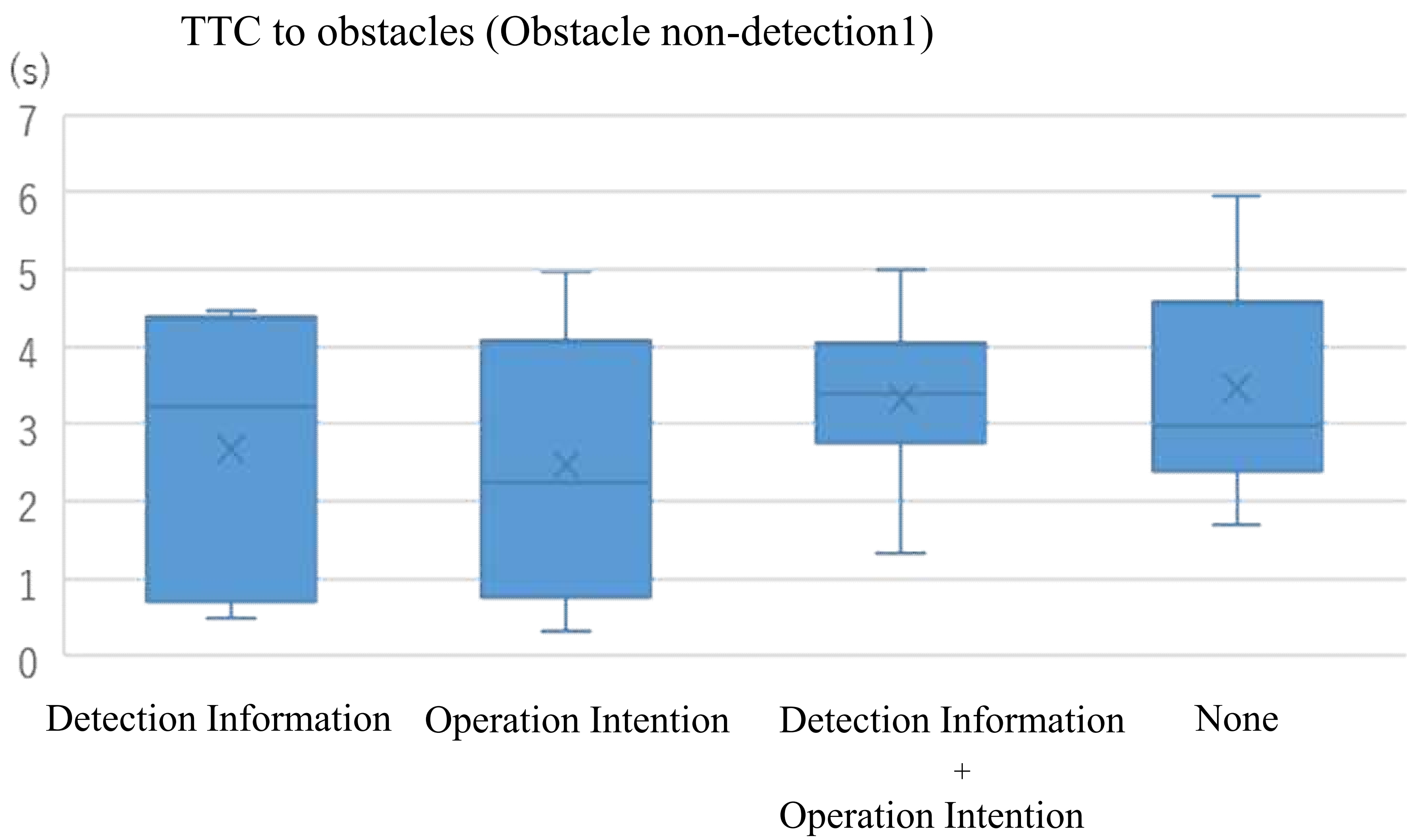
Scenario:

i. Overlooked hazard (Pylon, Collapse of the road surface, Stop vehicles at non-congested)
ii. Environment misrecognition (Misrecognition of lane mark at congested, Misrecognition of small obstacles at non-congested)

Equipment:

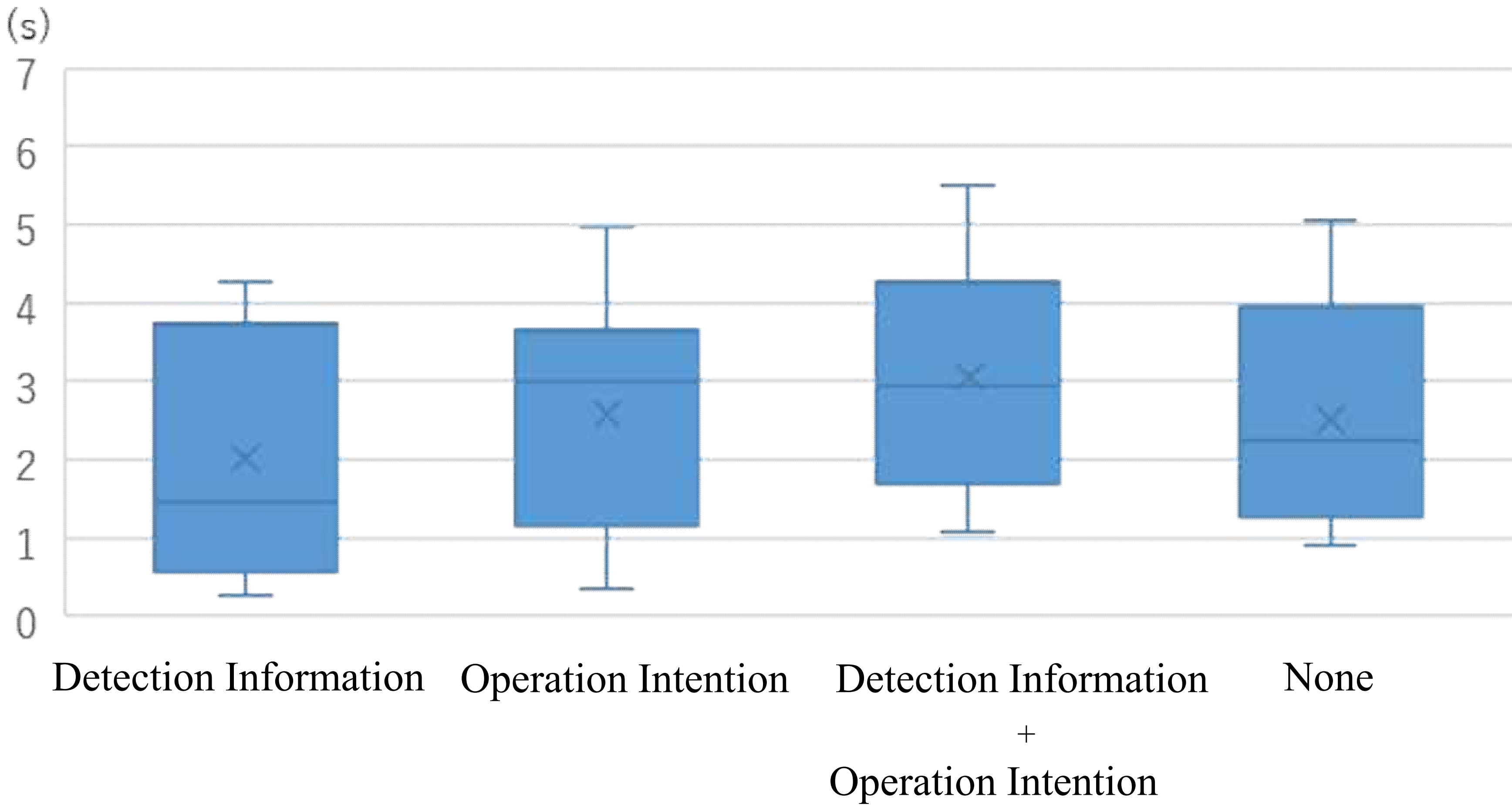
- Compact driving simulator at Univ. of Tsukuba

Response to pylon undetected

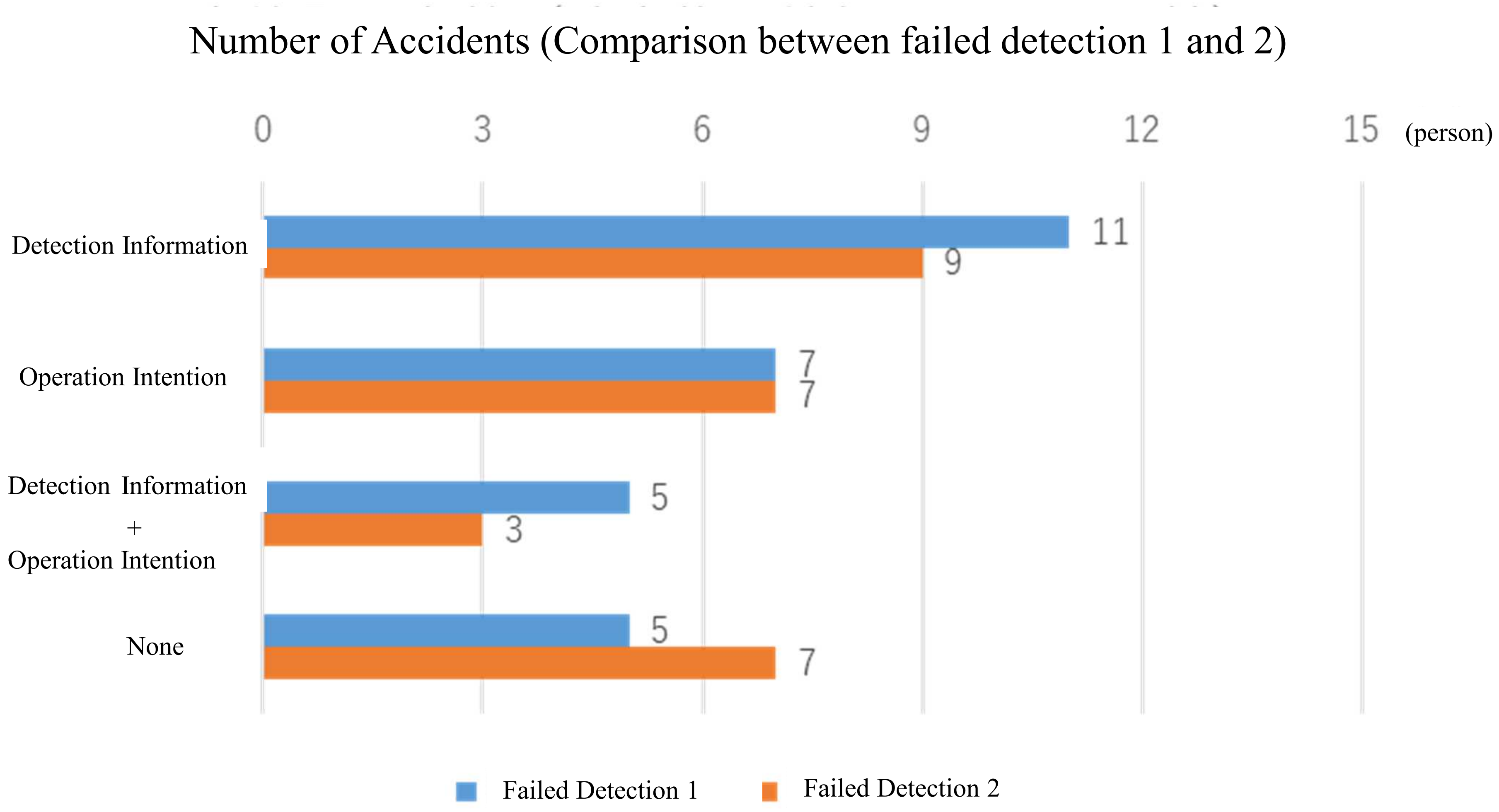


Response to non-detection of corrugated cardboard

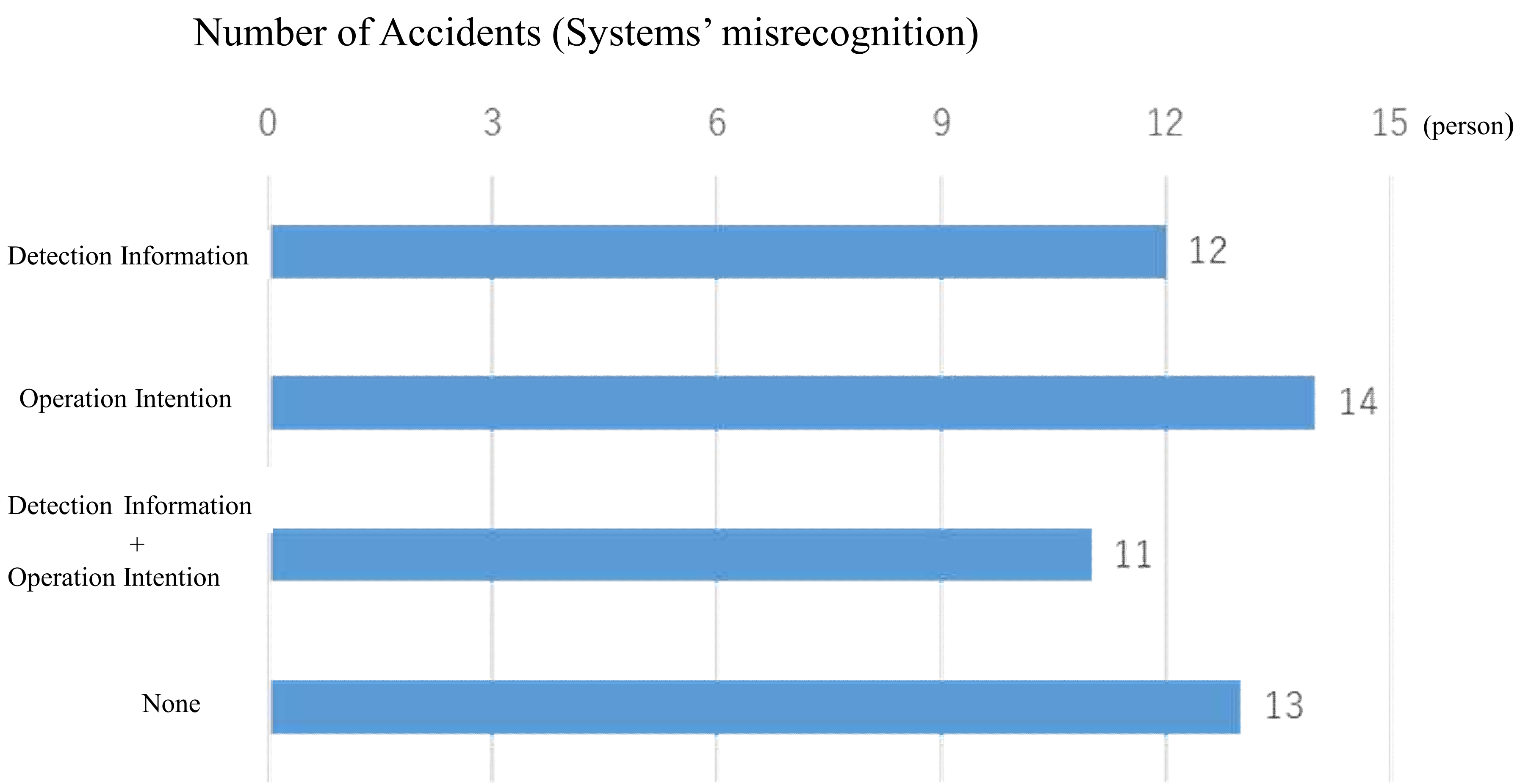
TTC to obstacles (Obstacle non-detection2)



Number of Accidents



Number of accidents



A-3-1 Result

- Effect of HMI
  - Possibility of being aware of a overlooked hazard by system increased in cases that both of intention and detection information were supplied.
    - However, the effect was not noticeable in this experiment.

- Utilization of the outcomes
  - It is not to draw a conclusion at the current stage.
    - It seems better when detection information & intention information are represented. However, it could not conclude whether it is essential or not.
      - Is DS a compact one? Was sample size small (15 people in each group)?
      - Is the subject elderly?
  - Further experiment will be conducted in FY2018.

A-2-2: Smooth understanding of system limitations that system cognizes via DS Experiment

(Purpose) A-2-2 is to verify an effect of presenting uncertainty information related to environment recognition.
(Automated driving Level) Level 2 equivalent (no subtask, hand-off)
(Method)
Subjects : Elderly people(age of 65+, average is 72) 30 people (10 people for each condition)
Independent Variable : Visualize HMI (between-subjects factor)

- Controlled condition (no HMI)
- Gradual change of icons' color depending on a range that system could see.
- Different colors depending on the range that system could see.

Dependent Variable :

- Steering start timing at intervention scenes
- Stability of driving performance after intervention.

Working hypothesis :

- Intervention can be done smoothly by presenting uncertain information.

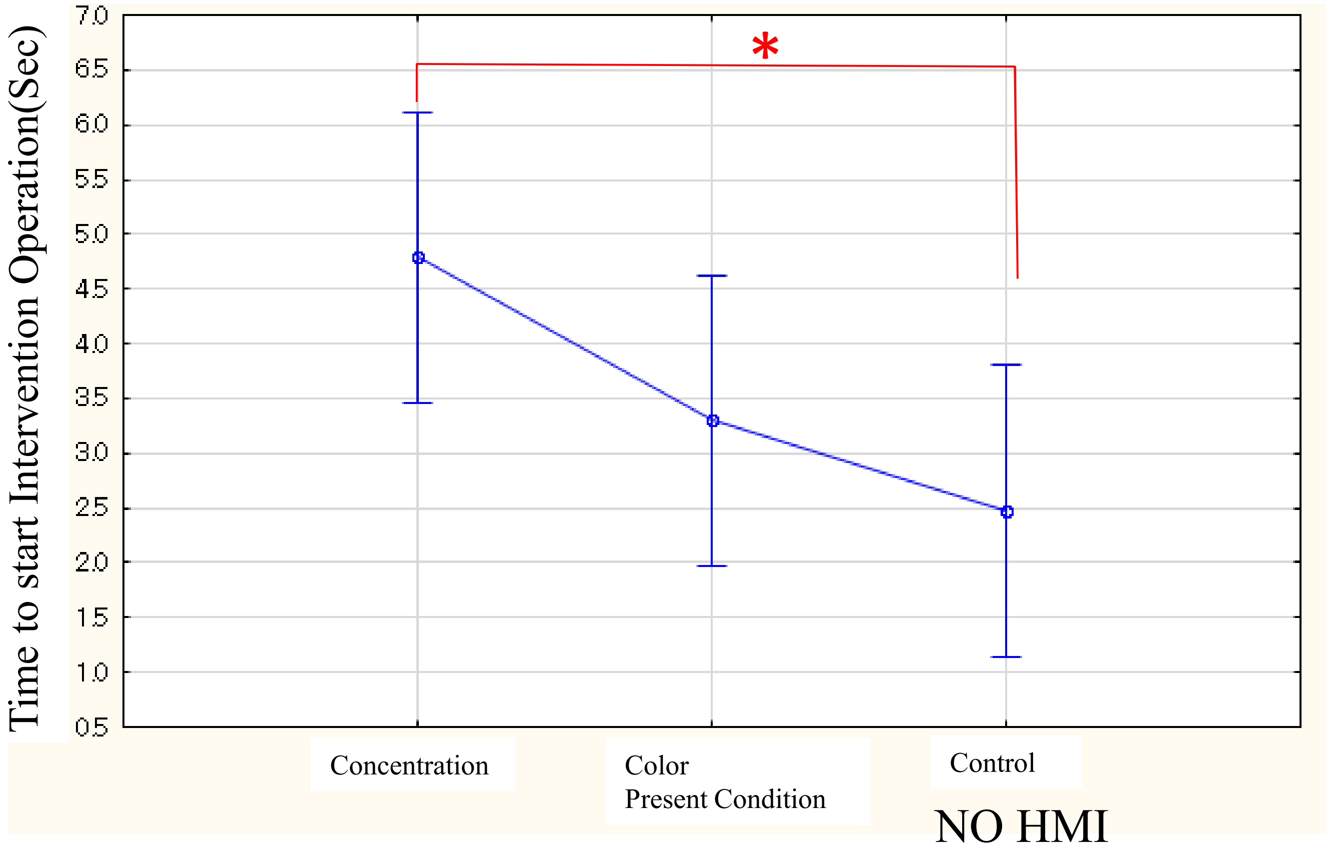
Scenario :

- Worse outlook due to fog: Gradual change of situation or sudden change of situation.
- Lane is rubbed off : Gradual change of situation or sudden change of situation.

Equipment :

- Motion-based driving simulator in JARI

A-2-2 Results (Rubbed Lines in cases of sudden change of situation)



In this experiment, the response time to cancel the system control is short when there is recognizable information (e.g., rubbed line).

If only investigating the time to understand the meaning of HMI, the response is delayed.

Delay is remarkable because the density is not noticeable unless you see it well, although color can be identified instantaneously.

A−2−1: Support for driver's peripheral environment recognition when an RtI is issued via DS Experiment

(Purpose) A-2-1 is to evaluate an effectiveness of display for supporting peripheral recognition when an RtI is issued in such scenes where a lane change is required. Note that there are vehicles that obstructs lane changing).

(driving automation level) Level 3 Cat B2 (Secondly activity: SuRT)

(Method)

Subjects：36 people with young age(average 37), 12 people for each of conditions

Independent Variable：Prior knowledge (between-subjects factor)

- Condition A: No support situation recognize display (control)
- Condition B: Electric Mirrors (Aggregated in the center)
- Condition C: Fisheye lens

Dependent Variable：

- Accident rate, Steering start timing of intervention scene, Risk of collision to other vehicles during intervening.

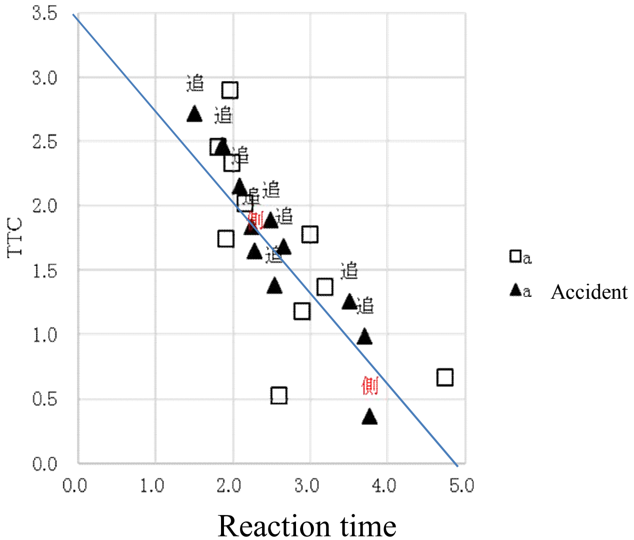
Working hypothesis：

- Drivers could adequately recognize situation and make proper decision of when and what to do by using support display for situation awareness.

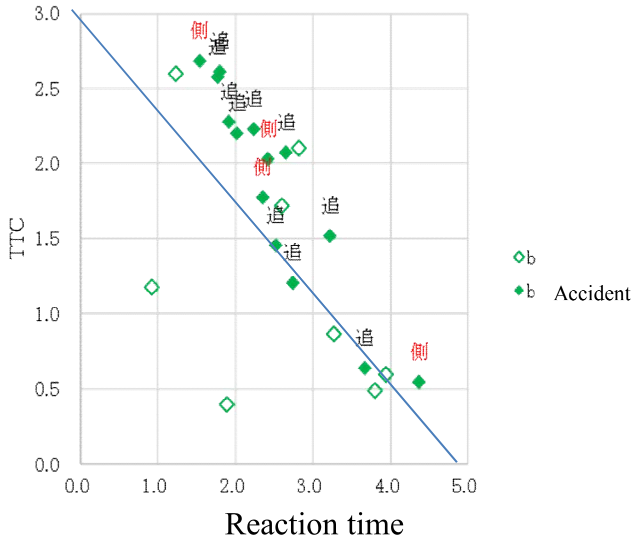
Equipment：

- Driving simulator in Univ. of Tsukuba

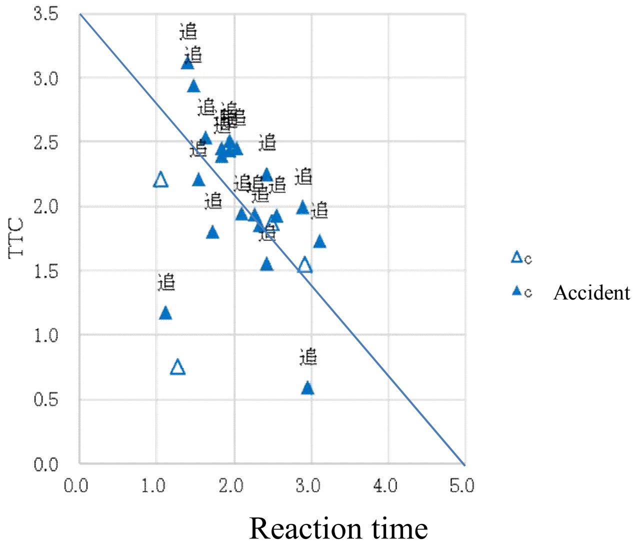
Result Example：Time to intervention in scenarios 9 and 10, TTC to a following vehicle in intervening in cases of A case where a lane change was made before being overtaken by a following car.)



Condition A
Controlled condition



Condition B
Electric Mirror



Condition C
Fisheye Lens

側: Side collision to a following vehicle that is driving on the next lane at high speed
追: Rear collision by following vehicle after changing lanes (No deceleration of the rear side car)

- The numbers of lane changes before being passed (i.e., the number of dots in each of above figure) are almost same regardless of conditions.
- Under the electronic mirror condition, side collision was outstanding though drivers made rapid decision to change lanes make a quick lane change judgement when the TTC is high.
    - Maybe they did not get the distance well?
- Decisions under Fisheye lens were made rapidly in a whole.

A-2-1: The issue of Driver's peripheral recognition support when an RtI is issued via DS Experiment

- Electric Mirror
  - Integration of side mirrors and room mirrors was planned to provide a wide-field support screen. However, only side-view mirrors were integrated because special shaped display (landscape) was required.
    - to secure a large space?
    - Or to change to several small displays
- Fish-eye Lens System
  - As one of ways to effectively utilize limited space, fish-eye lens are available, but cognitive load is high.

- It is necessary to discuss the method of supporting surrounding situation recognition through comparing the following issues:
  - How to display raw pictures in limited space such like electronic mirror, fisheye lens.
  - some ways to inform existence of other vehicle and its approaching at caution/warning phase.

← Experimental results of FY2017 suggest that improvident support display may confuse users.

A-3-3: Suppression support for issues about “Where exactly am I?” via DS Experiment

(Purpose) A-3-3 is to investigate an effect of support information for situation awareness on driving behavior in intervening in a scenario of heading for the entrance of the expressway
(Driving automation Level) Level 3 Cat B2 (Secondly activities: Watch TV)
(Method)
Subjects: 60 young adults (average 44 years), 20 people for each of conditions
Independent variable: Prior knowledge (within-subjects factor)

- Condition 1: Automated driving system that does not link with navigation (Even there was the JCT, but no RtI)
- Condition 2: Automated driving system that links with navigation.
- Condition 3: Condition 2 + Announce when passing a landmark

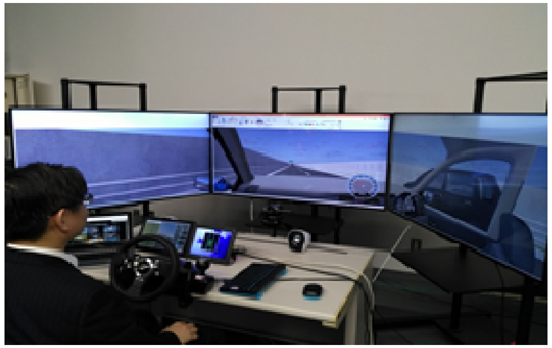
Dependent variable:

- Correct of direction selection, Intervention timing

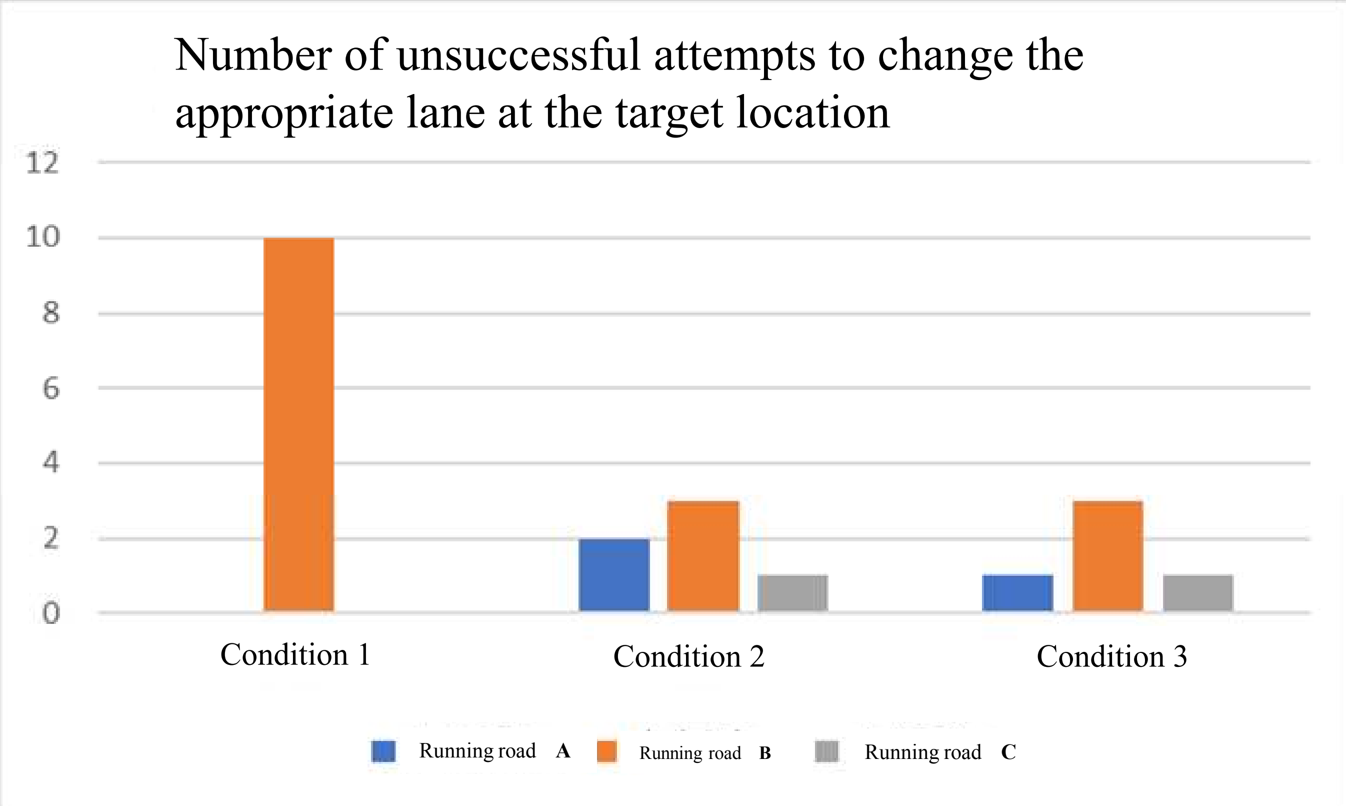
- Working hypothesis:
  - By announcing when passing through the landmark, you can recognize the handover in advance and do not mistake the choice of the way.

Equipment:

- Driving simulator at Univ. of Tsukuba



A-3-3:Result (Number of failed lane changes at the target location)



Condition 1 : Automated driving system that does not link with navigation

Condition 2 : Automated driving system that links with navigation

Condition 3 : Condition 2 + Announce when passing a landmark.

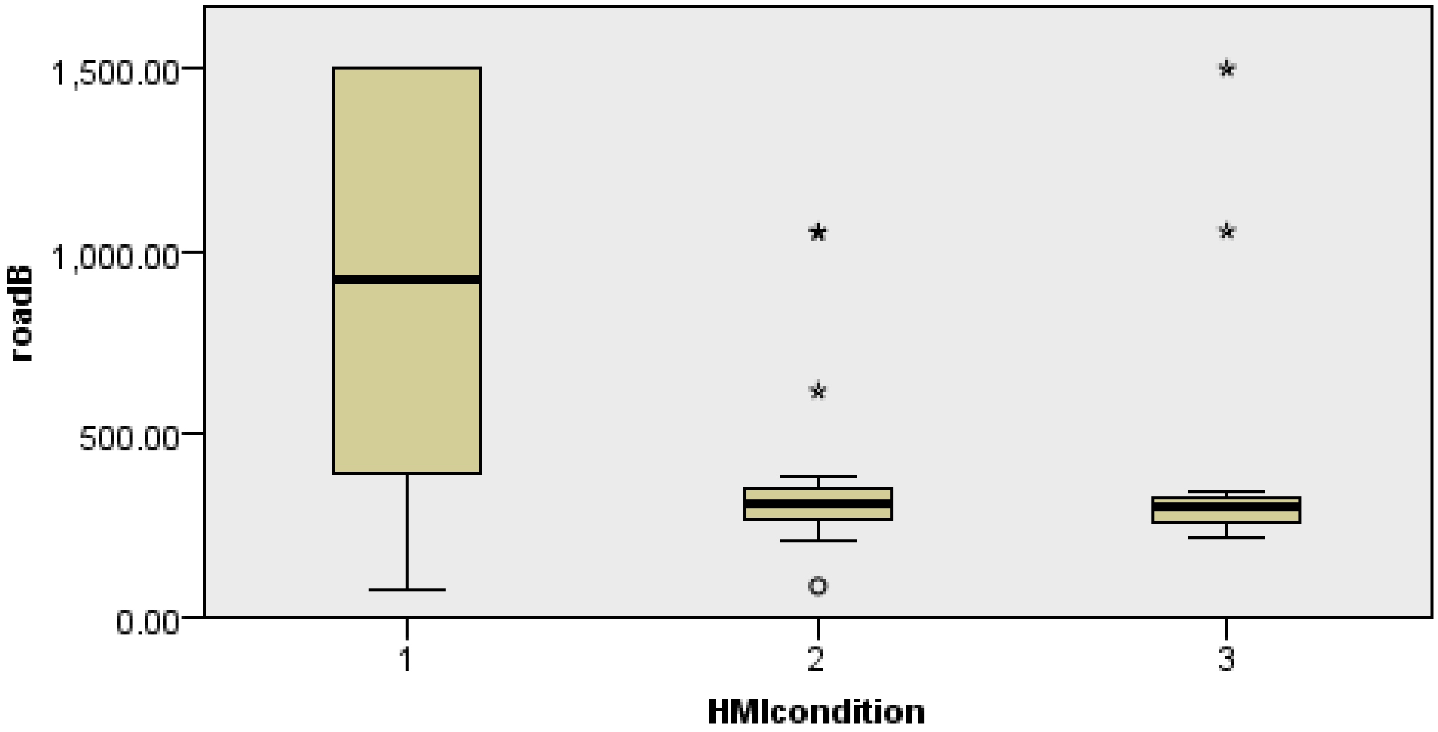
20 participants for each trial

Running road A : IC on left side
Running road B : JCT on right side
Running road C : Fee station

- It is important to present appropriate navigation display and information on exit, JCT to get off.

A-3-3:Result (Distance when switched to manual, road B)

Kruskal-Wallis's test with independent samples



Rather intervention under condition 1 (i.e., non-navigation) was fast. Meanwhile, there were many judgement errors in condition 1 on road B (?). This might be because of being unfamiliar with the way (?).

A-3-3: Added experiment to Suppression support for “Where exactly am I?” via DS Experiment

(Purpose) A-3-3 aims to verify whether there is a difference between automated and manual driving o the ability to grasp the current location of host vehicle.
(Driving automation Level) Level 3 Cat B2 (Secondly activities: watch TV)

(Method)
Subjects： 17 elderly people (average of 72 years)
Independent Variable：Driving mode（Within-subjects factor）

- Manual： 8 people Auto： 9 people

Dependent Variable：

- Correct of direction section, Intervention timing

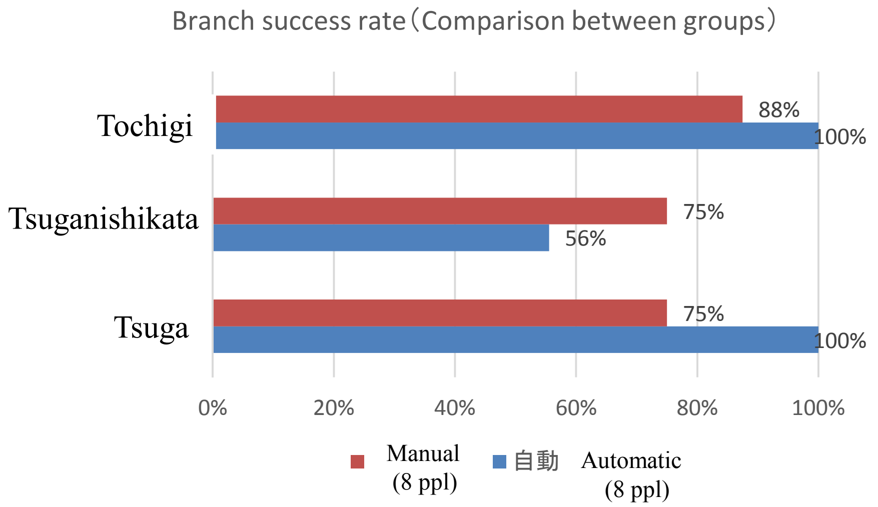
Working hypothesis：

- Automated driving condition is easier for driver to fail in selecting direction because it is separated from the context of driving.

Equipment：

- Driving simulator at Univ. Tsukuba

A-3-3:Result：Direction selection



When traveling to the direction of Tsuganishikata PA to the right, drivers did lots of mistakes in automated driving conditions.

For unexperienced routes, branching error occurred in both manual and automated driving. But, the influence of automatic operation is remarkable in relatively complicated situations.

《Automated driving group》

I misunderstood that I cannot drive in the zebra zone.
I did not know when I should intervene.
I was passing by.

《Manual driving group》

I was passing by.
I misunderstood PA and IC
I thought that "Tsuga" and "Tochigitsuga" are same.

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

Contents of Implementation in this fiscal year

1. Examination on driver state evaluation indicator during automated driving and feasibility of driver monitoring system (DMS).

2. Determination of basic HMI requirements to maintain good driver state: Examination of effect of arousal maintenance HMI

3. Derivation of relation between driver state and transition time:
   Examination of effect on transition behavior when vehicle control is changed from automated driving to manual driving.

DMS Feasibility Examination

DMS for evaluation:
-Frame rate: 60fps or more
-Resolution: VGA (640 x 480) or more

DMS installation:
-Distance to face: 650mm
-Location: Upper left of meter hood

Subject: Engineer in charge

Last year's result:

Indicator	Items to be detected	Calculated value
Eyelid opening degree	Eyelid opening degree (%): Distance from top to bottom lids/Iris diameter	
Blinks	Lid opening degree: 20% or less, Duration: 70～500ms, Interval: 500ms or more	**Frequency:** Counts in the last 2 minutes
Eye closure	Lid opening degree: 20% or less, Duration: 500ms or more	**PERCLOS**: Percentage of eye closure in the last minute (%)
Eye-gaze	What do drivers see for how long Detection range: Windshield, Sub-display Detection accuracy: +/-15 degrees	**Eye-gaze duration**: Average gazing duration of each gazed location for the last minute (sec./location) Eye-gaze percentage: Eye-gaze percentage for the last one minute
Saccade	High-speed eyeball movement when the eye-gaze target is changed. Detected based on the speed of eyeball and the amplitude (amount of movement) -Saccade (small) speed: 60 – 300 degrees/sec. Amplitude: 5-8 degrees -Saccade (large) speed: 60 – 300 degrees/sec. Amplitude: 16-32 degrees	**Saccade (small), (large) arising counts**: Saccade (small) (large) arising counts in the last 2 minutes

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

Test course experiment

Purpose: In the FY2016 driving simulator (DS) experiment, the basic composition of a DMS was clarified. In FY 2017, we conducted a test course experiment to examine the applicability of the evaluation index obtained for DS in the real environment, and examined the possibility of estimating driver condition by DMS in the real world environment

Overview: Using an experimental vehicle that has the automatic driving function, measure driver state before the RtI presentation (conscious-looking/glimpse) and driving behavior after presentation

Operation level: Level 2 equivalent
Subjects: 80 drivers

- Inattention (awareness) (N-back task): 40 people
- Inattention (SuRT task): 40 people

Overview of test course experiment

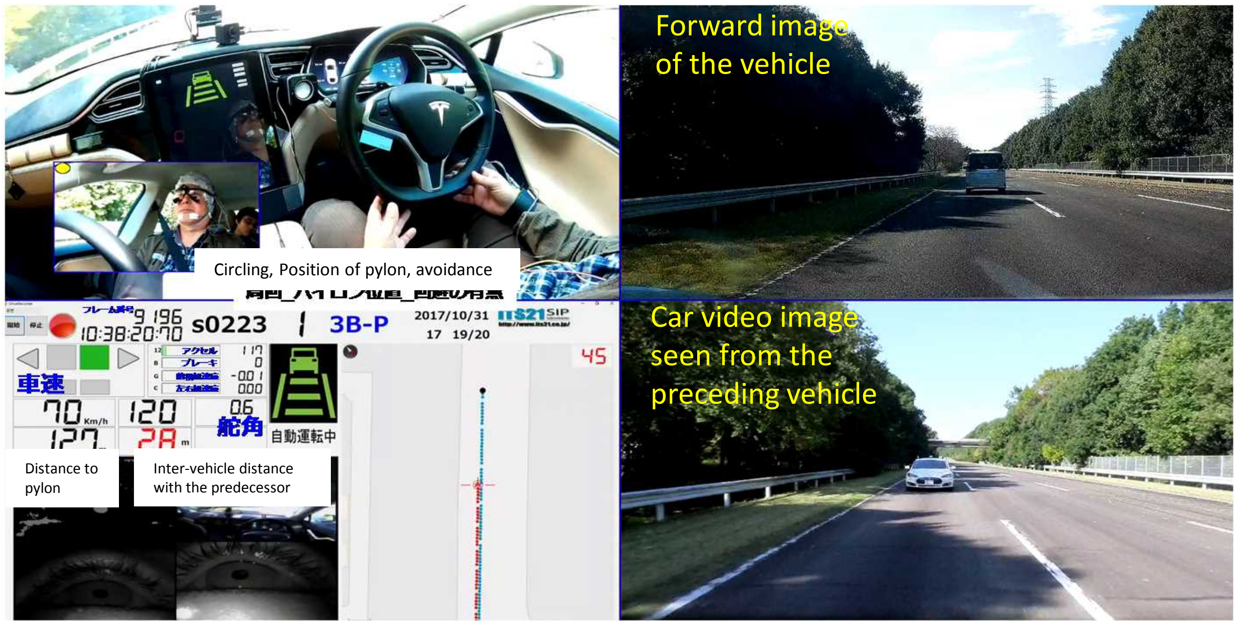
Switch indication (Display 6sec before arrive at pylon)

Automatic Driving

- Following the lead vehicle
- Inattention (awareness) (N-back task) or inattention (SuRt task)
- 4 conditions per person (only manual, only automatic, easy sub-task, hard sub-task, Intra-subject plan)
- Measurement of cognitive and physiological data

Manual Driving

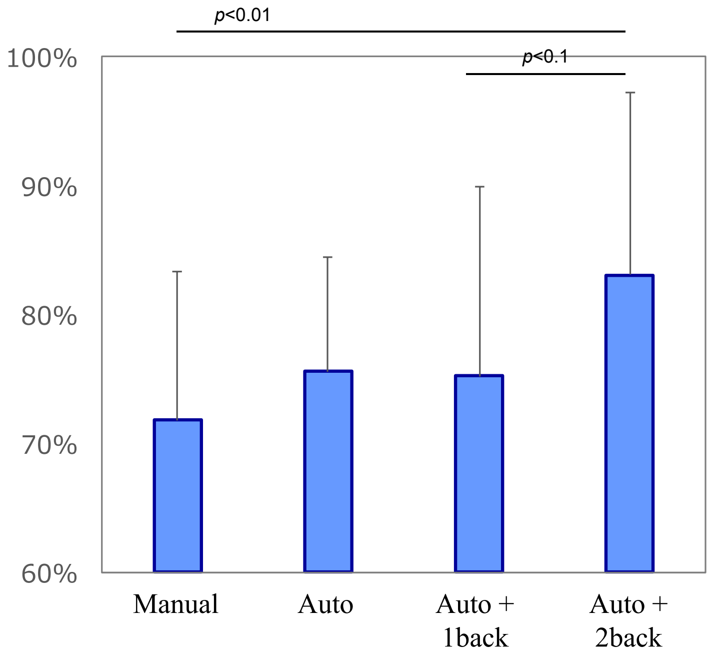
- A car ahead changes lanes, a pylon ahead
- The driver avoided the pylon manually
- There is a dummy event (even if the preceding car changes lanes, there is no pylon)
- Measure vehicle/driving behavior data after RtI



Result of the test course experiment(1/3)

As the burden of conscious inattentiveness increases, the proportion of smaller saccades increases. The higher the load during periods of inattention, the faster the proportion of small saccades increases.➔The results are similar to the FY2016 DS experiment

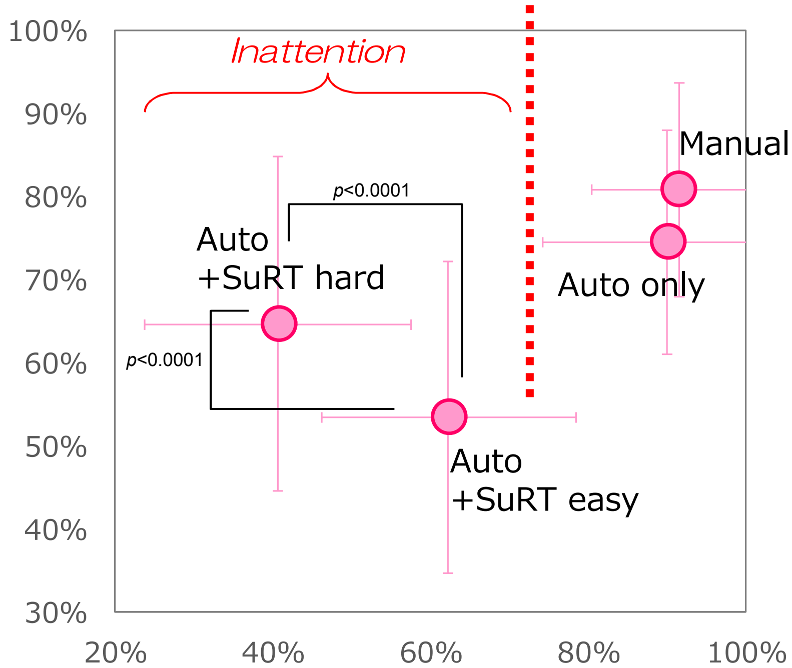
Readiness index value by experiment condition before RtI



Percentage of occurrence of saccades (5 to 16 degrees) 1 minute before switching display

N-back conditions

Percentage of occurrence of saccades (5 to 16 degrees) 1 minute before switching display



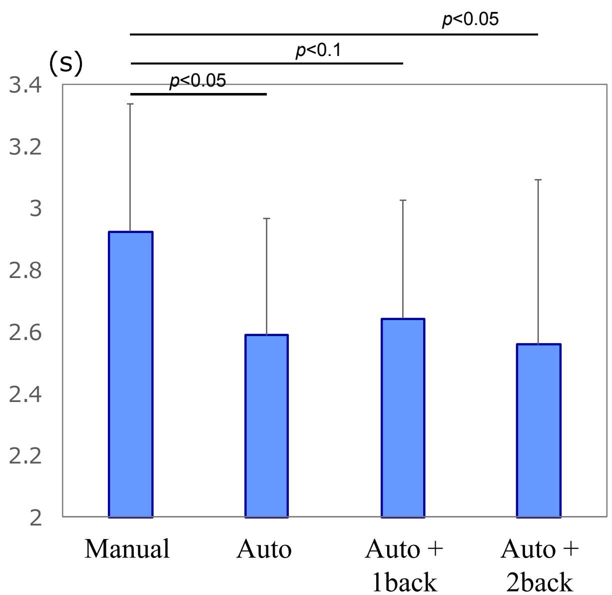
Percentage of forward visibility

SuRT conditions

Result of the test course experiment(2/3)

Compared to manual operation, the margin time for avoiding the pylon is shortened by inattentive consideration of consciousness, and handling the operation at the time of avoiding the pylon must be faster because of the inattention.➔The results are similar to FY2016 DS experiment

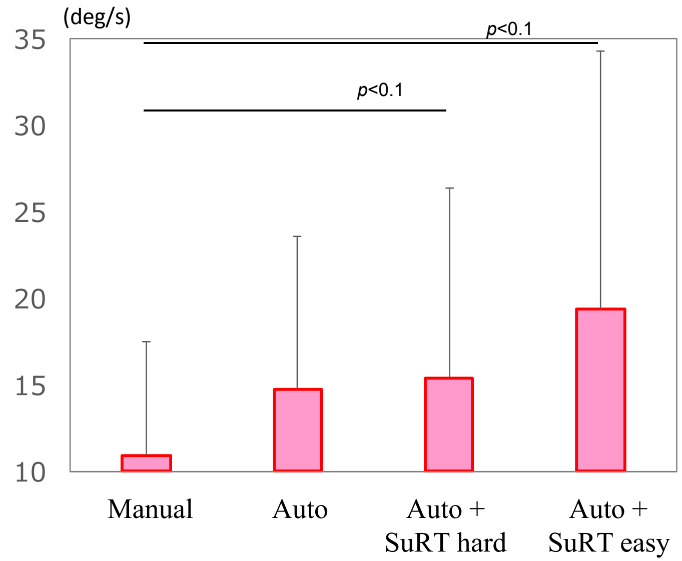
Experimental condition before RtI and operation performance after RtI



Margin time to pylon at lane change time

N-back conditions

➔Possibility of "delay" occurring until lane change



Steering speed up to maximum steering angle

SuRT conditions

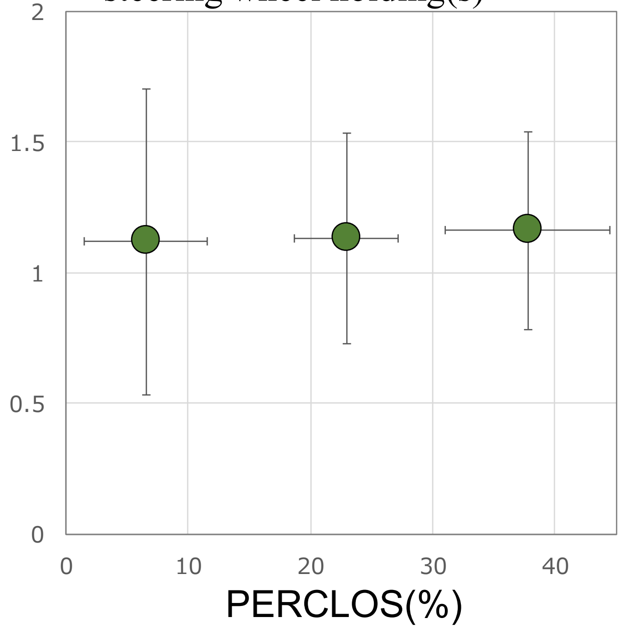
➔Possibility of steering not stabilizing after lane change

Result of the test course experiment(3/3)

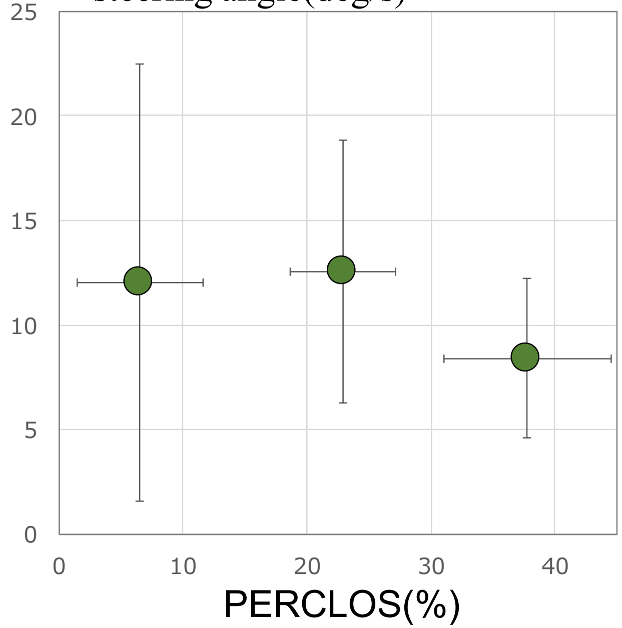
Compared to the DS experiment, it seems that sleepiness did not occur so much in the test course. In the case of little sleep time, the tendency was to decrease the time to the pylon at lane change

※Calculate PERCLOS for 1 minute before switch indication, targeting only for automatic operation.
Analysis of relationship with driving performance after manual operation.

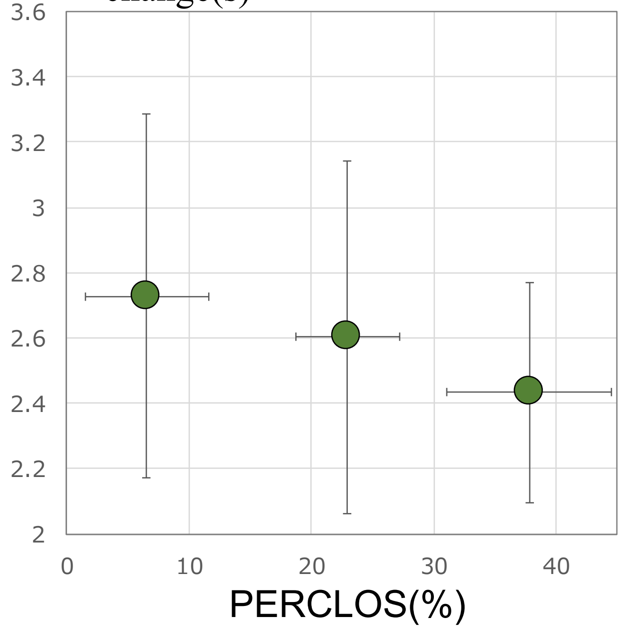
Time from switching display to steering wheel holding(s)



Steering speed to steering maximum steering angle(deg/s)



Time margin to pylon at lane change(s)



2. Formulation of HMI basic requirements for maintaining driver status: Study on the effect of HMI for maintaining arousal

(Fixed DS experiment)

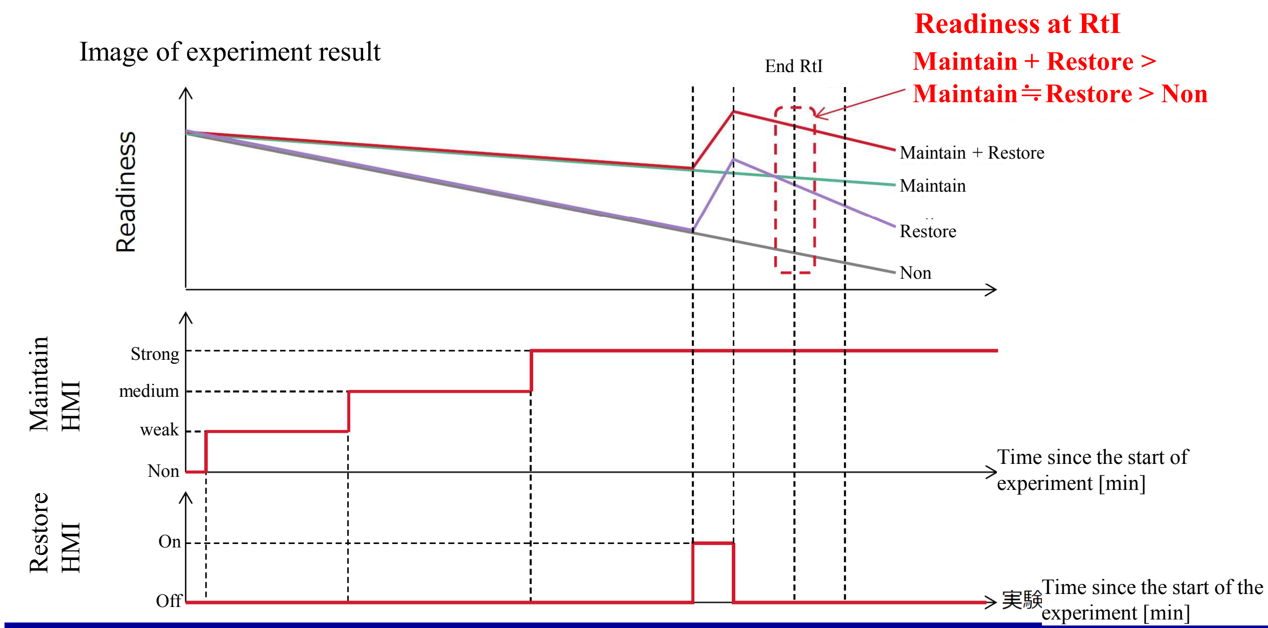
Purpose: Study of HMI that can maintain and restore driver's readiness

- Readiness maintained: Prevent the Readiness level from becoming below a certain level
- Readiness restored: Returning the Readiness level above a certain level

HMI: As one example, targeting "tactile" and "cold sensation"

- Readiness maintained: Continuous presentation of stimulus from start of operation;
  Combination of "Cool wind from the front and back of the seat;" "Sheet cooling" and "vibration"
- Readiness restored: Present stimulus (strong vibration) only once, one minute before RtI

Image of experiment result



- 36 drivers
- Automatic driving:LV3 equivalent
- HMI: 4 conditions
  (No HMI , Maintain HMI , Restore HMI , Maintain + Restore HMI : Plan for each subject)
- Scenario: Automatic operation for 30 minutes→RtI (Switch to manual operation)→Critical Event (Avoidance of Forward Stop Vehicles)

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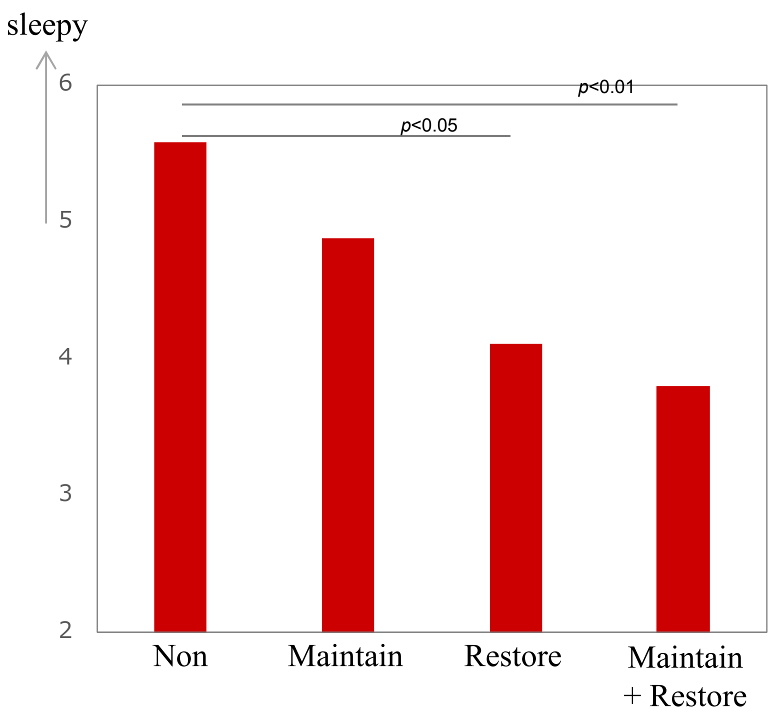
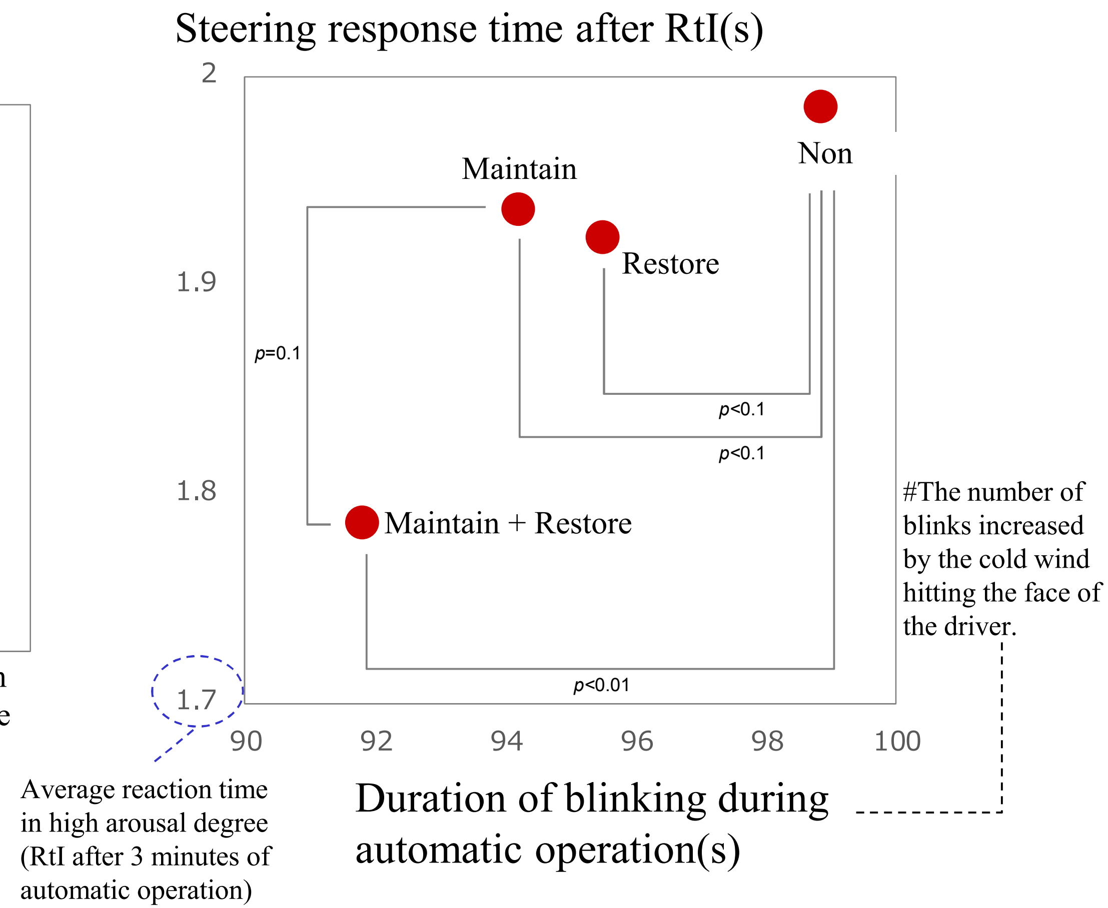
Result of the effect of HMI for maintaining arousal

It is suggested that maintaining readiness is effective by having both Maintain HMI and Restore HMI procedures active



Kalrolinska sleeping scale



Duration of blinking during automatic operation(s)

Subjective drowsiness (ex post evaluation): "Maintain + Restore" HMI is most effective in lowering arousal level

By "Maintain + Restore" HMI, driver reacts faster after RtI

3. Derivation of the relationship between driver state and transition time: (Motion DS experiment)

Study of the influence of driver condition on switching behavior from automatic to manual operation

Purpose: At the occurrence timing of different RtIs, we examined the relationship between driver condition (inattention or inattention of consciousness) during automatic driving and driving performance at each occurrence time. Finally, we clarified the relationship between driver state and transition time;

In addition, we verified the following two results obtained in last year's DS experiment using experimental devices in avoidance scenes. First, “Due to” inattention “during automatic driving,” there was a delay in obstacle avoidance behaviors in the handover transition scene. Second, it takes time to stabilize the vehicle after avoidance of obstacles by “inattention” during automatic driving

Experiment scenario: It is almost the same as Experiment 1 (For DS, a stopping vehicle is installed instead of a pylon)

- Follows the preceding vehicle during automatic driving
- One side three-lane road simulating a highway
- Automatic operation for 5 to 6 minutes ⇒ RtI assertion (switch to manual operation) ⇒ Critical Event (Avoidance of Forward Stop Vehicles)

↑ repetition

RtI assertion timing: 4 Set condition [Express by TTC with stop vehicle to avoid after manual operation]

TTC：10 Seconds (Used in JAMA [JARI])

TTC：6 Seconds (Used in last year's experiment)

TTC：4 Seconds (JAMA use case)

TTC：2 Seconds (The shortest time in the survey)

Subjects: 72 drivers 【N-back group (Conscious but inattentive) and SuRT group (inattentive)】

Automatic operation: equivalent to LV 2

Instruction for equivalent to LV 2

"During traveling, keep track of the surrounding traffic conditions and monitor surrounding conditions and the state of the automatic driving system so that there is no accident"

"Basically, always keep track of the traffic conditions in the surroundings and monitor the content of the accident for automatic driving monitoring"

"While doing surveillance work, please also do other tasks to the extent possible"

"Since the task measures the correct answer rate and reaction time, please try to correctly answer as soon as possible"

Driver status: "Conscious but inattentive (Perform 2-back)" and "Inattention (Perform SuRT hard)"

<Experimental devices for verification>

① Set choice judgment about stop direction of stopped vehicle:

- If the vehicle is stopped at the left end, avoid from the right
- If the vehicle is stopped at the right end, avoid from the left

② Change the curve curvature after avoidance of stopped vehicles:

- A road that places a stopped vehicle in a straight section and enters a curve after avoiding a stopped vehicle.
- In one trial, the curve curvature after avoidance becomes tight [enters a tight curve]

①

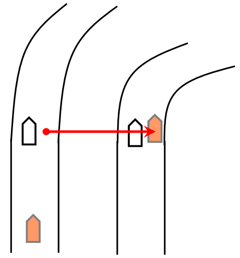
Right avoidance: 2/3 of all trials

Left avoidance: 1/3 of all trials

Hypothesis: As for the cognitive load during automatic traveling, behaviors to avoid obstacles are delayed due to the decrease in interference / judgment speed of working memory. With the addition of the selection judgment processing, following becomes more remarkable

- Collision rate increases
- Approach to obstacles when avoiding

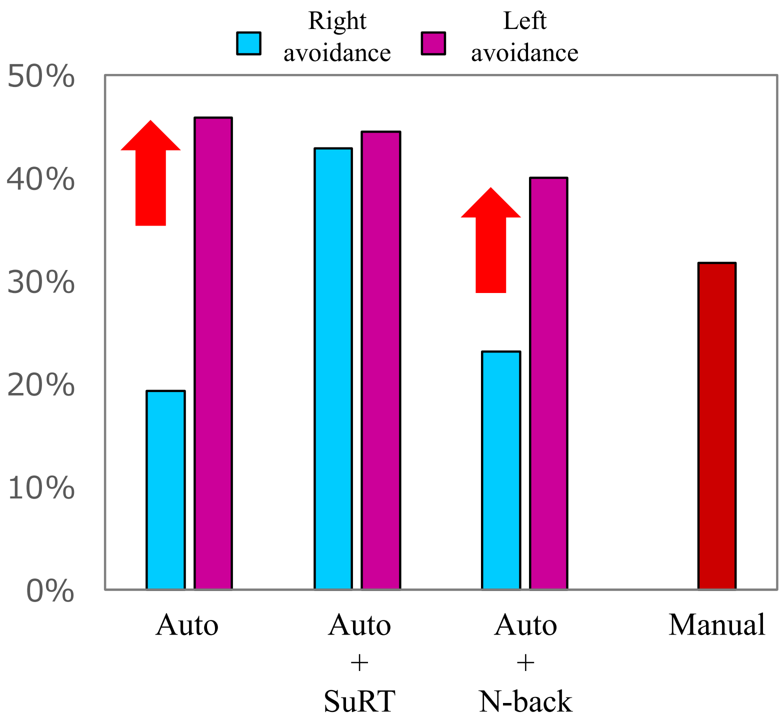
②



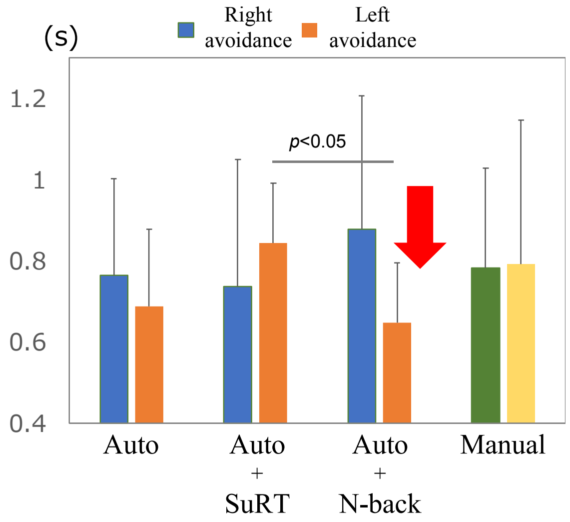
Hypothesis: The visual / operation load accompanied by inattention during automatic driving, the response behavior to the obstacles that were reacted to quickly becomes sharp due to the deterioration of the understanding of the surrounding situation, and as a result, the behavior of the vehicle becomes unstable after the reaction

- Lane departure rate increases
- Variation in steering after avoidance, varies avoiding behavior

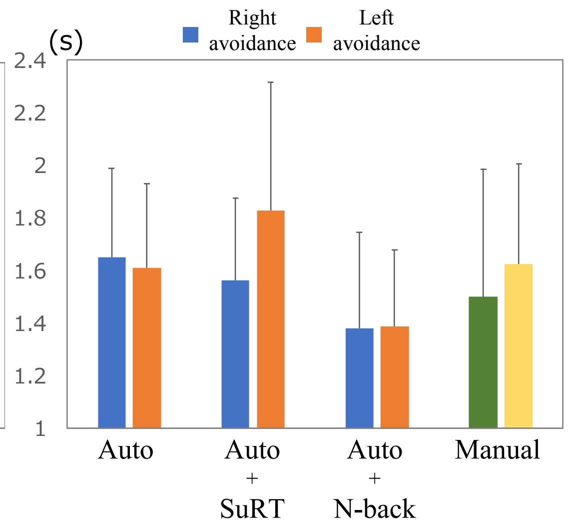
Results of the influence of driver condition on switching behavior from automatic to manual operation: Instruction for equivalent to LV2 - Influence of cognitive load



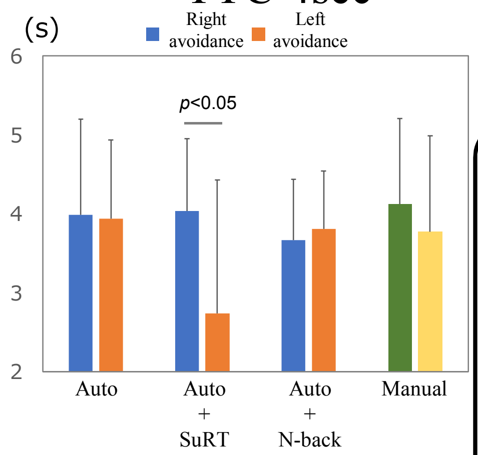
Collision rate with stop vehicle: TTC 2sec



TTC 4sec



TTC 6sec

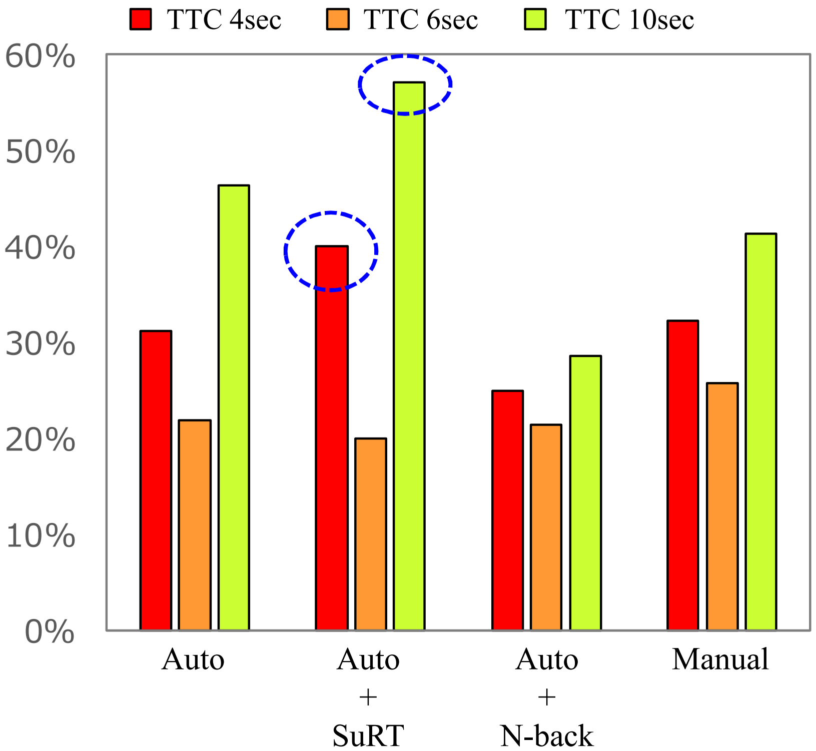


TTC 10sec

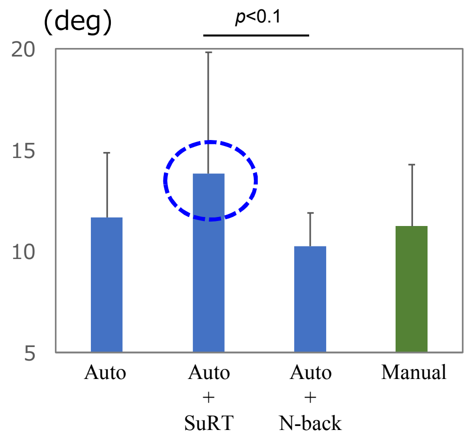
The margin time with stopped vehicles at lane change

When there is a "conscious but inattentive" situation, the collision rate increased under the condition of TTC 2 seconds, and the margin time decreased with the condition of TTC 4 seconds

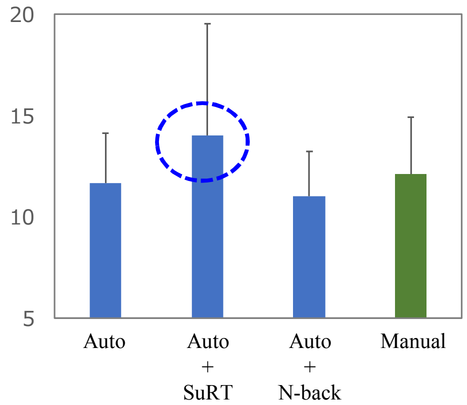
Results of the influence of driver condition on switching behavior from automatic to manual operation: Instruction for equivalent to LV2 - Influence of visual and operation load



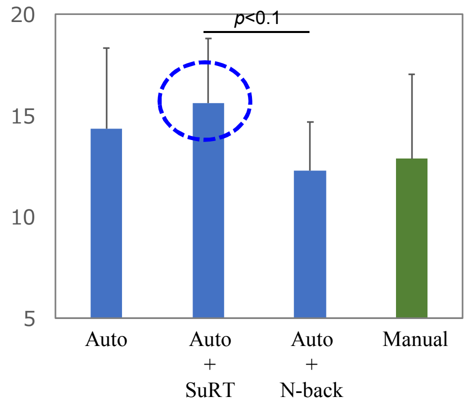
Lane departure rate after avoidance



TTC 4sec



TTC 6sec



TTC 10sec

Variation of steering after lane change

Due to inattention, the variation of the steering after the lane change became large, and the lane departure rate increased under the condition of TTC 4 seconds

Results of the influence of driver condition on switching behavior from automatic to manual operation: Instruction for equivalent to LV2 - Summary

	TTC 2sec	TTC 4sec	TTC 6sec	TTC 10sec
Consciously inattentive (N-back)	In the avoidance scenario, a selection and judgment process is added, thereby increasing the collision rate	In the avoidance scenario, a selection and judgment process is added, and the time margin corresponding to the stopped vehicle decreased	Compared to other conditions, there is less time to respond to stopped vehicles	Performance is similar to manual operation and automatic operation
Inattention (SuRT)	High crash rate [Collision can not be avoided in avoidance situation with too much margin]	Compared to other conditions, the lane departure rate is high with the curve after avoidance	The steering operation variation in the curve after avoidance is somewhat higher than the other conditions	The lane deviation rate on the curve increases after avoidance

Recommendation from task B <As of April 4, 2018>

- As a driver state, it is thought that it is necessary to monitor "conscious but inattentive," "inattentive," and "awakening degree" respectively
- Different driver conditions during automatic operation suggest that the performance indicators that may be affected are different after switching to manual operation
- In order to maintain Readiness, it seems necessary to present with a combination of "steady stimulation" and "temporary stimulation"

Results of FY2017

1. Examination on driver state evaluation indicator during automated driving and feasibility of driver monitoring system (DMS).

   The driver state evaluation indicator, which was the result of FY2016, was confirmed to be measurable in the test course environment.

2. Determination of basic HMI requirements to maintain good driver state: Examination of effect of arousal maintenance HMI

   The improvement of driver reaction to RtI was confirmed to be possible by using both ‘Maintenance’ and ‘Recovery’.

3. Derivation of relation between driver state and transition time: Examination of effect on transition behavior when vehicle control is changed from automated driving to manual driving.

   Based on the driver state of ‘cognitive distraction’ and ‘visual distraction’, the influence on transition behavior at various RtI presentation timing was clarified.

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

Outline and target of Task C

FY2017

i) Extraction of the influence on surrounding traffic participants by displaying automatic operation.
Observational experiment by traveling on real road environment

ii) Prototyping of external HMI and effectiveness verification based on combination of vehicle behavior and external HMI.
Drivers to drivers & pedestrians (test truck)

iii) Prototyping and effectiveness verification of external HMI display expressing that it is an automated vehicle.
Drivers to drivers & pedestrians (test truck)

iv) Investigation of effect of regionalism and demographic personal attributes on traffic participants' recognition to external HMI.

FY2018

We implement an external HMI to communicate to surrounding traffic participants considering regionalism and attributes of traffic participants. Based on the results obtained in demonstration experiments, we implement an external HMI communicating to the surrounding traffic participants. We extract design requirements and design guideline of vehicle behavior and external HMI to communicate to surrounding traffic participants based on the features of road traffic condition, regionalism and attributes of traffic participants.

Communication task between automated vehicle and other traffic participants

Outcome of FY2016
Grasp the current status of communication

Communication method

Vehicle behavior
+
Flashing lights

Contents of communication

Intention to yield

FY2017

Between automated vehicle and other traffic participants
Construction of evaluation index of communication

- Safety of traffic participants
- Security of traffic participants
- Facilitation of traffic flow
- ⋮
- Positive and negative effect

FY2017

Between automated vehicle and other traffic participants
Extraction of design requirement of communication

Automated vehicle vs Pedestrians
Communication method
Vehicle behavior, external HMI

Automated vehicle vs other drivers
Communication method
Vehicle behavior, external HMI

Experiment on communication between AV and other drivers

Experimental prototyping of external HMI and verification of effect by vehicle behavior, prototyping of external HMI expressing automatic operation and examining its effect.

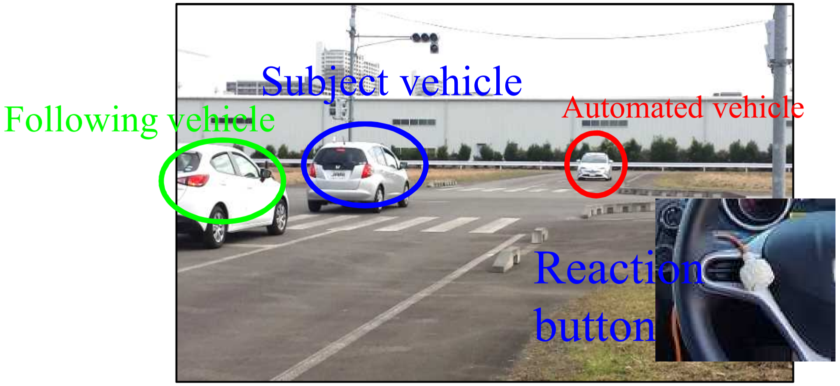
■ Purpose

Develop design requirements and guidelines for external HMI and vehicle behavior for automated vehicle / communication method between AV and other drivers in typical road environment / traffic situation where driver-to-driver communication occurs.

→ Communication scenes with the vehicles driver waiting to turn right in the intersection.

→ Verification of effect of vehicle behavior when communicating to a driver obtained in FY2016.

■ Status of the experiment in the test truck of JARI (Experiment vehicle assuming automated vehicle)



Instructions to subjects

- When he/she feels that vehicle is yield to him/her
- When judging that he/she can turn right

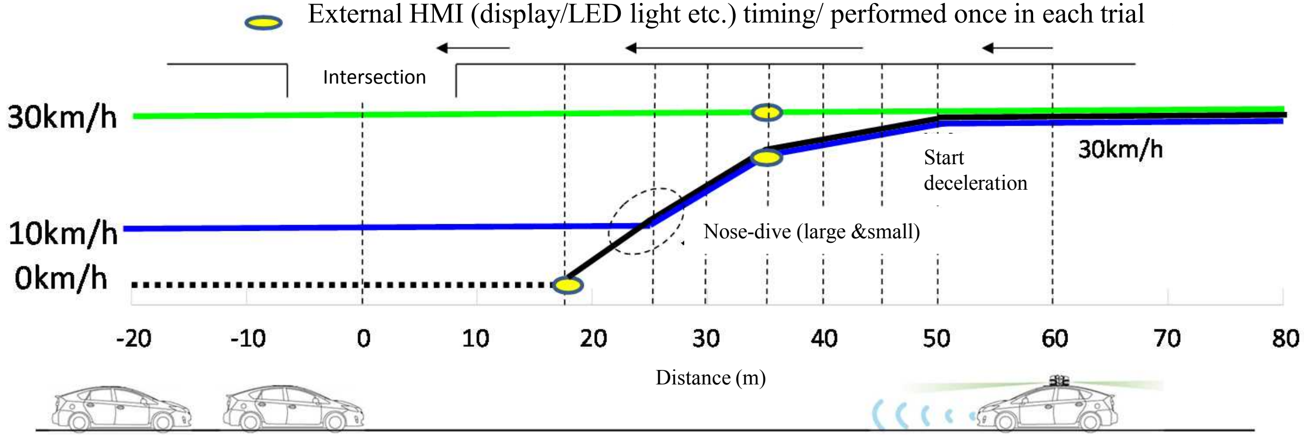
Pressing the reaction button at each time

Photo of automated vehicle-Driver(Subject) waiting to turn right

Method (Experiment on communication between AV and driver)

- Transmission of intention / state by combination of deceleration behavior of automated vehicle and external HMI

Vehicle behavior: Constant speed (30km/h→30km/h), Deceleration 1 (30km/h→10km/h, nose-dive(small)),
Deceleration 2 (30km/h→10km/h (→0km/h), nose-dive(large))



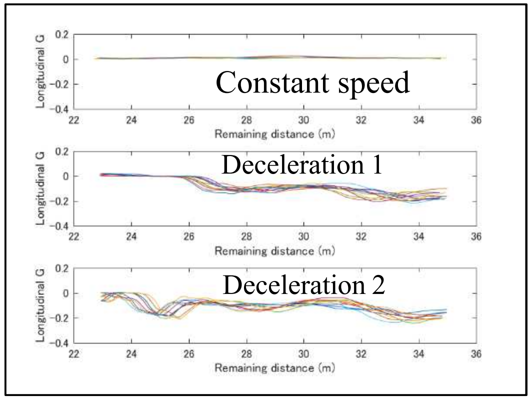


Figure: Timing of Experimental vehicle (Automated vehicle)'s vehicle behavior and external HMI

(will stop)

(after you)

(Automatic operating)

(LED Flashlight)

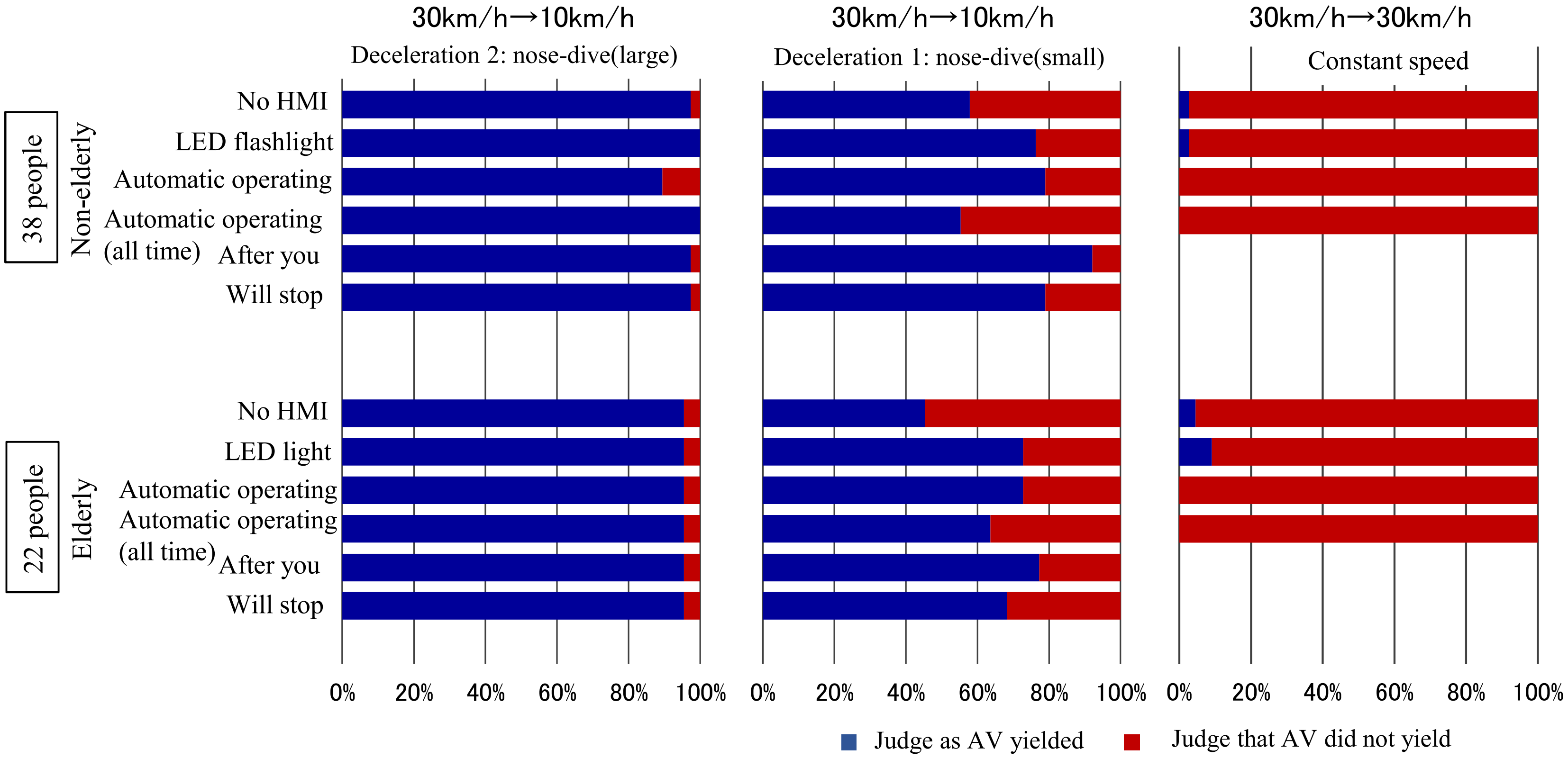
Transmission of intention / condition: Intention (stop, yield), state (Automatic operating) etc.
(Used message display by text, considering the certainty of transmission of AV's intention and state to drivers)

To yield by light
(No teaching of meaning)

Result (Experiment on communication between AV and driver)

Traffic facilitation

■ The result of the driver's judgment whether or not to yield (Pressing reaction button)

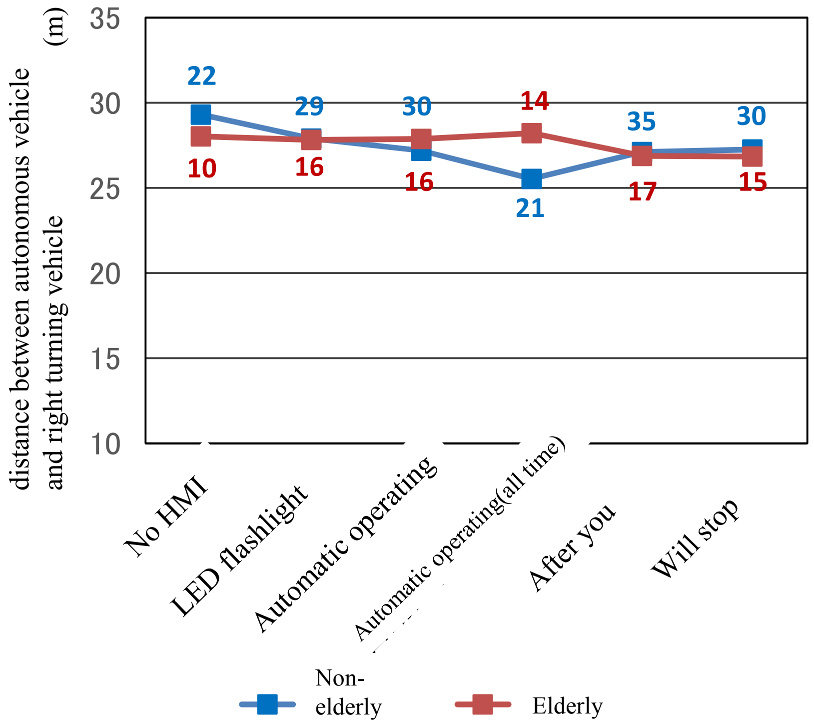


1. It is possible to cause the driver to recognize that the automated vehicle yields to him/her only with a large deceleration behavior.
2. In order to let the driver recognize that AV yields to him/her in a situation where the deceleration behavior is not sufficiently conducted, an external HMI is necessary.
3. When "automatic operating" is displayed, there decreases the number of non-elderly drivers who recognize that AV's deceleration behavior means "yielding to them". Even for the elderly people have a similar tendency.

Result (Experiment on communication between AV and driver)

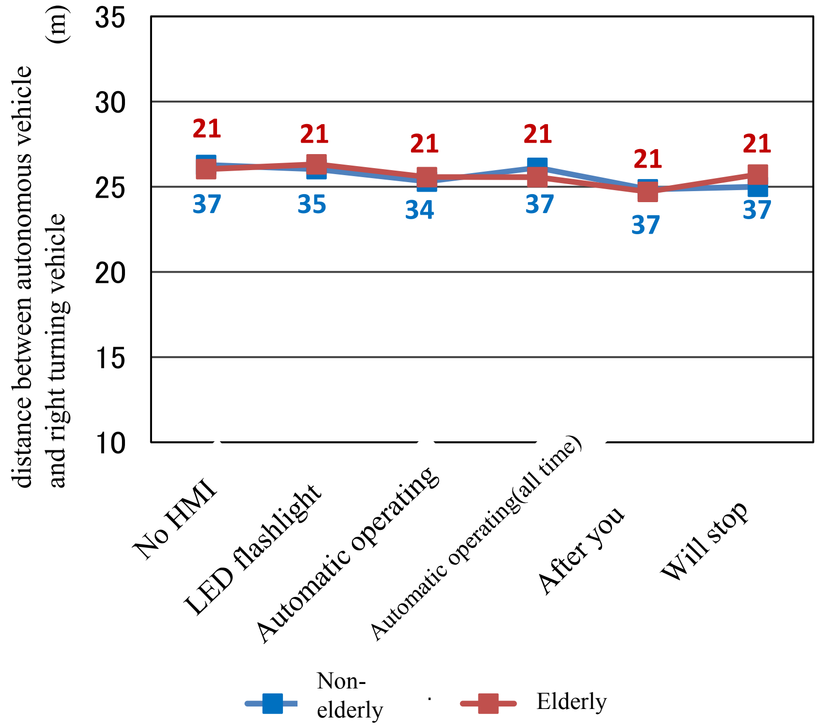
Traffic facilitation

- The distance between the automated vehicle and the right turning vehicle at the time when judged AV yielded to drivers.



30km/h→10km/h

Deceleration 1: nose-dive(small)



30km/h→10km/h

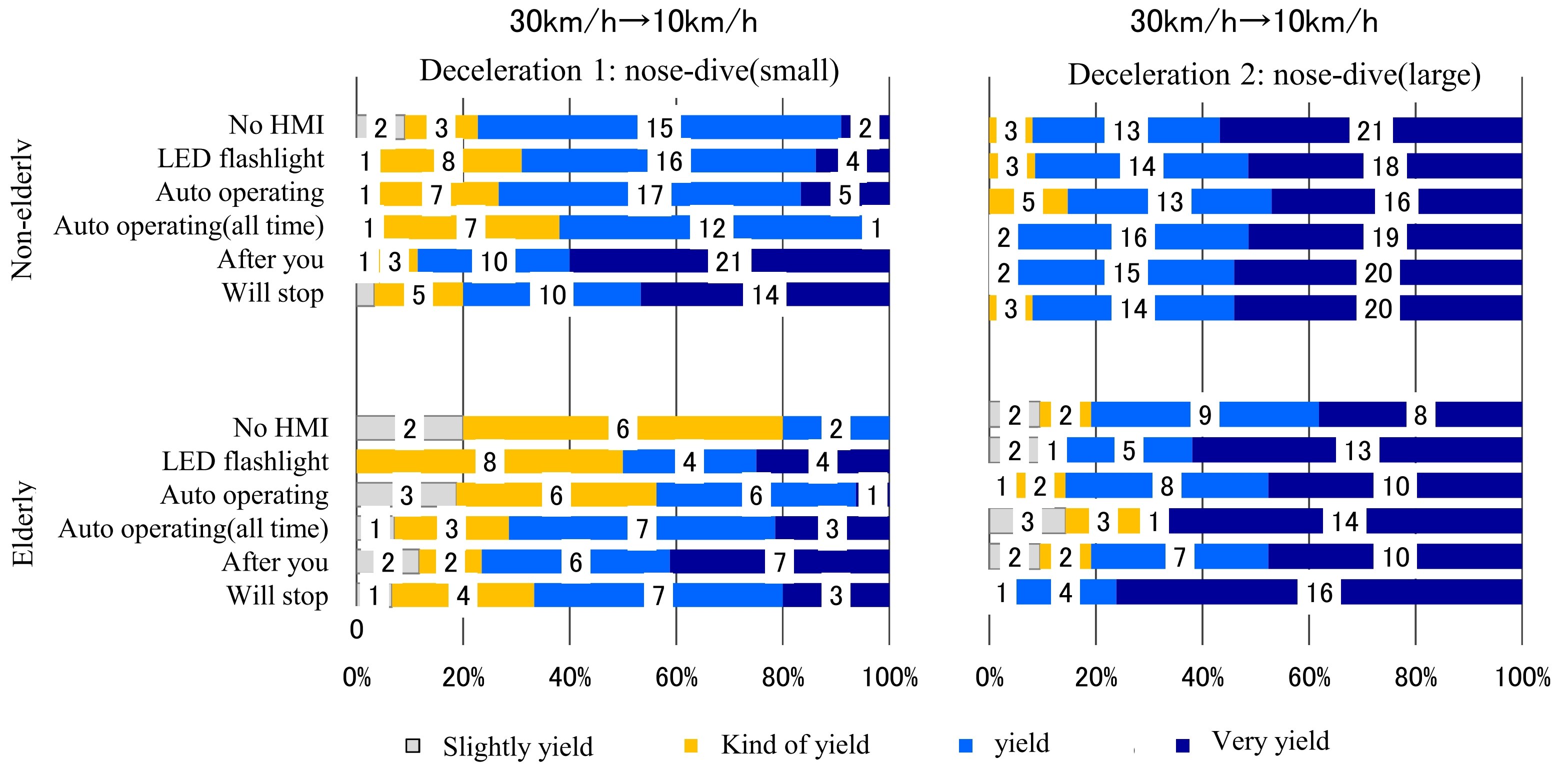
Deceleration 2: nose-dive(large)

1. In the state without large deceleration behavior, when it is transmitted to the driver waiting for the right turn by the external HMI, it can encourage recognition of yield earlier at a somewhat earlier timing.

Result (Experiment on communication between AV and driver)

Feeling of security

■ Degree of yield which the driver who judged AV yielded to him/her.

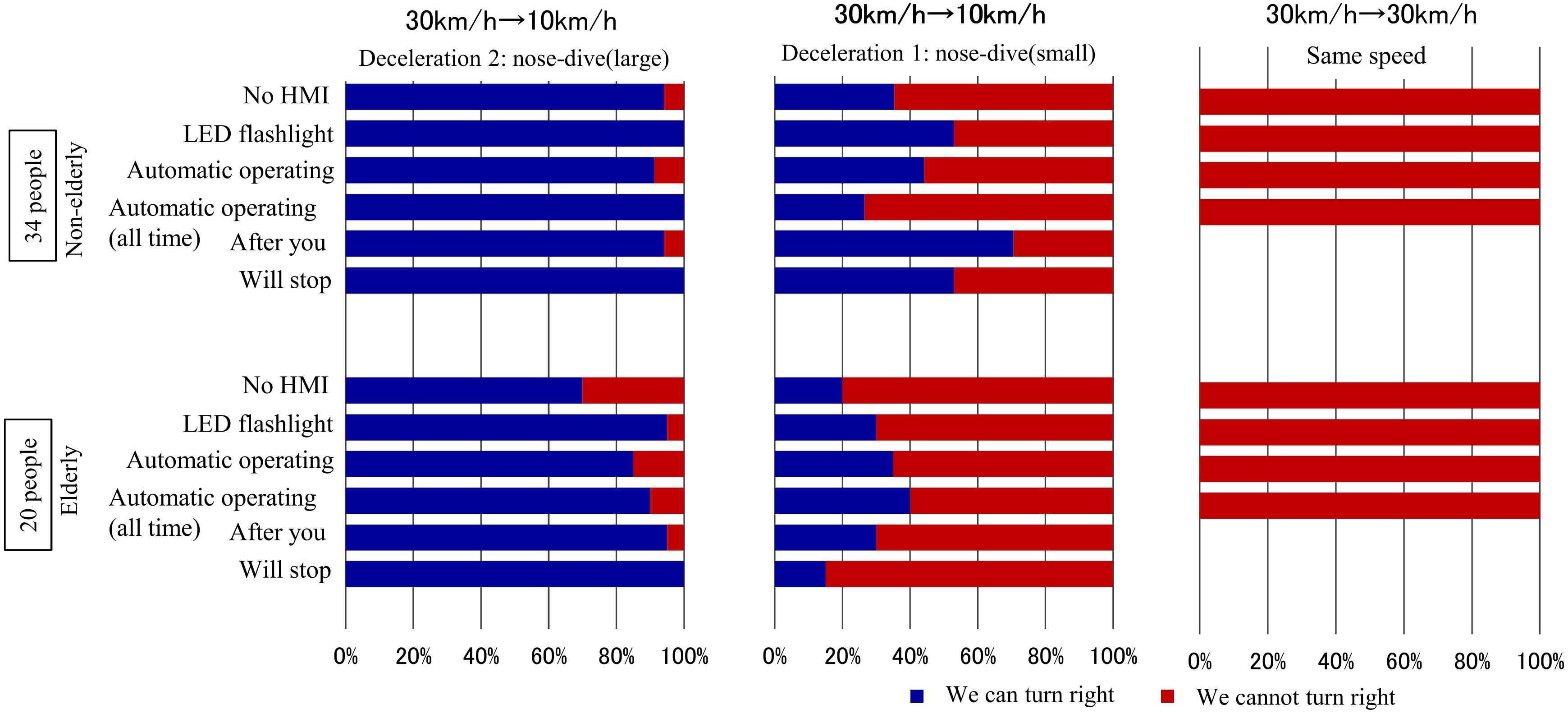


1. By reproducing the deceleration behavior greatly, it is possible to make the driver strongly recognize the intention such that AV yields to him/her.
2. When the deceleration behavior is not sufficiently conducted, if the intention of "yielding" is communicated by the external HMI, it is possible to make the driver understand the intention of "yielding" from the automated vehicle to the same degree as in the case of the large deceleration behavior.

Result (Experiment on communication between AV and driver)

Traffic facilitation

■ The result of the driver's judgement whether driver can turn right or no (Pressing reaction button)

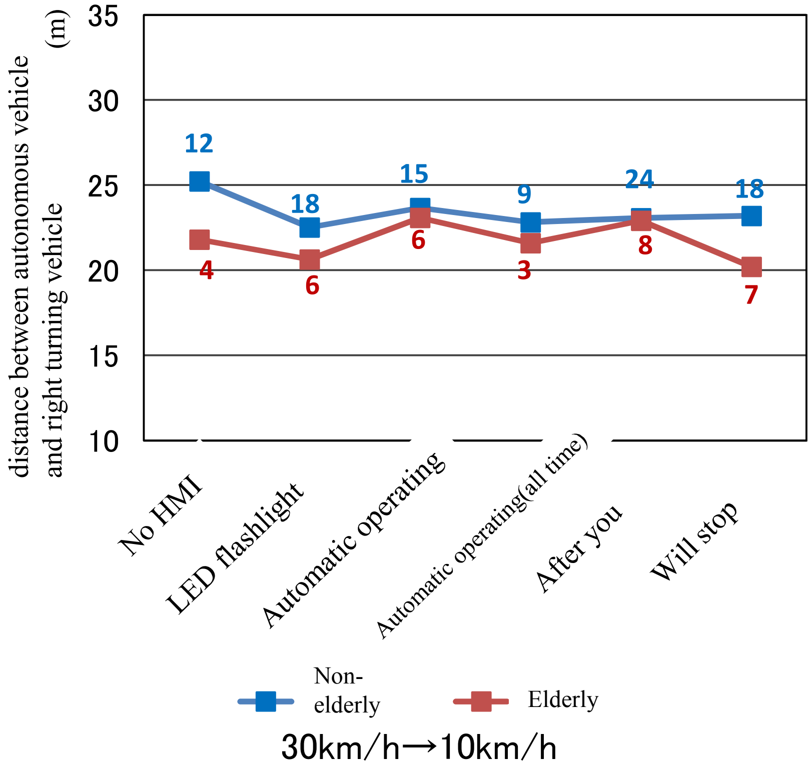


1. When the vehicle behavior is large, it can be urged to judge that a non-elderly driver can turn right.
2. Regardless of the magnitude of the deceleration behavior, if there is an external HMI, the possibility of urging the driver to judge that the vehicle can turn right can be increased.

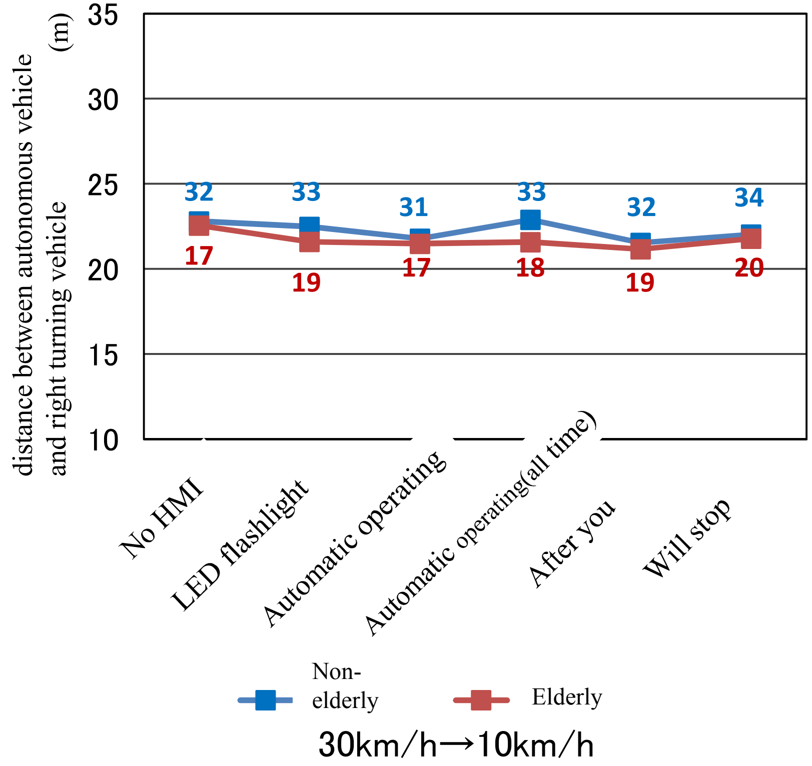
Result (Experiment on communication between AV and driver)

Traffic facilitation

- The distance between the automated vehicle and the right turning vehicle when judging that the vehicle can turn right.



Deceleration 1: nose-dive(small)



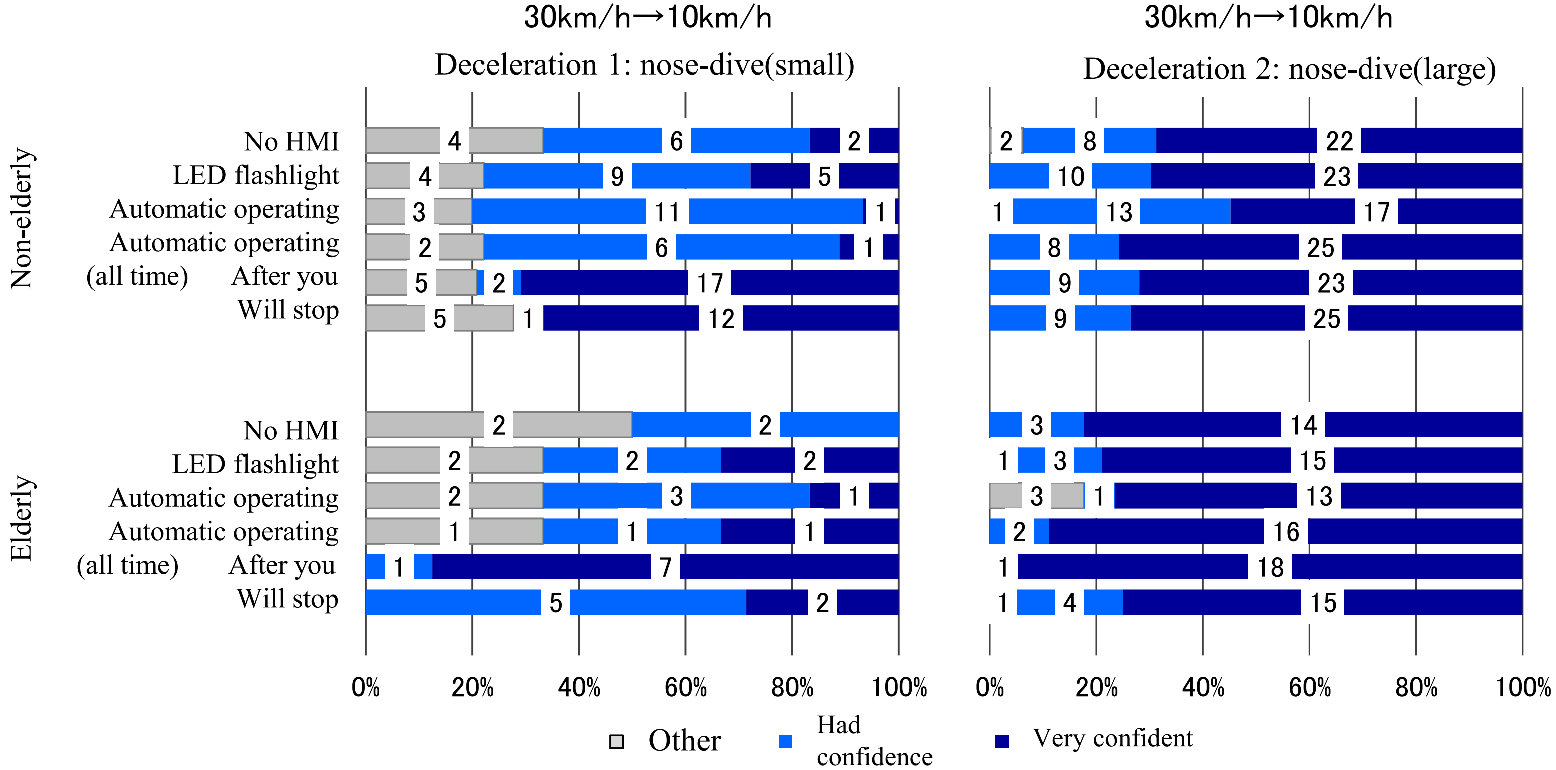
Deceleration 2: nose-dive(large)

1. The distance between the automated vehicle and the right turning vehicle when judging that the driver can turn to the right does not depend on the vehicle behavior and is generally similar. There is a possibility that the decision timing as to whether turning to the right can not depend much on the difference in the deceleration behavior and the presence or absence of the external HMI.

Result (Experiment on communication between AV and driver)

Feeling of security

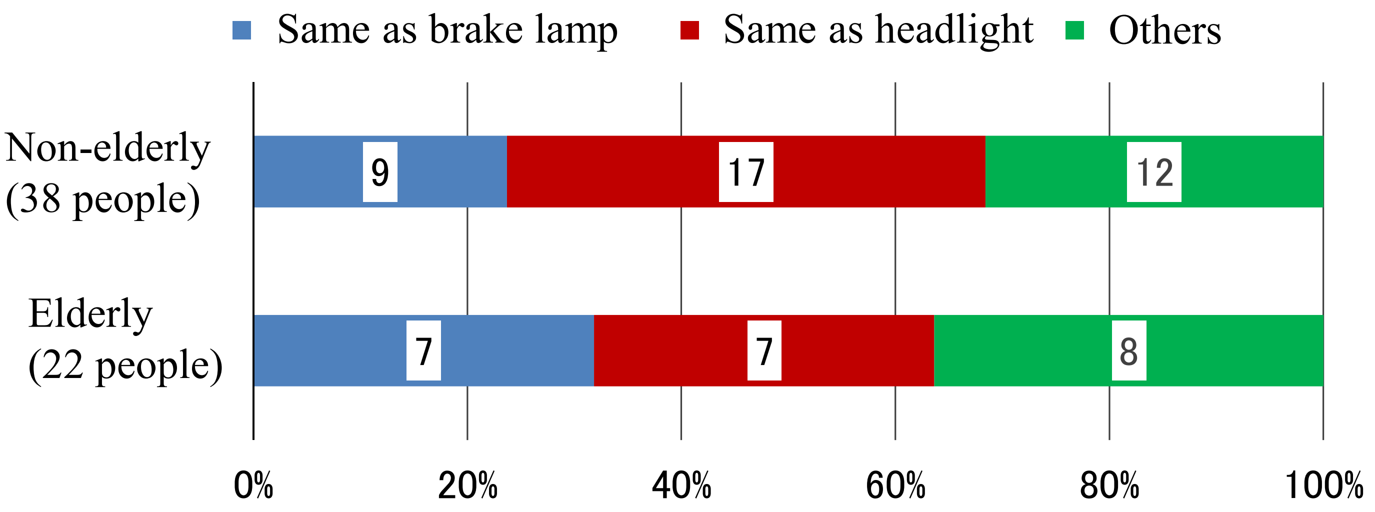
■ The degree of confidence that the driver judged to be able to turn to the right.



1. The large deceleration behavior makes the driver's higher confidence when judging that the vehicle can turn to the right.
2. Displaying “Automatic operating" on the external HMI can not raise the confidence in judging that a non-elderly can turn right.
3. Even in a situation where the deceleration behavior is not sufficiently conducted, if AV indicates the intention of “yielding” with the external HMI, drivers can increase the confidence when they decide that they can turn right.

Result (Experiment on communication between AV and driver)

■ Driver's recognition to LED flashing light after completion of experiment



1. Independent the difference between elderly driver and non-elderly driver, they tend to think external HMI is same as Lighting equipment.
(Same as the result of pedestrian experiment who has license)

Experiment on communication between AV and pedestrian

Prototyping of external HMI and Effect validation of combination between vehicle behavior and external HMI, prototyping of external HMI displaying automatic operation and its evaluation.

■ Purpose

Formulate design requirements and guidelines of AV on communication between AV and pedestrian based on vehicle behavior and external HMI, in typical road environment and traffic situation where driver-pedestrian communication is observed.

→ Communication scenes with the pedestrian waiting to cross at the no signalized crosswalk.
→ Verification of effect of vehicle behavior when communicating to a pedestrian obtained in FY2016.

■ Status of the experiment in the test truck of JARI (Experiment vehicle assuming automated vehicle)

Instructions to subjects

- When he/she feels that vehicle is yield to him/her
- When judging that he/she can cross the road

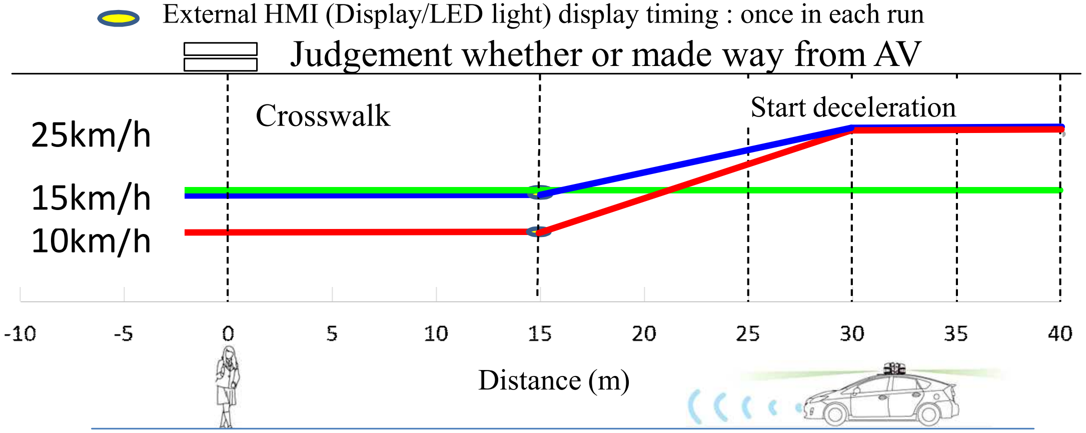
Pressing the reaction button at each time

Photo of automated vehicle-pedestrian(Subject) waiting to cross

Method (Experiment on communication between AV and pedestrian)

- Transmission of intention / state by combination of deceleration behavior of automated driving vehicle and external HMI

Vehicle behavior: Constant speed (15km/h→15km/h), Small deceleration (25km/h→15km/h, average -2.1m/s²), Large deceleration (25km/h→10km/h, average -1.7m/s²)



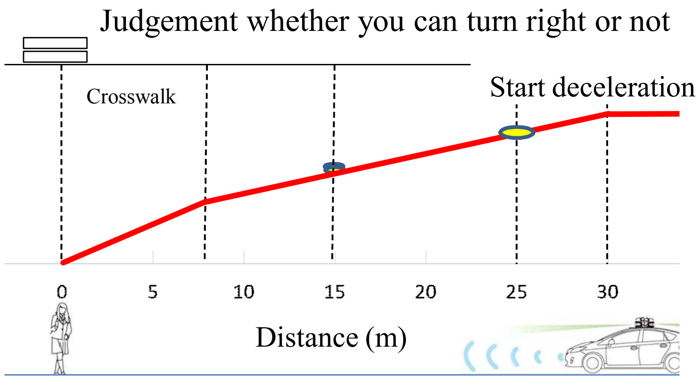


Figure: Experimental vehicle (Automatic driving)'s vehicle behavior and external HMI


(will stop)


(after you)


(Auto operating)


(LED Flashing light)

Transmission of intention / condition: Intention (stop, yield), state (automatic travel) etc.
(Used message display by text, considering the certainty of transmission of AV's intention and state to pedestrians)

Transmission by light
(No teaching of meaning)

Method (Experiment on communication between AV and pedestrian)

■ Experimental Condition (Vehicle behavior × External HMI)

Judgement experiment whether or not made way from AV

Experiment No.	Vehicle behavior	External HMI Contents	External HMI Presentation position
1	Constant speed 15km/h	—	—
2		"After you"	25m before
3		"Will stop"	25m before
4		LED flashlight "Auto operating"	25m before
5			25m before
6		"Move on"	25m before
7	Small deceleration 25km/h? 15km/h	—	—
8		"After you"	25m before
9		"Will stop"	25m before
10		LED flashlight "Auto operating"	25m before
11			25m before
12		"Move on"	25m before
13	Large deceleration 25km/h? 10km/h	—	—
14		"After you"	25m before
15		"Will stop"	25m before
16		LED flashlight "Auto operating"	25m before
17			25m before
18		"Move on"	25m before

Judgement experiment whether you can turn right or not

Experiment No.	Vehicle behavior	External HMI Contents	External HMI Presentation position
19	Large deceleration 25km/h? 0km/h	—	—
20		"After you"	25m before
21		"Will stop"	25m before
22		"Auto operating"	25m before
23		"Move on"	25m before

■ Subject

Non-elderly(with license): 6 people of male(age of 20~38), 8 people of female(age of 29~53)
Non-elderly(no license): 3 people of male(age of 19~25), 10 people of female(age of 18~59)
Elderly(no license): 2 people of male(age of 73~75), 12 people of female(age of 68~82)

Lower grade students:
11 people of male(age of 8~10),
4 people of female(age of 8~10)

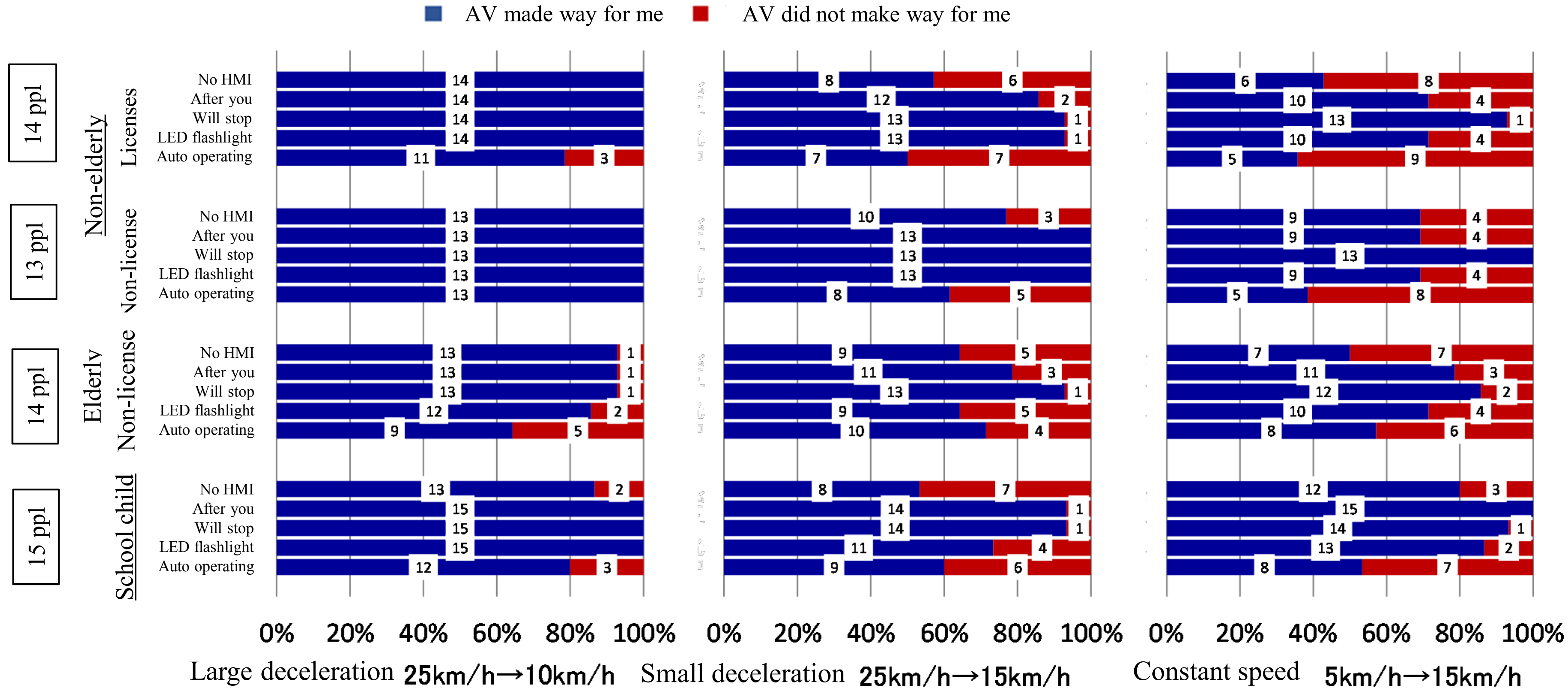
■ Measurement item

Distance between automated vehicle and crosswalk, Automated vehicles' speed, etc.
Timing felt that they felt AV yielded to them, Timing felt that they could cross, Conviction at the time of judgement of crossing, etc.

Result (Experiment on communication between AV and pedestrian)

Traffic facilitation

■ Result of pedestrian judgement as to whether or not to yield (Pushing reaction button)

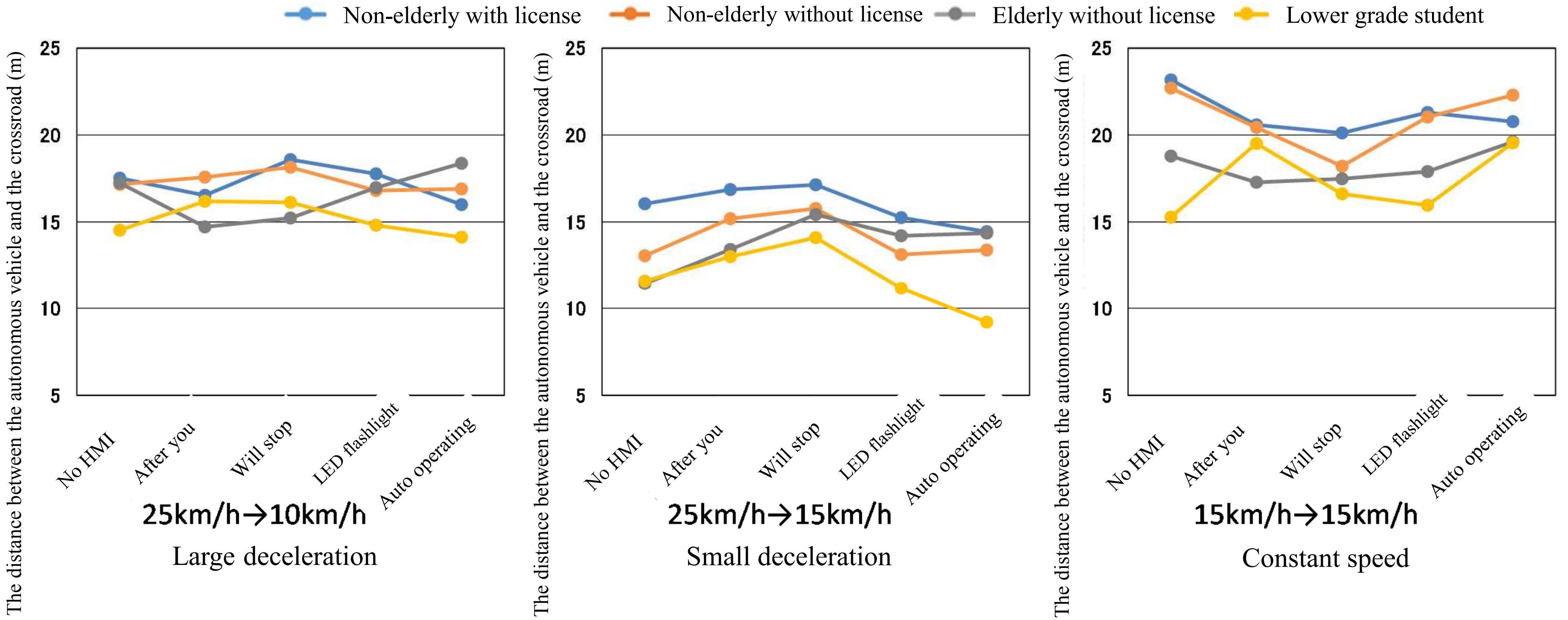


1. It is possible to make the pedestrian recognize that the automated vehicle yields to him/her only with a large deceleration behavior.
2. In order to let the pedestrian recognize that AV yields to his/her in a situation where the deceleration behavior is not sufficiently conducted, an external HMI is necessary.
3. If external HMI is displayed as "Automatic operation", there decreases the number of pedestrians who recognize that AV's deceleration behavior means "yielding to them".

Result (Experiment on communication between AV and pedestrian)

Traffic facilitation

- The distance between the automated vehicle and the crosswalk when pedestrian judge as they can cross.

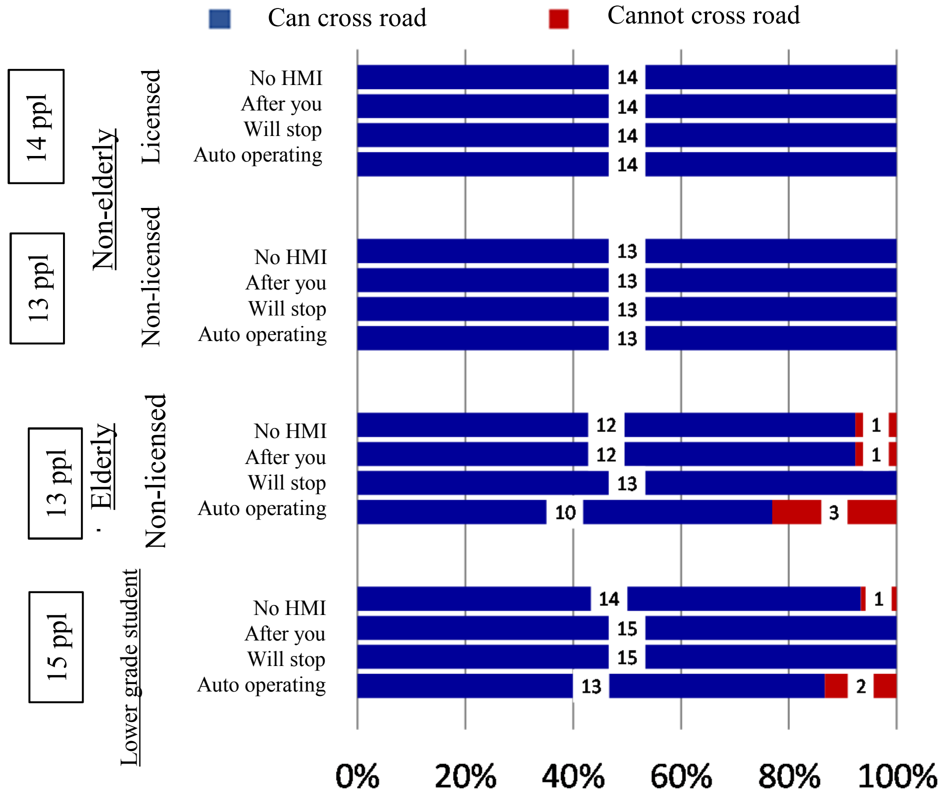


1. Large deceleration behavior can encourage pedestrians to recognize to cross at earlier timing.
2. In the case when the intention of stopping is transmitted to the pedestrian with the external HMI in a state without accompanying large deceleration behavior, it is possible to urge recognition at an earlier timing.
3. Low grade students had hard to understand when they see "Automatic operating" as external HMI.

Result (Experiment on communication between AV and pedestrian)

Traffic facilitation

■ Result of pedestrian judgement whether crossing or not.(Push reaction button)

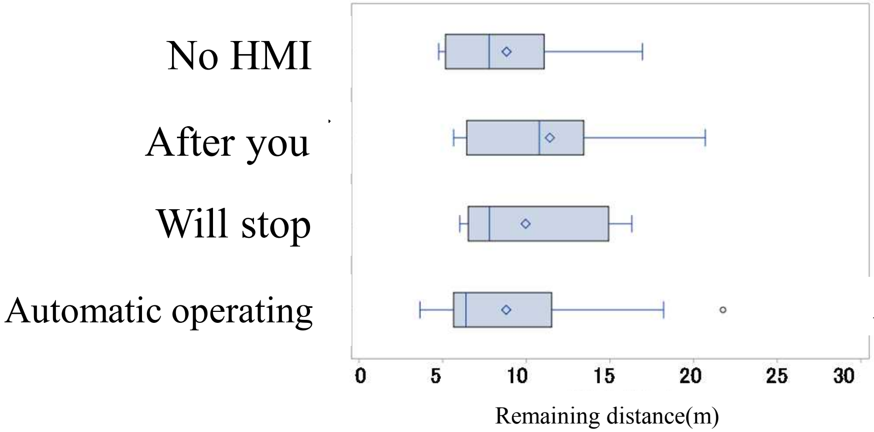


1. If AV says “Will stop" on the external HMI, AV can encourage any pedestrian attribute to be crossable.
2. Non-elderly (whether having license or not) tend to think they can cross the road with or without external HMI.
3. Elderly tend to think they cannot cross the road when AV display external HMI “Automatic operating”.

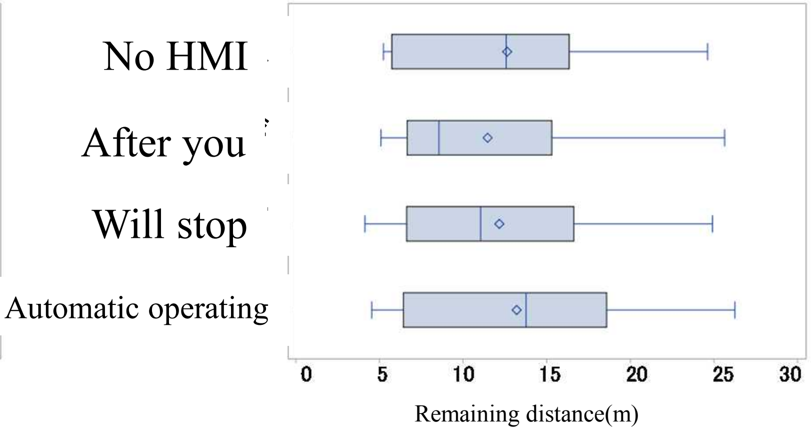
Result (Experiment on communication between AV and pedestrian)

Traffic facilitation

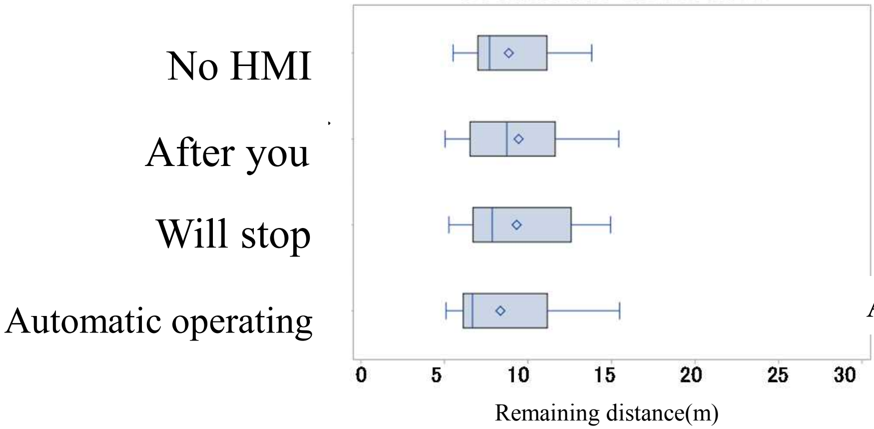
- The distance between the automated vehicle and the crosswalk when pedestrians judge as they can cross.



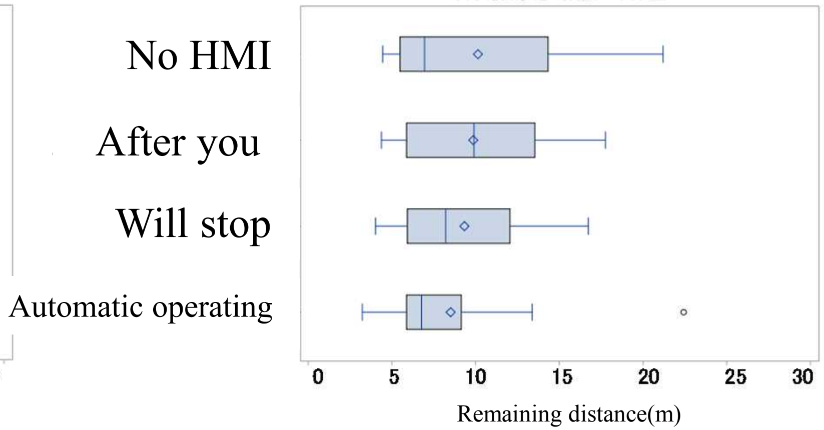
Non-elderly, licensed



Elderly, non-licensed



Non-elderly, licensed

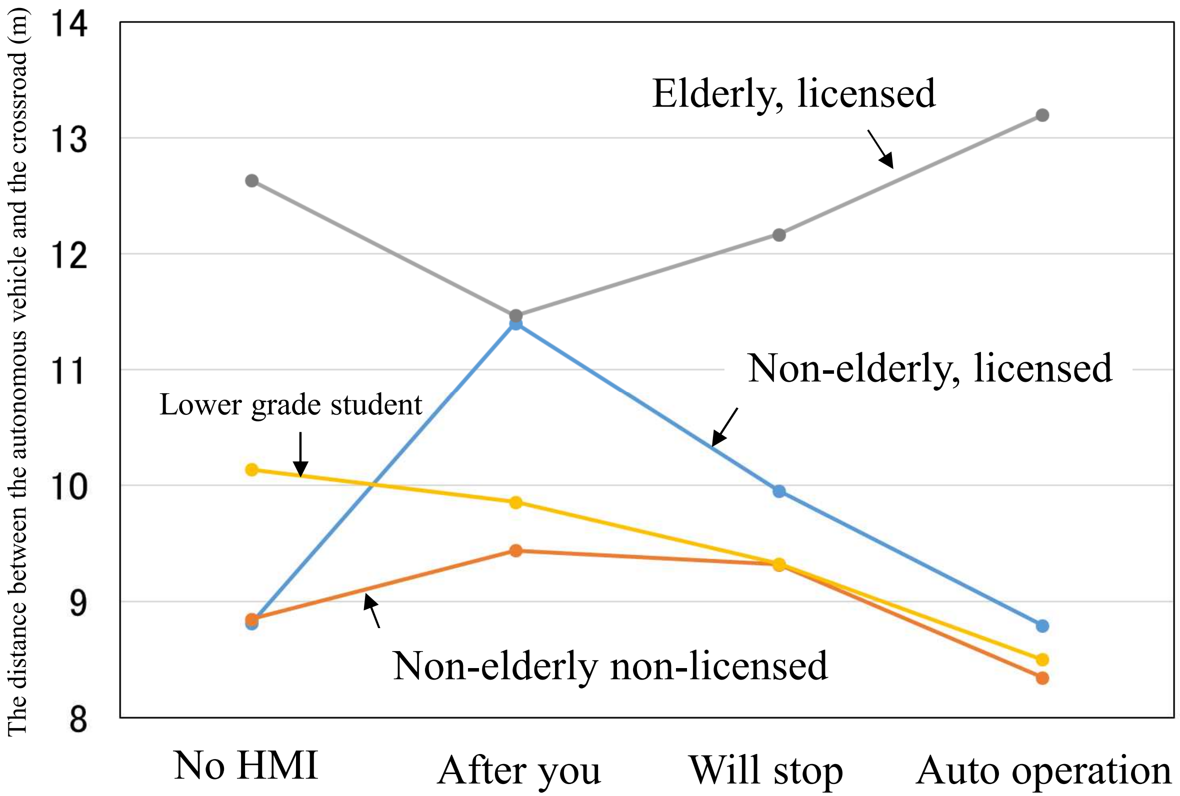


Lower grade student

Result (Experiment on communication between AV and pedestrian)

Traffic facilitation

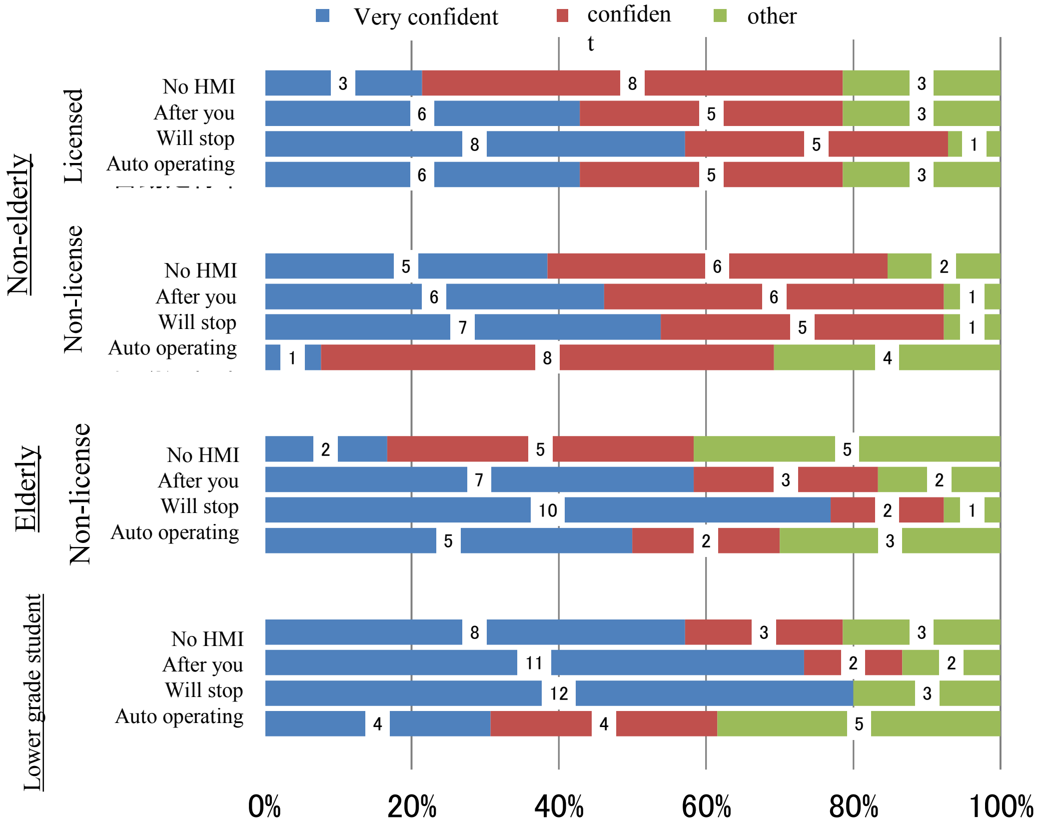
- The distance between the automated vehicle and the crosswalk when pedestrians judge as they can cross.



1. The distance between automated vehicle and the crossroad when pedestrian judge as they can cross, will change depends on external HMI and pedestrian's attribute.

Result (Experiment on communication between AV and pedestria Feeling of security

■ Degree of confidence felt by a pedestrian who judged as they can cross.



1. The automated vehicle can increase the judgement of the crossing of the pedestrian by using external HMI.
2. If automated vehicle displays "Automatic operating", people tend to have unconfident by crossing road depends on pedestrian attribute.

Result (Experiment on communication between AV and pedestrian)

Feeling of security

■ Changing the pedestrian's confirmation behavior when judging whether they will cross or not

Pedestrians who completely lacked visibility in the left direction (opposite to the direction of the automated vehicle) in the condition using the external HMI

number	age	age・attribute	sex	External HMI
Subj15	10	Lower grade student	Male	Auto operating
Subj16	10	Lower grade student	Male	Auto operating
Subj37	8	Lower grade student	Female	After you
				Will stop
Subj35	73	Elderly without licensed	Female	Auto operating
Subj25	46	Non-elderly with license	Female	Auto operating
Subj31	44	Non-elderly with license	Female	Will stop
Subj46	29	Non-elderly with license	Female	After you

Pedestrians who visibility has been reduced to the left and right multiple times on the left and right sides with the external HMI

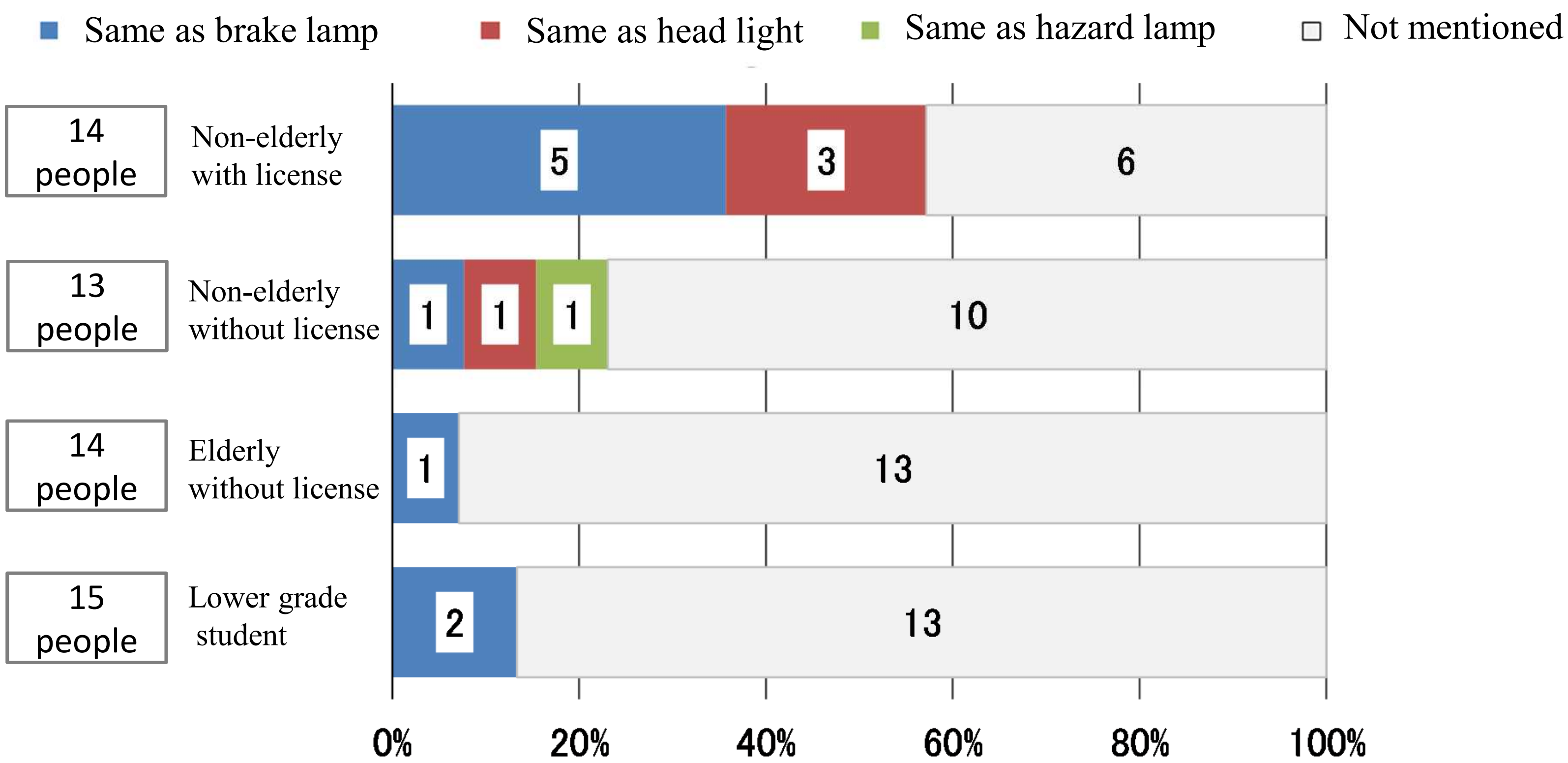
number	age	age・attribute	sex	External HMI
Subj09	10	Lower grade student	Male	After you
				Will stop
Subj23	77	Elderly without licensed	Female	After you
Subj24	68	Elderly without licensed	Female	Auto operating
Subj52	77	Elderly without licensed	Female	Will stop
Subj45	21	Non-elderly without license	Female	After you
				Will stop
Subj20	31	Non-elderly with license	Male	After you
Subj54	35	Non-elderly with license	Male	Auto operating

⇩

1. Consideration is required to encourage pedestrians themselves to conduct confirmation behavior without strongly relying on cross-sectional judgment for external HMI regarding transmission of intention and states via the external HMI

Result (Experiment on communication between AV and pedestrian)

■ Pedestrian recognition for LED light just after completion of experiment



1. Non-elderly with license holder tend to think external HMI, LED flashlight as other lighting device.
2. Any subject without license holder tend to think external HMI, LED flashlight as normal car lighting.

Survey on regionality and personal attribute of communication using external HMI

Examination of influence / effect on driver / pedestrian due to external HMI and vehicle behavior.

■ Purpose

Survey on differences and features due to regionalism and attributes on driver's and pedestrian's recognition, decision-making, acceptability, etc. on combinations of specifications and vehicle behavior of outside HMI extracted through test road experiments, general roads / premises road observations .

→ We will use the scene when driver waiting to turn right in intersection's communication.
We combined the vehicle behavior which we set on experiment and external HMI.

→ We will use the scene when people cross the no signal intersection's communication
We combined the vehicle behavior which we set on experiment and external HMI.

■ Method

Web-based survey with video

Target district in this survey

Sapporo, Tokyo 23 wards, Osaka, and Tottori / Shimane prefectures

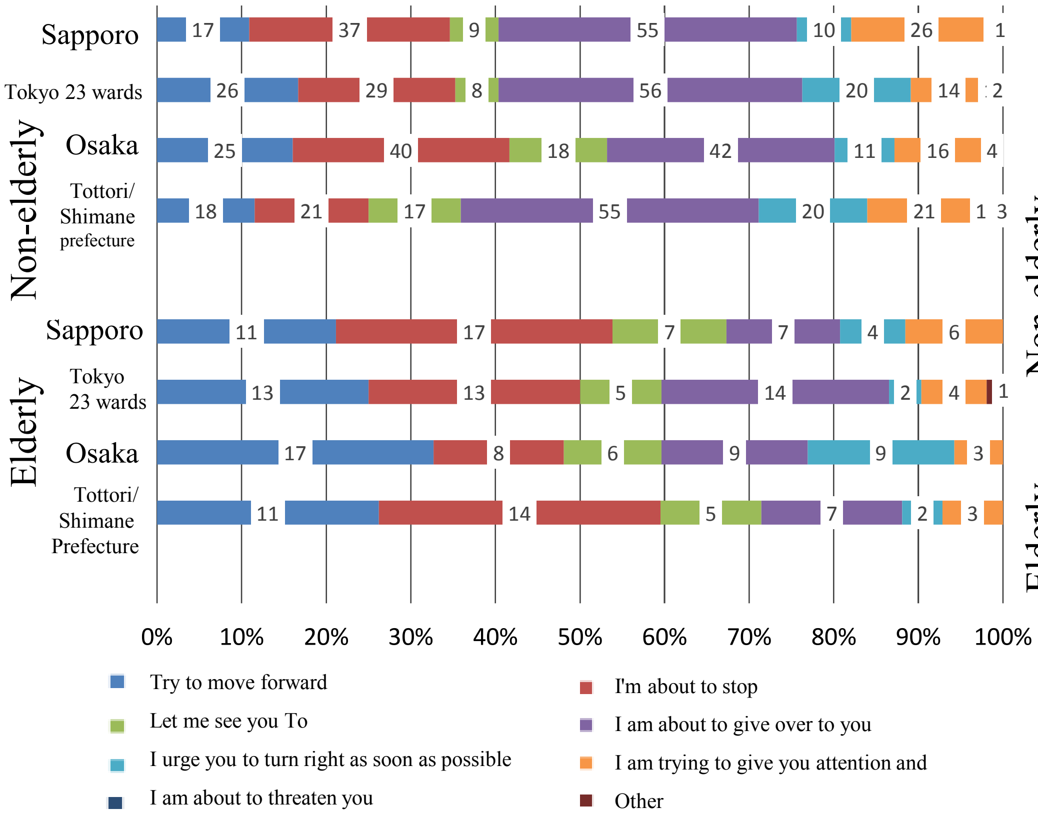
Study target

Non-elderly Male & Female, age of 10s~60s (up to 64 years), Driver license holder and non-holder.
Elderly Male & Female, age of 60s (65 years to) ~80s, Driver license holder and non-holder.

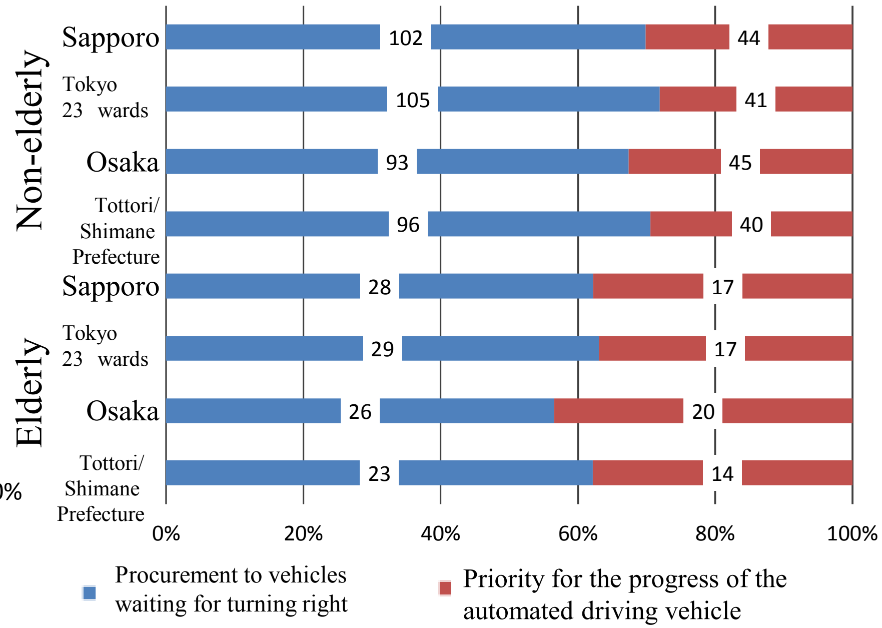
Result (Survey of communication between AV and driver using external HMI)

Sapporo, Tokyo 23 wards, Osaka (156 non-elderly and 52 elderly in each region)
Tottori / Shimane prefectures (156 non-elderly and 42 elderly)

Traffic facilitation



I am trying to give you a way, I'm about to stop, I urge you to turn right. → Procurement to vehicles waiting for turning right
I am about to intimidate you, trying to give attention and warning to you, to advance. → Priority for the progress of the autonomous vehicle.



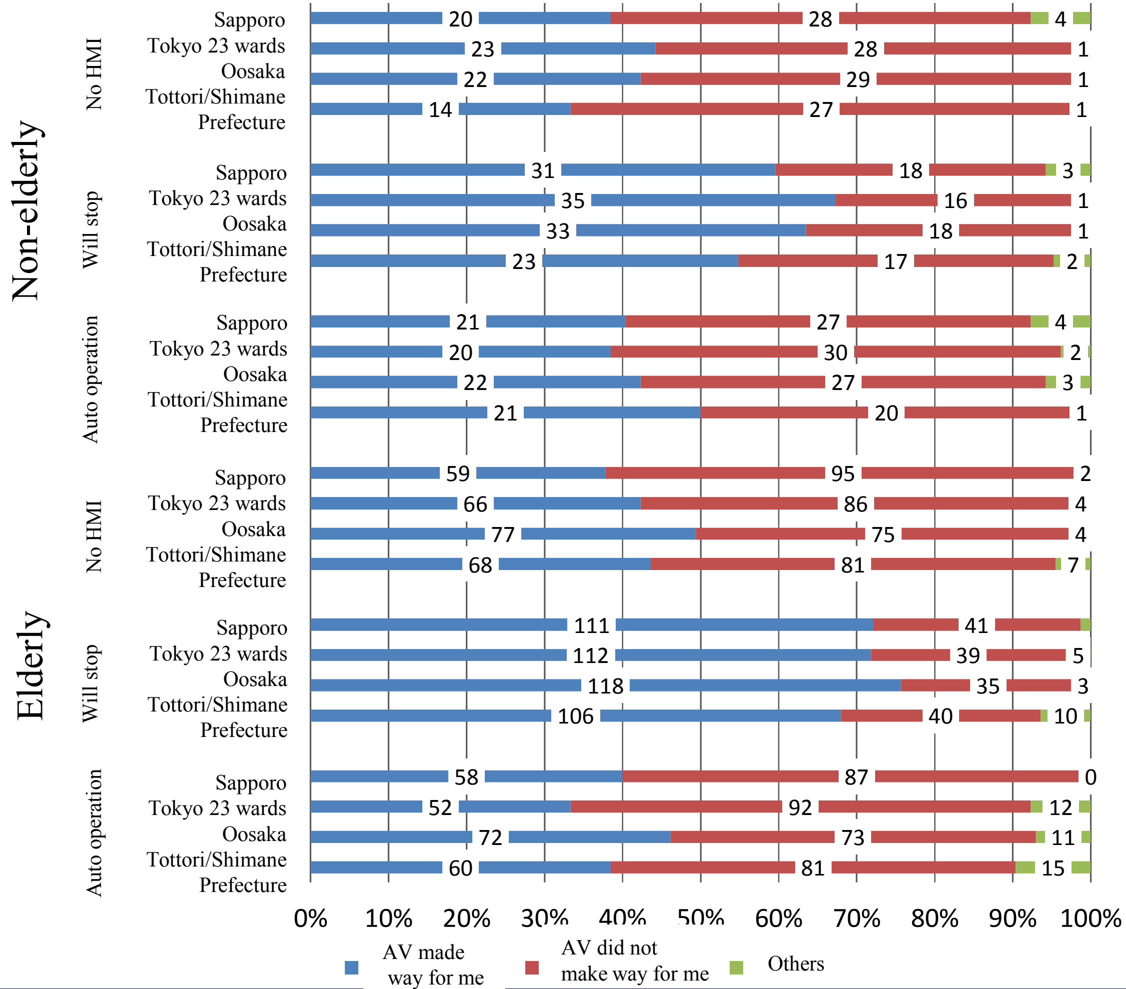
1. Compare to non-elderly driver, elderly driver tend to think LED flashlight as "Progress" and not to think as "give the way".
2. Depends on the region, elderly driver's thinking of "Progress" and "Stop" are different.

Result (Survey of communication between AV and driver using external HMI)

■ External HMI (Stop chart, vehicle behavior)'s interpretation in each region

Sapporo, Tokyo 23 wards, Osaka (156 non-elderly and 52 elderly in each region)
Tottori / Shimane prefectures (156 non-elderly and 42 elderly)

Traffic facilitation



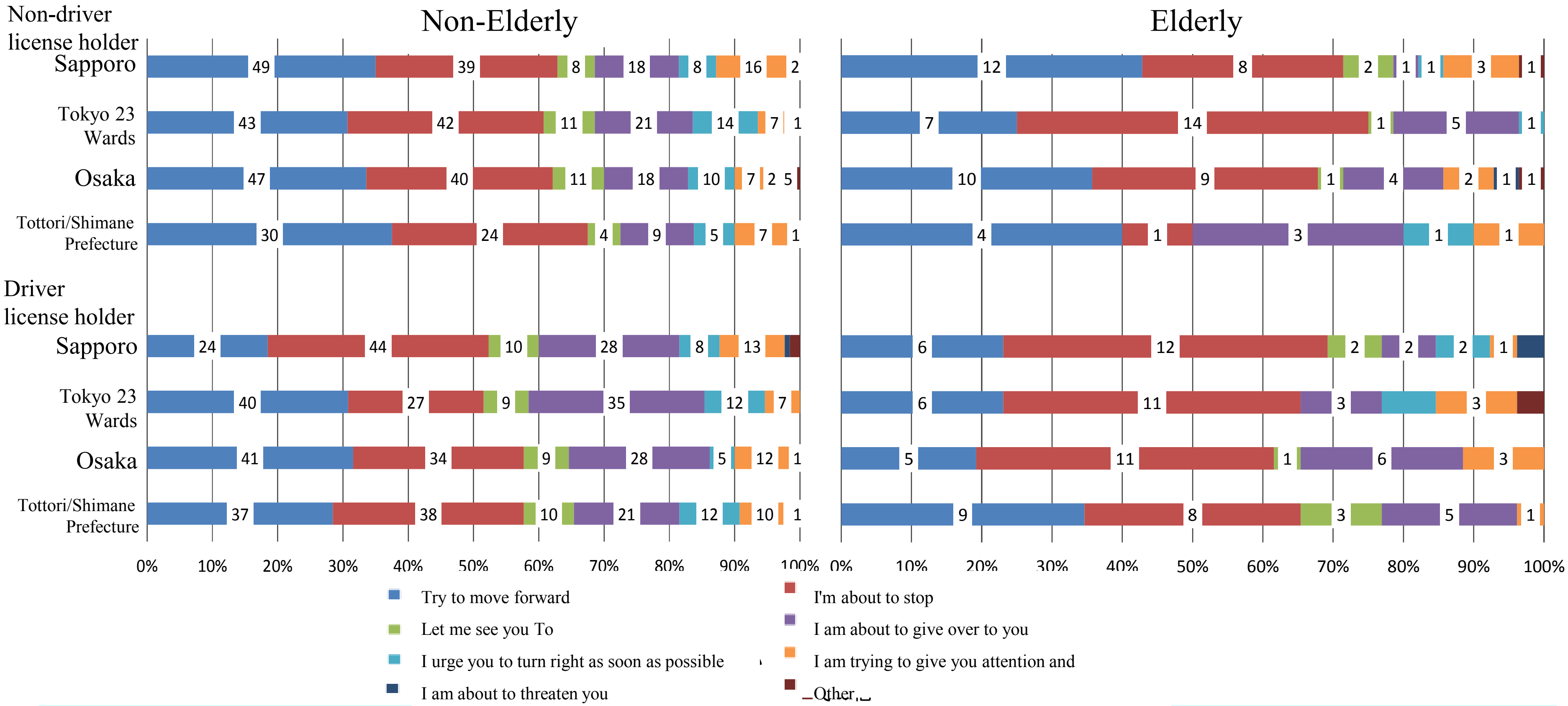
1. By transmitting the intention of "stop" with an external HMI, it is possible for both elderly drivers and non-elderly drivers to recognize the intention of "concession", and there are few differences depending on the region.
2. Even if the state of "Auto operation" is conveyed by the external HMI, there is a possibility that the driver can not recognize the intention of "handover".
3. When communicating the state of "Auto operation" on the external HMI, the recognition rate of the intention of "handover" to non-elderly drivers is reduced depending on the area.

Result (Survey of communication between AV and pedestrian using external HMI)

■ The result of interpretation of LED flashlight's external HMI

Traffic facilitation

Sapporo, Tokyo23Wards, Osaka, Tottori/Shimane Prefectures (Non-Elderly: 266ppl, 263ppl, 266ppl, 207ppl, Elderly: 58ppl, 61ppl, 58ppl, 39ppl)



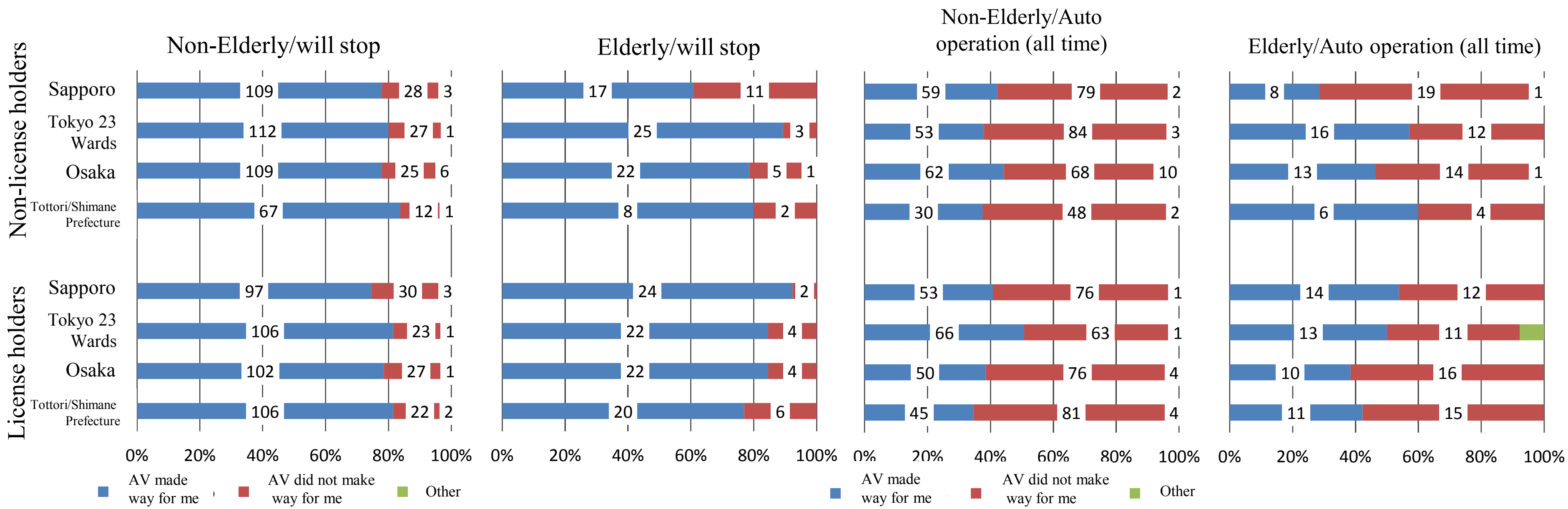
1. LED flashlight is interpreted as "Progression" and "will stop" at nearly the same rate for non-elderly people with no license, and there is little difference depending on the region. For license holders, interpretation of "will stop" may be somewhat strong depending on the region.
2. LED flashlight may be interpreted as "progression", "yield", "will stop" at different rates depending on the region for elderly people without license.

Result (Survey of communication between AV and pedestrian using external HMI)

■ Result of External HMI (Stop chart, vehicle behavior)'s interpretation in each region

Sapporo, Tokyo23Wards, Osaka, Tottori/Shimane Prefectures (Non-Elderly: 266ppl, 263ppl, 266ppl, 207ppl, Elderly: 58ppl, 61ppl, 58ppl, 39ppl)

Traffic facilitation



	Non-Elderly/will stop			Elderly/will stop			Non-Elderly/Auto operation (all time)			Elderly/Auto operation (all time)		
Non-license holders												
Sapporo	109	28	3	17	11		59	79	2	8	19	1
Tokyo 23 Wards	112	27	1	25	3		53	84	3	16	12	
Osaka	109	25	6	22	5	1	62	68	10	13	14	1
Tottori/Shimane Prefecture	67	12	1	8	2		30	48	2	6	4	
License holders												
Sapporo	97	30	3	24	2		53	76	1	14	12	
Tokyo 23 Wards	106	23	1	22	4		66	63	1	13	11	
Osaka	102	27	1	22	4		50	76	4	10	16	
Tottori/Shimane Prefecture	106	22	2	20	6		45	81	4	11	15	

1. When communicating the intention of "will stop" with external HMI, there is a high possibility that people think they are made way by AV. (There were no difference by region and holding license or not)
2. About 60% of non-elderly people are not recognized as "concession" when communicating "Auto operation" with external HMI, there is almost no difference depending on the region. In the elderly, there is a possibility that the recognition rate of "yield" may decline due to differences by region and possession / non-possession of driver's license.

Extraction of the influence on surrounding by displaying automatic operation

Investigation of the influence on behavior etc. of other traffic participants on the campus road and the general road

■ Purpose

Observe communication between other traffic participant and experimental vehicles with external HMI expressing various contents on general roads and campus roads. Measure and evaluate the characteristics of behavior of traffic participants to experiment vehicle with external HMI and examine the evaluation index on effect and influence of communication.

■ Observation method

For general roads and campus roads, experimental vehicle by manual operation is prepared and communication scenes with other traffic participants are recorded. In the campus road, the intention and state of the experimental vehicle are indicated by the external HMI.

■ Test vehicle for observation

After you | Will Stop | Automatic Operating

For campus road observation

During observation experiment
Automated driving system

For general road observation

Result（Extraction of the influence on surrounding traffic participants by external HMI.）

■ Example of observation of communication on campus road.

Communication scenes with pedestrians on the campus road

Example of communication situations with the vehicle on the campus road (following car)

Observed communication

1. After the pedestrian visually confirms the external HMI for use (“will stop", “yield", etc.), the crossing starts by confirming the lateral direction.
2. After pedestrians visually confirm the external HMI ("stop", "yield", etc.), crossing starts by checking only the direction of the experimental vehicle. Dependence on safety confirmation?
3. After pedestrians visually recognized the external HMI ("stop", "transfer", etc.), they did not cross the road immediately, but while traveling in parallel, they confirmed the experimental vehicle many times and started crossing at the remote place.
4. While the external HMI (“Automatic Operating") is displayed, the experimental vehicle starts to decelerate, the following vehicle starts overtaking before stopping. Distrust of external HMI?

1. Intention transmission such as “yield” by external HMI may possibly simplify pedestrian confirmation behavior.
2. There is a possibility that the transmission by external HMI temporarily causes the pedestrian to suspiciously suspect the vehicle.
3. There is a possibility that candidates for evaluation index (safety, smooth) of communication with pedestrian, such as lateral confirmation of the pedestrian before crossing, confirmation time, timing of crossing start (relationship with vehicle behavior).

Result（Extraction of knowledge of the influence on surrounding by displaying auto operation.）

■ Examples of observation of communication on general road

Example of pedestrians' communication
in a no signalized crosswalk

Observation example of communication with
vehicles when parking vehicles are avoided

Observed communication

1. After viewing the deceleration behavior of the experimental vehicle at the side of the pedestrian crossing, pedestrians check the left-right direction and start crossing (viewing the posting of the external HMI after visiting)
2. As the pedestrian approaches the pedestrian crossing while walking, while walking visually recognizes only the stop of the experimental vehicle and starts crossing (without noticing the posting of the external HMI)
3. While the opponent vehicle is stopped waiting for the parked vehicle, the experiment vehicle starts to decelerate and before the stop, the other vehicle starts off immediately after turning on the blinker.

1. There is a possibility that the candidates for evaluation index (safety, smooth) with the presence or absence of conflicts with other traffic participants, etc. depends on confirmation on left and right pedestrians before crossing, confirmation tie, timing of crossing start (relationship with vehicle behavior).
2. The timing of the turn signal turning on of the opponent vehicle, the start timing, the presence or absence of a conflict with other traffic participants, etc. after the vehicle behavior (or after the display of the outwardly directed HMI) are candidates for the evaluation index (safe, smooth) for communication with the driver There is a possibility.

Summary of interim report of Task C in FY2017

- Recognized “yield” mainly from the deceleration behavior of the automated vehicles.
- By utilizing the external HMI when the deceleration behavior is not sufficiently conducted, it is possible to promptly and strongly recognize the “yield” intention from the automated vehicle, and it is effective also in judgement of action and conviction.
- The indication “Automatic Operating” at the external HMI deteriorates recognition of the intention of “yielding” from automated vehicle by other traffic participants.
- When transferring “yielding" with an external HMI, it may change pedestrian's confirmation behavior at the time of judgment of traversal, and there is a possibility of decreasing visual behavior to the surroundings.
- LED flashlight may cause other traffic participants to recognize it as existing lighting equipment and it may induce various interpretations.
- Transmission of “will stop" intention to pedestrians is less influenced by differences in the area and elderly / non-elderly, there is a possibility that it is easy to recognize the intention of “yielding".
- Transmission by external HMI may temporarily lead to pedestrian suspicion for vehicles.
- As indicators of communication evaluation, index candidates accompanying pedestrian confirmation behavior are extracted.

Recommendation for communication design between automated vehicle and other traffic participants.

- In order to allow the driver and pedestrians to recognize the intention to transfer from the automated vehicles, mainly utilize the deceleration behavior. In situations where the deceleration behavior cannot be sufficiently utilized, it is effective to make use of external HMI to make the driver or pedestrian recognize the intention to transfer from the automated vehicle at an early timing and convince the behavior decision.

- An external HMI that transmits a state in which a driver or a pedestrian cannot predict a vehicle behavior or an intention transmission (for example, “Automatic operating") hinders the driver and pedestrian from recognizing the intention of the automated vehicle.

- In order to utilize external HMI with flashing lights, standardization, education and learning for drivers and pedestrians are required.

- We propose and recommend evaluation indices such as safety of traffic participant, security of the target person, facilitation of traffic, etc., in order to evaluate communication between the automatic driving vehicle and the pedestrian. (Under review ISO / TC22 / SC39)

Task D：Proposal for guidelines and activities for ISO

Proposal for guidelines and activities for ISO: Achievements in FY2017

- “DTR21959 Road vehicles：Human Performance and State in the Context of Automated Driving: Part 1-Terms and Definitions”

  → Created in a process led by Japan and made the final standard

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

- Start preparing to create “DTR21959 Part 2: Experimental guidance 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)

"B-i large-scale FOT:" Purpose of Experiment

As a baseline for the public road test of R and D in task B-i (implemented from May 2018), we will acquire driver readiness constitution indices at LV 0 to 2 in various situations

Base line

Understand the variation of Readiness during manual operation

→ Readiness verifies whether it can detect variations during manual operation

■ Internal factors of the driver

- Driver attributes (including age differences)
- Driver's equipment operation
- Inattention and fatigue
- Operation duration

■ External factors such as road traffic environment

- Traffic environment change such as interrupt and congestion
- The complexity of the traffic environment

"Long-distance driving in the suburbs" vs "Driving in Urban Tokyo"

Experiment in R & D

Comparison of readiness of automatic operation vs. manual operation and the relationship between readiness and driving behavior (OEDR task, takeover action)

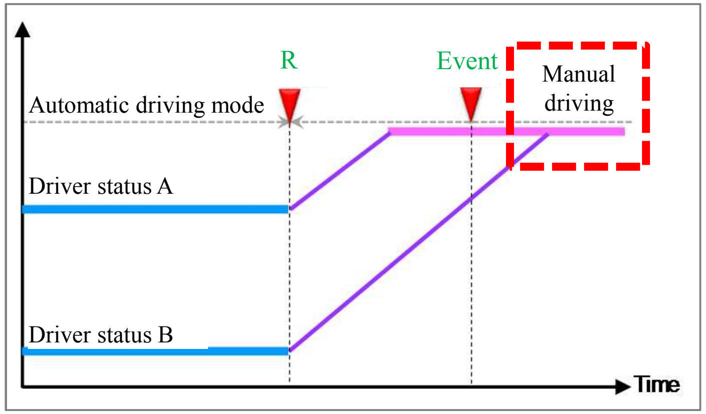


Figure: Conceptual diagram of Readiness

“B-i large-scale FOT:” Experiment conditions and measurement items

Experimental conditions

- Experimental vehicles: Commercial vehicles with LV 0 to 2
- Subject
  - General drivers or similar subjects
  - Age group: Three of 20-39 years old, Three of 40-59 years old, Three of over 60 years old
- Driving route and time
  - Road set by SIP

  Long-distance driving in the suburbs: 2-3 hours / Driving in Urban Tokyo: 0.5-1 hours

  * The order of driving routes is to take counterbalance

  * In consideration of experimental safety, planned setting of break time

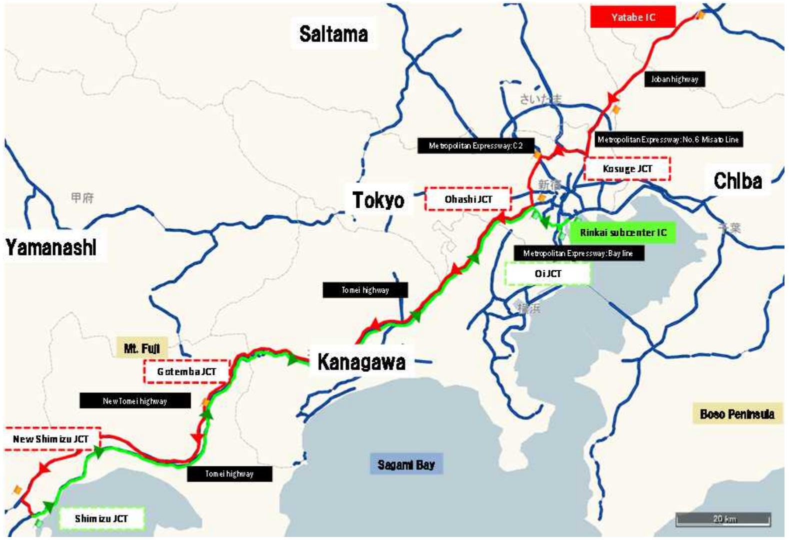


Figure: “ Long-distance driving in the suburbs” and “Driving in Urban Tokyo”

Measurement items

- Data on “Driver, Vehicle, Traffic Environment”
  - Vehicle data (CAN data)
  - GPS data
  - Video surroundings of vehicle
  - Driver's video
- Other measurement items
  - Subjective evaluation of driver status

    *The ride staff regularly ask questions to the driver
  - Observation record of the surrounding environment (weather, traffic congestion, interruption, confluent vehicles, lane change, and so on) by the ride staff and driver status (execution of secondary task, and so on)

"B-i large-scale FOT:" Implementation status

Participating companies	Total number of subjects	Experimental period	Total mileage
Company E	9	November 27, 2017 - December 8, 2017	About 2,241Km
Company C	20	December 4, 2017 - December 18, 2017	About 3,583Km
Company A	9	January 9, 2018 - January 26, 2018	About 2,225Km
Company B	9	January 25, 2018 - January 31, 2018	About 2,826Km
Company D	9	January 31, 2018 - February 22, 2018	About 2,066Km
Company E	5	March 13, 2018 - March 20, 2018	About 815Km

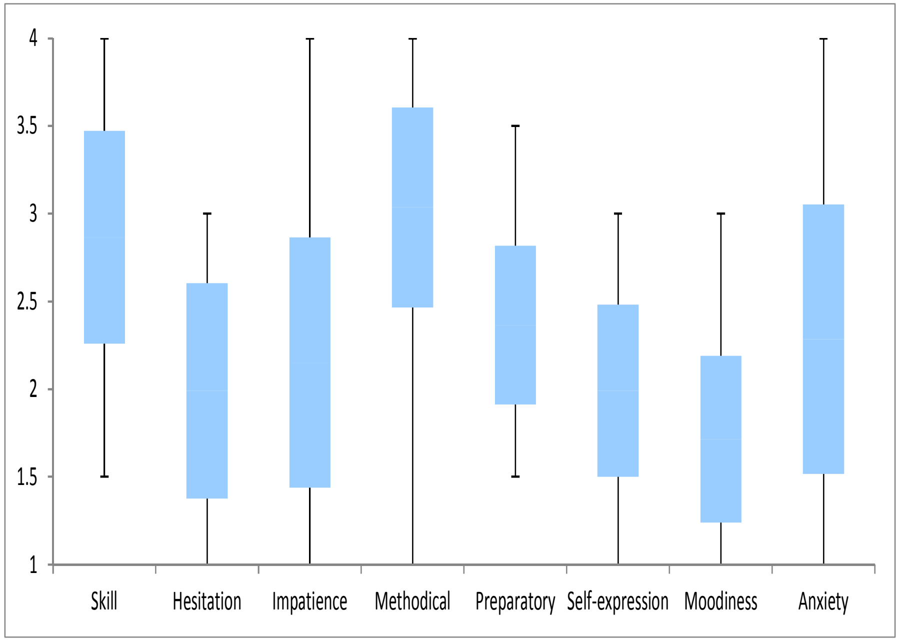
Driving route

Operating hours

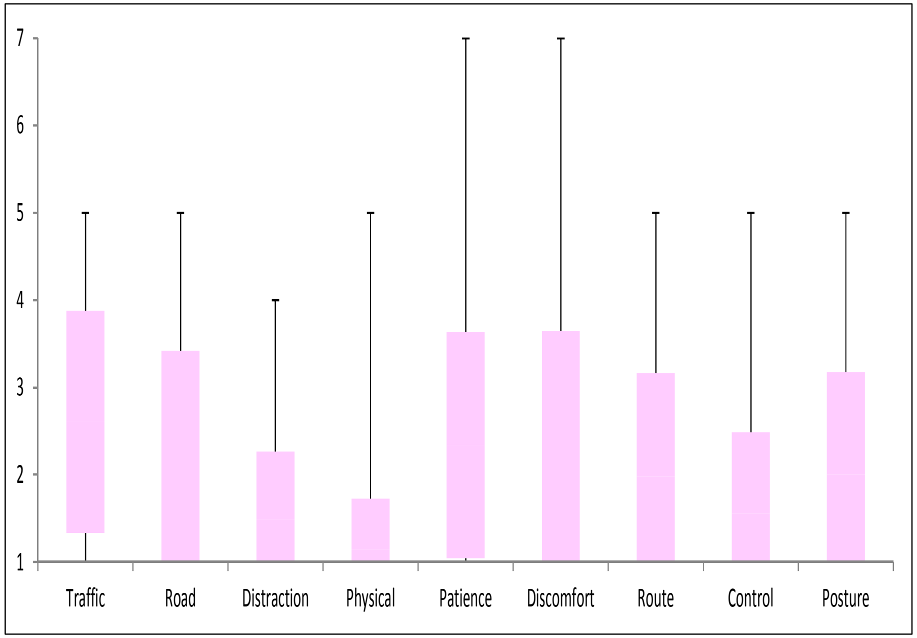
	Long-distance driving in the suburbs ⇒ Driving in Urban Tokyo	Driving in Urban Tokyo ⇒ Long-distance driving in the suburbs	Total
AM	15		15
AM/PM	7	9	16
PM	14	16	30
Total	36	25	61

"B-i large-scale FOT:" Subject attribute - Driving style and burden during driving

Subject's driving style (n=56)

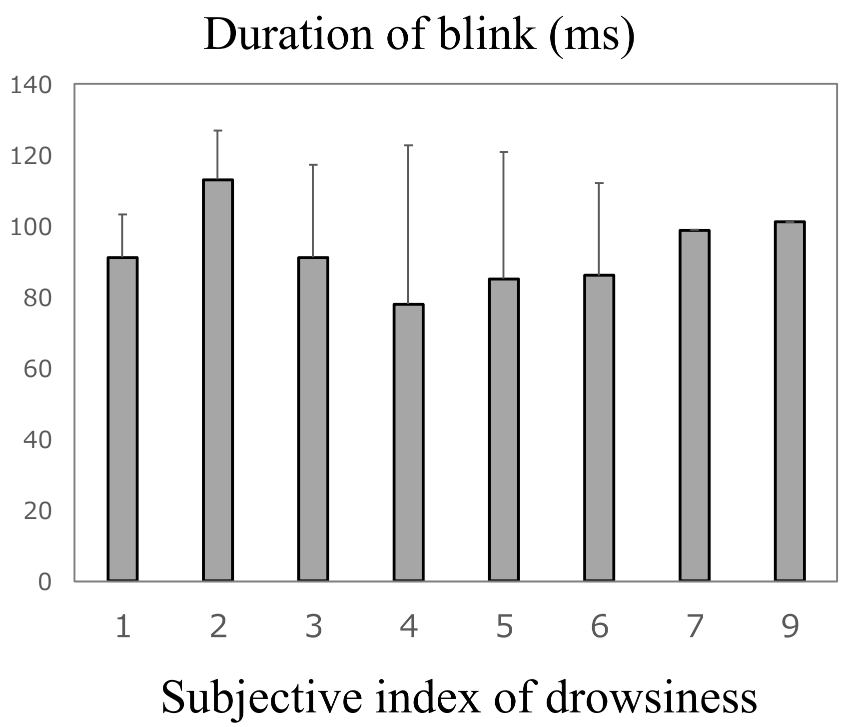


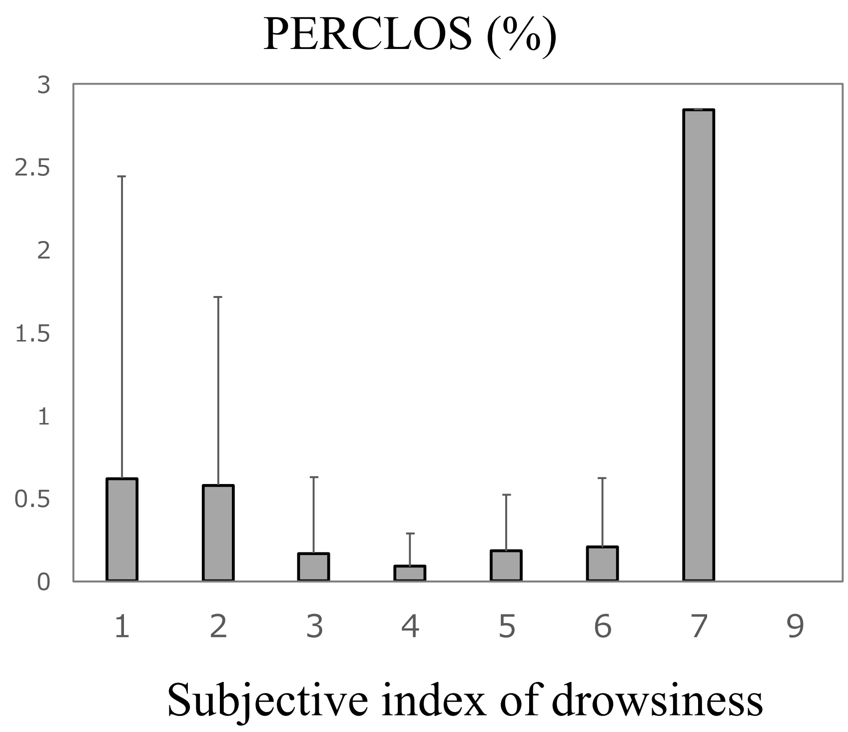
Subject's burden during driving (n=56)



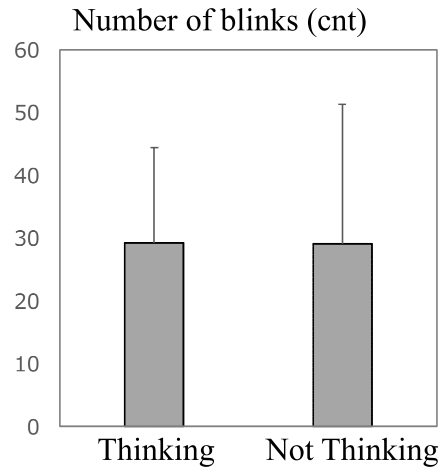
- The subjects' driving style tends to be high, "Skill" and "Methodical." In addition, because relatively high results are also seen for "Preparatory," there is a tendency to have more confidence in driving, and there is a tendency that there are many styles that are driven mainly by traffic flow
- Although the burden during the driving of the subject was the most burdensome to the "driving situation," it did not feel a burden on the whole

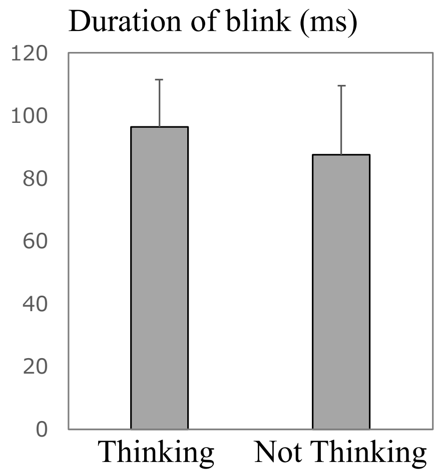
"B-i large-scale FOT:" Experimental Results: Drowsiness and DMS index

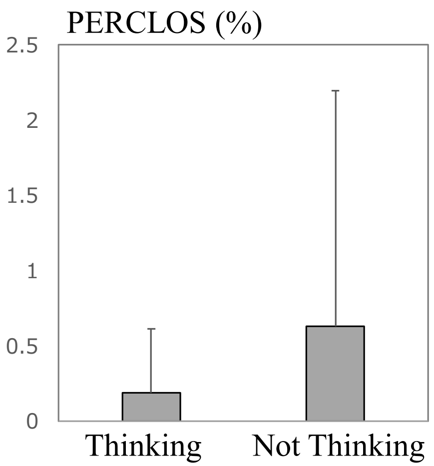


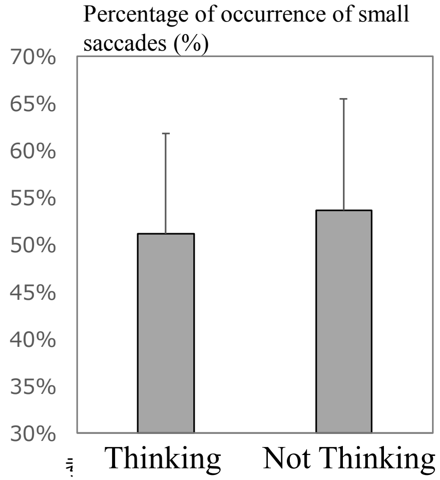


"B-i large-scale FOT:" Experimental Results: thinking and DMS index

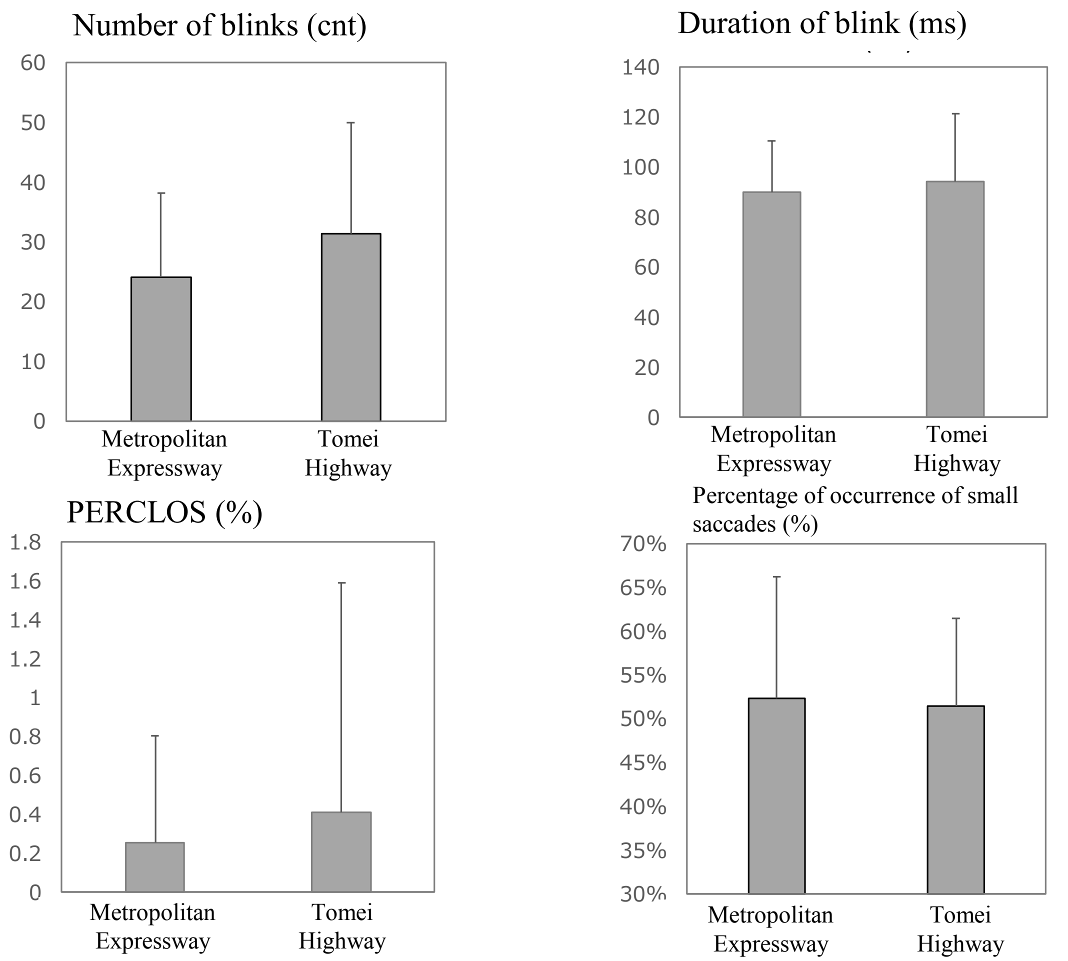






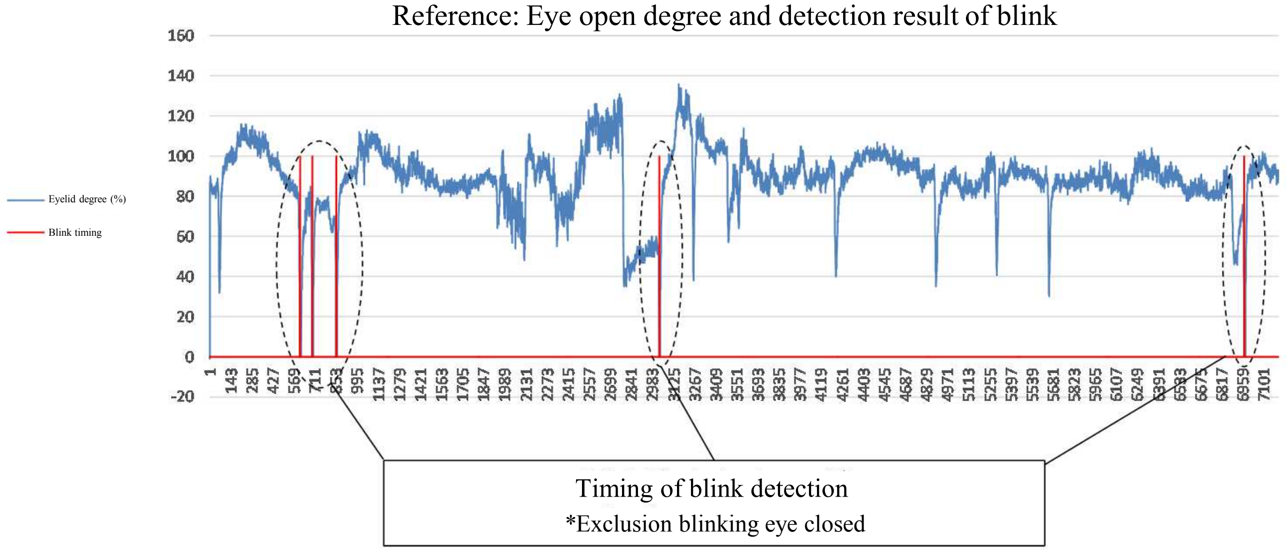


“B-i large-scale FOT:” Experimental Results: Driving route and DMS index



Confirmation status of the DMS index

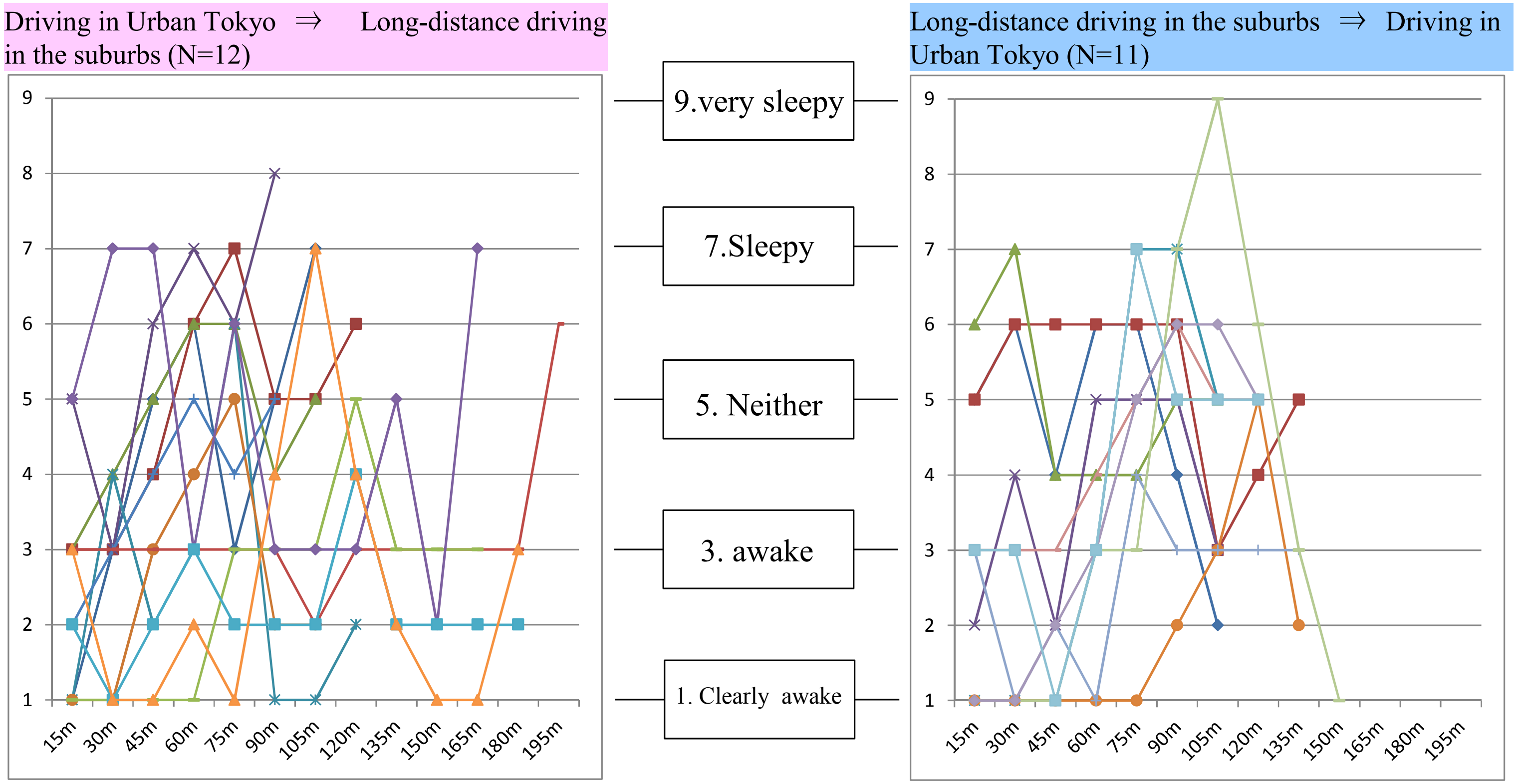
- Indicators that can be measured with the driver monitoring system derived in the FY 2016 experiment
  - The “width of instantaneous movement of eyes (saccades)” and the “frequency of occurrence (soccer)”
  - Frequency of blink (degree of open eyelids)
  - Percentage of time watching the screen inside the car (gaze)
  - Percentage of closing eyes (open eyelids)
- Measurement confirmation with image data in experiment
  - Based on the camera specifications (results of FY 2016), we imaged using a prototype DMS and we were able to confirm the items that became indicators
  - Utilize the definition of Readiness of Lv 0, Lv 1 after switching of driving by analyzing the correspondence between driving data and DMS data



Evaluation of subjectivity during experiment (drowsiness)

Changes in arousal level by driving route (n=23)

*Data excluding 1-2 changes in drowsiness

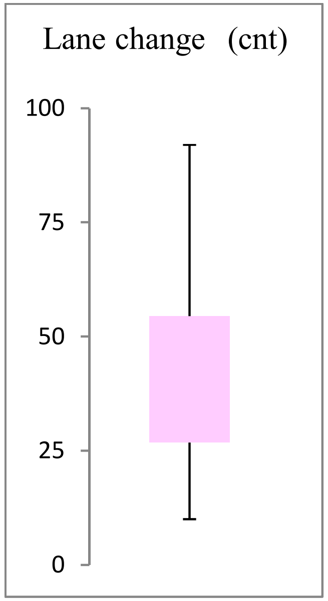


- Overall, the experimental results show how the degree of arousal has decreased with the lapse of time
- In the experiment, resting was allowed for 1.5 hours after driving, and the tendency for the degree of awakening to recover temporarily appears

Event record at the time of experiment

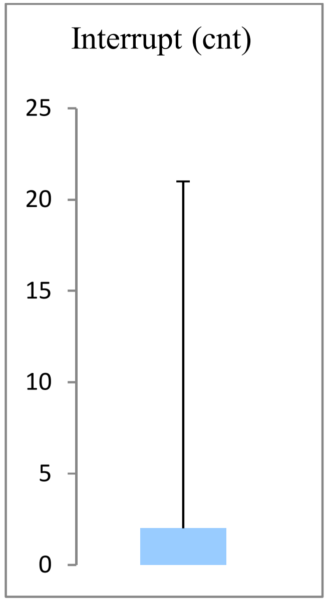
Amount of events at the time of experiment (n=47)

Driving behavior

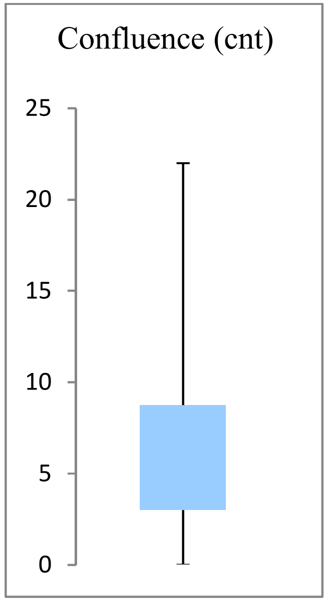


Average	43.522
Unbiased variance	498.477
Standard deviation	22.327
Minimum	10.000
The first quartile	26.750
Median	38.500
The third quartile	54.500
Maximum	92.000
Interquartile range	27.750

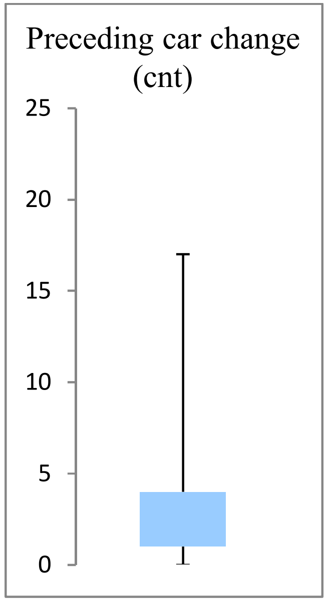
Environmental change



Average	2.935
Unbiased variance	25.751
Standard deviation	5.075
Minimum	0.000
The first quartile	0.000
Median	1.000
The third quartile	2.000
Maximum	21.000
Interquartile range	2.000



Average	6.891
Unbiased variance	30.055
Standard deviation	5.482
Minimum	0.000
The first quartile	3.000
Median	5.000
The third quartile	8.750
Maximum	22.000
Interquartile range	5.750



Average	3.268
Unbiased variance	17.101
Standard deviation	4.135
Minimum	0.000
The first quartile	1.000
Median	2.000
The third quartile	4.000
Maximum	17.000
Interquartile range	3.000

- Variable data could be acquired as a change in the surrounding environment during manual driving

"B-i large-scale FOT" Summary

- Although "B-i large-scale FOT" progressed as planned, the analysis of the comprehensive data will be in the next fiscal year

- For the DMS prototype, we confirmed the operation in the real environment
  *Continue examination of issues on facial image data

- From the data acquired so far, it seems that enough readiness fluctuation has been acquired as the baseline of the R & D experiment

- Continue to analyze readiness, build baseline data, and proceed with verification of the readiness constitution index within the baseline

- A public road experiment of R & D is scheduled from May 2018. By integrating with this result, we can verify the relationship between the readiness comparison of automatic operation vs. manual operation, and the relationship between readiness and driving behavior (OEDR task, takeover action)