Ministry of Land, Infrastructure and Transport

TS Korea Automobile Testing & Research Institute

Take-over time comparison by Demographics, Behavior, and Warning strength

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Korea Automobile Testing & Research Institute
Automated Driving Research Office

Introduction

- Objective

    - Take-over time comparison according to the demographics, driver's behavior, TOR warning strength

        - Demographics(Different participants)

        - Driver's Behavior(Different task)

        - Take-over warning(Different strength)

- Participants

    - Recruiting condition = Driving experience * Age * Gender

- Experiment Condition

    - Driver's Behavior (Oral/ Visual perception)

    - TOR Warning strength(Normal, Strong)

- Measurements

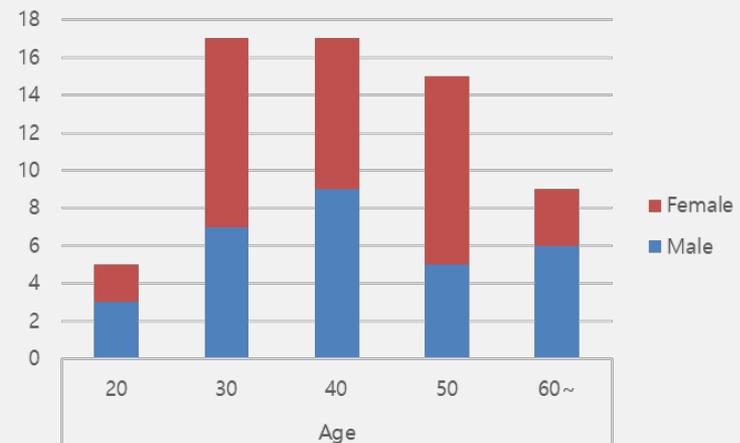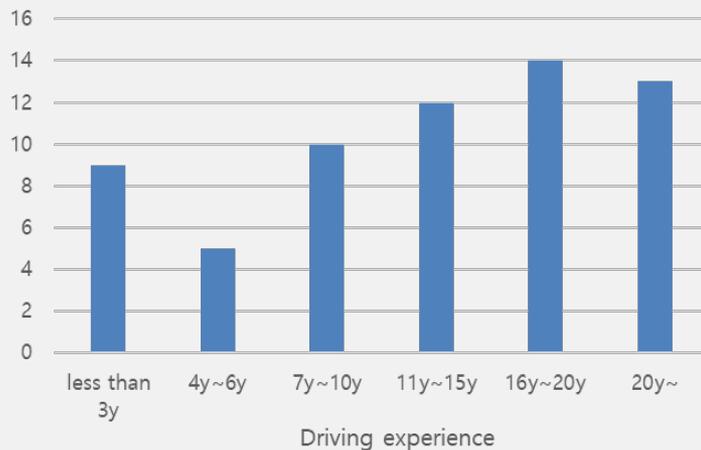   - Steering wheel torque & angle, braking pressure

Participants

- Well balanced 63 persons participated

  - Driving experience : 1y ~ 39y

  - Age : 20 ~ 79 years old

  - Male : Female = 30 : 33

- Screening Criteria:

  - Driving on average more than twice a week

  - Self-reported good health by participants

  - No seriously medical problem

Driver's Behavior(1)

- Driver's Behavior

    - In AD., the behavior of drivers is various and unpredictable.

    - The possible actions depending on technical level are also different.

    - The big difference of driver's behavior between level 2 and 3 AD vehicles is the obligation to keep eye front.

    - To propose reasonable TOR times, it's necessary to standardize driver 's behavior. So, Two types of NDRT were designed to make driver pay attention to another task.

        - The purpose of the NDRT is to force the driver to distract attention from driving task in AD

NDRT: Non-Driving Related Tasks(= Side task), A.D. : Automated Driving

Driver's Behavior(2)

- Oral Task(auditory 1-back task)

  - An auditory delayed digit recall task(e.g. the 1-back task requires the driver to memorize previous number and say out loudly the number when next number is spoken)

  - Interval : 2 sec.

  - The ration of correct answer : 97%

  - The n-back task is a continuous performance task that is commonly used as an assessment in cognitive neuroscience to measure a part of working memory

Time(s)	2		4		6		8	
Driver listening	4		2		3		4	
Correct Answer by driver	-	X		4		2		3

Jaeggi, S.M. et. Al., (2010). "The concurrent validity of the N-back task as a working memory measure". Memory. 18 (4): 394–412.

Driver's Behavior(3)

- Visual perceptional Task(Arrow Task modified "Eriksen Flanker Task")

  - In cognitive psychology, the Eriksen Flanker Task[1] is used to measure information processing and selective attention
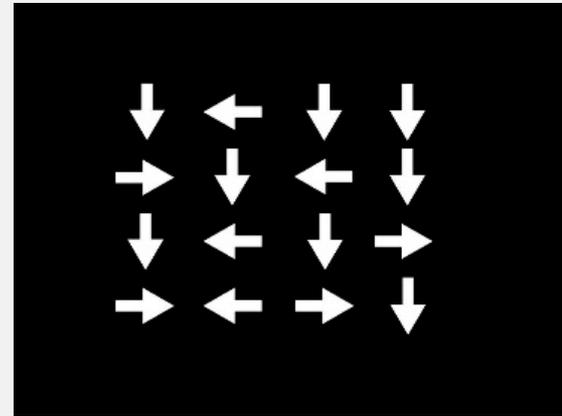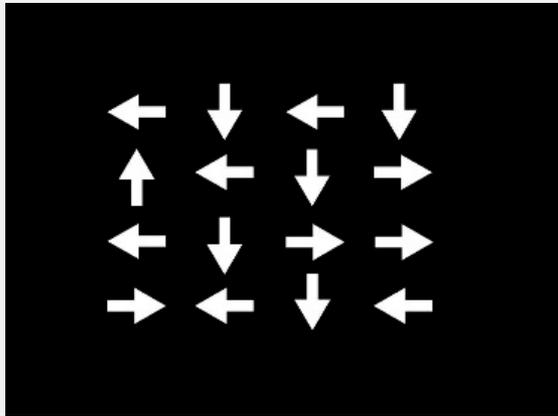
  - Visual perceptional task intend to make eye-off from the front.

  - Driver shell concentrated to percept an upward arrow in the monitor.

  - Interval : 8 sec.

  - The ration of correct answer : 93%

1. Eriksen, B. A.; Eriksen, C. W. (1974). "Effects of noise letters upon identification of a target letter in a non- search task". Perception and Psychophysics. 16: 143–149.
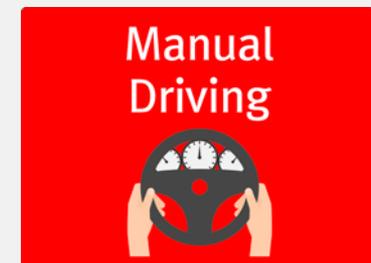
TOR Warning

● Optical warning

    ● symbol+ Text + Background color

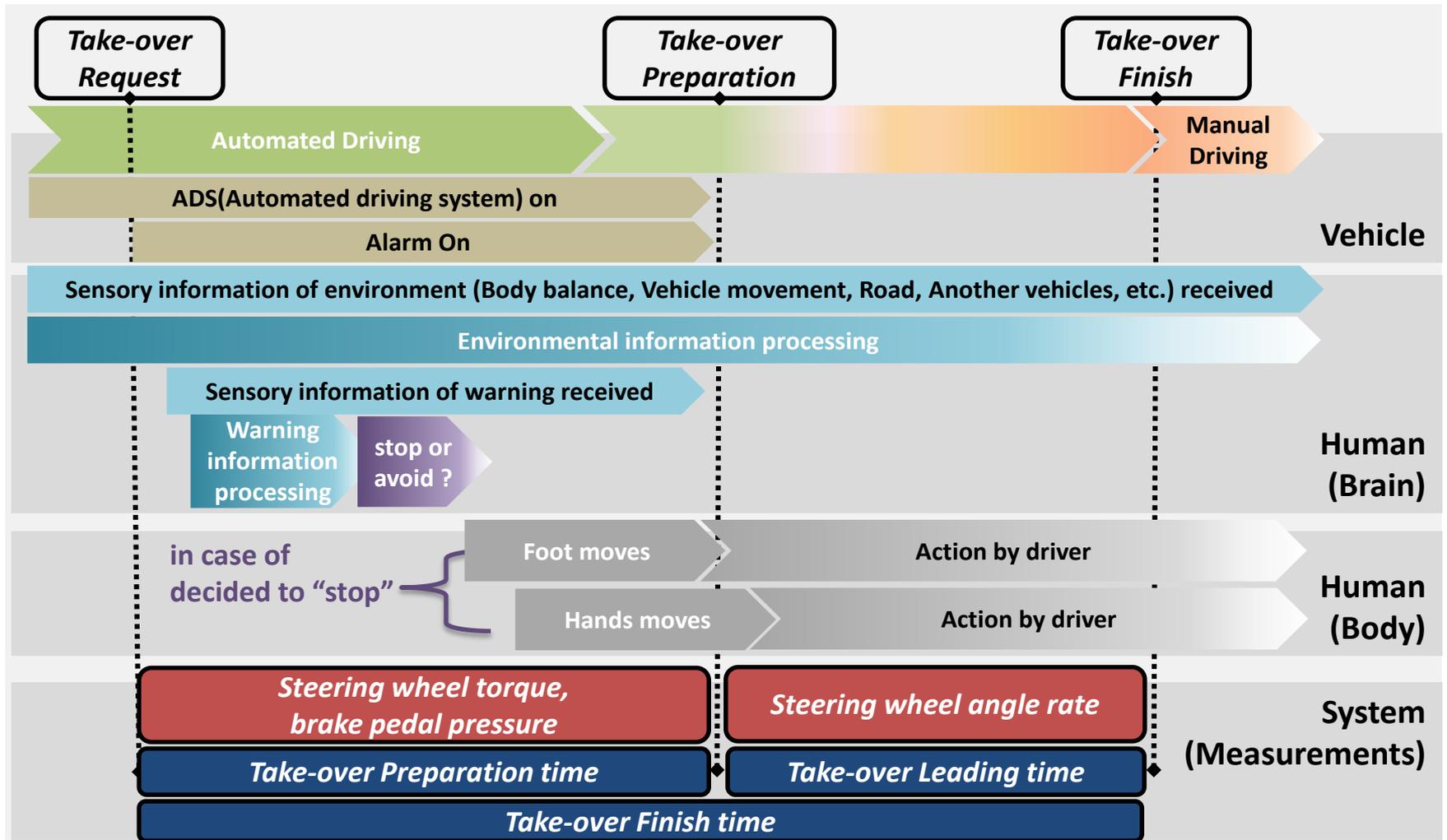Automated Driving Status symbol   Normal(Always on)   Strong(Blinking 5Hz)

● Oral warning strength

    ● Normal (70db)

    ● Strong (85db)

Take-over request process and Measurements

Take-over Request		Take-over Preparation		Take-over Finish	

Automated Driving → **Manual Driving**

ADS(Automated driving system) on

Alarm On

Vehicle

Sensory information of environment (Body balance, Vehicle movement, Road, Another vehicles, etc.) received

Environmental information processing

Sensory information of warning received

Warning information processing | **stop or avoid ?**

Human (Brain)

in case of decided to "stop"

Foot moves → **Action by driver**

Hands moves → **Action by driver**

Human (Body)

Steering wheel torque, brake pedal pressure

Steering wheel angle rate

System (Measurements)

Take-over Preparation time

Take-over Leading time

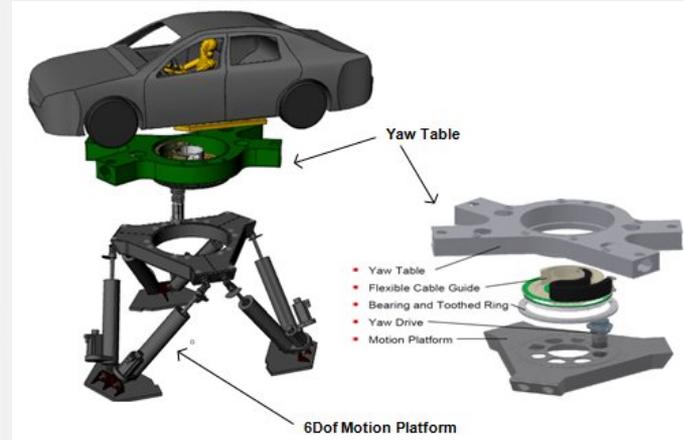**Take-over Finish time**

System Layout

Examples

- Visual perceptional and Oral task(video clip)

KATRI Driving Simulator

- 360° Dom screen, Medium size sedan, Motion platform

Test Case

Test [n]	Test [n]	Test [n]	Test [n]	Test [n]	Test [n]	Test [n]	Test [n]	Test [n]
SET A			SET B			SET C		

[n] : 1…9

Order	Test	NDRTs	TOR Warning
Shuffle *. To prevent guessing test case	1~3	Visual perceptional task	No take-over request *. To prevent guessing the TOR
		Oral task	
		No task	
	4~9	Visual perceptional task	Normal Warning
		Oral task	
		No task	
		Visual perceptional task	Strong Warning
		Oral task	
		No task	

Test set

- SET A,B(Training)

Training (MD)	Training (MD↔AD)	Training (MD)
3min	4min	3min

← 10min →

- SET C~E(Tests)

MD	Test	Test	Test	MD
1min	4min	4min	4min	1min

← 13min →

- Test

MD→AD | AD | AD→MD | MD

Alarm

10"

3min

NDRT(N/O/V)
Random start between
2m 10" ~ 2m 25"

1min

N : No NDRT, O : Oral, V : Visual perceptional, MD : Manual Driving

TOR scenario

Side wind to make gentle lane departure at TOR
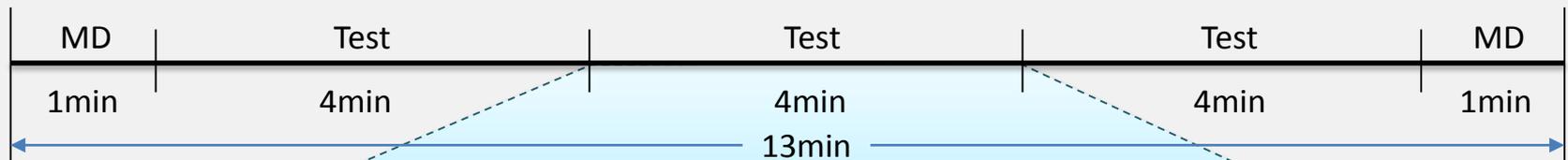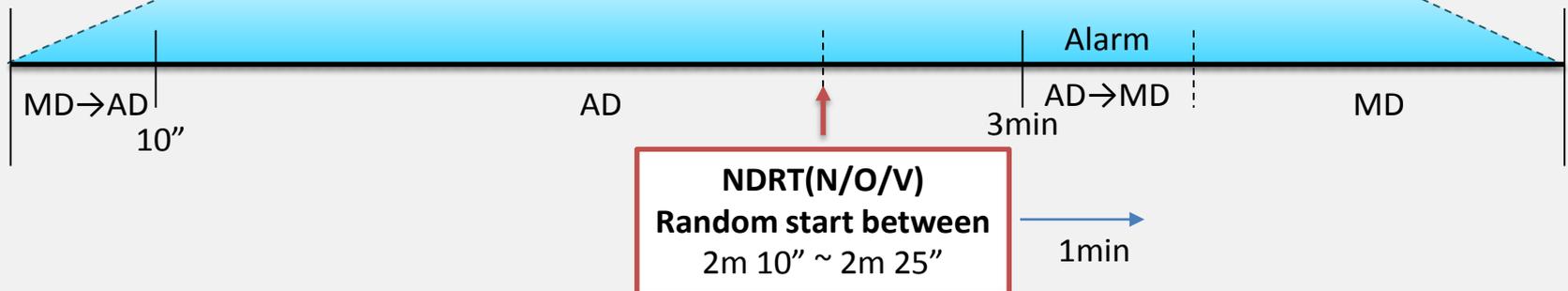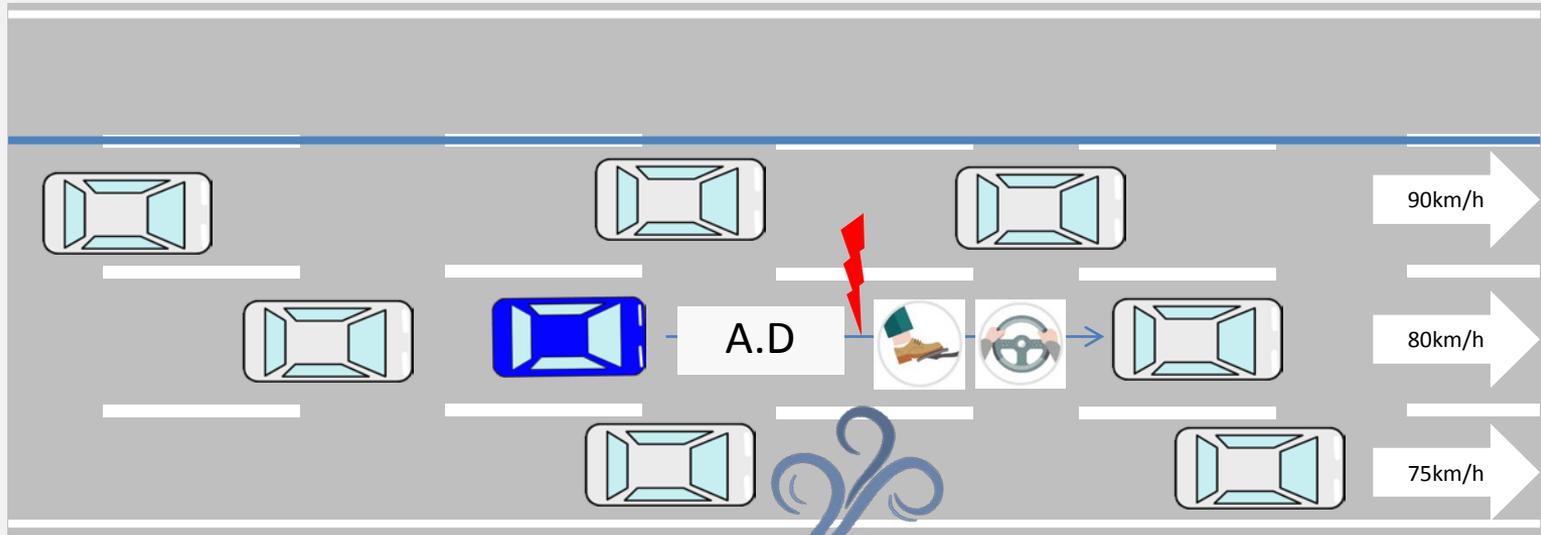
- Take-over request at automated driving

    - Traffic condition = LOS C(Avg. 80km/h, 12 vehicles(per 1 line, within 1km))

        - Set by actual traffic data of ROK' highway

    - Simulated partial section of the Gyeongbu highway (13km)

LOS C(Stable flow) : Ability to maneuver through lanes is noticeably restricted and lane changes require more driver awareness.
Minimum vehicle spacing is about 220 ft(67 m). **LOS A is free flow. LOS F is brakedown flow.**
- Highway Capacity Manual (HCM), The publication of the Transportation Research Board of the United States.

Results

● Take-over time distribution

	Take-over Preparation	Take-over Leading	Take-over Finish
Mean	1.762	0.263	2.024
SD	0.743	0.527	0.898
Median	1.606	0.100	1.808
Max	5.743	6.328	7.731
95%ile	3.111	1.061	3.763

*. Take-over finish is the summation value of each take-over case
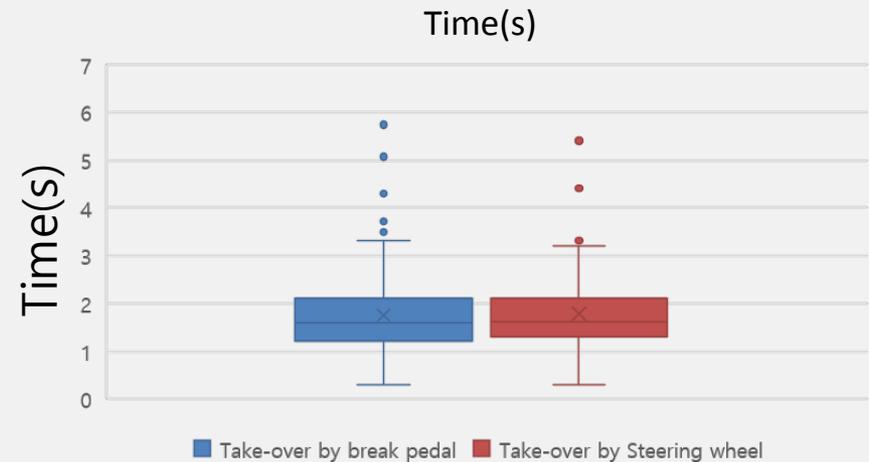*. Leading time is not always long in case of delayed preparation time
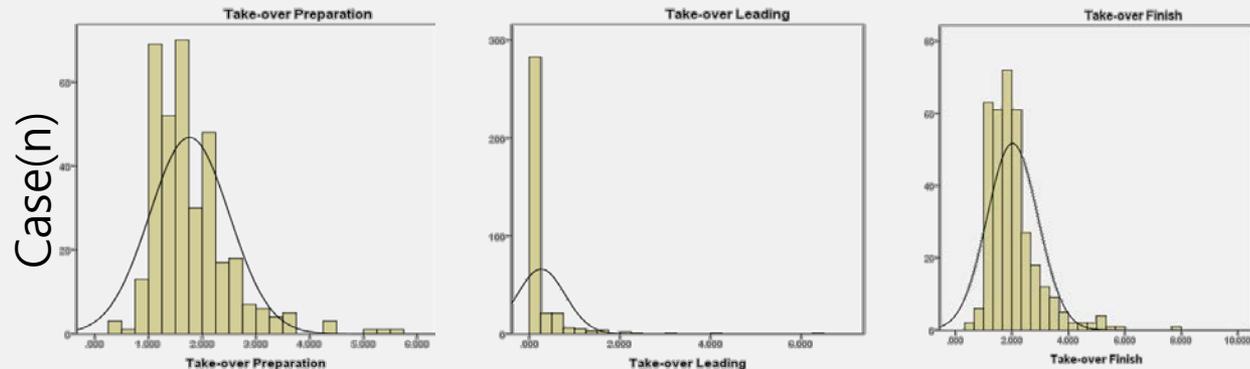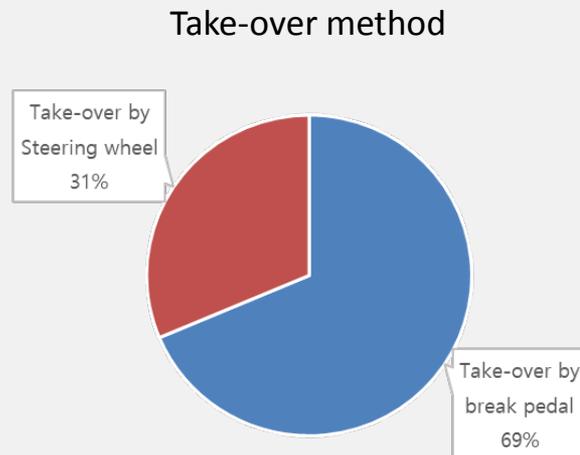

SD : Standard Deviation

Results

- Take-over method

  - Brake pedal was mostly used to take-over(69%).

  - Take-over methods didn't related with the take over time.

  - Drivers were hands on the steering wheel after brake.

Take-over method

Time(s)
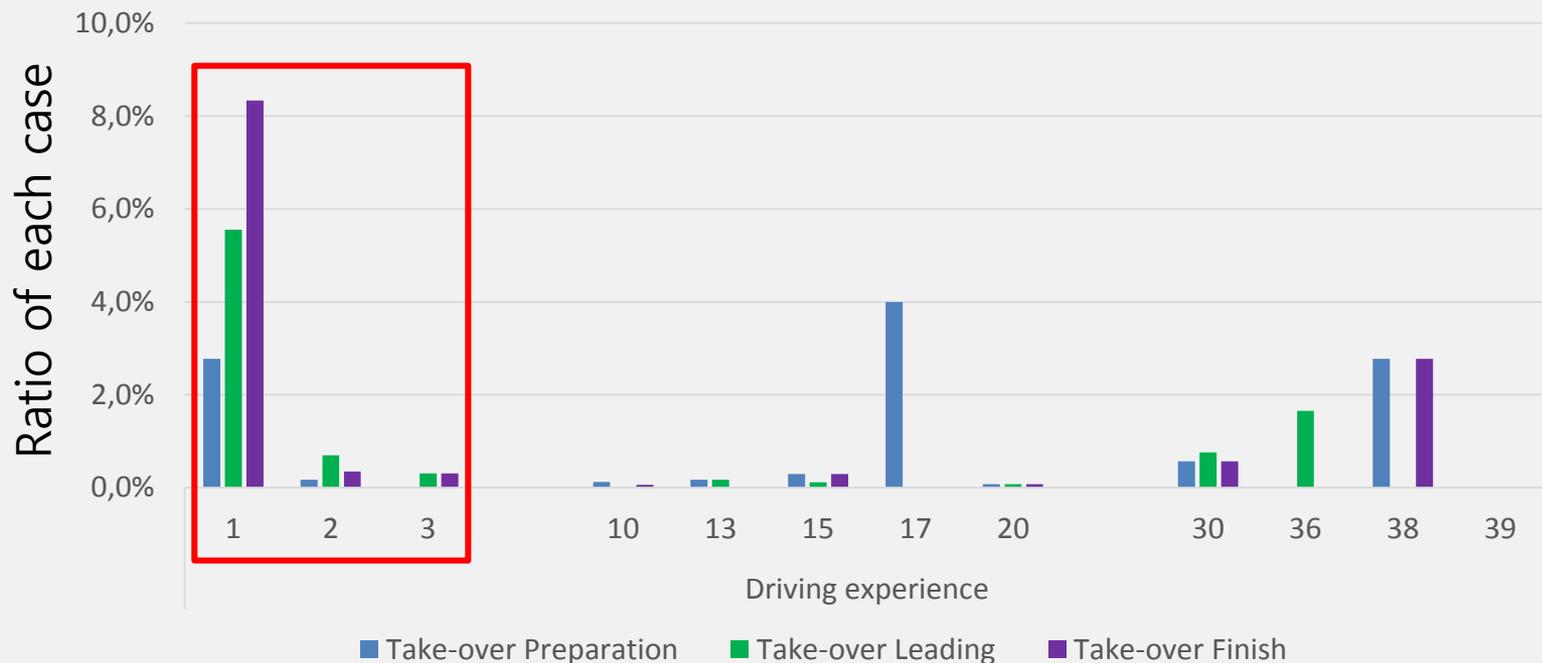
Results

- Worst case by the demographics
  - Resampling data over 95%ile(worst case) of each take-over Preparation, Leading, and Finish
  - In cases of gender and age
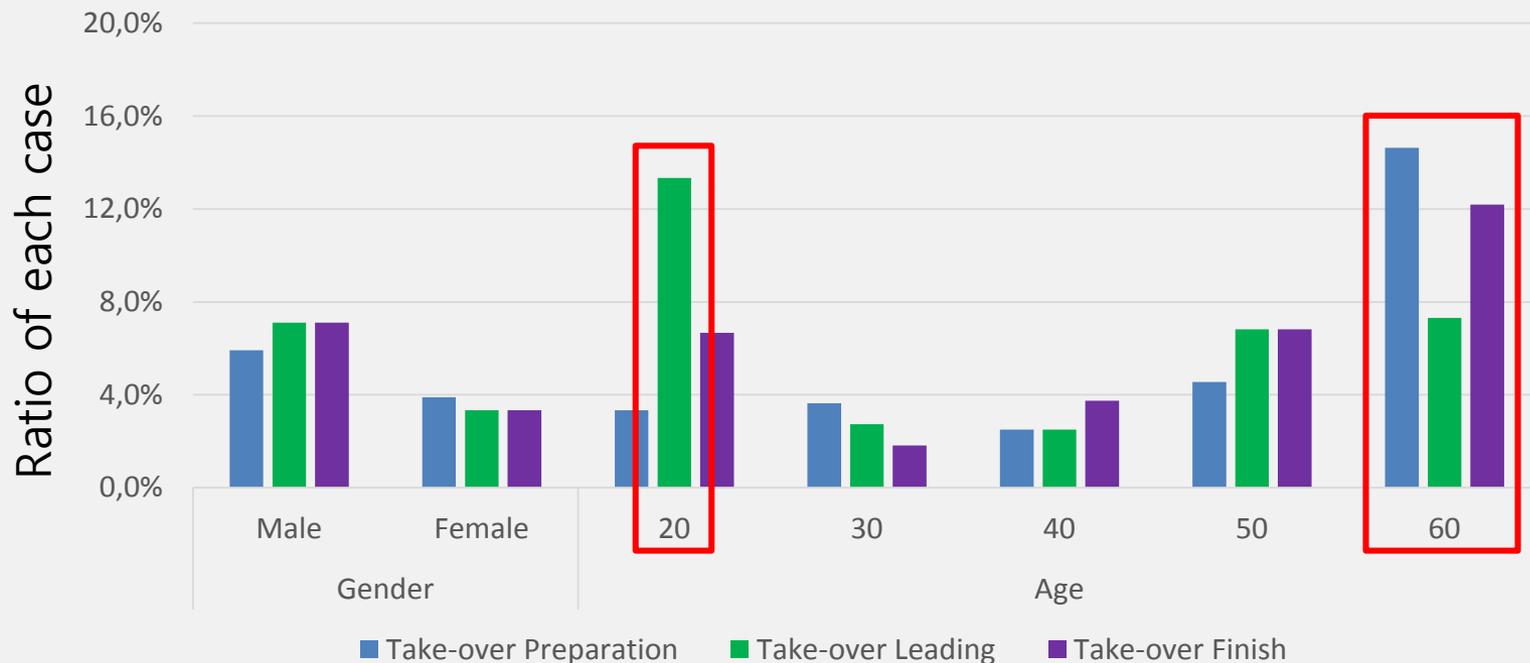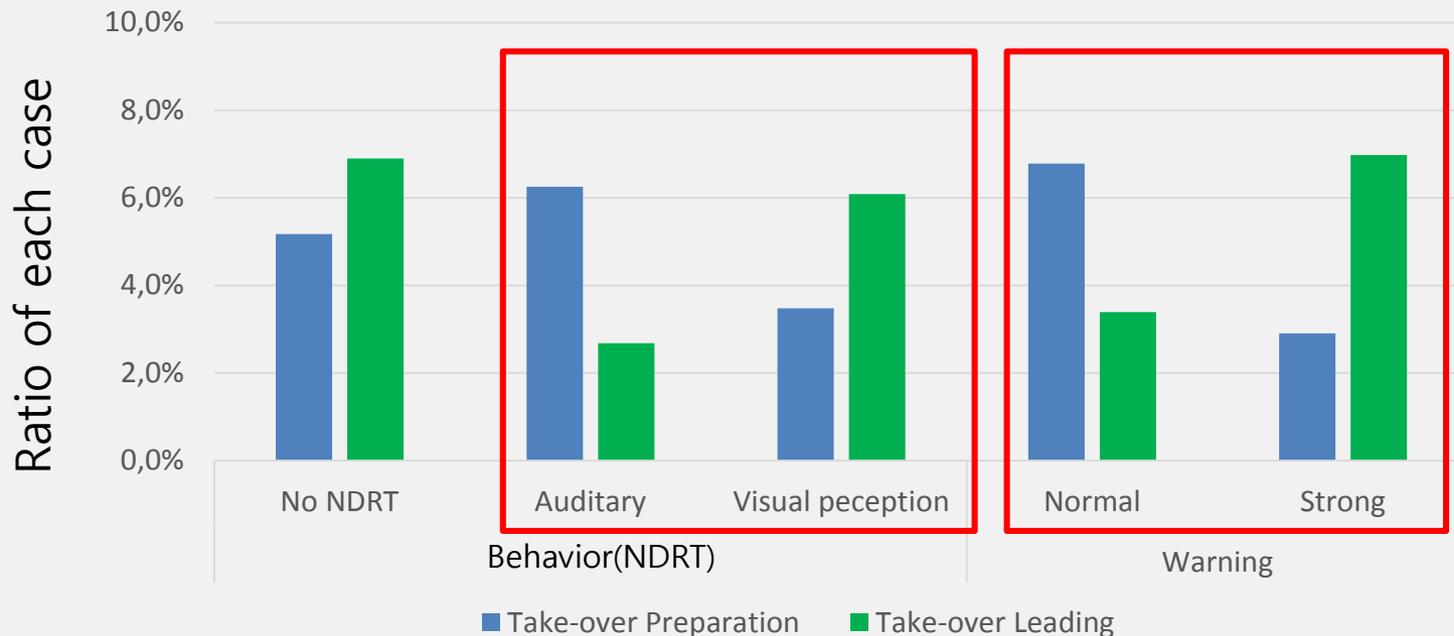
Results

- Worst case by the demographics

    - Resampling data over 95%ile(worst case) of each take-over Preparation, Leading, and Finish

    - In case of driving experience

Results

- Worst case by behavior and warning.

    - Resampling data over 95%ile(worst case) of each take-over Preparation and Leading

    - In cases of NDRT and warning

Conclusion

- In terms of demographics

    - Most participants were reacted(preparation) within 3.1s, and stable(leading) within 1s(95%tile).

    - The 20s and the 60s had slower response in worst case.

        - In 20s, leading time was slower than others, because of short driving experience(<3y)

        - In 60s, preparation time was slower than others, because of lower cognitive ability.

    - Participants less than 3 years, driving experience was take long time to react in worst case

- In terms of Driver's behavior

    - Visual perception task : Leading time increase, because of blocked environment information.

    - Auditory task : Memory processing disturb attention to transit to driving task(preparation time).

    - (Stop or avoid?) Most participants(69%) were react using the brake.

- In terms of Take-over warning(Request method)

    - Strong warning can help to decrease the preparation time, but increasing the leading time.

    - Normal warning make leading time shorter, but preparation time was increased.

Suggestion

- In terms of take-over warning(Request method)

    - In terms of intensity of acoustic warning, to start immediately with the highest intensity level are not recommended.

    - **Warning intensity suggest the escalation from normal intensity to strong intensity.**

- Take-over time

    - At least 6 seconds + α were required based on take-over preparation result.

    - **We suggest take-over time is not less than 8 seconds**

        - It's a max value of take-over finish time.

        - The leading time may depend on scenario's complexity and difficulty.