Human Factors Research on the Transition from Automated to Manual driving

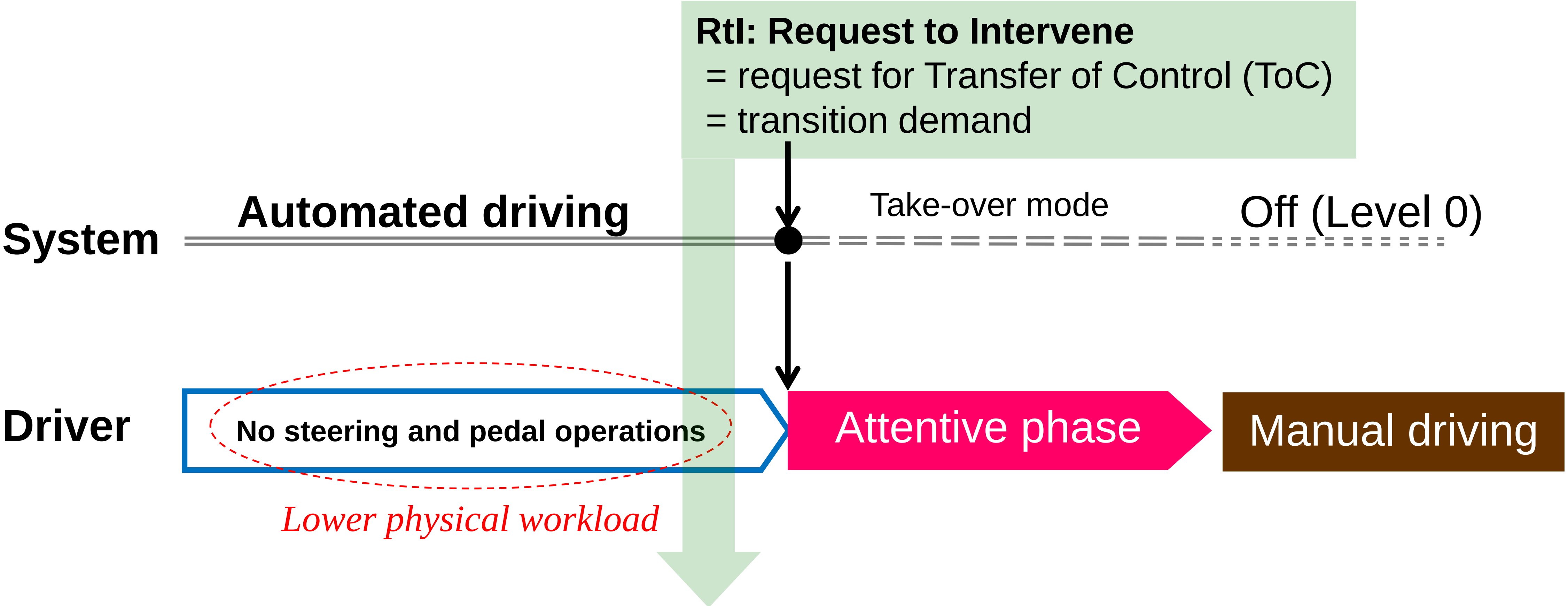
Toshihisa Sato

Human-Centered Mobility Research Center,
National Institute of Advanced Industrial Science and Technology (AIST)

Overview

- System-initiated transition from automated driving system to manual driving in Level 2 (L2) and Level 3 (L3) systems
- Human factor issues on driver’s availability when the RtI (Request to Intervene) is presented
- Research findings from “SIP-adus Human Factors Project Phase 1 and Phase 2”
- Future research perspectives to enhance driver’s acceptance of L2 and L3 automated driving systems

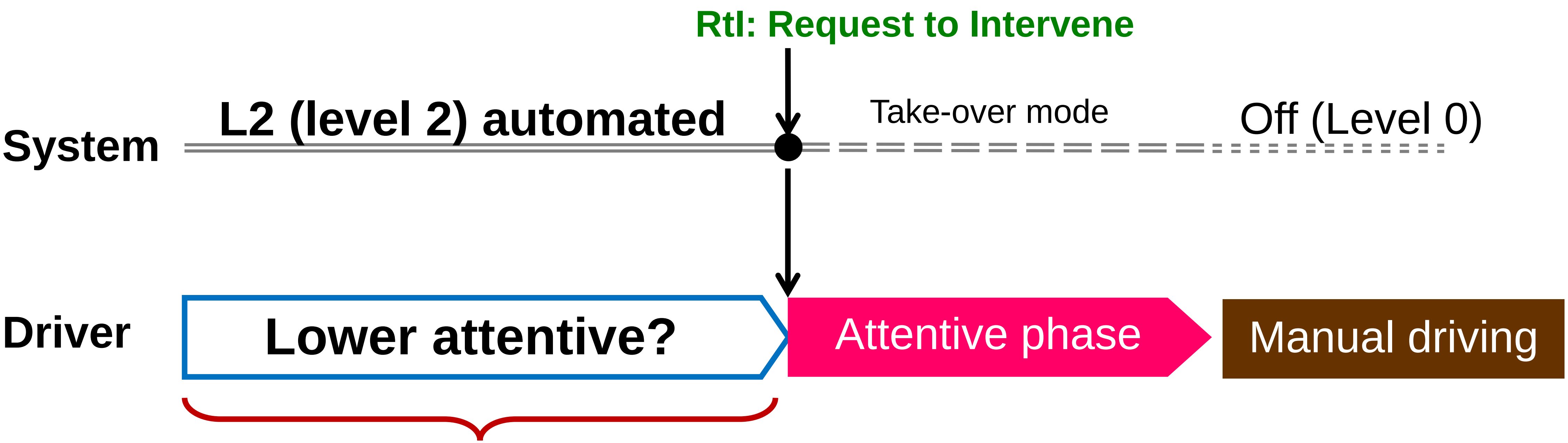
‘System-initiated transition’ from automated to manual driving



Ready to the transition (Available to take-over the driving task)

➔Human factor issues to manage the workload of the driver’s preparation for RtI

Transition from L2 automated to manual driving



How to measure the driver's states?

Readiness/availability is conceptually a dynamic state of the driver during automated driving that influences successful driver's take-over performance. The required level (criterion) of readiness/ availability can be experimentally determined as the level that leads to a successful take-over in terms of time and quality within the driver state transition phase post transition control phase (ISO/DTR 21959-1: 2018).

Concept of “Driver Monitoring System”

<SIP-adus HF Phase 1>

Measurement

Driver Readiness/ Availability

Using of Automated driving

Driver Monitoring System (DMS)

Measurement of the readiness/availability

Detection of the readiness lower than <u>criteria</u>

Negative effects on take-over performances

Main System

Selection and execution of the methods for negotiating the lower readiness

Countermeasures to improve the readiness

- Information provision
- Warnings

etc.

MRM (Minimum Risk Maneuver)

Estimation using "Driver Monitoring System"

<SIP-adus HF Phase 1>

Driver Monitoring System

Readiness	Evaluation metrics	Estimation of negative take-over performance	Criteria
Visually loaded condition	•Proportion of time glancing at front scene •Number of saccade	Abrupt operation (lower stability)	Threshold 1
Cognitively loaded condition	•Number of blinks •Number of saccade	Delay of operation (less margin to obstacles)	Threshold 2
Drowsy condition	•PERCLOS •Duration of blinking	Late response	Threshold 3

Estimation using regression formula

Main system

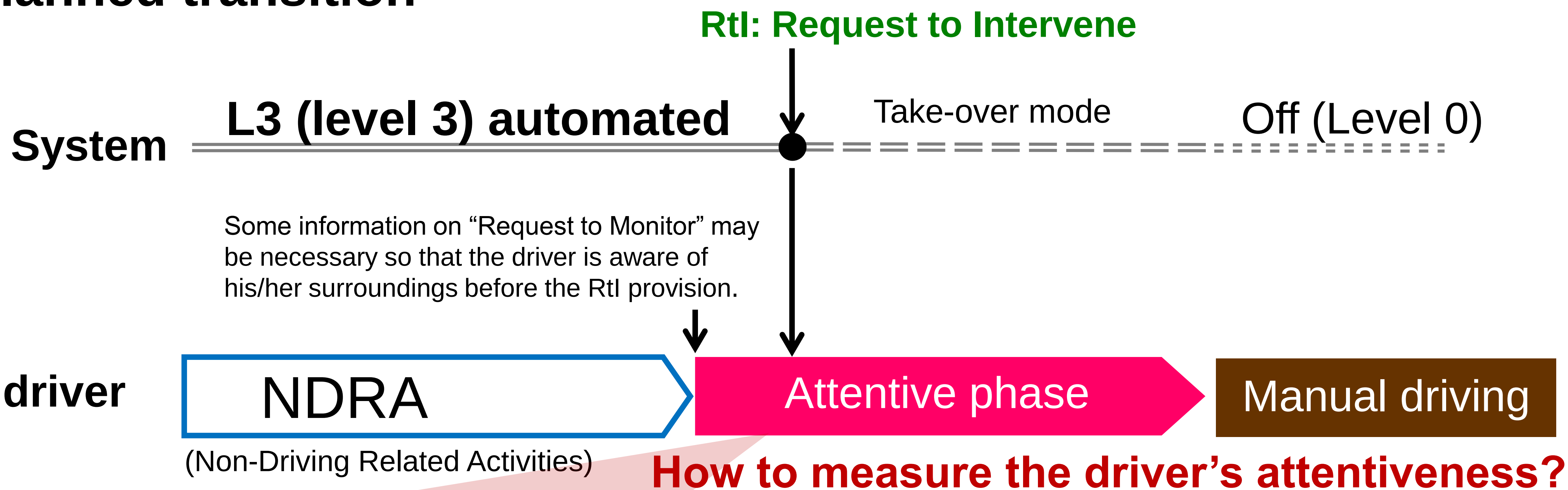
Judgment of intervention	Selection of intervention methods	Improve the readiness 【Warnings, etc.】
Judgment of intervention	Selection of intervention methods	Improve the readiness 【Stop of the system】
Judgment of intervention	Selection of intervention methods	MRM (Minimum Risk Maneuver)

System status, Road traffic environments

System intervention

Transition from L3 automated to manual driving

-Planned transition-



How to measure the driver’s attentiveness?

<SIP-adus HF Phase 2 findings>

- **Evaluation metrics of the attentiveness: driver’s gaze, head movements**
- **Time series changes indicating an appropriate attentiveness: stable for more than a few seconds**
- **Time duration for an appropriate attentiveness: the rate of gaze-on-front tends to increase for about 5-20 seconds after the monitoring request.**

Transition from L3 automated to manual driving

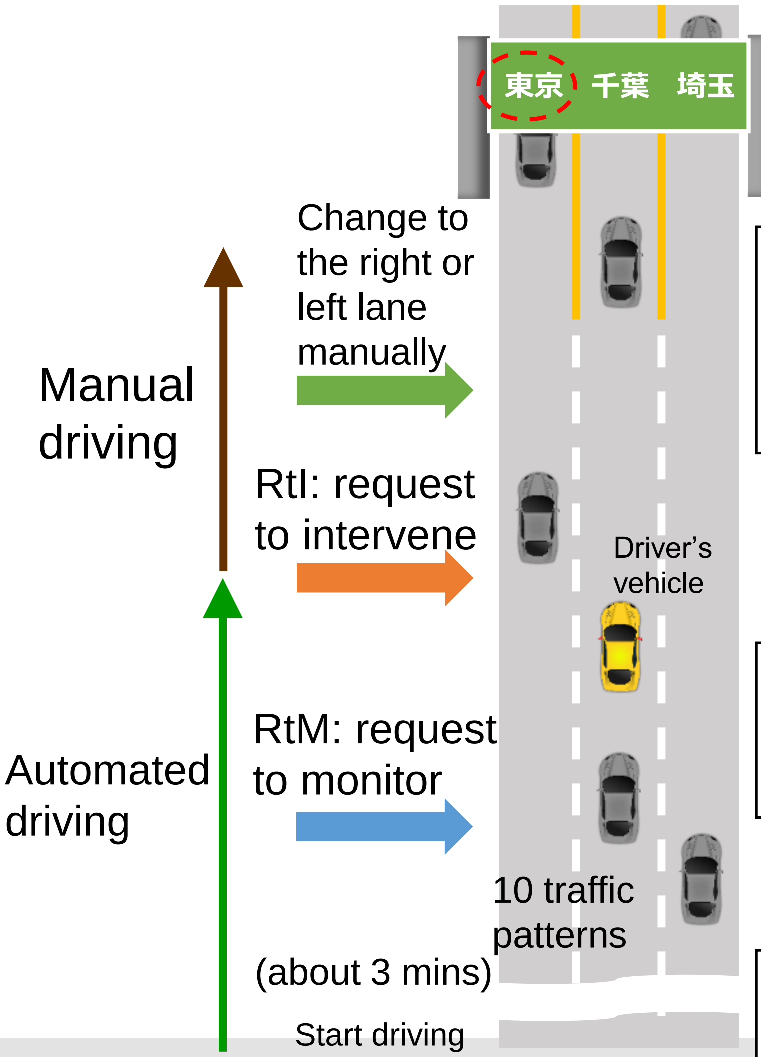
-Planned transition-

<SIP-adus HF Phase 2>

AIST Create the Future, Collaborate Together

Experiment methods

Typical driving scene in driving simulator experiments: lane change task after the transition in a straight road of highway



After the transition

Participant's task
「Please drive toward Tokyo (select the lane indicating Tokyo) manually」

Before the transition

Participant's task
「Please monitor the environment」

Participant's NDRA
「Please play Tetris」

<Measures>

Before the transition

- ✓Gaze
- ✓Head movements

After the transition

- ✓Reaction time of steering
- ✓Reaction time of blinkers
- ✓Crash rate
- ✓Rate of cutting the yellow line
- ✓etc.

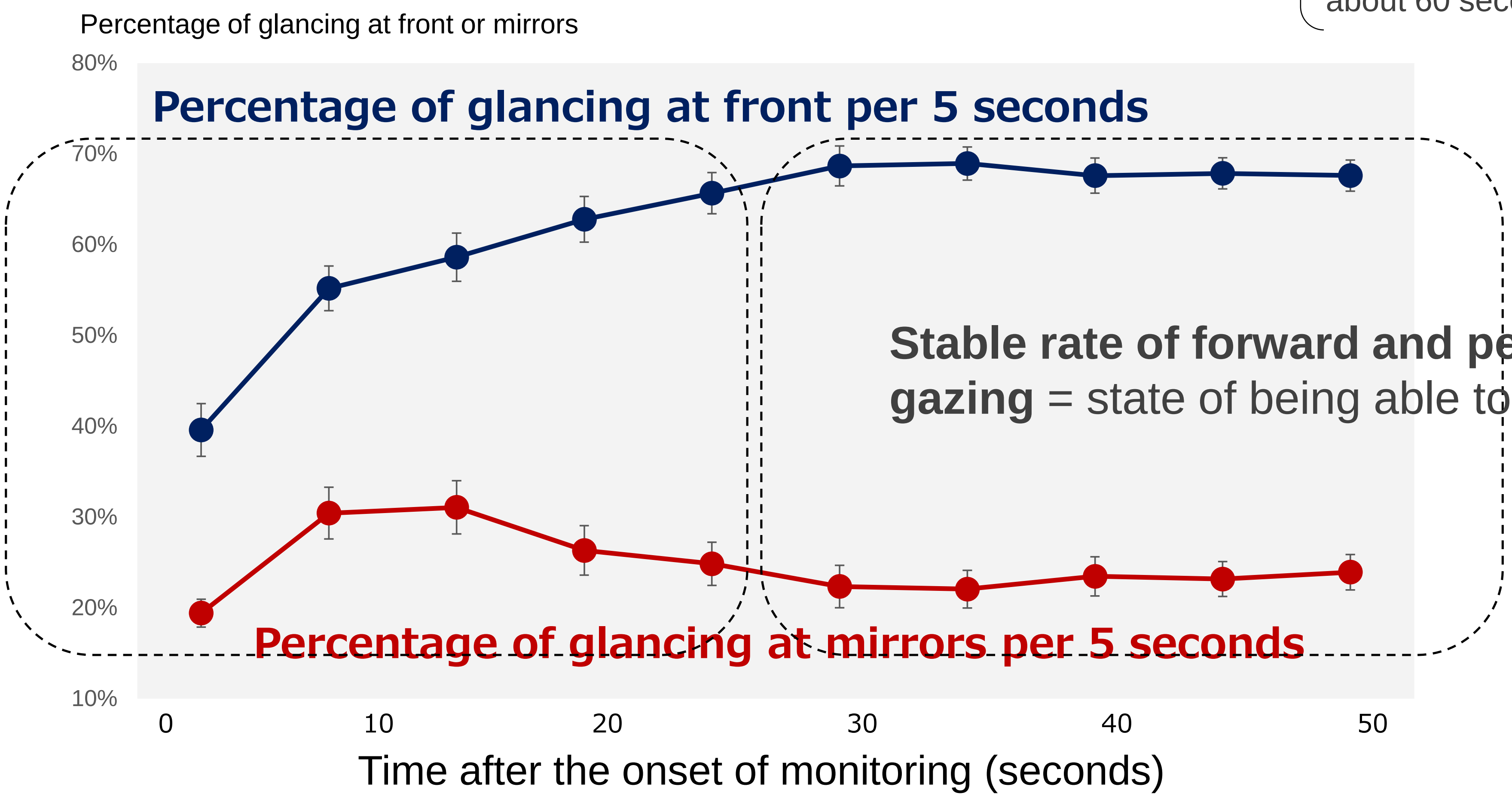
Transition from L3 automated to manual driving
-Planned transition-

<SIP-adus HF Phase 2>

Experiment results (1/2)

Time series analysis of driver's visual behavior after the driver begins to monitor the surrounding situations

In a situation where the time between the RtM and RtI was about 60 seconds



Process of increasing situational awareness by focusing attention on either the front or the mirror

Stable rate of forward and peripheral (mirror) gazing = state of being able to recognize both

Transition from L3 automated to manual driving

-Planned transition-

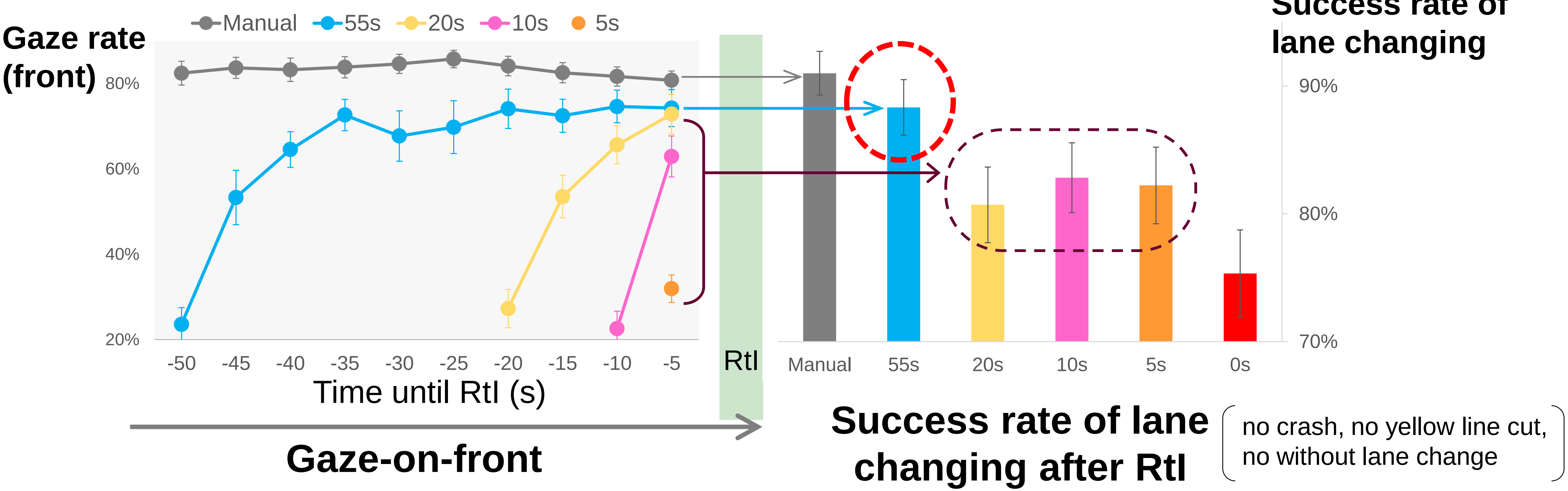
<SIP-adus HF Phase 2>

Experiment results (2/2)

Driver’s visual behavior before the transition and success rate of lane changing after the transition

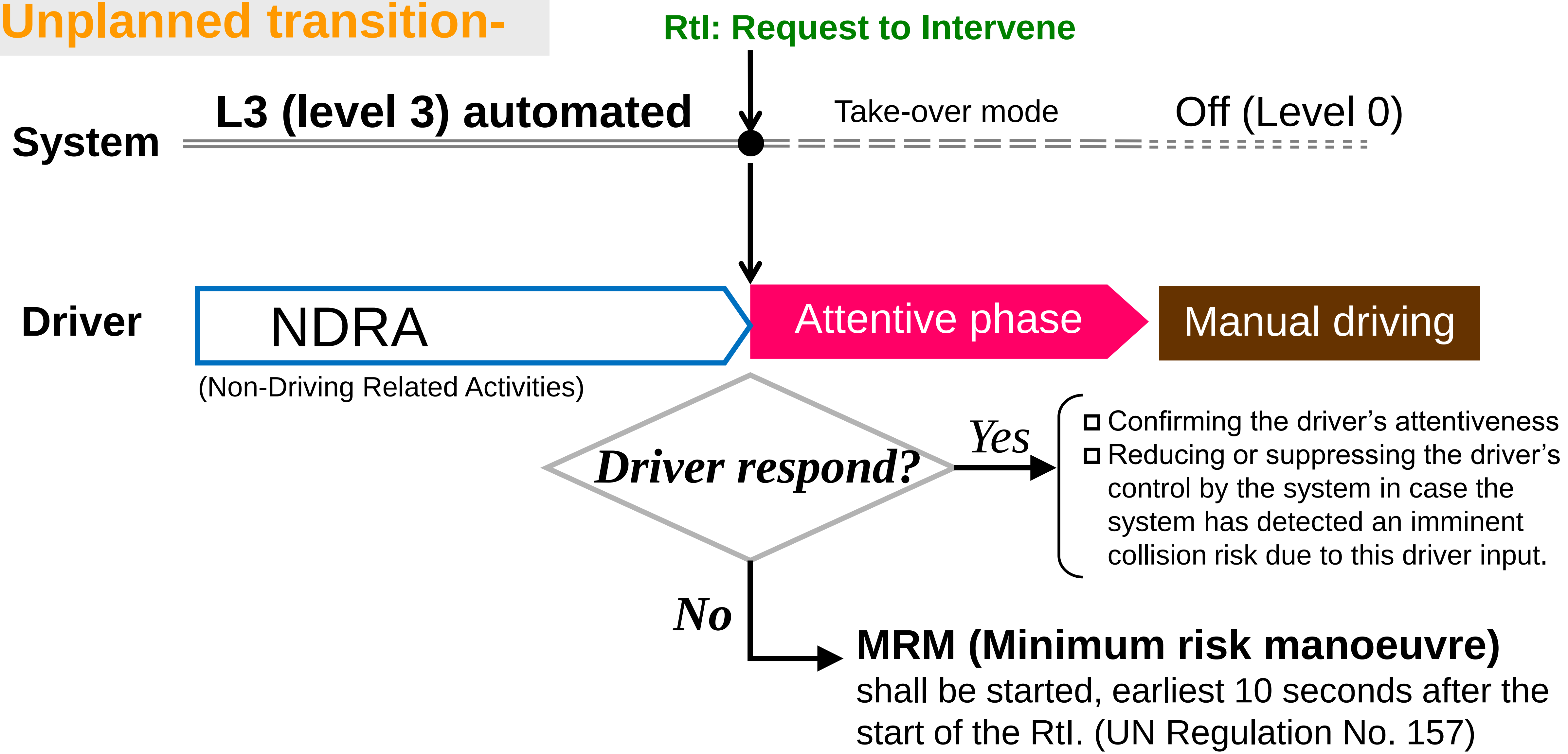
- The 55s condition elicited a stable gaze-on-front rate of about 70% before the RtI, and the success rate of lane changing was comparable to the manual driving condition (the highest success rate among all the automated conditions).

Mean and standard error of all 30 participants

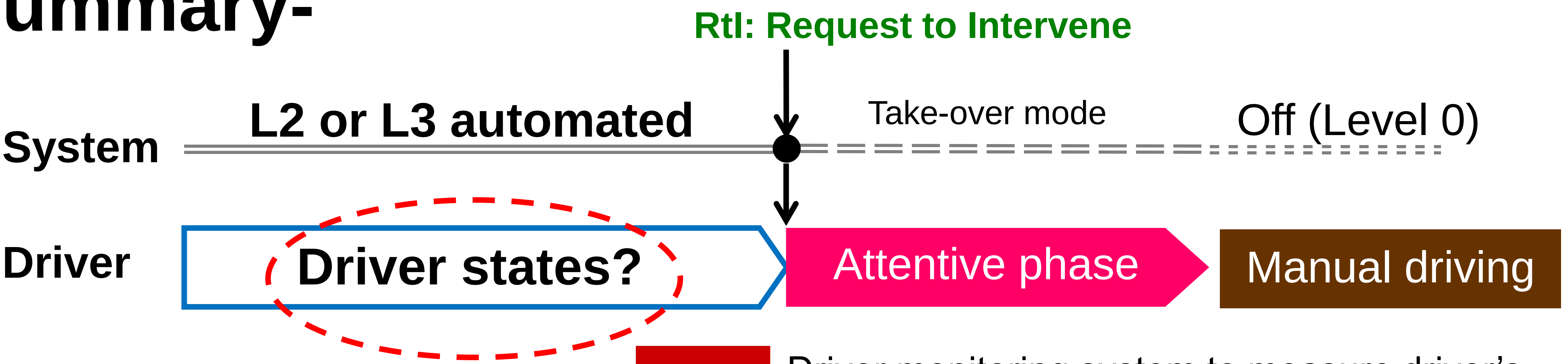


Transition from L3 automated to manual driving

-Unplanned transition-



System-initiated transition from automated to manual driving
-Summary-



Human factor issues are different between the system levels.

L2 Driver monitoring system to measure driver's readiness/availability and to detect it lower than criteria

L3 Planned To promote the attentive phase that the driver comes back in the driving-loop and recognizes the surrounding situations

L3 Unplanned To confirm the driver's attentiveness (and his/her appropriate driving controls) or to execute MRM

Related works

NDRA engagements and their effects on the control transition

Jaussein M., Lévêque L., Deniel J., Bellet T., Tattegrain H. and Marin-Lamellet C. (2021) How Do Non-driving-related Tasks Affect Engagement Under Highly Automated Driving Situations? A Literature Review. Front. Future Transp. 2:687602. https://doi.org/10.3389/ffutr.2021.687602

Naujoks F., Befelein D., Wiedemann K. and Neukum A. (2018) A Review of Non-driving-related Tasks Used in Studies on Automated Driving. In: Stanton N. (eds) Advances in Human Aspects of Transportation. AHFE 2017. Advances in Intelligent Systems and Computing, vol 597. Springer, Cham https://doi.org/10.1007/978-3-319-60441-1_52

HMI of RtI and take-over time

Morales-Alvarez, W., Sipele, O., Léberon, R., Tadjine, H.H. and Olaverri-Monreal, C. (2020) Automated Driving: A Literature Review of the Take over Request in Conditional Automation. *Electronics*, *9*, 2087. https://doi.org/10.3390/electronics9122087

Take-over time and the influencing factors (experimental conditions)

Soares, S., Lobo, A., Ferreira, S., Cunha, L. and Couto, A. (2021) Takeover performance evaluation using driving simulation: a systematic review and meta-analysis. Eur. Transp. Res. Rev. Vol. 13, 47. https://doi.org/10.1186/s12544-021-00505-2

Zhang, B., De Winter, J., Varotto, S., Happee, R. and Martens, M. (2019). Determinants of take-over time from automated driving: A meta-analysis of 129 studies. Transportation Research Part F: Traffic Psychology and Behaviour, Vol. 64, pp. 285-307. https://doi.org/10.1016/j.trf.2019.04.020

Assessment metrics of **take-over performance**

Cao, Y., Zhou, F., Pulver, E., Molnar, L., Robert, L., Tilbury, D. and Yang, J. (2021) Towards Standardized Metrics for Measuring Takeover Performance in Conditionally Automated Driving: A Systematic Review. SSRN Electronic Journal, http://dx.doi.org/10.2139/ssrn.3867520

Take-over performance of **elderly drivers**

Gasne, C., Paire-Ficout, L., Bordel, S., Lafont, S. and Ranchet, M. (2022) Takeover performance of older drivers in automated driving: A review, Transportation Research Part F: Traffic Psychology and Behaviour, Vol. 87, pp. 347-364. https://doi.org/10.1016/j.trf.2022.04.015

Future research perspectives

Driver’s acceptance of the transition in real environments

Field operational tests are important, and we should evaluate the effects of “duration of engaging in NDRA”, “willingness to the NDRA”, “type and duration of the notification”, and “want to take-over (=driving contexts)” on the driver’s acceptance of the RtI.

Influences of driver’s experiences of the automated driving systems in his/her daily trips on the attitudes to the transitions

Long-term assessments are necessary, and driver’s experiences including the frequencies and outcomes receiving the RtI in his/her daily trips might influence the attitude to the system-initiated transitions.

HMI (Human Machine Interaction/Interface) to increase the values of the automated systems

NDRAs are not limited to watching a smartphone. HMI in L2 and L3 automated systems might contribute to increasing the values using the automated systems (driving pleasures, driving comfort, etc.) in addition to the disengagement in manual driving operations.

Thank you for your attention!