

Understanding the Interplay between the Driver, the Vehicle, and the Environment for Adapting Driving Automation

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& **Prof. Christel DEVUE**



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Over a century of increasing technology



1886

First automobile



1958

Cruise control



1999

Adaptive cruise control



2013

Lane centering assistance, combined with adaptive cruise control

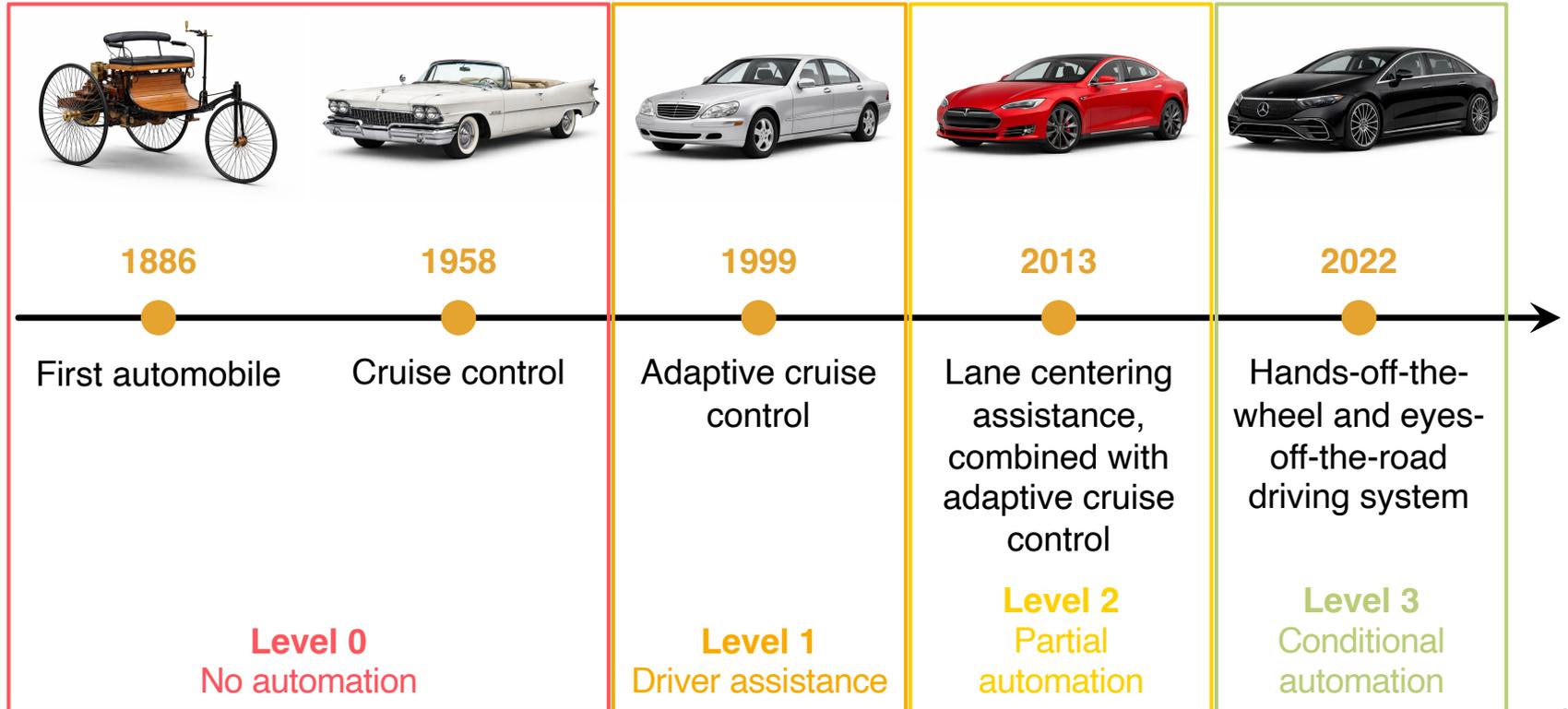


2022

Hands-off-the-wheel and eyes-off-the-road driving system

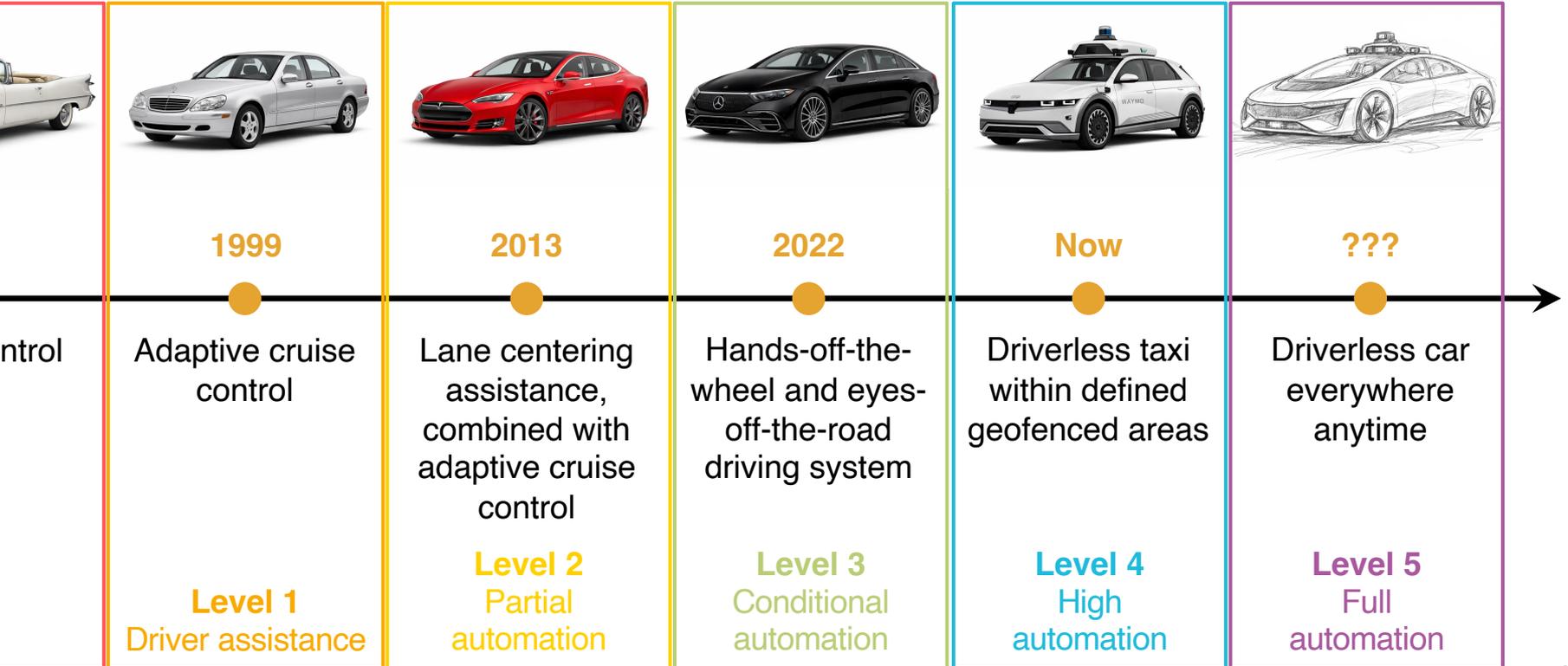


Levels of driving automation



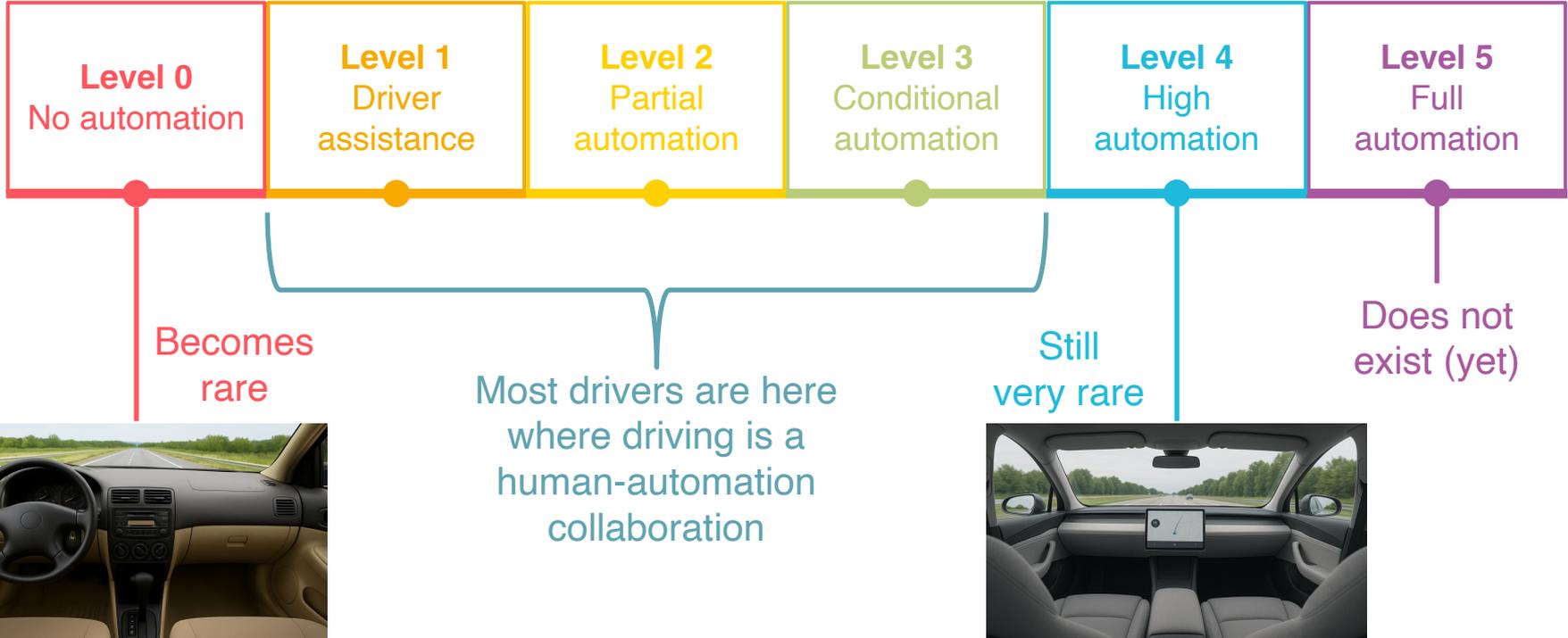


Levels of driving automation



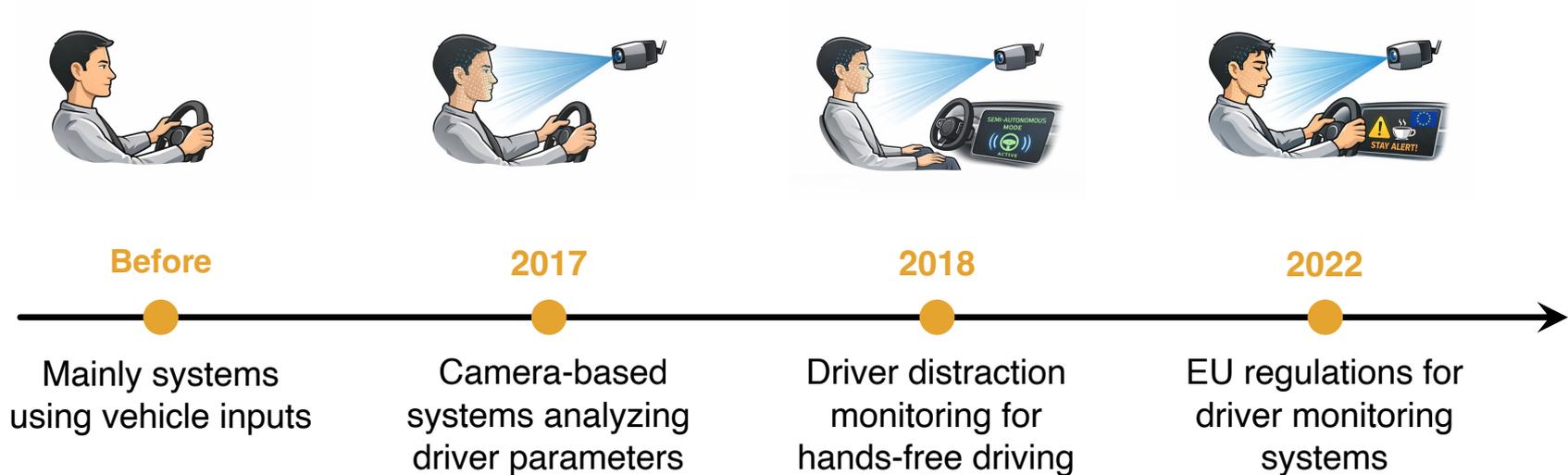


Driving today is a human-automation collaboration





Evolution of driver monitoring systems (DMS)



Today, production vehicles integrate DMS as a standard feature, but is this enough for road safety?



**How can driver monitoring reduce risk
across driving automation levels?**

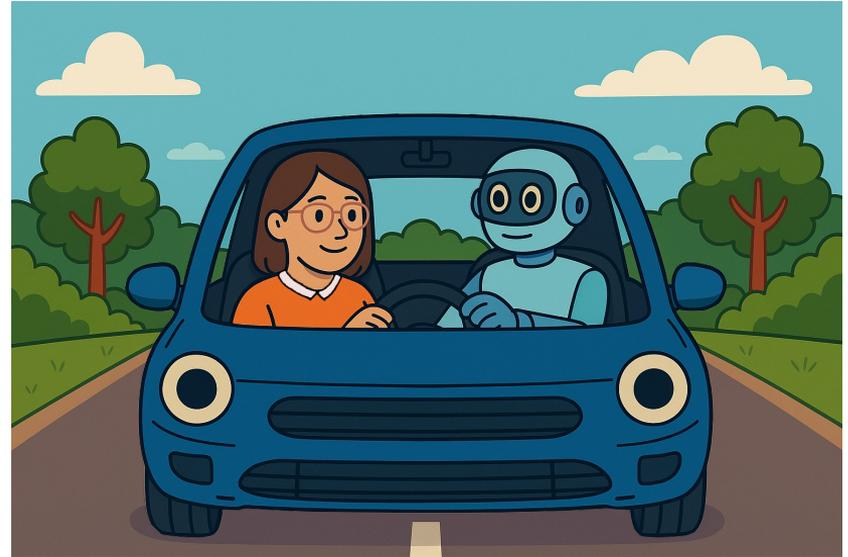
**How involved should the driver be
in driving automation?**



Extending driver monitoring beyond warnings for adapting driving automation

Adaptive automation dynamically adjusts to both driver state and driving situation.

- ▶ It requires to understand the interplay between
 1. the **driver**,
 2. the **vehicle**,
 3. and the **environment**.





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Chapter 3

Driver reliance on ACC

Chapter 4

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Background and Related Work



Survey and Synthesis of State of the Art in Driver Monitoring,
A. Halin, J. G. Verly, and M. Van Droogenbroeck.
Sensors, 2021.

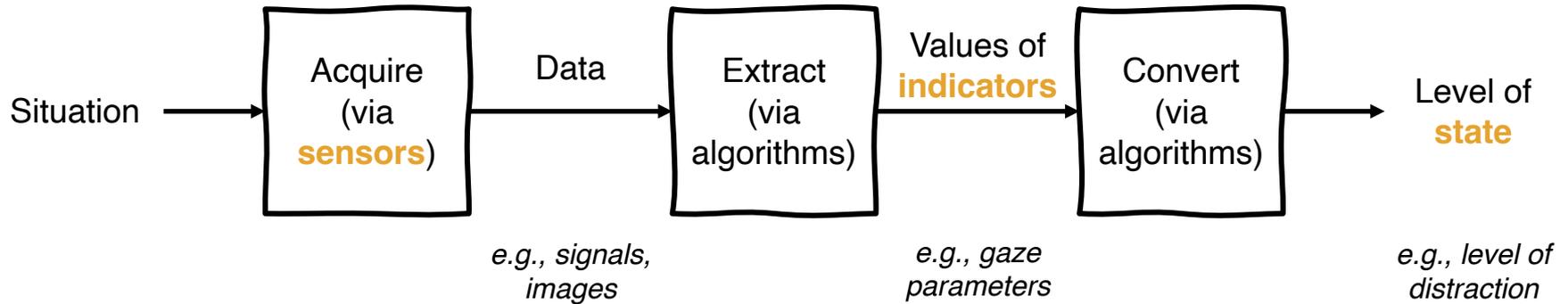


Driver distraction monitoring for road safety





Driver-state characterization through states, indicators, and sensors



Driver-based indicators



Heart activity



Brain activity



Gaze parameters

Vehicle-based indicators



Speed



Braking behavior



Wheel steering

Environment-based indicators



Road geometry



Traffic conditions



Weather

Driver-centric sensors



Internal camera



Wearable

Vehicle-centric sensors



CAN bus

Environment-centric sensors



External camera



Contribution 1: Definition of an indicator

A “quantity” or “item” is called an indicator for a given (sub)state if it satisfies all the following conditions:

1. it has a precise definition based on science (*e.g.*, physics, mechanics, chemistry, biology, physiology);
2. it can be measured, or characterized in some way, with real-time constraint when necessary, based upon data obtained from relevant sensors available in the application of interest;
3. it must take values (such as numbers or labels) within a pre-specified domain, and these values must preferably correspond to physical units (such as seconds or Hertz);
4. it is not a unique and full descriptor of the state;
5. it is recognized, in the literature, as being linked, in some meaningful way, to the state or trend thereof;
6. it is possibly useful with respect to one or more related, or unrelated, states;
7. it is reproducible, meaning that its value is always the same for fixed data.

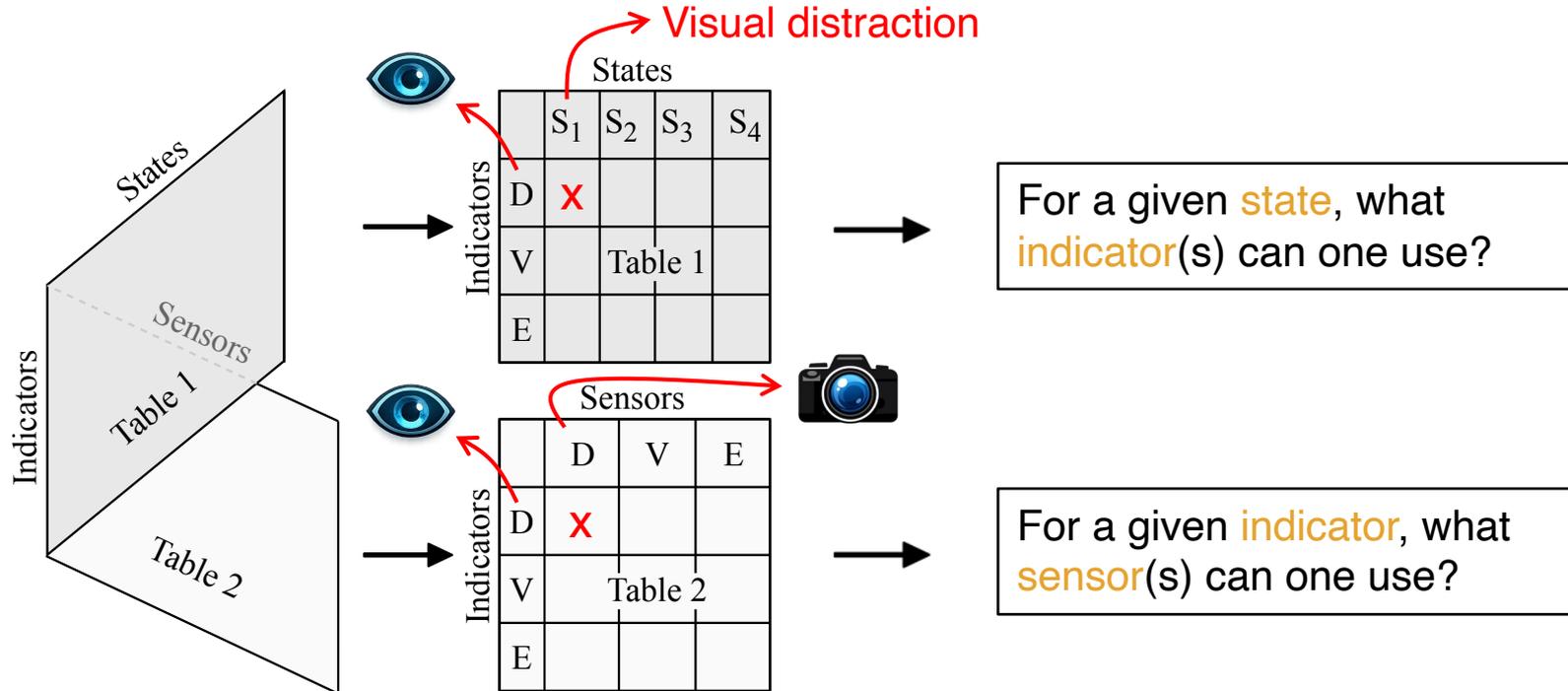
measurable

physical units

reproducible



Contribution 2: Two interlocked tables





Contribution 3: Role of DMS in driving automation



Level 0 No automation	Level 1 Driver assistance	Level 2 Partial automation	Level 3 Conditional automation	Level 4 High automation	Level 5 Full automation
Monitoring	Monitoring with relevant indicators		Monitoring fallback-ready driver	Monitoring when driver in control	/



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ACC Use and Its Impact on Driving Performance



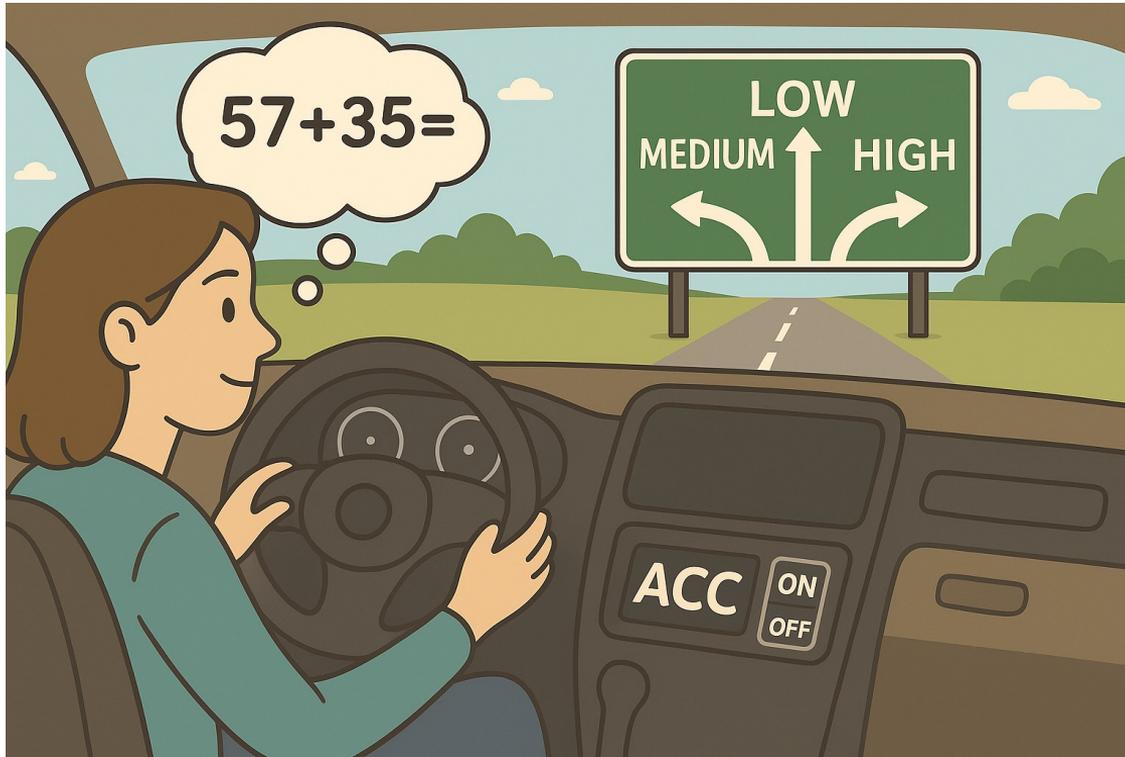
Effects of Cognitive Distraction and Driving Environment Complexity on Adaptive Cruise Control Use and Its Impact on Driving Performance: A Simulator Study,

A. Halin, M. Van Droogenbroeck, and C. Devue.

In *AutomotiveUI*, 2025.



A driving simulator study



to explore the effects of **cognitive distraction**

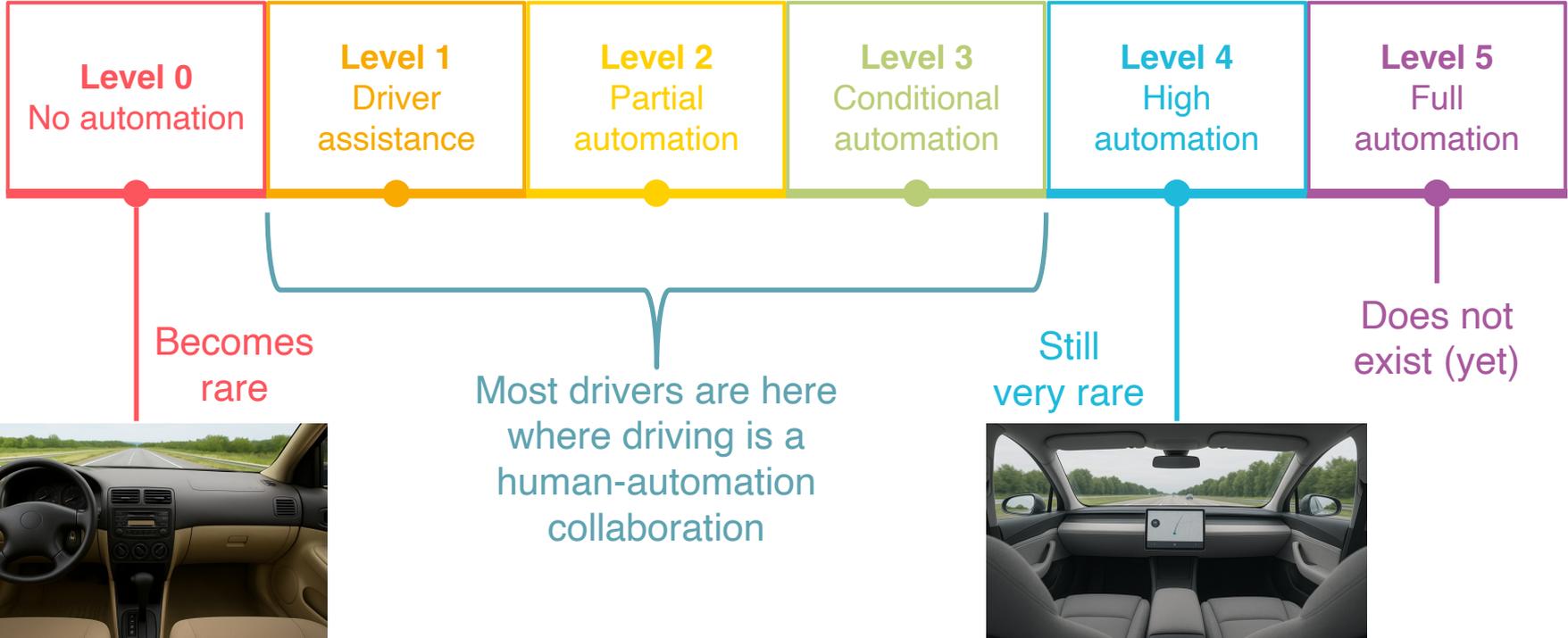
and **driving environment complexity**

on the use of **adaptive cruise control (ACC)**,

and its impact on **driving performance**.

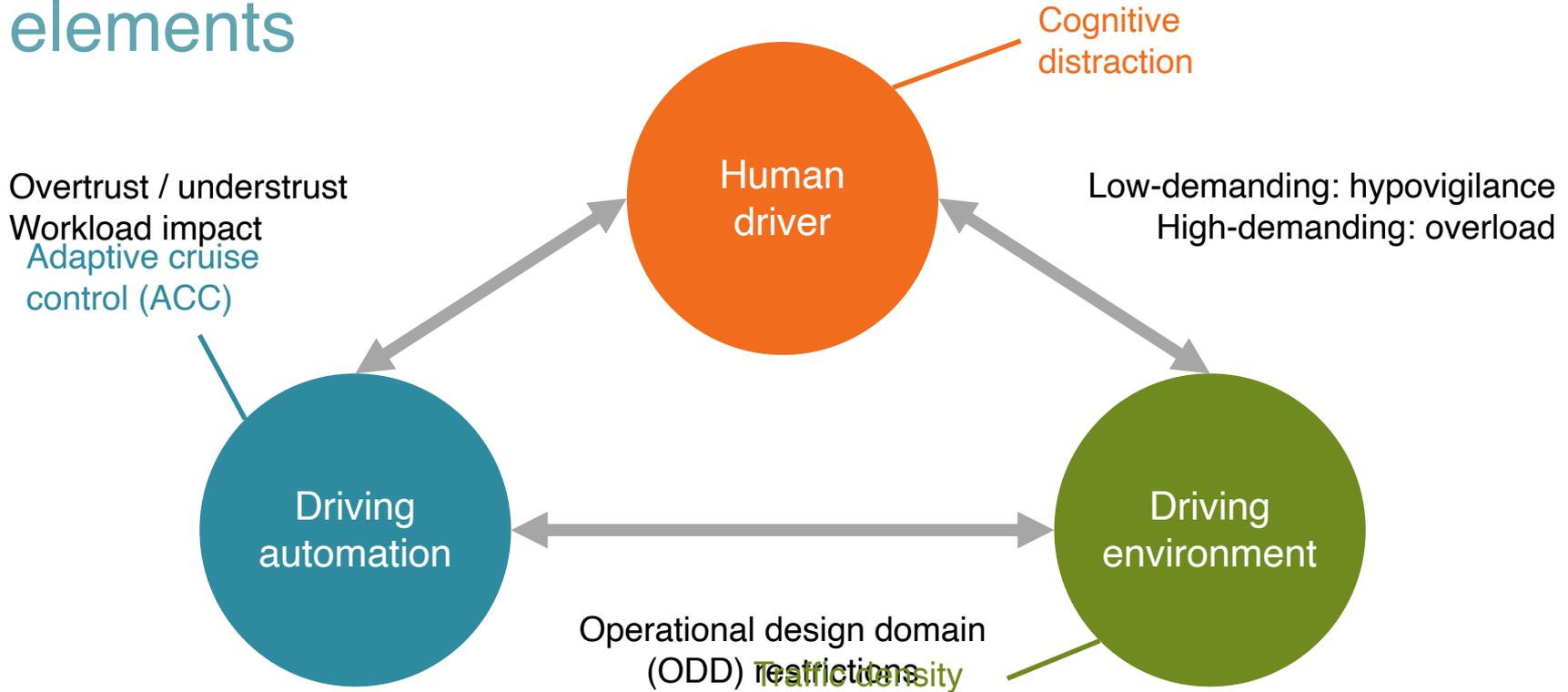


Driving today is a human-automation collaboration





Effective collaboration depends on three elements





We aimed at answering the following research questions

RQs
1-2

How do driving environment complexity and cognitive distraction influence **ACC use**?

RQs
3-4

How does ACC use influence **driving performance** in different driving environment and cognitive distraction conditions?

Within-subject driving simulator study with 6 scenarios of ~8 minutes



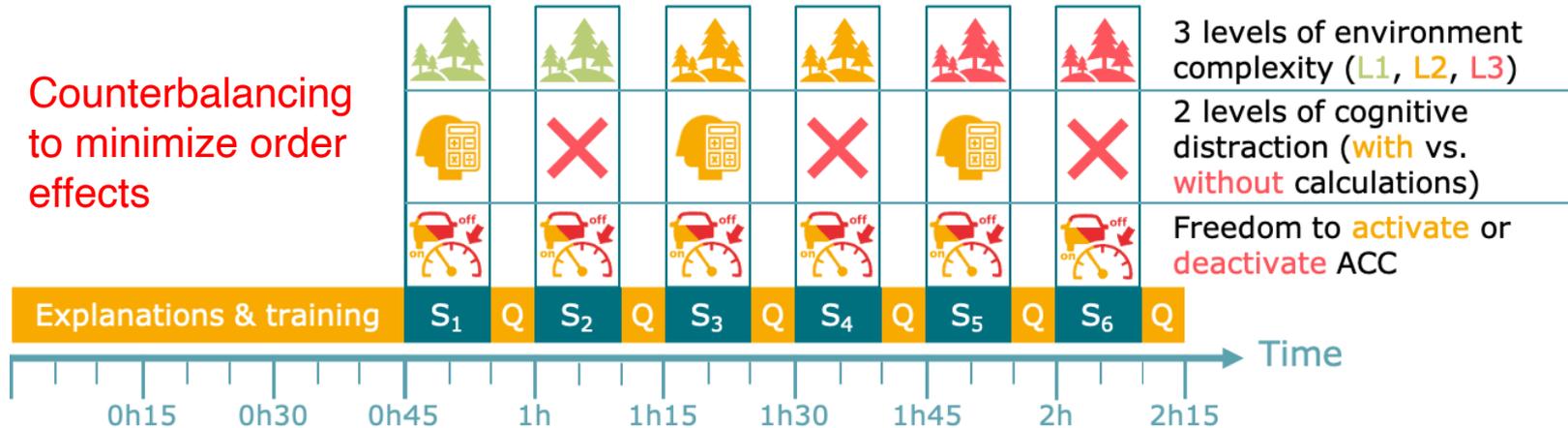


User study

 Within-subject driving simulator study with 6 scenarios of ~8 minutes

 29 participants, instructed to respect traffic laws, including speed limits

Counterbalancing
to minimize order
effects





Measurements

▶ Adaptive Cruise Control (ACC) use:

- number of ACC activations
- percentage of ACC engagement time
- feedback questionnaires



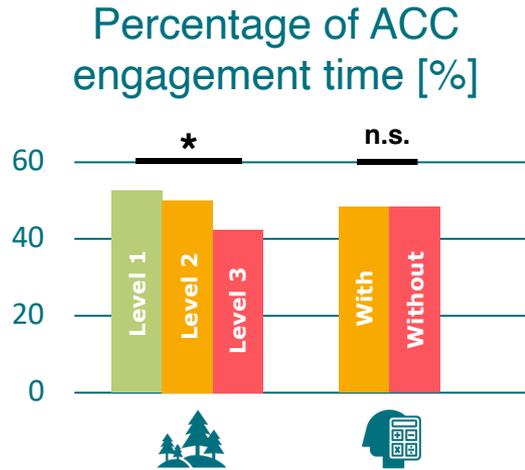
▶ Driving performance:

- percentage of time within the speed limit
 - › strict adherence vs allowing a margin of error
- standard deviation of lateral position (SDLP)
- number of lane changes
- feedback questionnaires





Result 1: Environment impacts ACC use

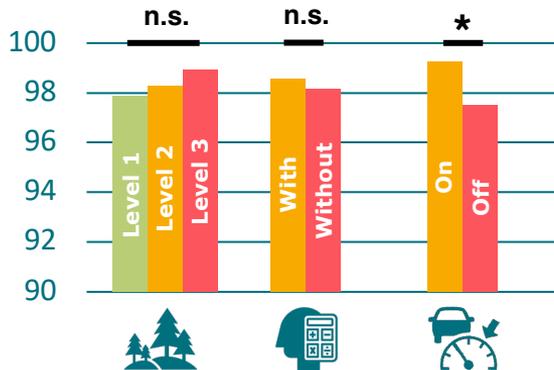


- ▶ Drivers use the ACC less in complex driving environments.



Result 2: ACC use impacts longitudinal driving performance

Percentage of time within the speed limit (with 5% margin of error) [%]



- ▶ Speed adherence is better when ACC is activated.



Result 3: All conditions impact lateral driving performance

Standard deviation of lateral position (SDLP) [m]

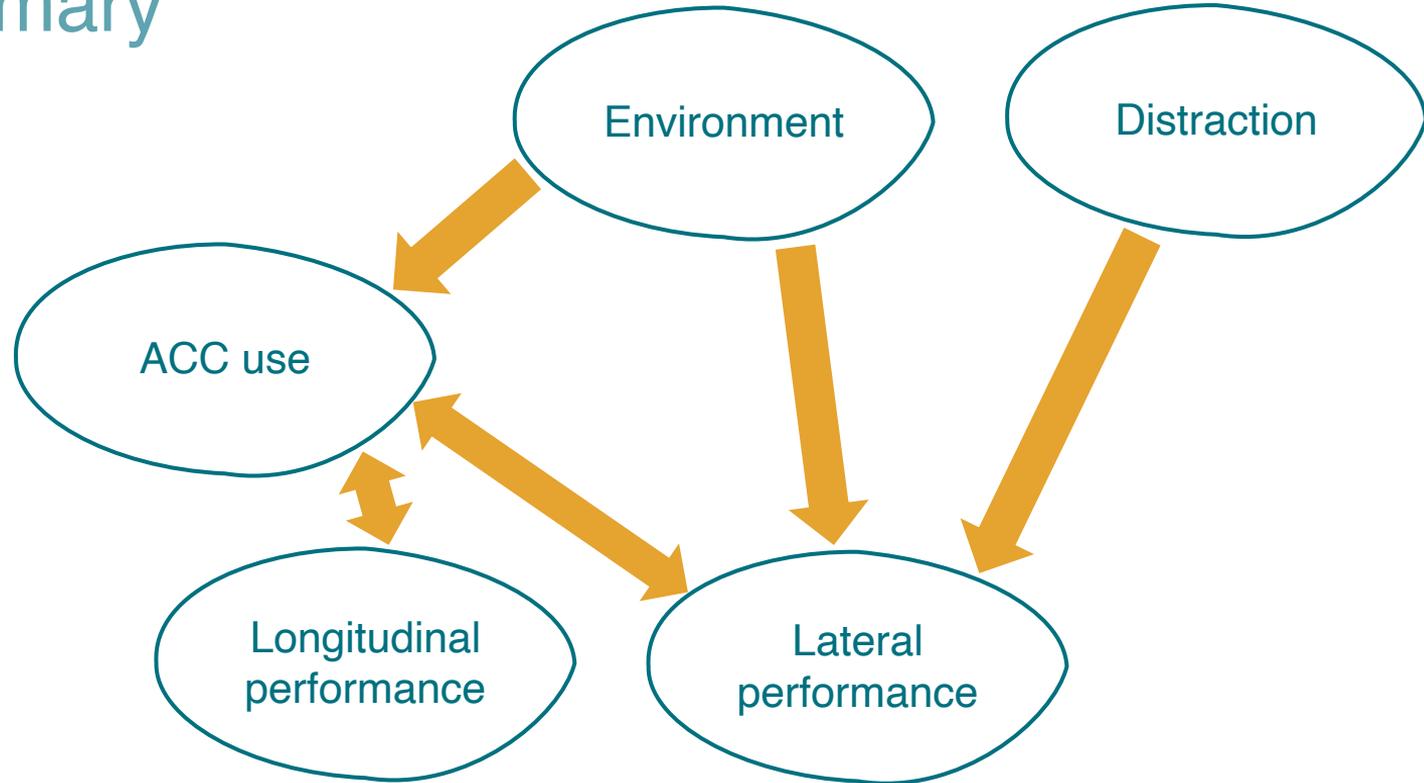


Lateral control is better

- ▶ in the easiest environment compared to the medium level;
- ▶ when participants are distracted;
- ▶ when participants use the ACC.



Summary





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EDA- and Gaze-Based Indicators of Driver Cognitive Distraction



Are Electrodermal Activity-Based Indicators of Driver Cognitive Distraction Robust to Varying Traffic Conditions and Adaptive Cruise Control Use?,
A. Halin, M. Van Droogenbroeck, and C. Devue.
 In AutomotiveUI Adjunct, 2025.



Gaze-Based Indicators of Driver Cognitive Distraction: Effects of Different Traffic Conditions and Adaptive Cruise Control Use,
A. Halin, A. Delière, C. Devue, and M. Van Droogenbroeck.
 In AutomotiveUI Adjunct, 2025.



User study

Same study as in Chapter 3



Within-subject driving simulator study with 29 participants



3 levels of environment complexity (L1, L2, L3)



2 levels of cognitive distraction (**with** vs. **without** calculations)



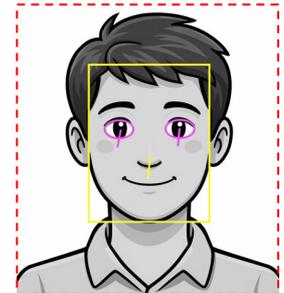
Freedom to **activate** or **deactivate** ACC at any time



BIOPAC MP160 for electrodermal activity (EDA) recording



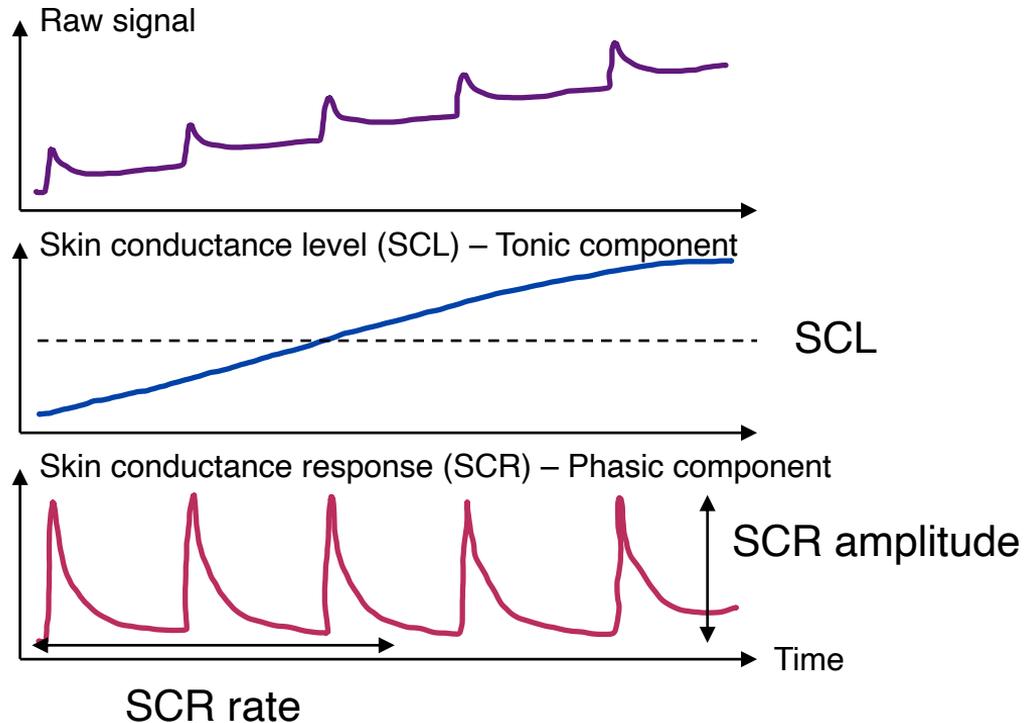
DMS recording infrared images at 60Hz





Measurements

► Electrodermal activity (EDA)-based indicators





Result 1: EDA parameters

- ▶ SCL & SCR amplitude are influenced by the environment; SCR rate is not.
- ▶ All three EDA-based indicators have higher values with distraction.
- ▶ All three EDA-based indicators have lower values when ACC is activated.

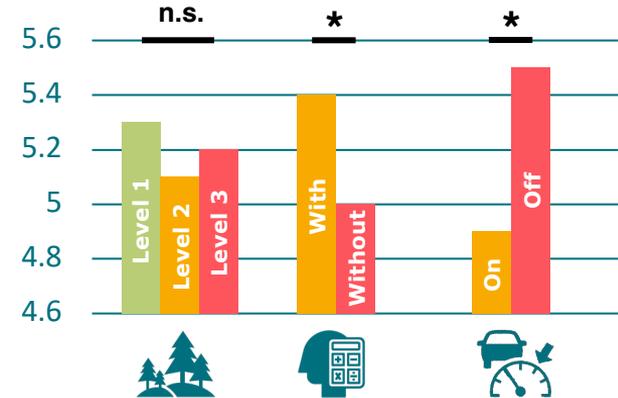
SCL [μ S]



SCR amplitude [μ S]



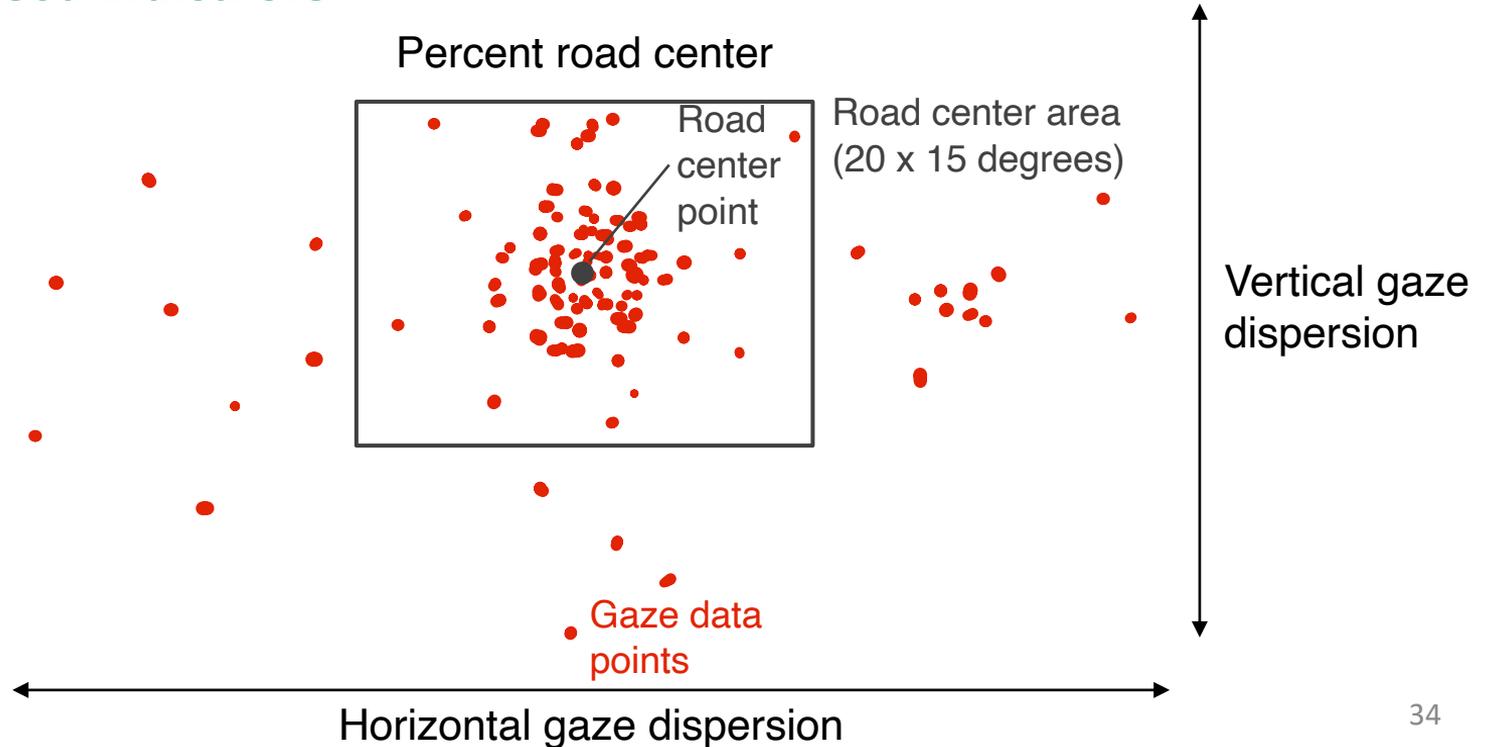
SCR rate [#peaks/min]





Measurements

► Gaze-based indicators

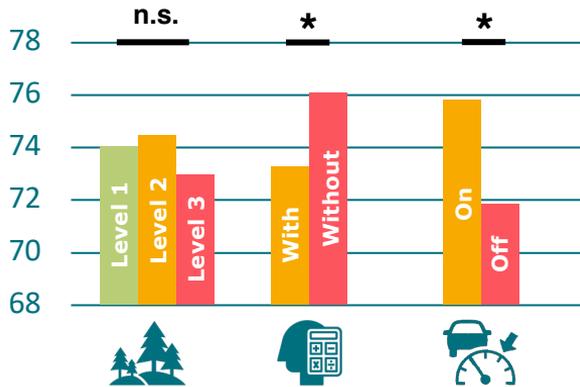




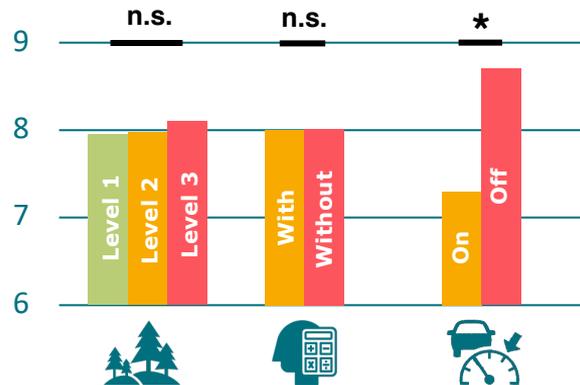
Result 2: Gaze parameters

- ▶ The most complex environment increases vertical gaze dispersion.
- ▶ ACC use increases gaze concentration according to all parameters.
- ▶ Cognitive distraction decreases percent road center and increases vertical gaze dispersion. **Not consistent with the literature!**

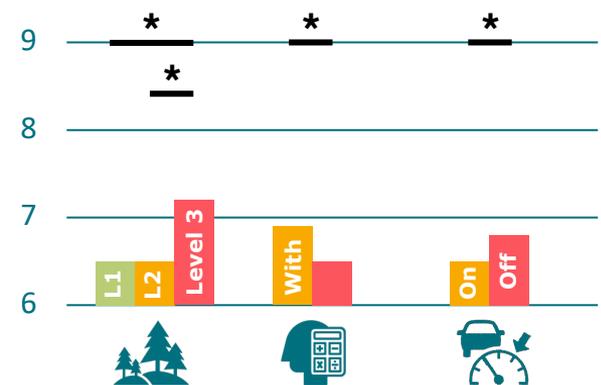
Percent road center [%]



Horizontal gaze dispersion [°]



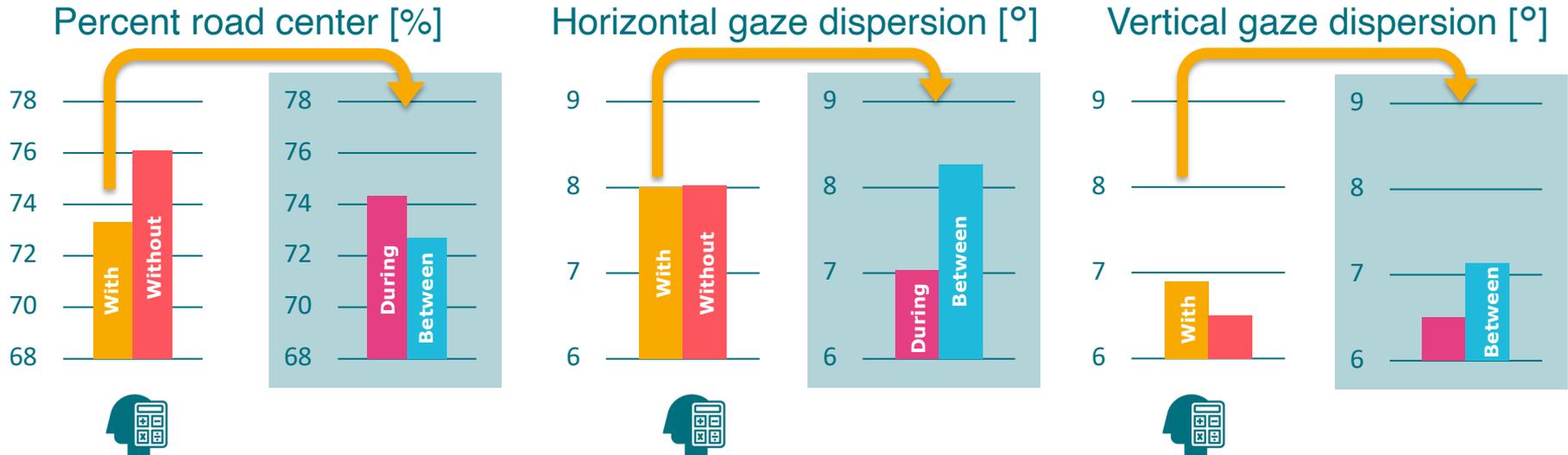
Vertical gaze dispersion [°]





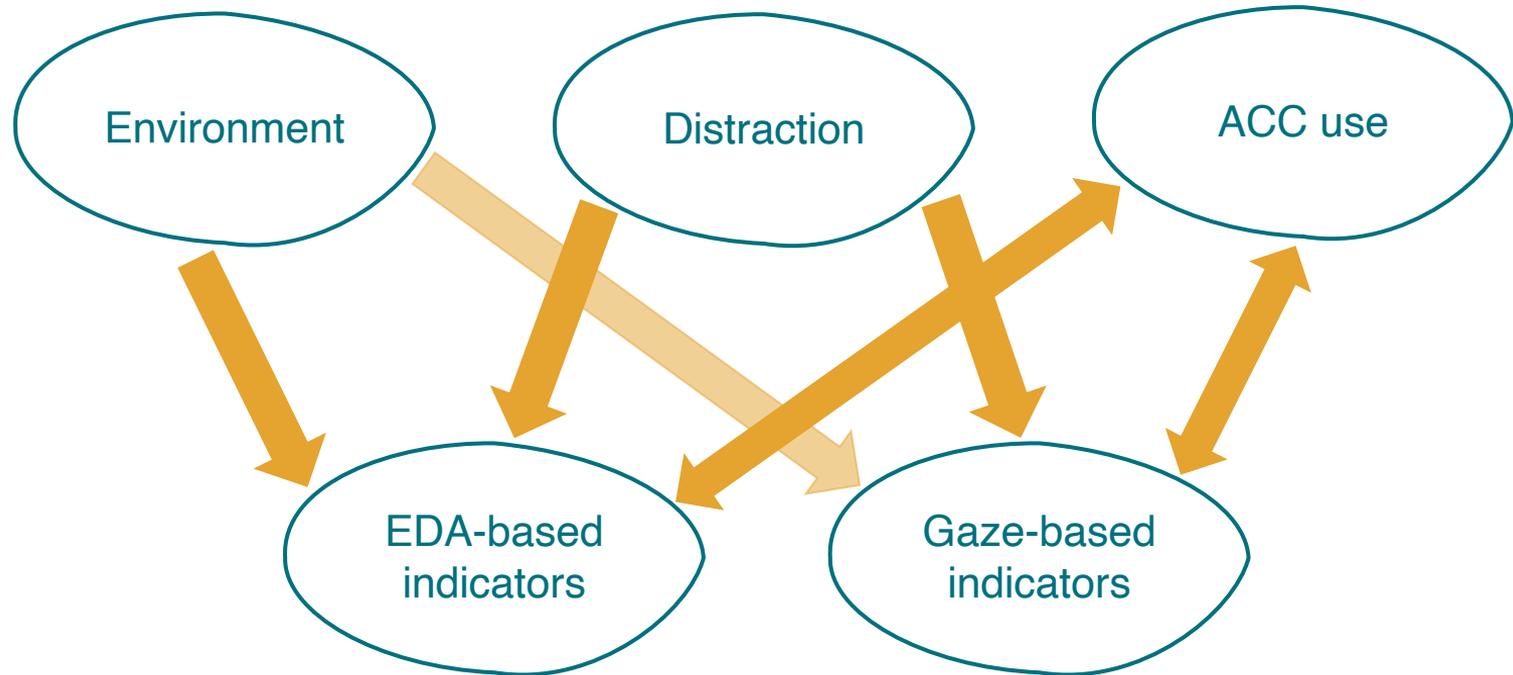
Result 2bis: Gaze parameters with distraction

- ▶ Gaze concentration **during calculations** and compensatory effect with huge dispersion **between calculations**.





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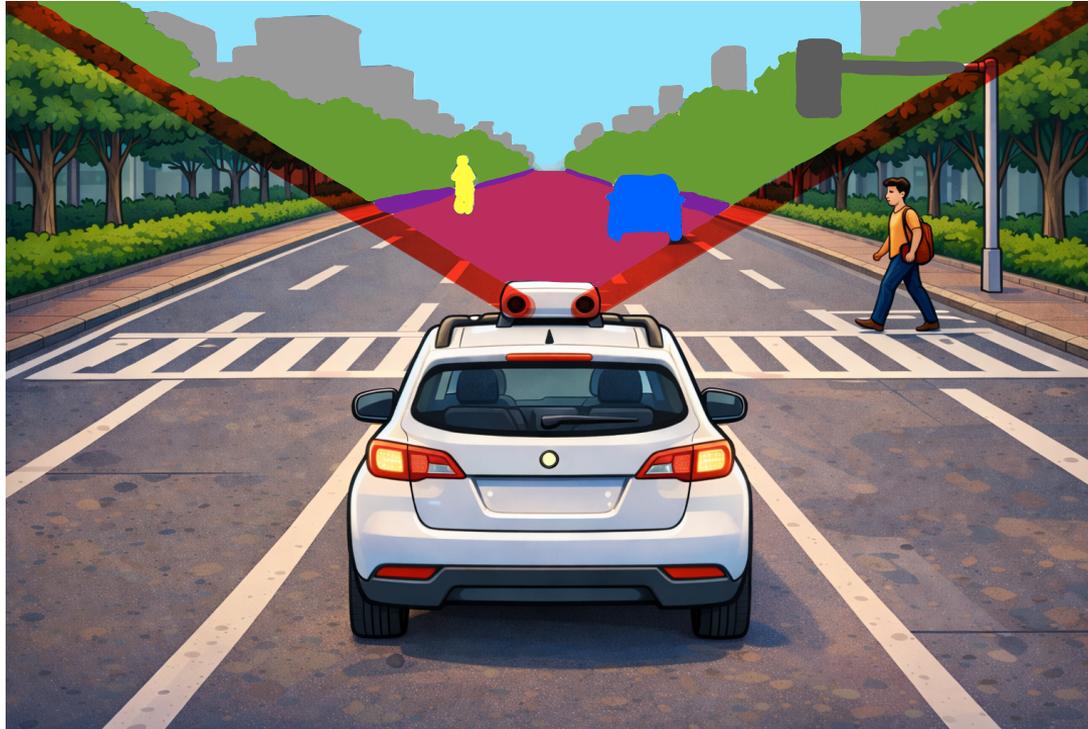
Test-Time Adaptation in Dynamic Environments



Multi-Stream Cellular Test-Time Adaptation of Real-Time Models Evolving in Dynamic Environments,
 B. Gérin*, **A. Halin***, A. Cioppa*, M. Henry, B. Ghanem, B. Macq, C. De Vleeschouwer, and M. Van Droogenbroeck.
 In CVPRW, Workshop on Autonomous Driving, 2024.



Analysis of the environment





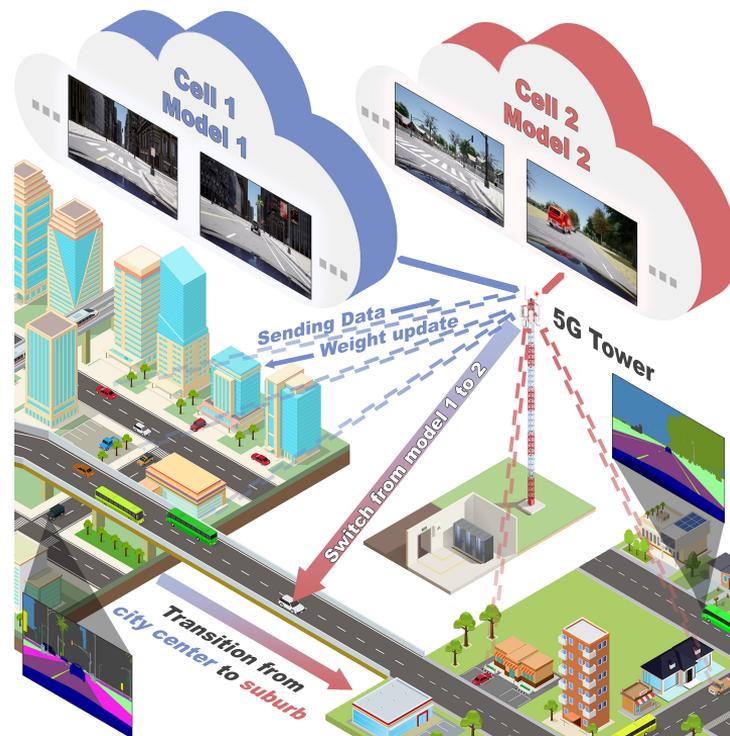
Multi-stream cellular test-time adaptation

Motivation:

Dynamic environments (both spatially and temporally)

Objective:

Adaptation of models





Contribution: DADE dataset

Characteristics:

- ▶ Multi-agent long videos
- ▶ Environment division
- ▶ Cell connection
- ▶ Available ground truths

In numbers:

- ▶ 100 + 300 video sequences
- ▶ 40-45 minutes in average
- ▶ 7 locations
- ▶ 6 weather conditions





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Physically Interpretable Probabilistic Domain Characterization



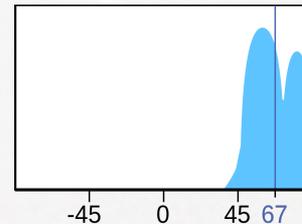
Physically Interpretable Probabilistic Domain Characterization,
A. Halin*, S. Piérard*, R. Vandeghen, B. Gérin, M. Zanella, M. Colot, J. Held, A. Cioppa, E. Jean, G. Bontempi, S. Mahmoudi, B. Macq, and M. Van Droogenbroeck.
In ACCVW, Workshop on AI-based All-Weather Surveillance System (AWSS), 2025.

Weather characterization based on images

Classification
sunny

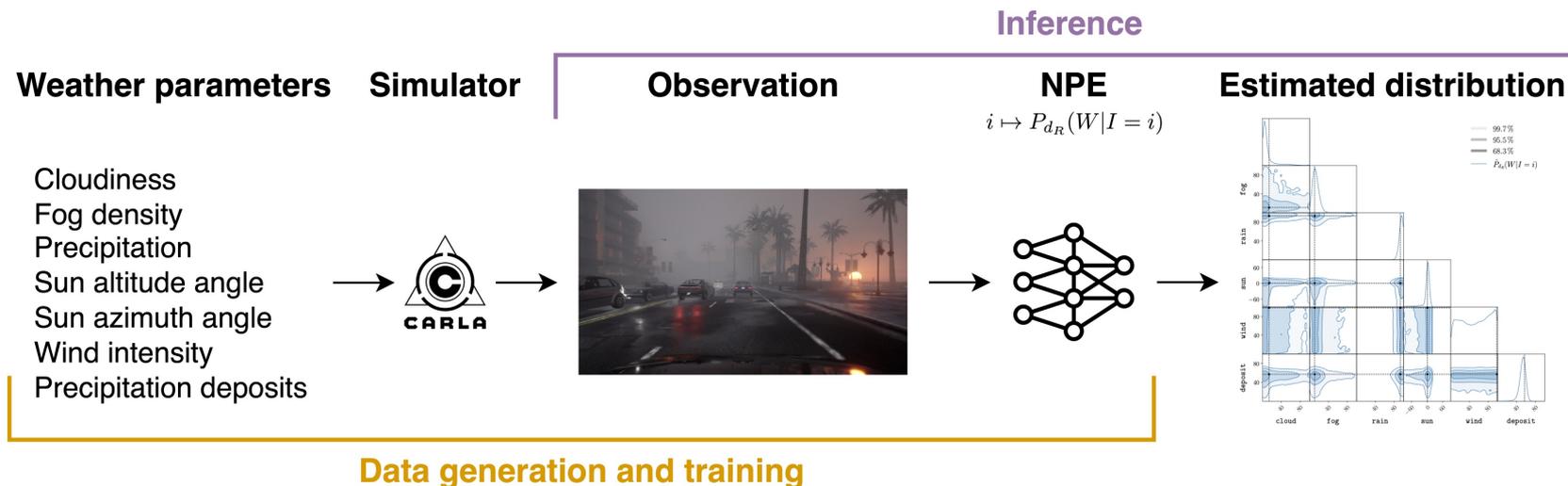
Regression
67

Likelihood



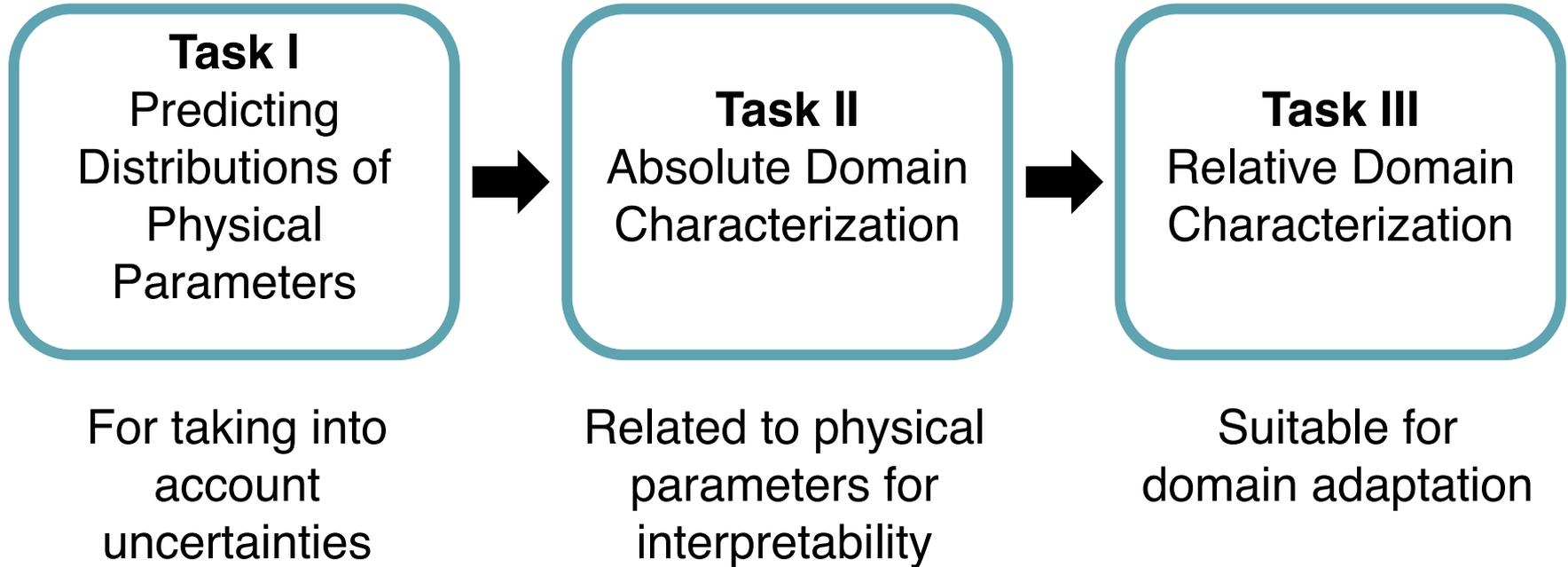


Weather characterization based on images





Contributions





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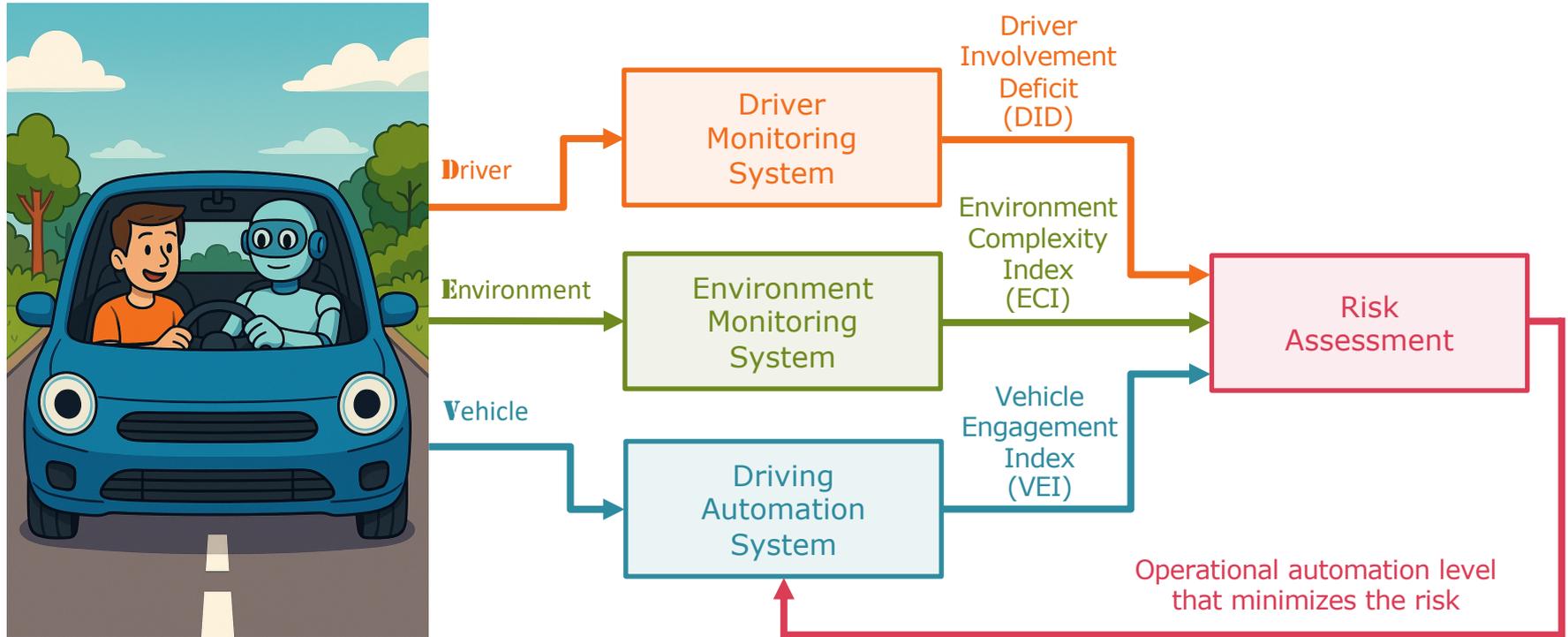
A Framework for Risk-Aware Adaptive Automation of Driving



DEV: A Driver-Environment-Vehicle Closed-Loop Framework for Risk-Aware Adaptive Automation of Driving,
A. Halin, C. Devue, and M. Van Droogenbroeck.
In *AutomotiveUI Adjunct*, 2025.



The DEV closed-loop framework for risk-aware adaptive automation

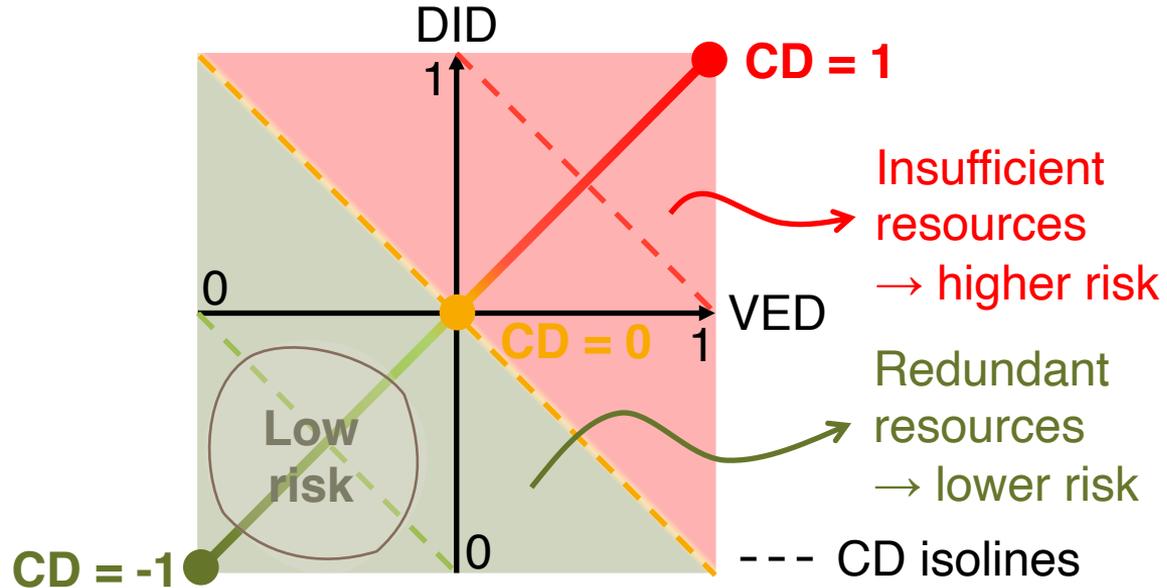




Risk assessment

Considering a fixed ECI,

cumulative deficit: $CD = VED + DID - 1$





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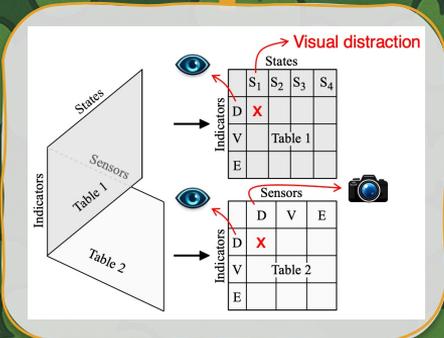
DEV

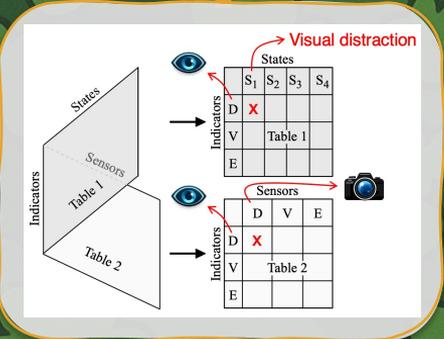
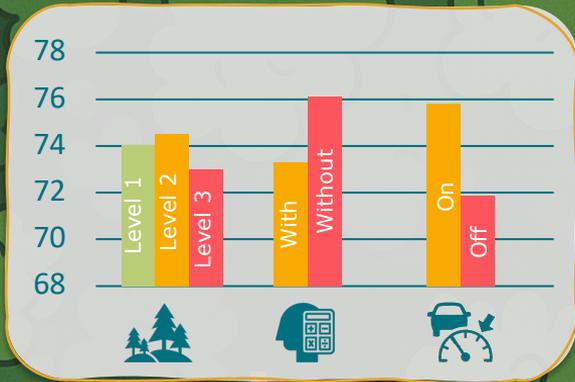
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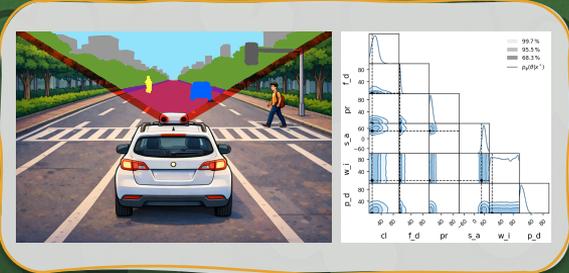
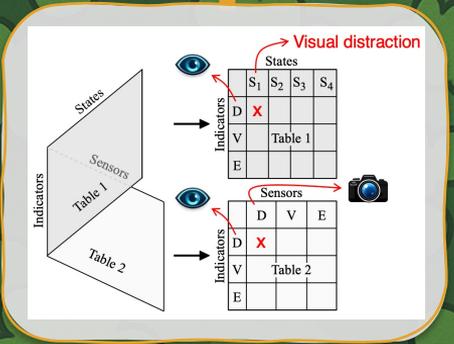
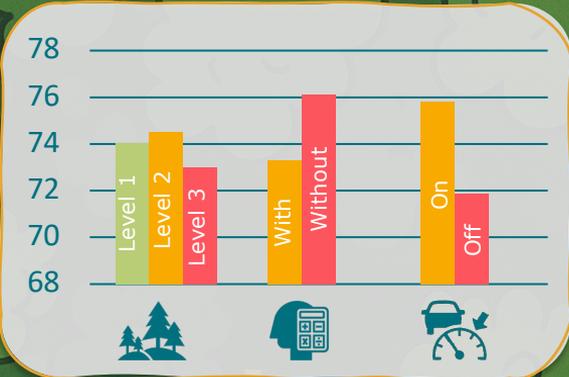
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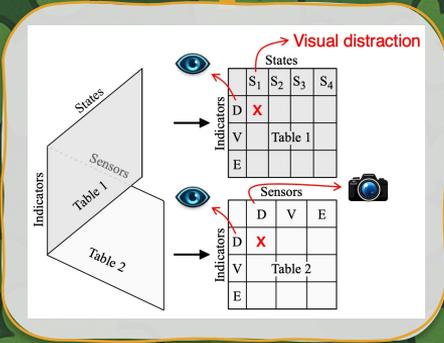
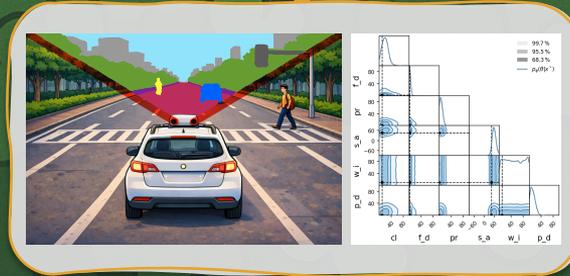
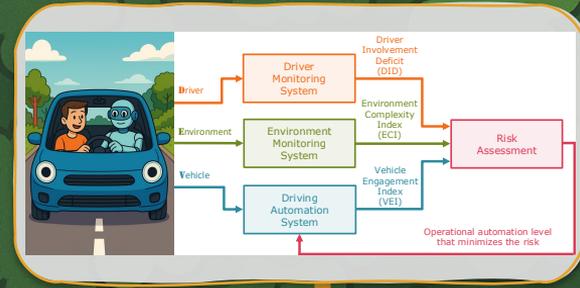
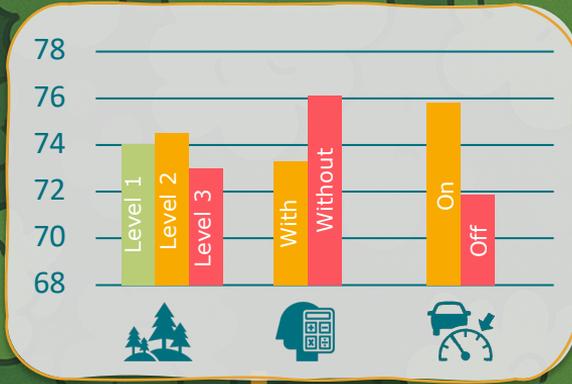
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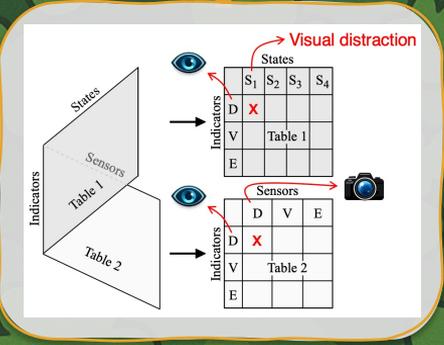
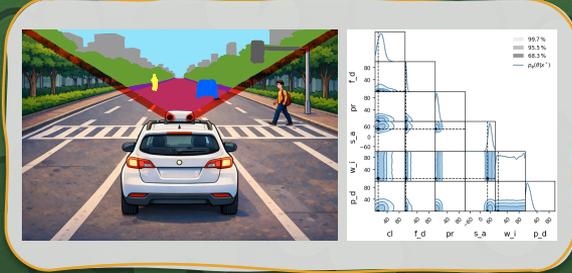
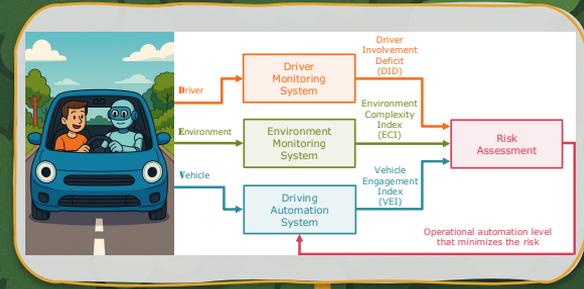
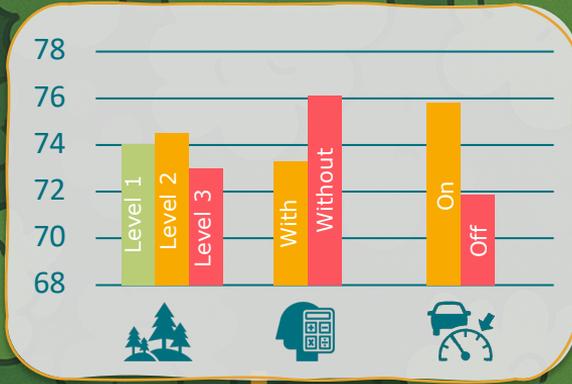
Conclusion











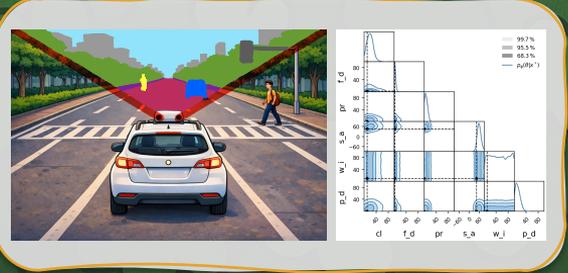
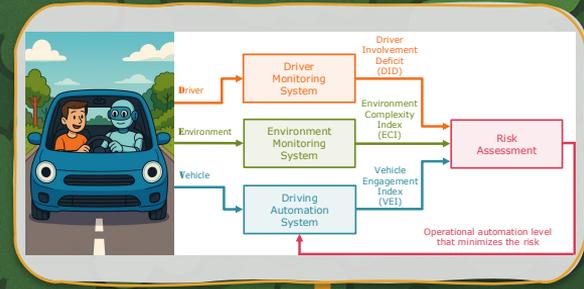
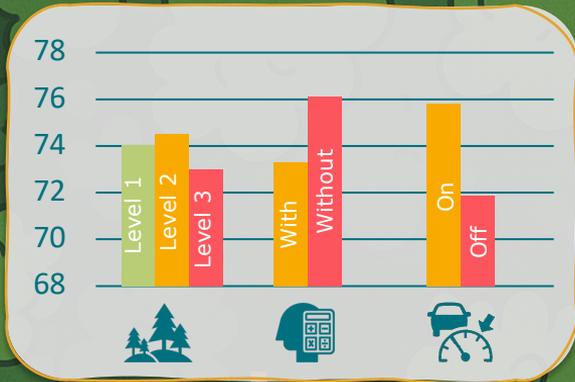


Perspectives

1. Define DID, ECI, and VED
 2. Develop a model for risk assessment
 3. Implement strategies for risk mitigation
 4. Design a HMI ensuring usability and acceptability
- From existing systems to useful indexes
- Understanding the interplay between D-E-V and how it impacts driving performance
- Find the best interventions
- Human studies

Challenges

- ▶ Inter-individual variability
- ▶ Real-world generalization
- ▶ And many more!



Drive safe!

