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Situation Awareness at Autonomous Vehicle Handover: Preliminary Results of a Quantitative Analysis

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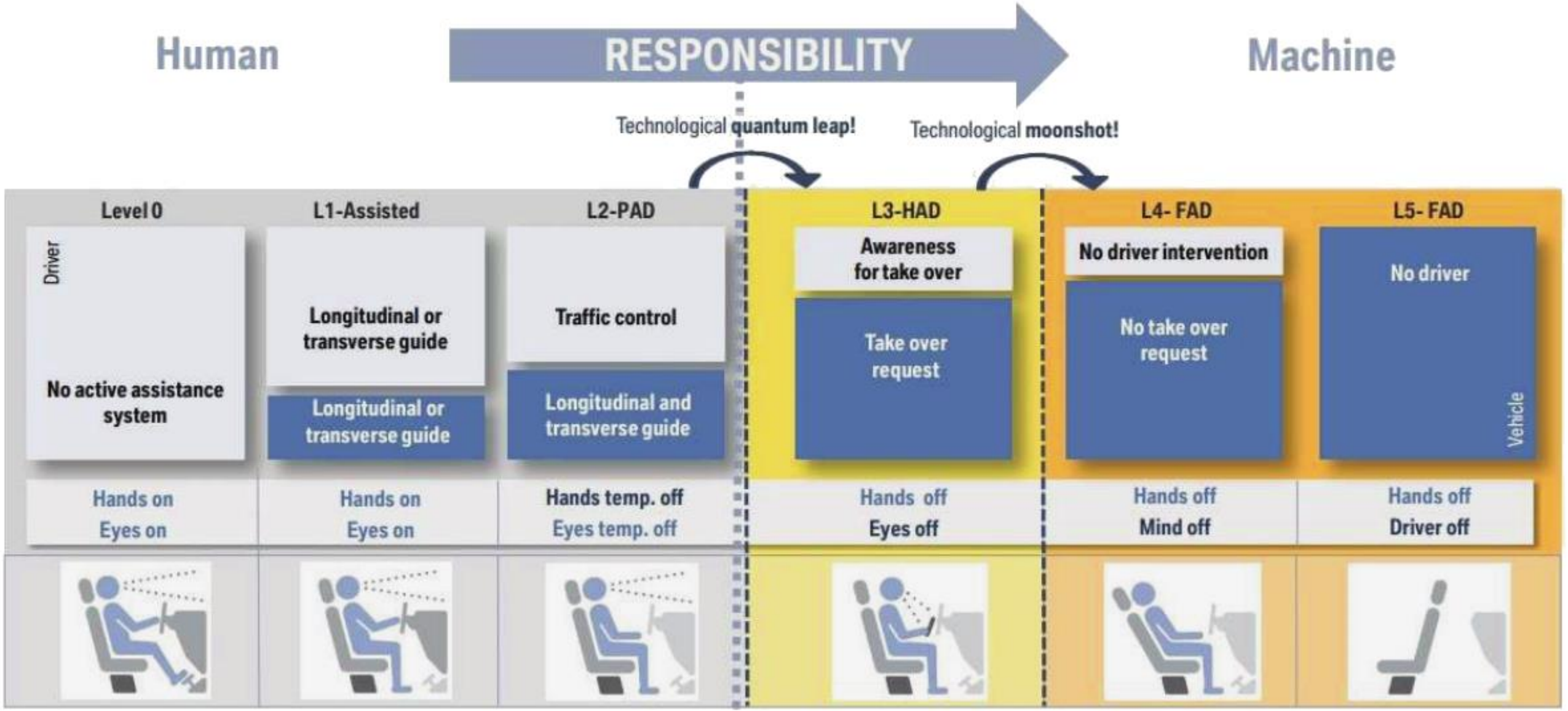
Introduction: Level of Autonomy



Defined by SAE International

Introduction: Handover process

Research questions

- What is the time threshold for a safe handover process at different speeds?
- How quickly can SA be restored depending on the complexity of a scenario?
- What input modalities and assistant functions can improve the above?
- What are the main factors that influence handover time and quality?
- What are the best strategies to decrease the chance of potential accidents during a handover request (e.g., decreasing velocity automatically)?

Levels of SA

- **Level 1 SA:**
  Perception of the environment
- **Level 2 SA:**
  Comprehension of the current situation
- **Level 3 SA:**
  Projection of future status

Problems with LoA 3

Driver is allowed to divert attention

WHILE

should be able to take back control anytime

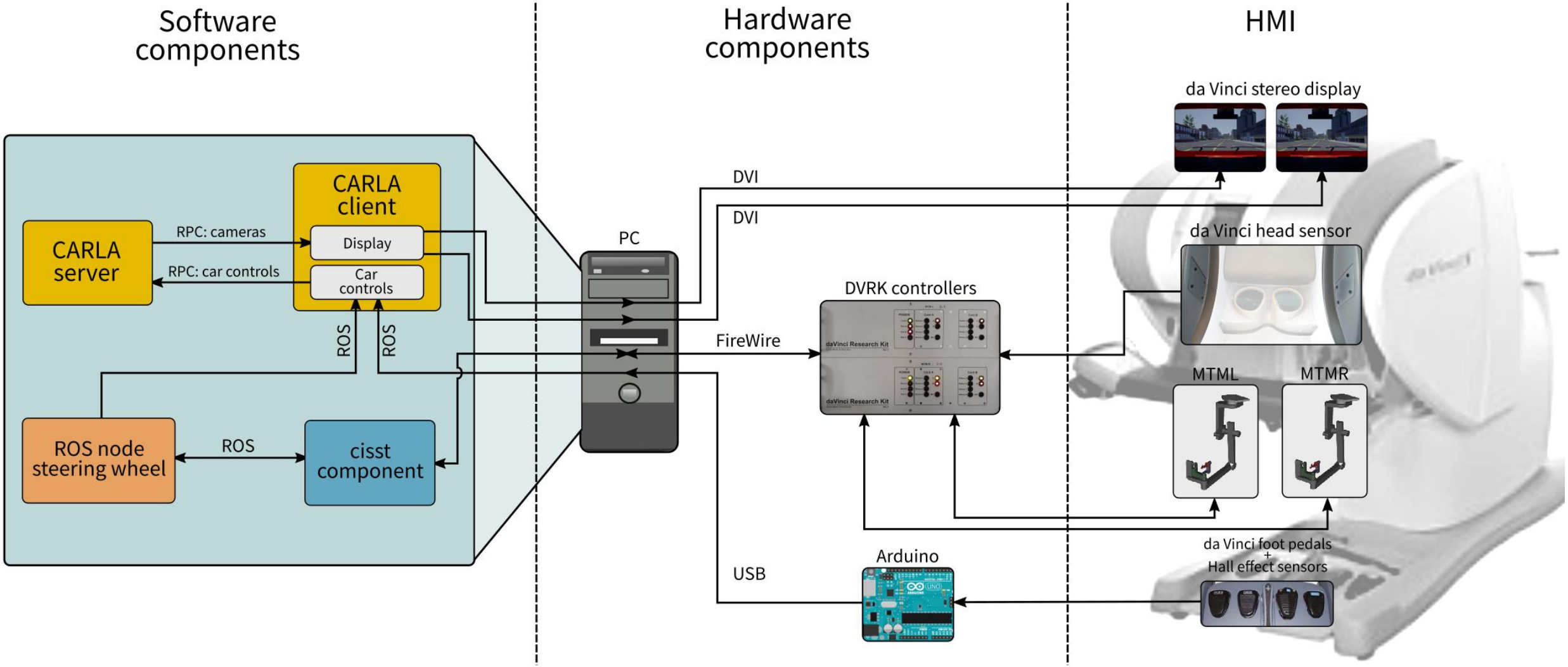
↓

Possible loss of SA

↓

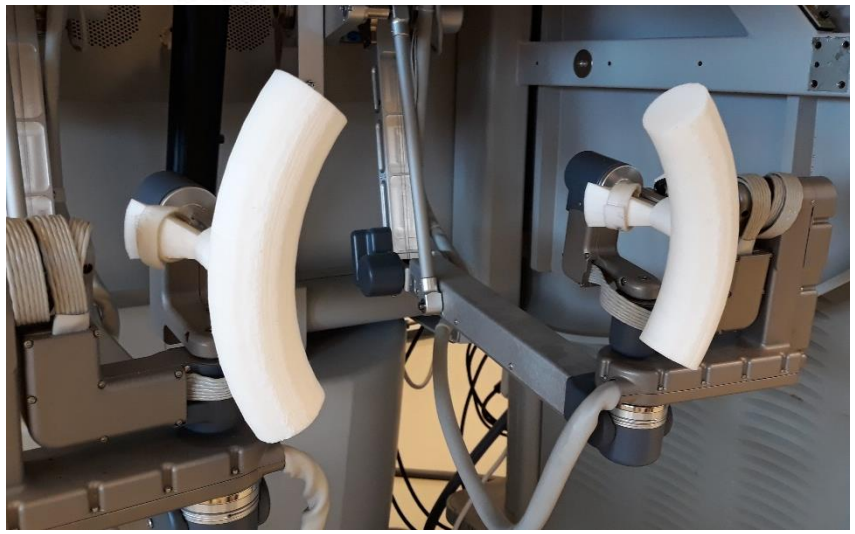
Weaker handover performance

System architecture



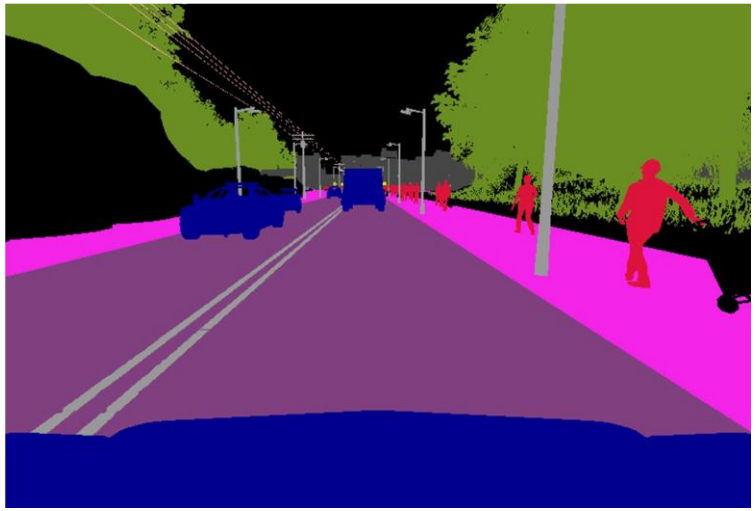
System architectire – da Vinci Master Console

Image credit: http://www.provence-urologie.fr



- Robot-assisted Minimally Invasive Surgery (RAMIS)
- Open programming interface via the Da Vinci Research Kit (DVRK), ROS interface
  - https://research.intusurg.com/dvrk
- Display ideal to control and measure attention, stereo vision
- Foot pedals
- Master Tool Manipulators (MTMs) can be used as a steering wheel
  - 3D printed wheel segments
  - Impedance control for steering wheel-like behavior

System architecture – CARLA Simulator

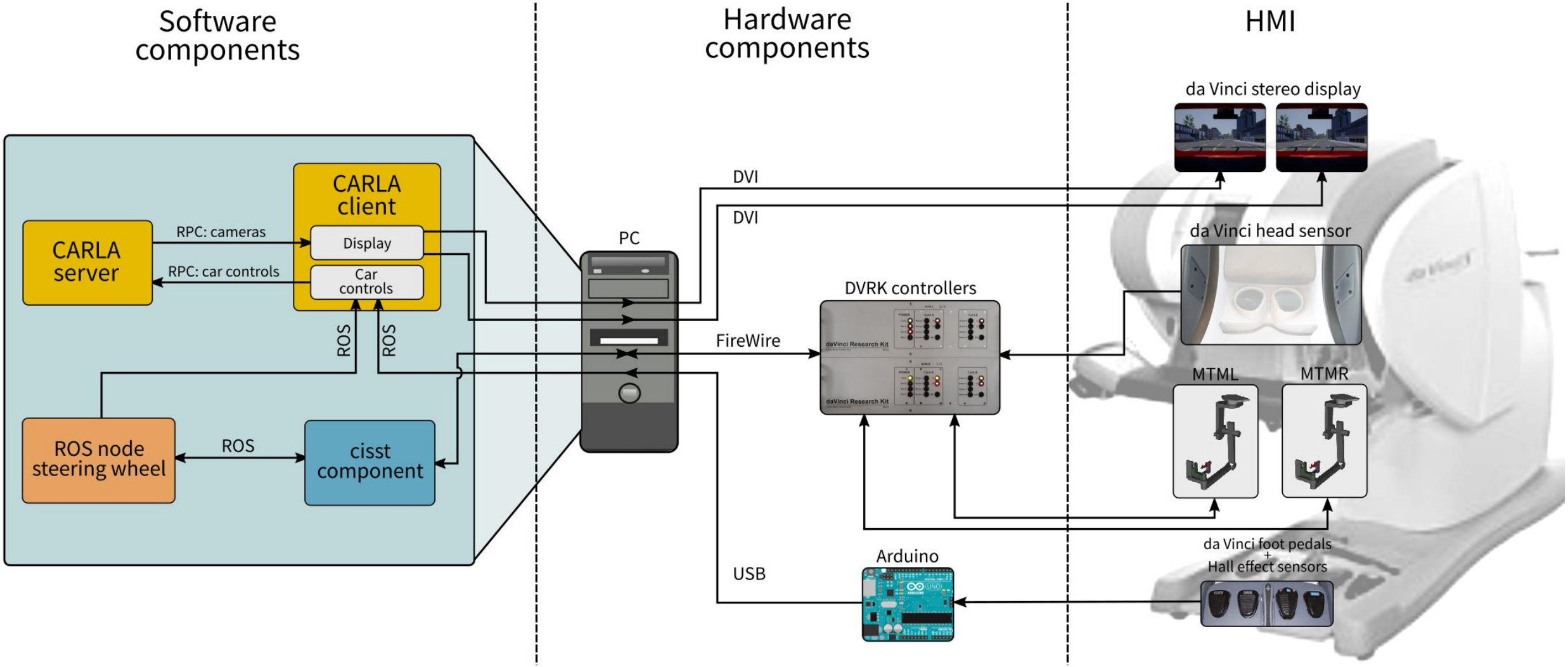


Images: A. Dosovitskiy, G. Ros, F. Codevilla, A. Lopez, and V. Koltun, "CARLA: An Open Urban Driving Simulator," in Proc. of the 1st Annual Conference on Robot Learning, Mountain View, CA, USA, Nov. 2017, pp. 1–16.

CARLA

- Open-source driving simulator
- Used widely in the research of autonomous driving
- ROS interface
- Built-in scenarios
- https://carla.org/

System architecture



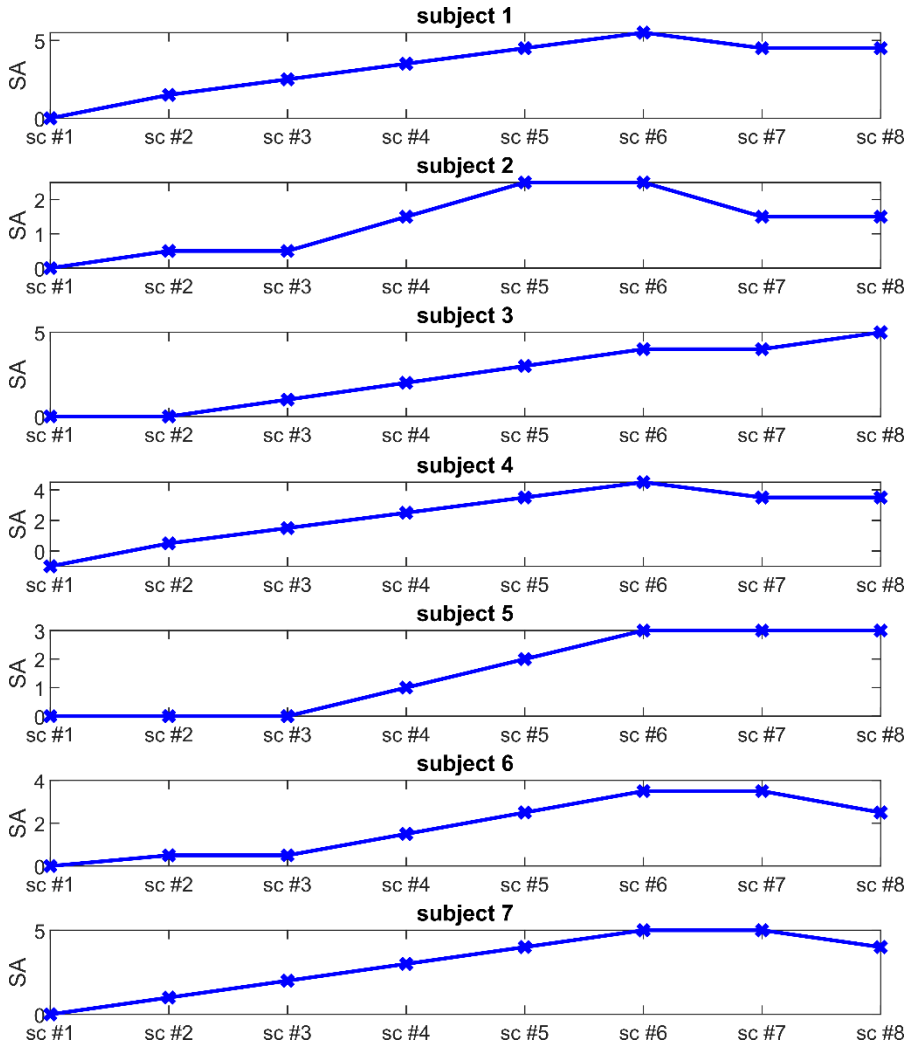
Experimental protocol

- 1 min practice
- 8 successive scenarios
  - True/False alarm
  - Car coming from front/ No car coming from front
  - Clear weather/Heavy rain
- 40–60 sec of autonomous driving
  - Head out of the display
  - Type a text message on a smartphone
- Audio alarm, 2 sec to handover

Experimental protocol

- 7 test subjects
- Questionnaire before experiment
  - Age
  - Driving experience
- Questionnaire after each scenario
  - Evaluate own reaction
  - Details of the environment
  - Questions on the simulated event

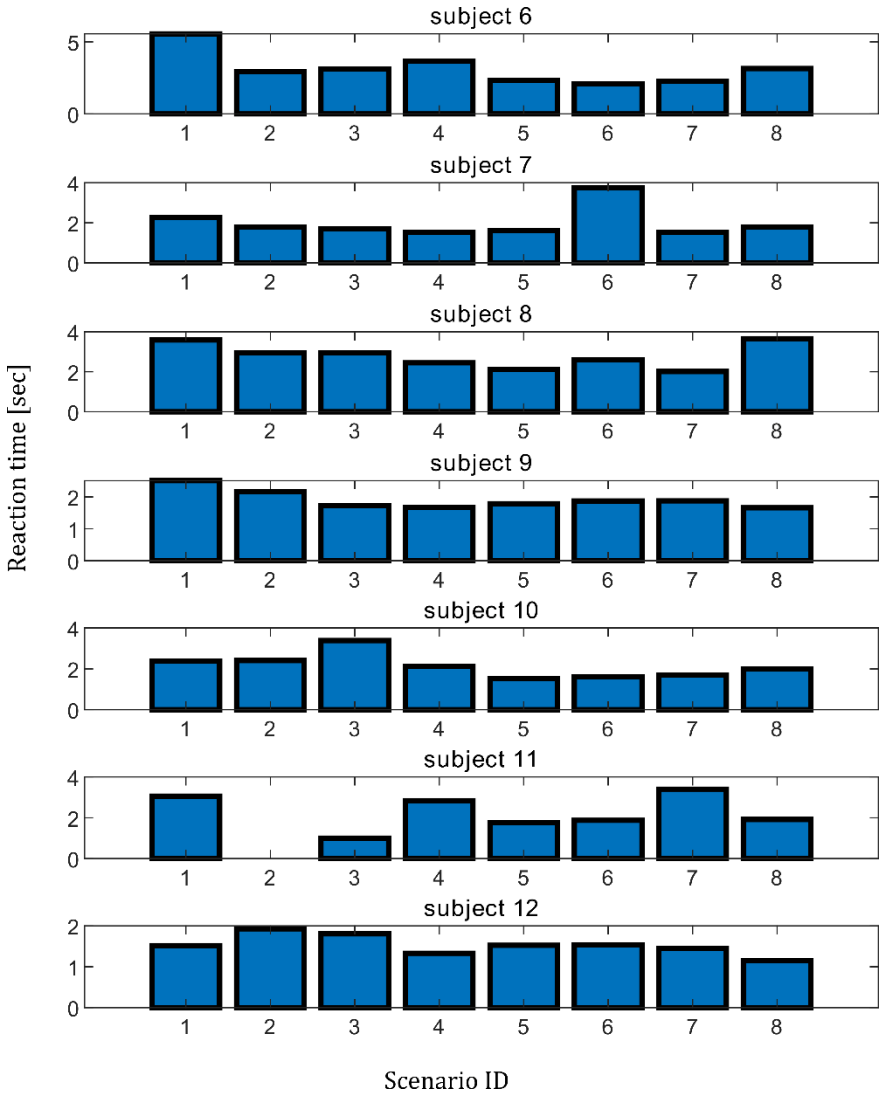
Results – Situation awareness (SA)



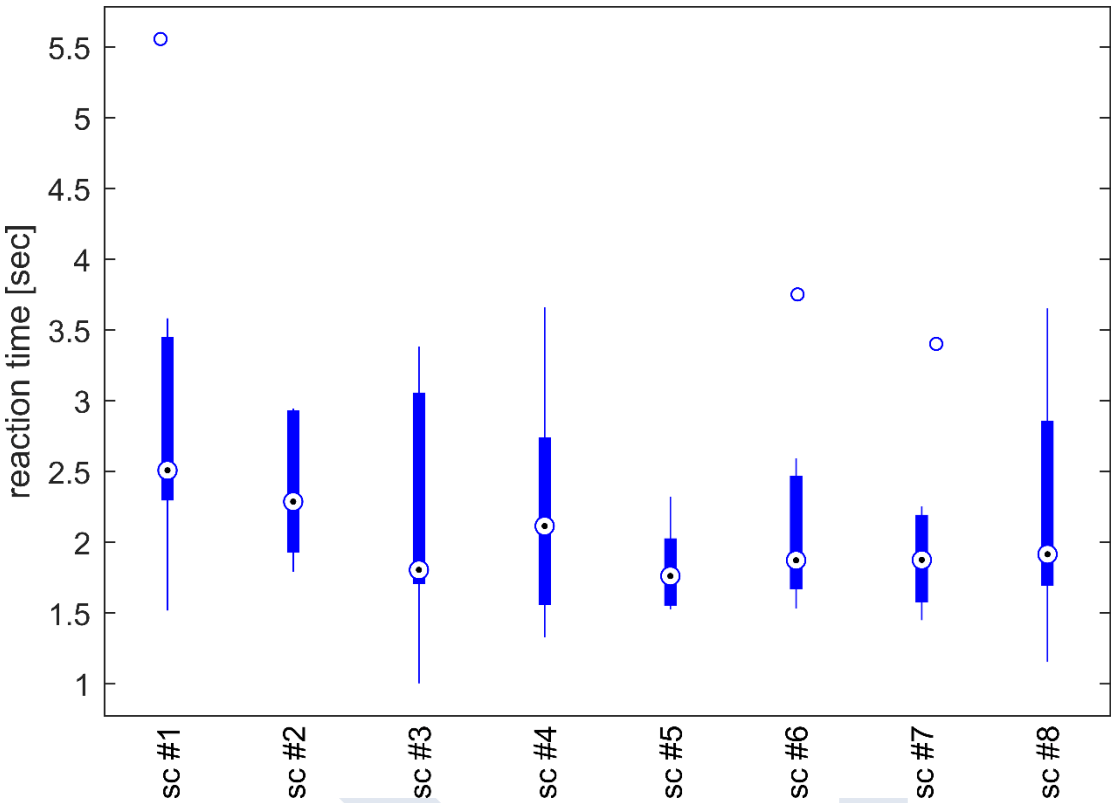
The evolution of Situation Awareness (SA) of the participants along the scenarios.

- SA scoring
  - Questions about the environment
  - 1 point for good answer
  - 0 point for neutral answer (I do not know)
  - –1 point for a wrong answer.

Results – Takeover time



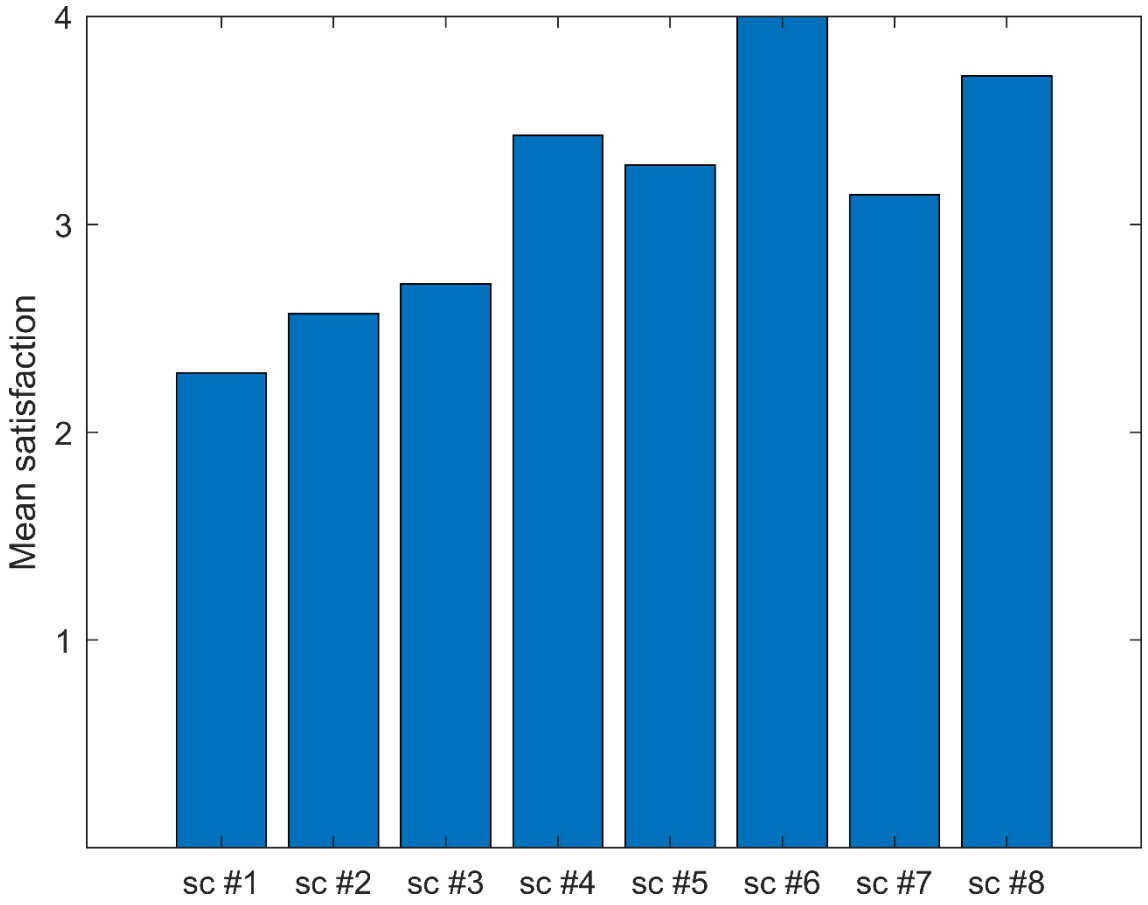
The takeover times (time between the handover request and the first physical reaction) of the participants in the 8 scenarios.



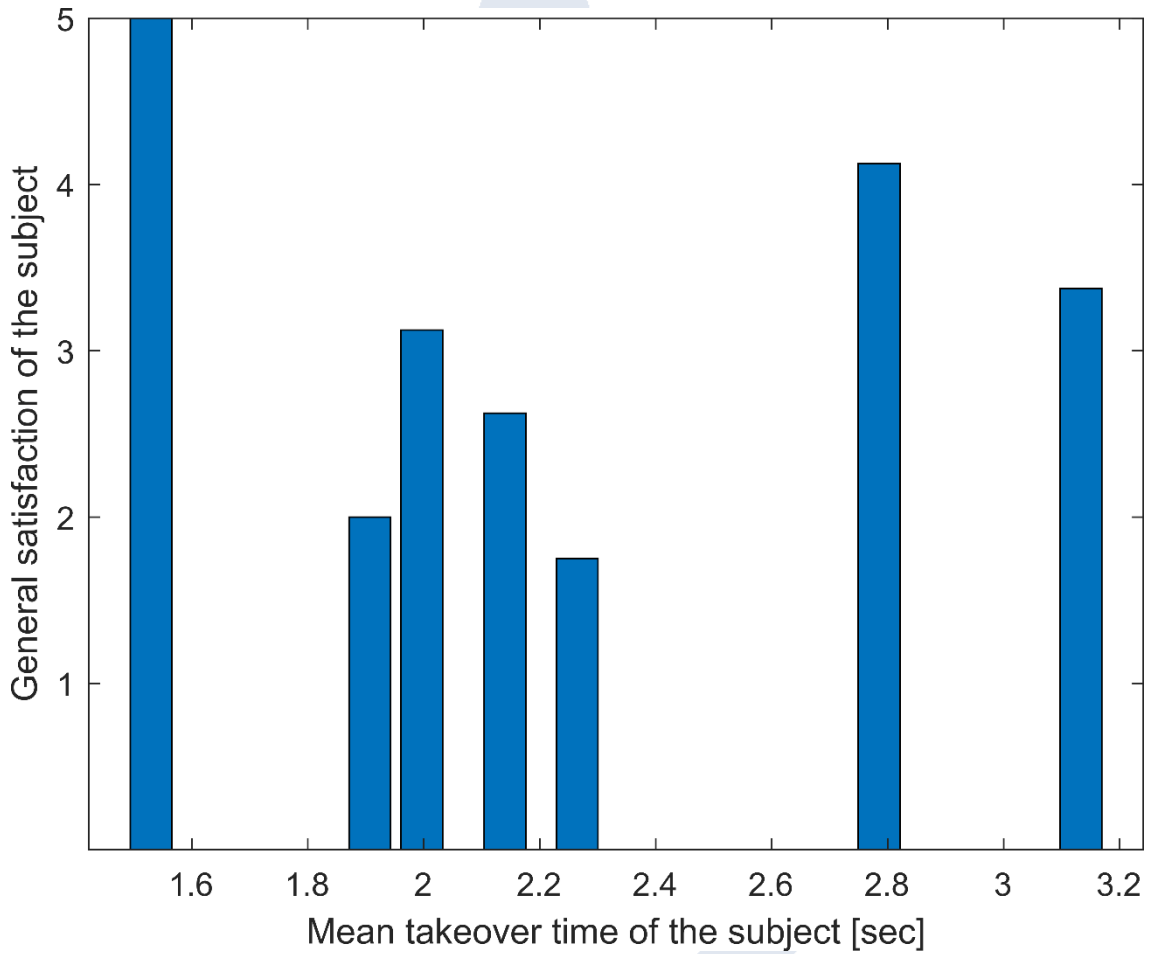
The takeover times in the 8 scenarios depicted in a compact boxplot:

- ***circles:*** *outliers*
- ***dotted circles:*** *medians*
- ***thick lines:*** *the ranges where the second and third quadrant of the takeover times are (25–75%)*
- ***thin lines:*** *the range of all the other takeover times in the current scenario*

Results – Own satisfaction



The mean satisfaction (averaged for all the participants) for each scenario on a scale of 1–5 (1–bad, 5–excellent).



The mean satisfaction of the subjects and their mean takeover times. Repeated scenarios' outcome was averaged for the same subject

Conclusions

- Objective human performance assessment platform
- DVRK and CARLA Simulator
- Emergency situations of L3 autonomous driving
- Upcoming studies:
  - Greater number of test subjects
  - Improved scenarios

Results

Measured takeover times are concordant with the values in the literature

Slight decrease of takeover time over the successive scenarios

→ increasing SA

Increase of SA scores from questionnaire over successive scenarios

→ increasing SA

Satisfaction with own performance does not seem to correlate to takeover time

Open-source implementation available on GitHub:
https://github.com/ABC-iRobotics/dvrk_carla

Acknowledgement

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http://irob.uni-obuda.hu

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Thank you!