Driver Response Times when Resuming Manual Control from Highly Automated Driving in Truck Platooning Scenarios

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Driver Response Times when Resuming Manual Control from Highly Automated Driving in Truck Platooning Scenarios

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MOTIVATION

- Automated platooning of trucks is getting increasing interest for its potentially beneficial effects on fuel consumption, driver workload, traffic flow efficiency and safety. Nevertheless, one major challenge lies in the safe and comfortable transitions of control from the automated system back to the human drivers, especially when they have been inattentive during highly automated driving. Studies specifically look into driver takeover performance when leaving a truck platoon are still scarce.

- Previous empirical studies showed large variance in driver take-over response times (RT), especially in non-emergency conditions. A close examination of driver takeover process and variability in normal operations is needed to ensure a minimum level of safety.

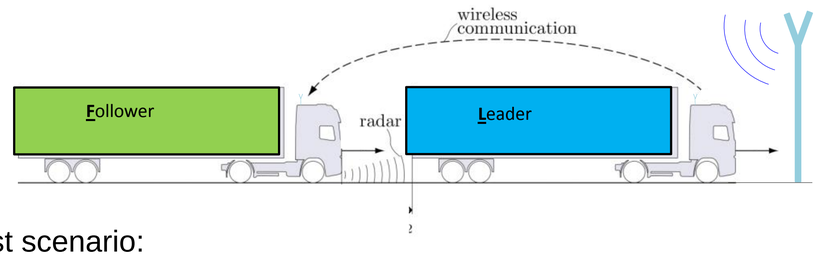
- The present study discussed how various task conditions influence driver perception-response times to resume manual control from highly automated driving. The parameters retrieved in this study will be utilized towards the design of an adaptive transition approach.

EXPERIMENTAL DESIGN

- 22 professional truck drivers participated in the experiment in the TNO high fidelity moving based simulator (DAF truck mock up)

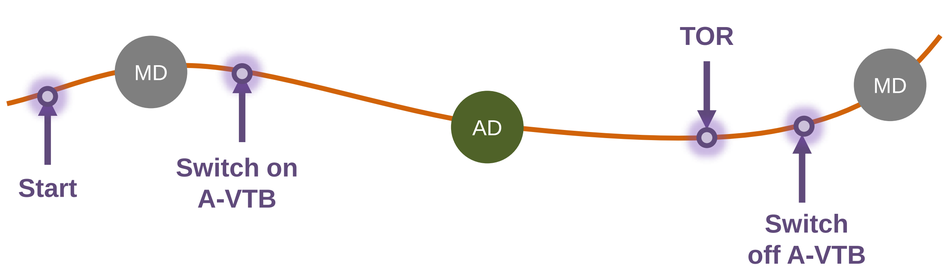
- Truck platooning system for testing: Adaptive Virtue Tow Bar (A-VTB)

- Two trucks are virtually connected via wireless communication
- The first truck: manually driven by a professional truck driver
- The second truck: driving behind the first truck automatically
- Deactivate the automated system: pressing the ‘on/off’ button near the steering wheel when the system requests manual take-over



- Test scenario:

The drivers started with manual driving (MD), then activated the A-VTB system to follow the lead truck automatically. After four to eight minutes of automated driving (AD), a take-over request (TOR) was issued and the drivers were asked to take over control whenever they felt ready to do so without time restrictions. They continued with a short MD phase until the end of the scenario.

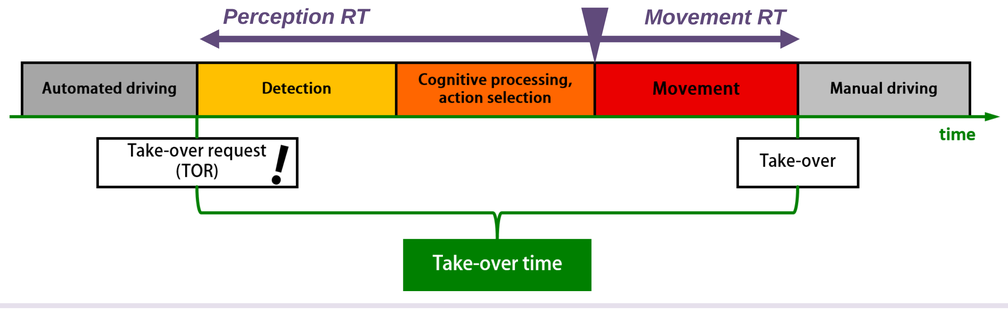


- Each participant performed three experimental conditions during AD (within-subject design):

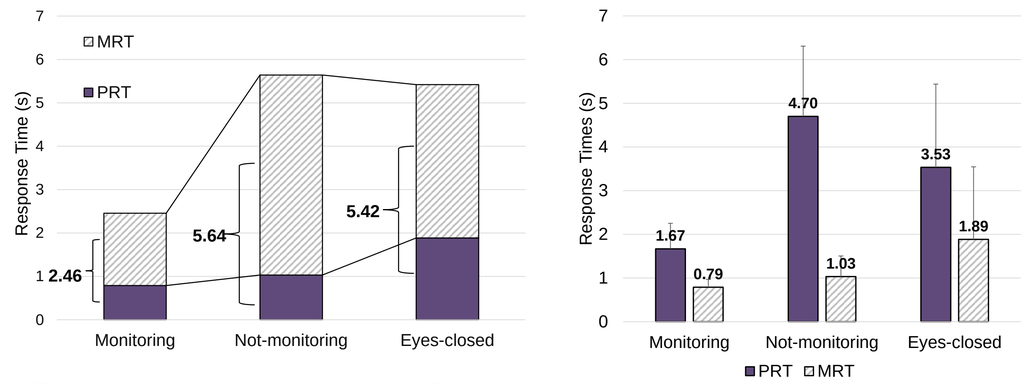
- **Driver Monitoring** (3 trials per pp) → monitoring the surroundings
- **Driver Not-monitoring** (3 trials per pp) →provided with a hand-held tablet PC and were asked to use this
- **Eyes-closed** (1 trial per pp)→ not allowed to open their eyes until receiving the take-over request

- Dependent measures: driver behavior and perception-response time when taking over (manually annotated from the video recordings)

- **Perception response time:** RT from the onset of the TOR until the start of driver hand movement reaching for the steering wheel
- **Movement response time:** RT from the start of driver hand movement until the driver pressed the A-VTB button to reclaim control
- **Take-over time:** RT from the TOR onset until the driver pressed the A-VTB button to reclaim control (the sum of perception RT and movement RT)

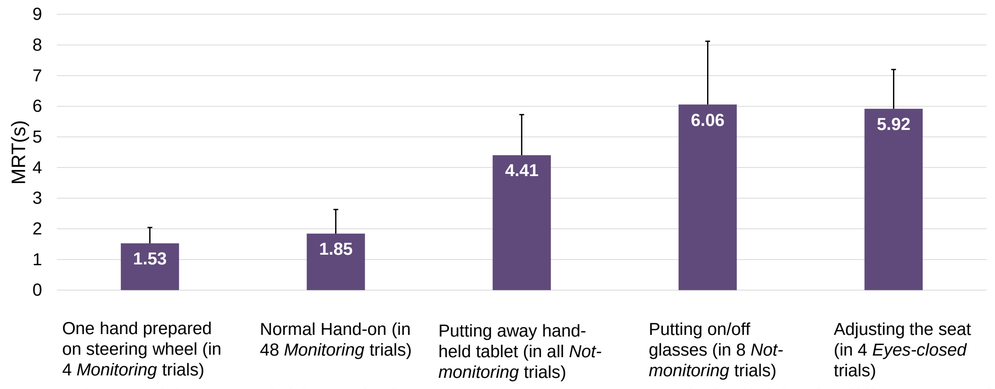


RESULTS



- **Take-over time**: Not-monitoring ≈ Eyes-closed >> Monitoring
- **Perception RT**: Eyes-closed > Not-monitoring ≈ Monitoring
- **Movement RT**: Not-monitoring > Eyes-closed >> Monitoring
- For all conditions: Movement RT >> Perception RT
- Larger variance in movement RT within Not-monitoring and Eyes-closed conditions

“≈” : no statistically significant difference; “ > ” : statistically significant difference at the level of .05; “ > >” statistically significant difference at the level of .001



- Various driver activities during TO process caused individual differences in movement RTs.

KEY POINTS

- Driver **task conditions influenced take-over RT significantly**. For *Not-monitoring* condition, the longer take-over RT was mainly caused by the additional hand movement RT to put away the device rather than a longer perception RT. *For Eyes-closed* condition, both slower perception and movement RTs contributed to the longer take-over RT.

- **Movement RT is the dominant factor influencing total take-over RT**, influenced by driver activities to resume physical readiness. To help the driver with a rapid resumption of physical readiness is important in addition to the development of efficient warning systems.

- In summary, this study showed **substantial differences in RT components between conditions and individual drivers**. A personalized driver readiness predictor can support a safe and comfortable transition instead of a single take-over time criterion.

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