Wizard-of-Oz studies on test track and public roads

L3Pilot Final Event

Linda Pipkorn
Chalmers University of Technology

Overall aim, research focus and questions

- **Overall aim:**
  > To inform the design of **safe** Automated Driving Functions (ADFs)
  > Understanding drivers' behavior during transitions of control from ADFs to manual

- **Research focus:**
  > Data collected in realistic environment (test track) and real traffic
  > Detailed analysis of driver response process and glance behavior

- **Research questions**:
  > Take-over performance: How do drivers respond when they are required to retake control in take-over situations?
  > Visual attention: What is the effect of ADF use on driver attention to the road?

Overview of all supplementary studies

	ADEST study	Traffic Jam Pilot study	L3Pilot Test track study	L3Pilot Wizard of oz pilot	Intoxication study
Test environment	Test track	Test track	Test track	Public road	Test track
System type	Assistance	Manual and ADF	ACC and ADF	ADF	Manual, Assistance and ADF
Conflict scenario	Lead-vehicle cut-out + stationary object	Road-work zone	Lead-vehicle cut-out + stationary object	None	None
Conditions	Hands on wheel requirement (yes/no)	Automation duration (4 min/14 min)	Take-over request timings (9 s/18 s time-to-collision)	Repeated exposure to take-over requests	Intoxicated (yes/no)
Analysis	Response process to conflict	Take-over performance	Take-over performance	Take-over performance + visual attention	Visual attention
Publications (published or submitted)	Driver conflict response during supervised automation: Do hands on wheel matter? (2021, TRF)	Automation Aftereffects: The Influence of Automation Duration, Test Track and Timings. (2021, IEEE ITS)	It's about time! Early take-over request in conditional automation enables safe response to a lead-vehicle cut-out scenario. (2021, submitted)	Driver glance behaviour before and after take-over requests in conditional automation on public road. (2021, submitted)	The influence of alcohol, automation, and non-driving related tasks on driver visual behavior on test track (2021, in prep.)

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General Method

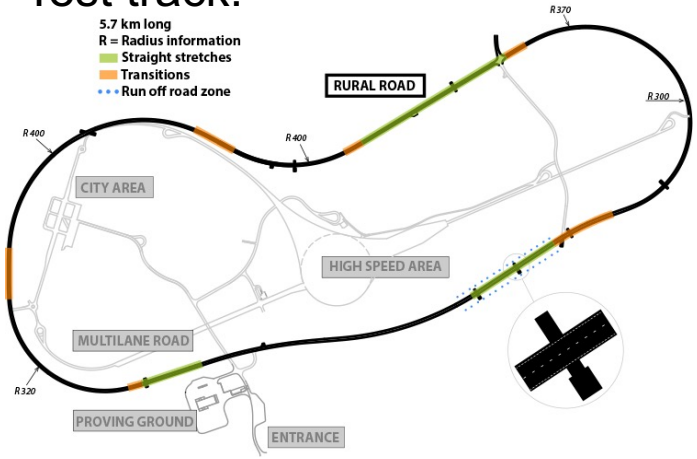
Test-environments:

- ASTA Zero test track (TJP, L3 TT)
- Public road in Gothenburg (L3 PR)

Vehicle:

- XC90 Wizard of Oz vehicle to simulate an ADF

Test track:



Public road:

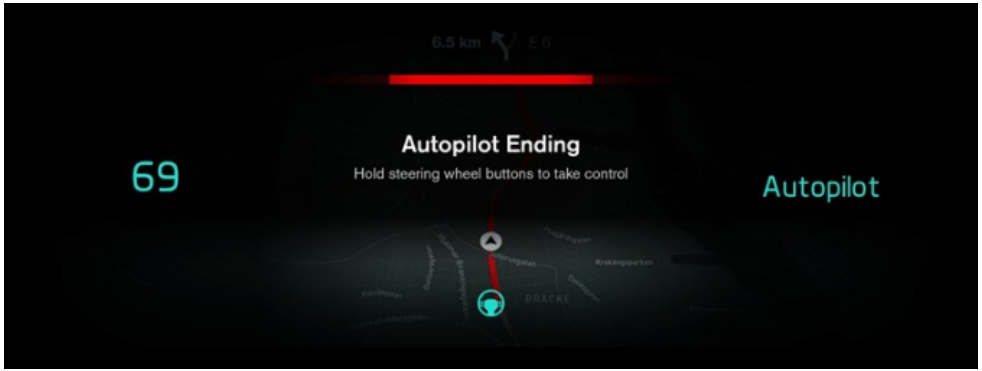
General Method

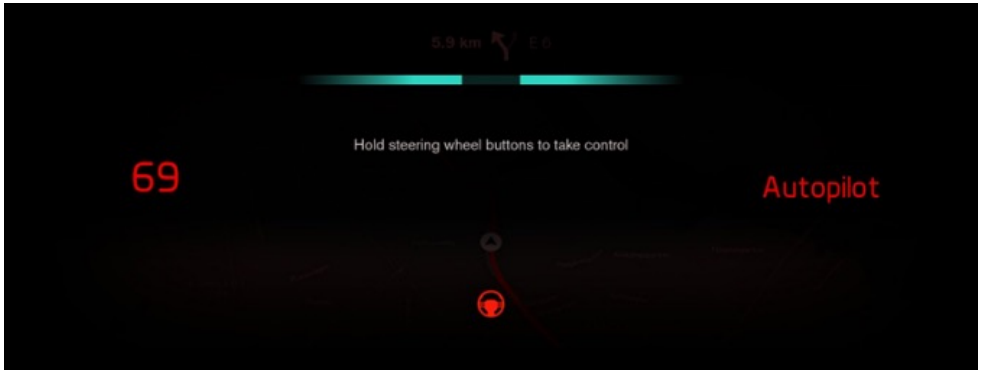
ADF:

- Unsupervised
- Need to respond to take-over request (TOR).

Take-over request:

- Audio & visual
- Press and hold steering wheel buttons to deactivate

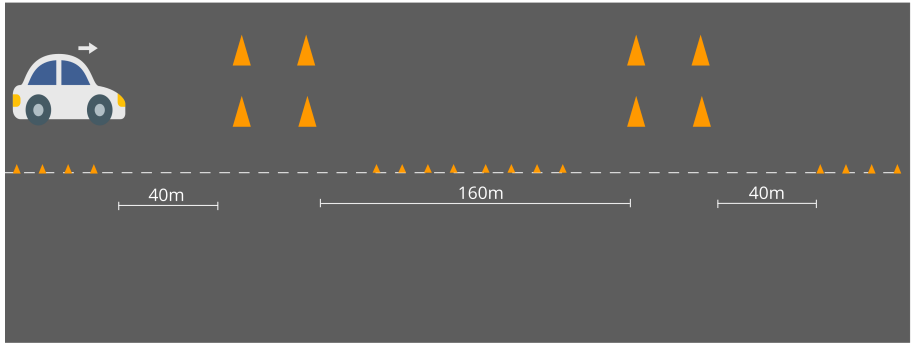




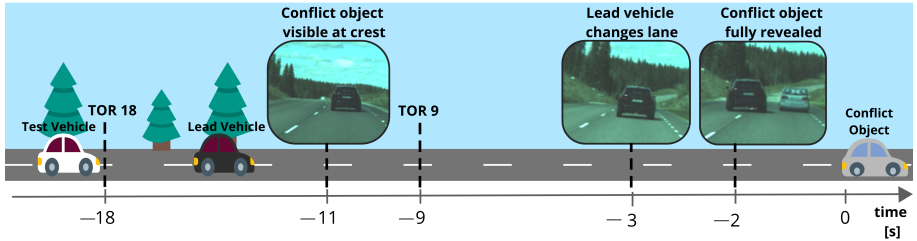
Methods

- No event (L3 PR), a cone zone (TJP) or a lead-vehicle cut-out (L3 TT).
- **Baseline driving:** Manual (L3 PR, TJP) and ACC (L3 TT) baseline recorded for comparison
- **Data processing:** Manually coded driver actions and glance from video. Vehicle signals.

Traffic jam pilot study (TJP):



L3Pilot test track study (L3 TT):



Overall aim, research focus and questions

Take-over performance

- How do drivers respond when they are required to retake control in take-over situations?

Visual attention

- What is the effect of ADF use on driver attention to the road?

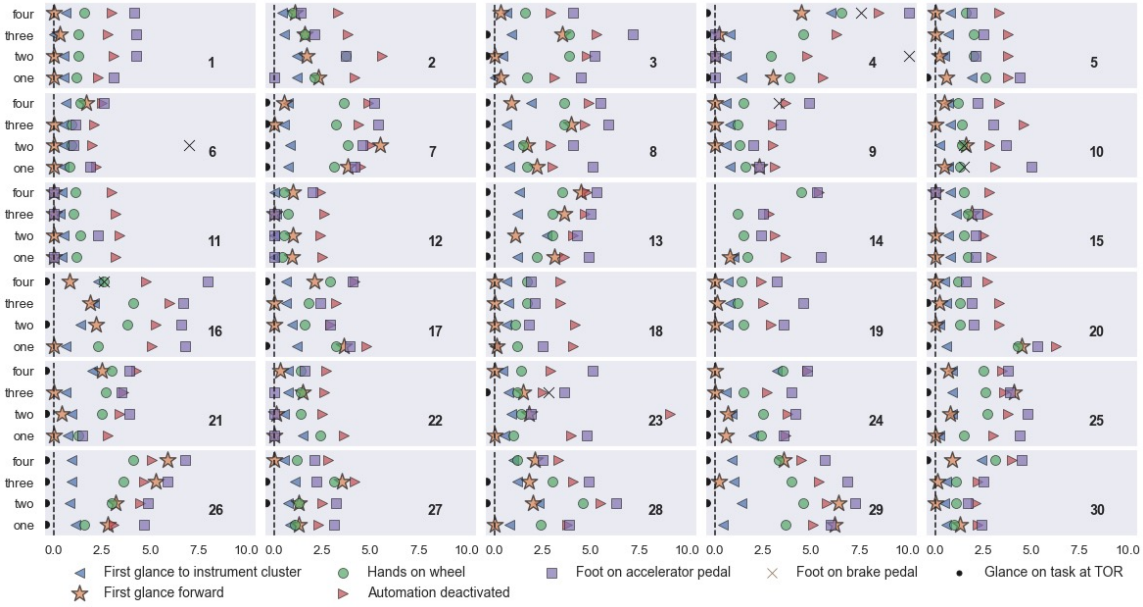
Findings: Take-over performance

Take-over performance

- Response process and response times to a take-over request for first glance to instrument cluster, first glance forward, hands on the steering wheel, feet on pedals, automation deactivation.
- Vehicle trajectories when passing cone zone (TJP) and stationary object (L3 TT)

Findings: Take-over performance

- All participants responded to the TOR. Some needed multiple attempts.



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Findings: Take-over performance

- All participants responded to the TOR. Some needed multiple attempts.
- Few put foot on brake pedal (L3 PR). All put the foot on the accelerator within 10 s from the TOR.

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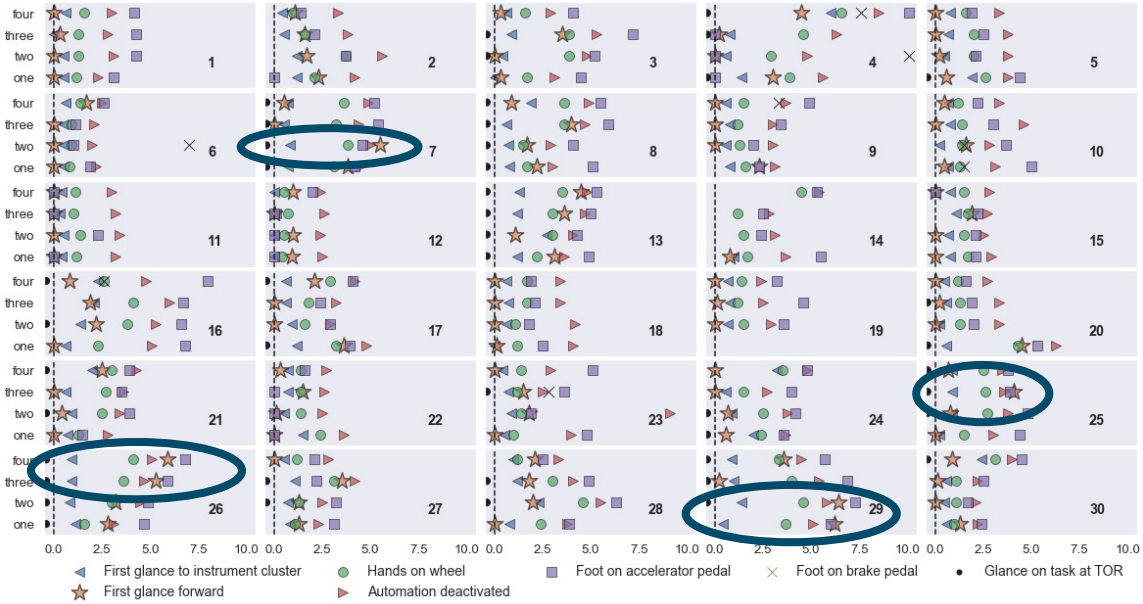
Findings: Take-over performance

- All participants responded to the TOR. Some needed multiple attempts.
- Few put foot on brake pedal (L3 PR). All put the foot on the accelerator within 10 s from the TOR.
- Some deactivated automation before looking to the forward road.



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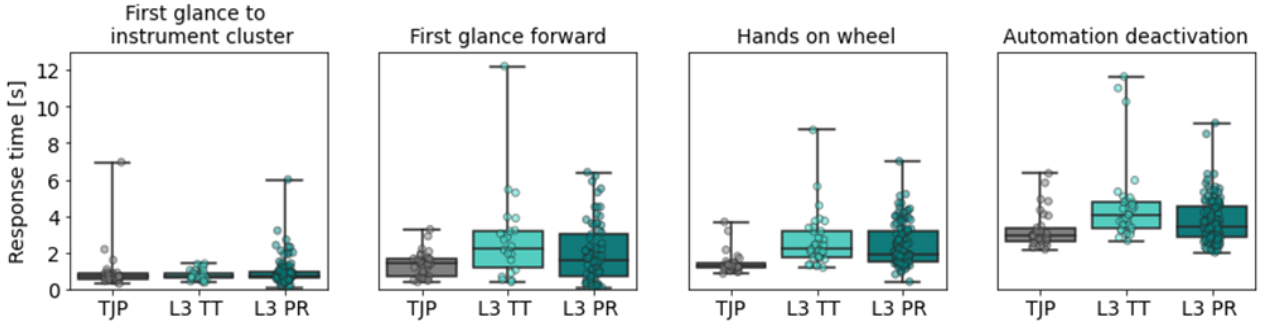
Findings: Take-over performance

Drivers' response to the TOR: a process of actions that requires time.



	First glance to IC [s]			First glance forward [s]			Hands on wheel [s]			Foot on accelerator [s]			Automation deactivated [s]		
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Median	0.7	0.7	0.7	1.4	2.2	1.6	1.2	2.2	1.6	N/A	N/A	3.9	2.9	4.1	3.4
90%ile	1.0	1.2	1.5	2.0	5.1	4.5	1.8	3.8	3.8	N/A	N/A	6.0	4.7	5.8	5.3
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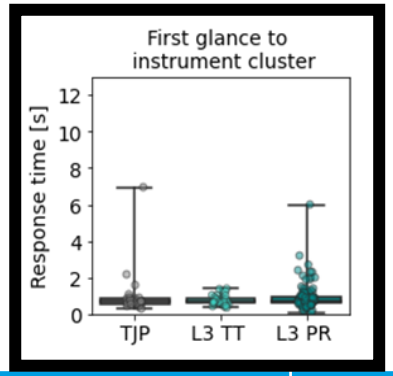

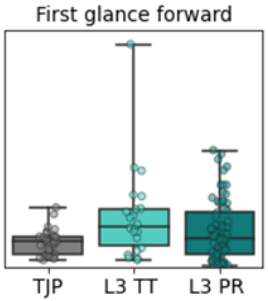

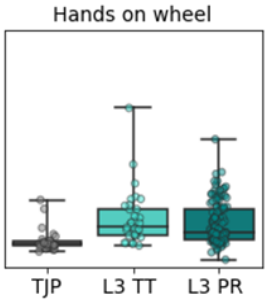

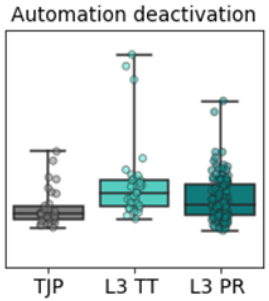

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90%ile	1.0	1.2	1.5	2.0	5.1	4.5	1.8	3.8	3.8	N/A	N/A	6.0	4.7	5.8	5.3
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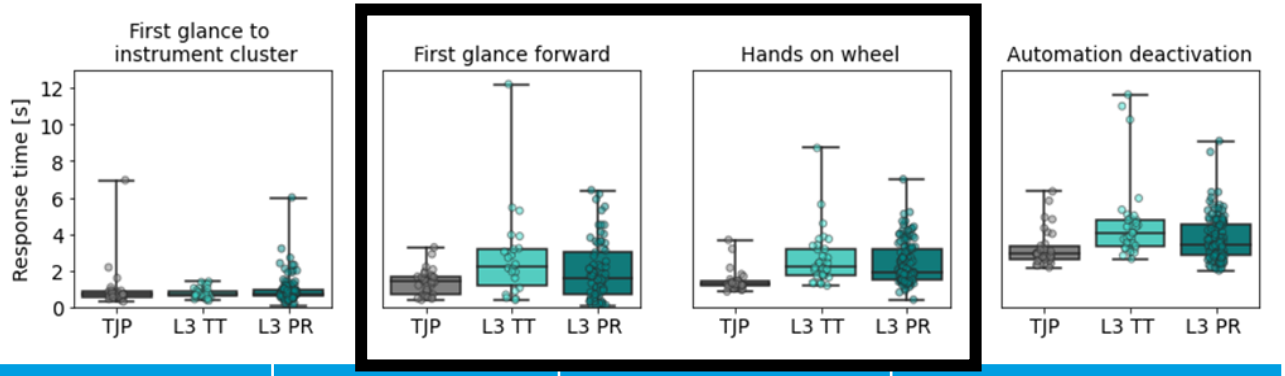

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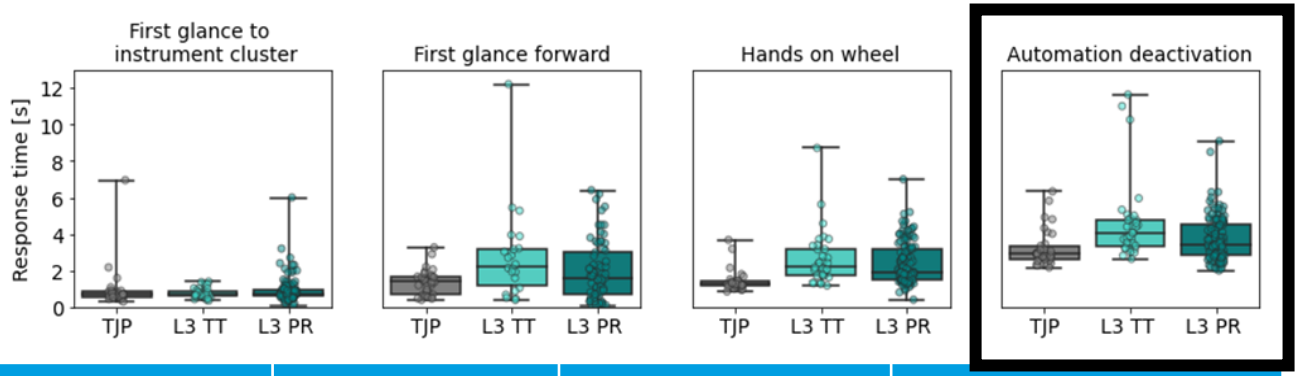

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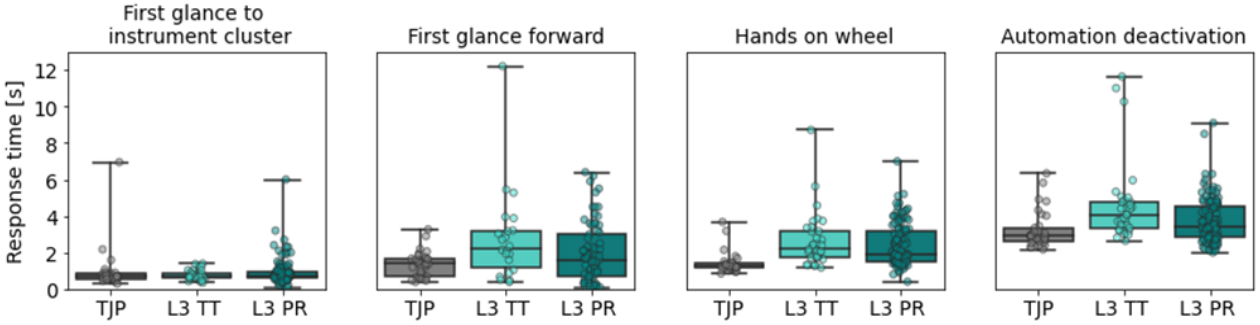

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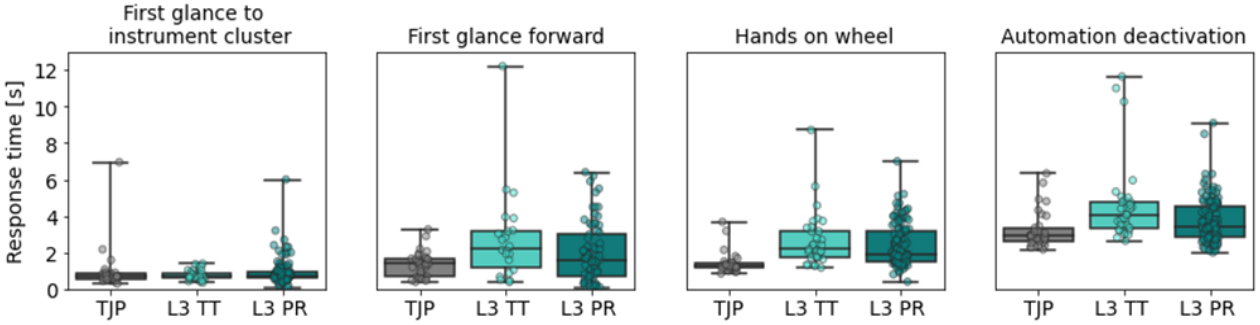

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Study	**TJP**	**TT**	**PR**	**TJP**	**TT**	**PR**	**TJP**	**TT**	**PR**	**TJP**	**TT**	**PR**	**TJP**	**TT**	**PR**
Median	0.7	0.7	0.7	1.4	2.2	1.6	1.2	2.2	1.6	N/A	N/A	3.9	2.9	4.1	3.4
90%ile	1.0	1.2	1.5	2.0	5.1	4.5	1.8	3.8	3.8	N/A	N/A	6.0	4.7	5.8	5.3
Max	7.0	1.4	6.0	3.3	12.2	6.4	3.7	8.7	6.6	N/A	N/A	10.1	6.3	11.6	9.1

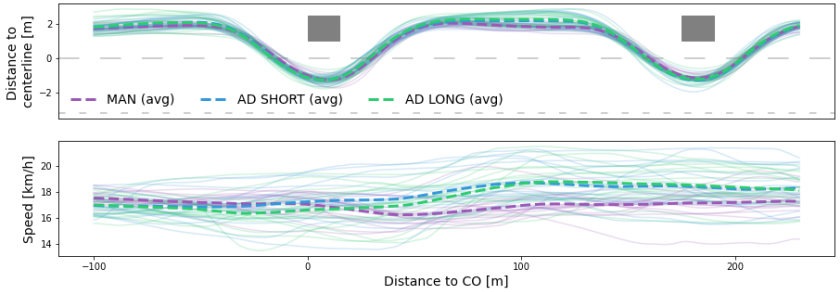
[1] Pipkorn, L., Victor, T., Dozza, M., & Tivesten, E. (2021). Automation Aftereffects: The Influence of Automation Duration, Test Track and Timings. IEEE Transactions on Intelligent Transportation Systems.
[2] Pipkorn, L., Tivesten, E., & Dozza, M. (2021). It's about time! Early take-over request in conditional automation enables safe response to a lead-vehicle cut-out scenario. Manuscript submitted for publication.
[3] Pipkorn, L., Tivesten, E., & Dozza, M. (2021). Driver response to take-over requests in automated driving in real traffic. Manuscript in preparation.

Findings: Take-over performance

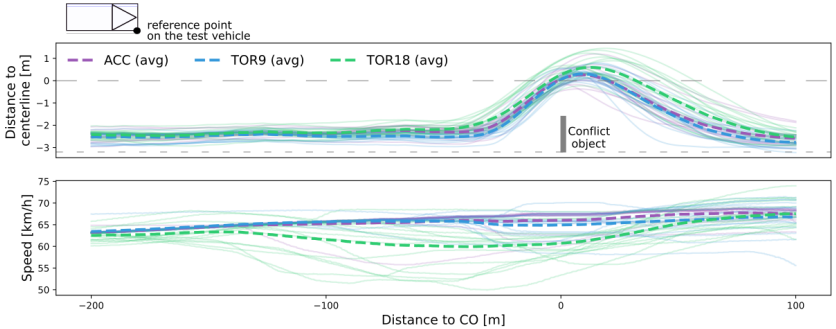
After automation deactivation:

- All participants managed to maneuver through the cone zone (TJP) and pass the stationary object (L3 TT).
- No crashes occurred.

Traffic jam pilot study (TJP):



L3Pilot test track study (L3 TT):



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In real traffic, drivers are able to transition control from ADF to manual driving in response to a take-over request. However, the transition should be considered as a process of actions (look to instrument cluster, hands on wheel, deactivate automation) that requires a certain amount of time. In addition, some drivers may deactivate automation in response to the take-over request before looking to the forward roadway. Thus, ADF needs to be responsible for safe driving, up to the point of deactivation and some time after.

To conclude,

The critical question of what happens if a driver voluntary or involuntary fails to respond to a take-over request remains unknown.

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The critical question of what happens if a driver voluntary or involuntary fails to respond to a take-over request remains unknown. Future ADFs should preferably be able to detect if a driver is not fallback-ready and activate a safety back-up response to prevent the risk of a crash.

Overall aim, research focus and questions

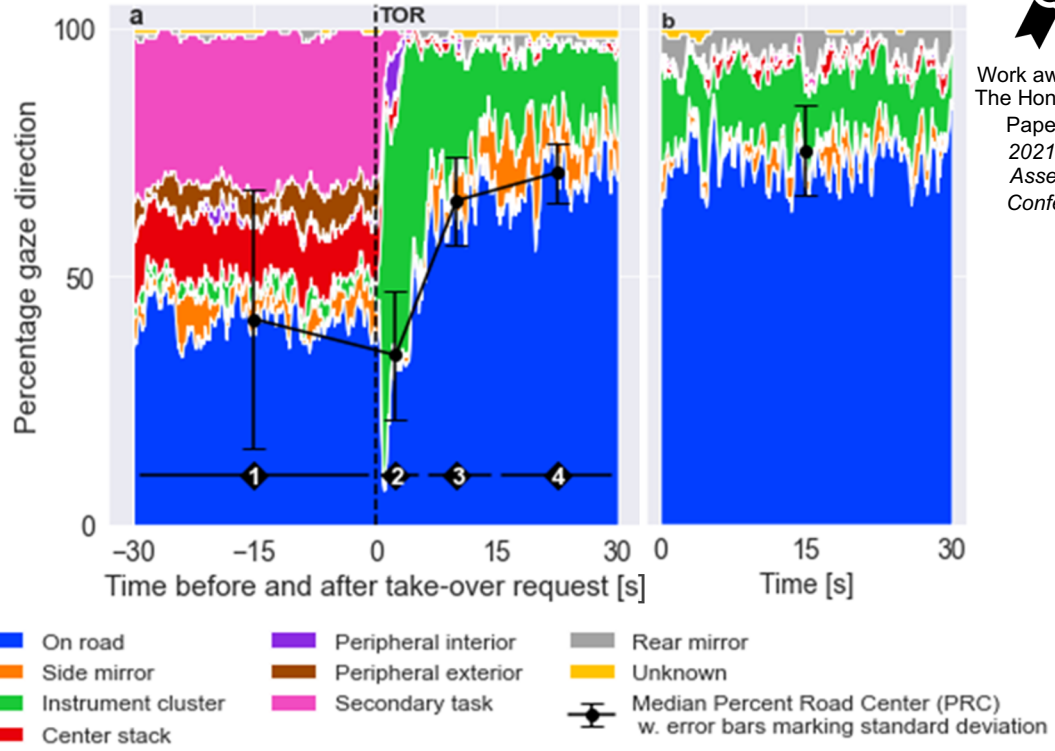
Take-over performance

- How do drivers respond when they are required to retake control in take-over situations?

Visual attention

- What is the effect of ADF use on driver attention to the road?

Findings: Visual attention

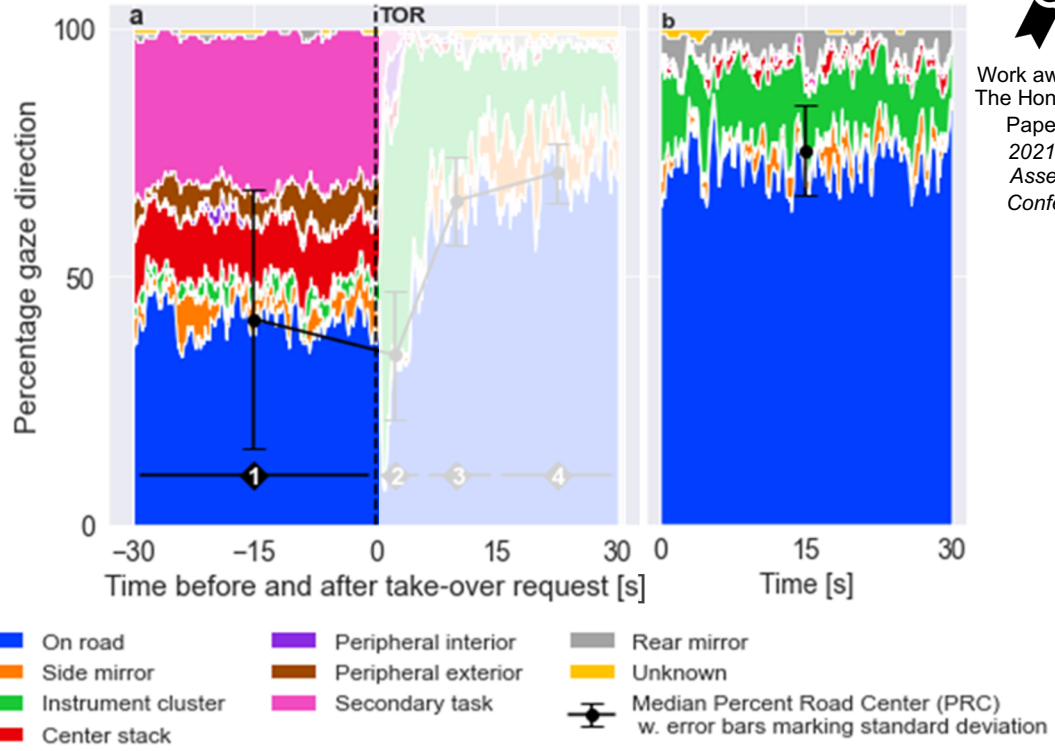


Work awarded with The Honda Student Paper Award *2021 Driving Assessment Conference*

Pipkorn, L., Dozza, M., & Tivesten, E. (2021). *Driver visual attention before and after take-over requests in conditional automation on public road.* Manuscript submitted for publication.

Findings: Visual attention

- Reduced visual attention to the forward road during automation, compared to manual.



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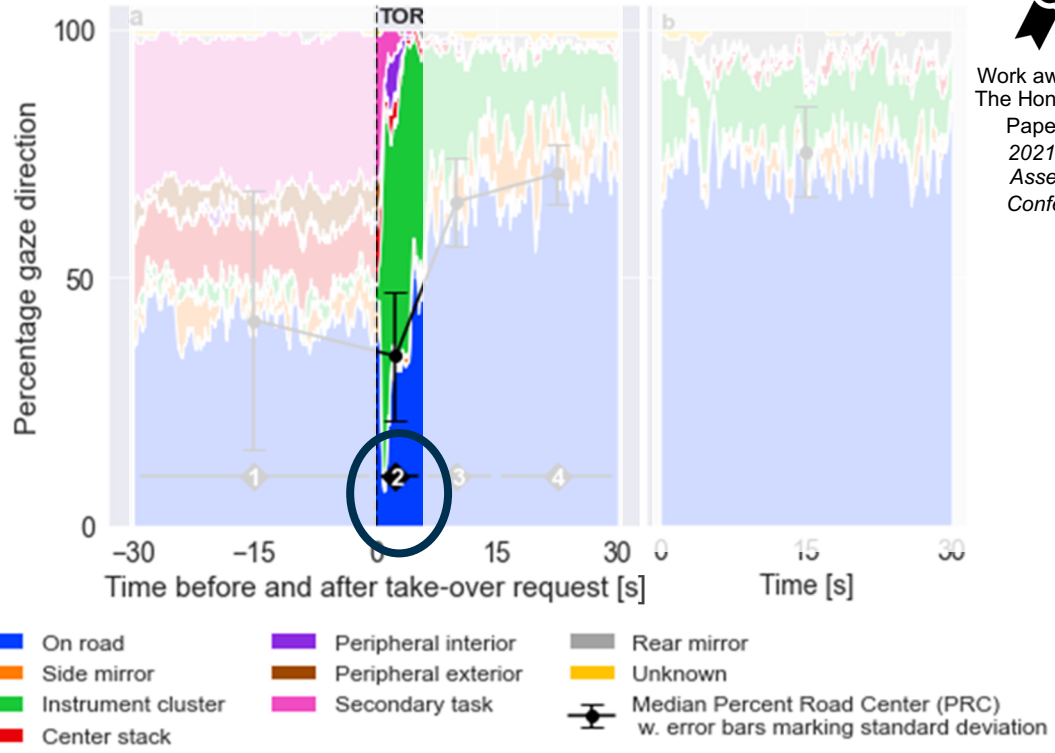
- Reduced visual attention to the forward road during automation, compared to manual.
- 1 s after a take-over request only 8% of gaze are on road



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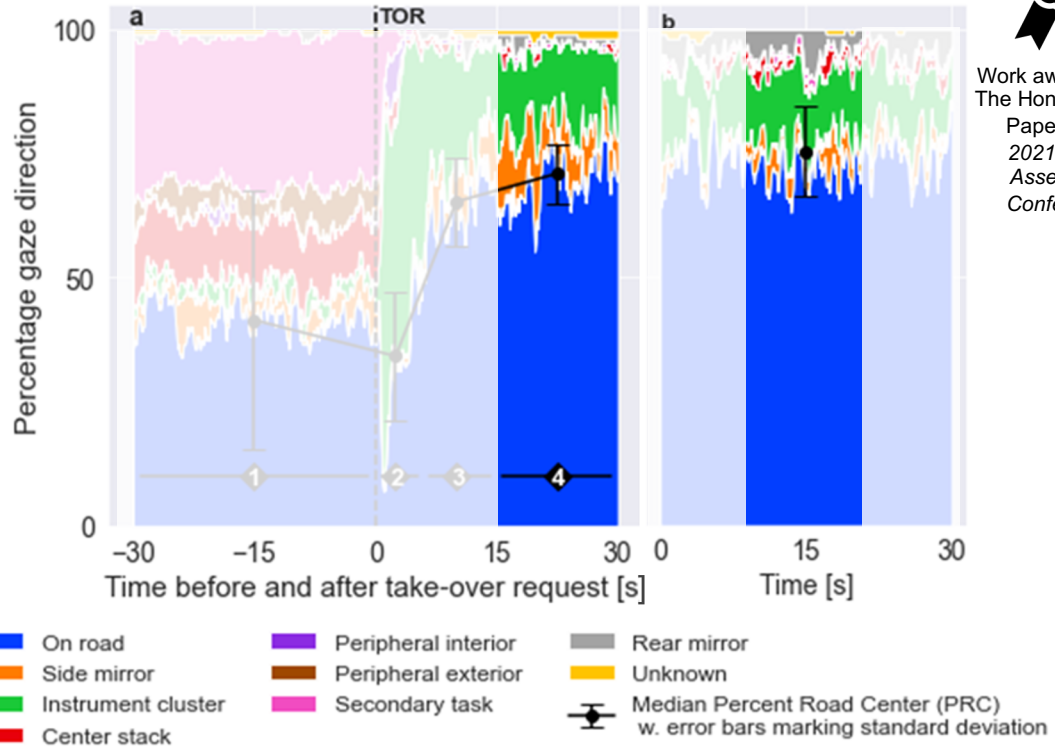
Findings: Visual attention

- Reduced visual attention to the forward road during automation, compared to manual.
- 1 s after a take-over request only 8% of gaze are on road
- Levels of visual attention towards the forward road did not return to the levels observed during manual driving until after 15 s had passed.



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Before, and shortly after, receiving a take-over request, drivers look less to the forward road than in manual driving. In fact, a take-over request may trigger drivers to look off road rather than on road.
Thus, drivers may not be aware of the driving environment when taking back control and may therefore miss safety-critical events.

Publications list

- Pipkorn, L., Victor, T. W., Dozza, M., & Tivesten, E. (2021). Driver conflict response during supervised automation: Do hands on wheel matter?. Transportation Research Part F: Traffic Psychology and Behaviour, 76, 14-25. https://doi.org/10.1016/j.trf.2020.10.001

- Pipkorn, L., Victor, T., Dozza, M., & Tivesten, E. (2021). Automation Aftereffects: The Influence of Automation Duration, Test Track and Timings. IEEE Transactions on Intelligent Transportation Systems. Doi: 10.1109/TITS.2020.3048355

- Pipkorn, L., Tivesten, E., & Dozza, M. (2021). It's about time! Early take-over request in conditional automation enables safe response to a lead-vehicle cut-out scenario. Manuscript submitted for publication.

- Pipkorn, L., Dozza, M., & Tivesten, E. (2021). Driver glance behaviour before and after take-over requests in conditional automation on public road. Manuscript submitted for publication.

- Pipkorn, L., Tivesten, E., & Dozza, M. (2021). Driver response to take-over requests in automated driving in real traffic. Manuscript in preparation

- Tivesten, E., Broo, V, Ljung Aust, M. (2021). The influence of alcohol, automation, and non-driving related tasks on driver visual behavior on test track. Manuscript in prep.

Thank you for your kind attention.

Linda Pipkorn
Linda.pipkorn@chalmers.se

Thomas Streubel
thomas.Streubel@chalmers.se

Marco Dozza
marco.dozza@chalmers.se

Emma Tivesten
Emma.Tivesten@volvocars.com

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