ASSESSING SITUATION AWARENESS WHILE DRIVING WITH AUTOMATION

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BACKGROUND

SITUATION AWARENESS (SA) IN DRIVING WITH AD

▶ While driving in automated mode, the driver is no longer in control of the vehicle and monitors instead the driving situation.

▶ Due to being out of the loop, situation awareness can be reduced compared to manual driving.

▶ In takeover situations, situation awareness is believed to be crucial for safe reactions especially in demanding situations.

▶ At a takeover request (TOR) the driver needs to reach a sufficient level of SA to react appropriately.

MEASURING SITUATION AWARENESS (SA)

▶ There are many measures used for assessing SA during driving with / without AD:

  ▶ Subjective SA via questionnaires during or after a drive

  ▶ Correctness of situational understanding via interviews / questioning (SAGAT, Online-Probes; e.g. *Endsley, 1995; Strybel et al., 2016*)

  ▶ Quality of driving behaviour / driving errors

  ▶ Analysis of gaze behaviour as prerequisite of SA

▶ Frequently, results from different measures contradict each other (e.g. *van den Beukel, van der Voort & Eger, 2016; Cortens, 2019; Schwindt et al. 2023*)

THEORY

SITUATION AWARENESS IN DRIVING
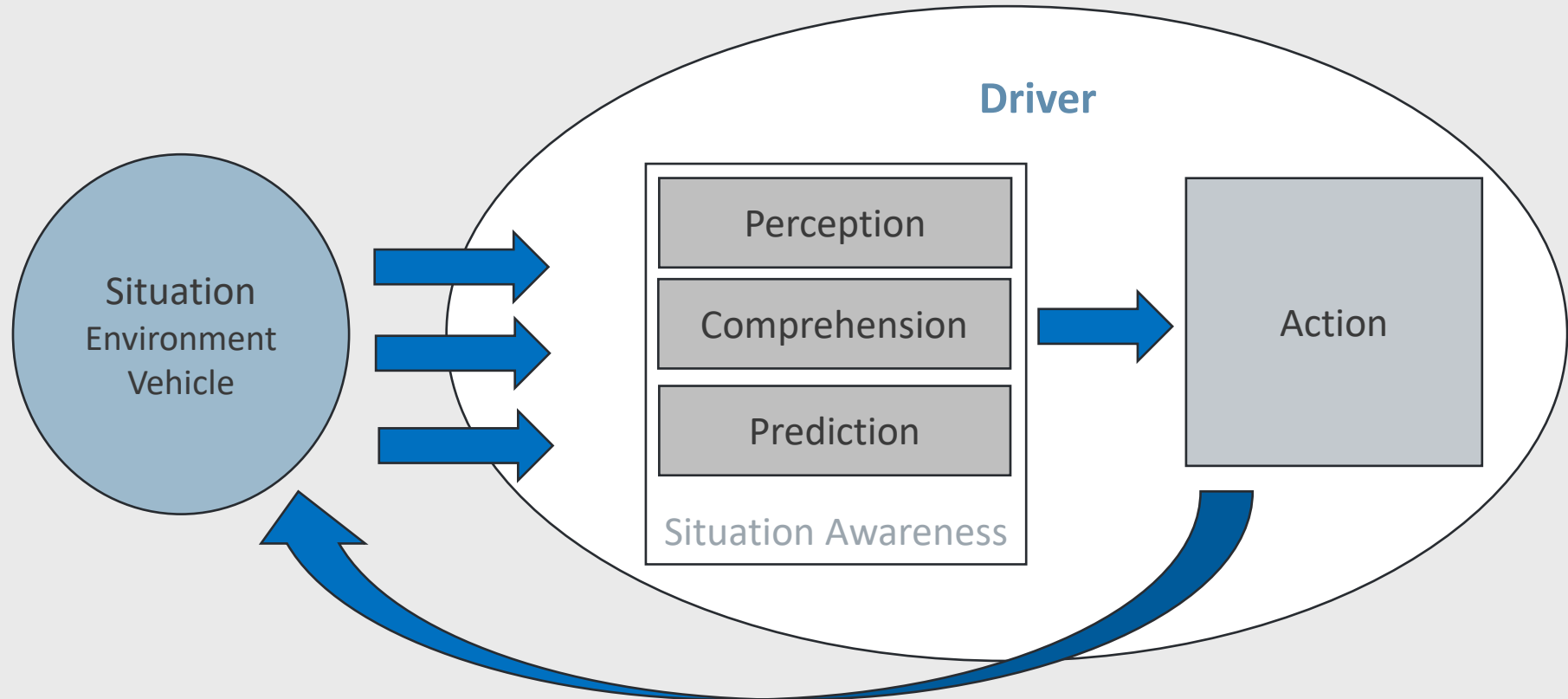
During manual driving: Driver is in the loop:

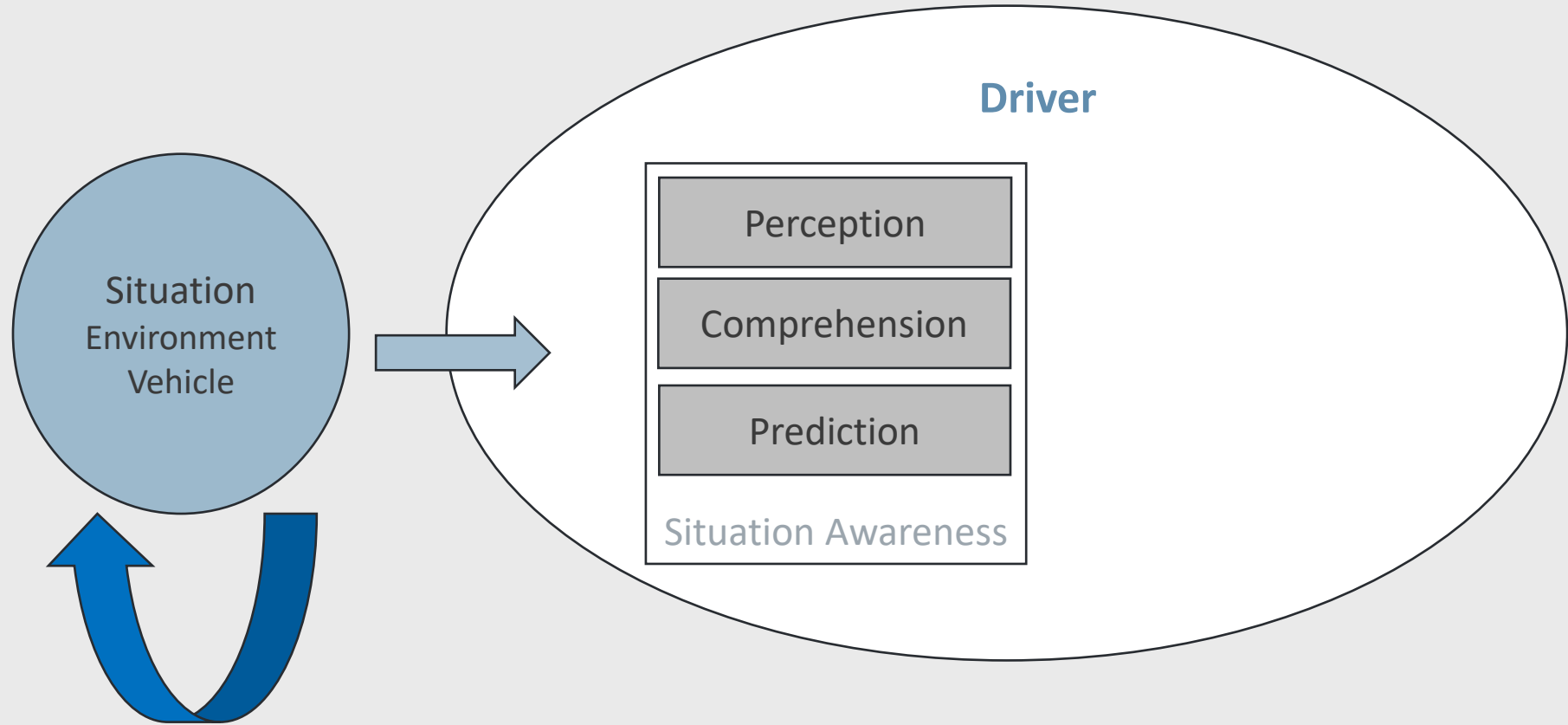▶ Interacts continuously with vehicle / environment → Feedback loop between driver & situation

Situation awareness necessary for successful interaction

▶ Components of situation awareness: (visual) perception, comprehension of situation, prediction of future development

SITUATION AWARENESS IN AUTOMATED DRIVING

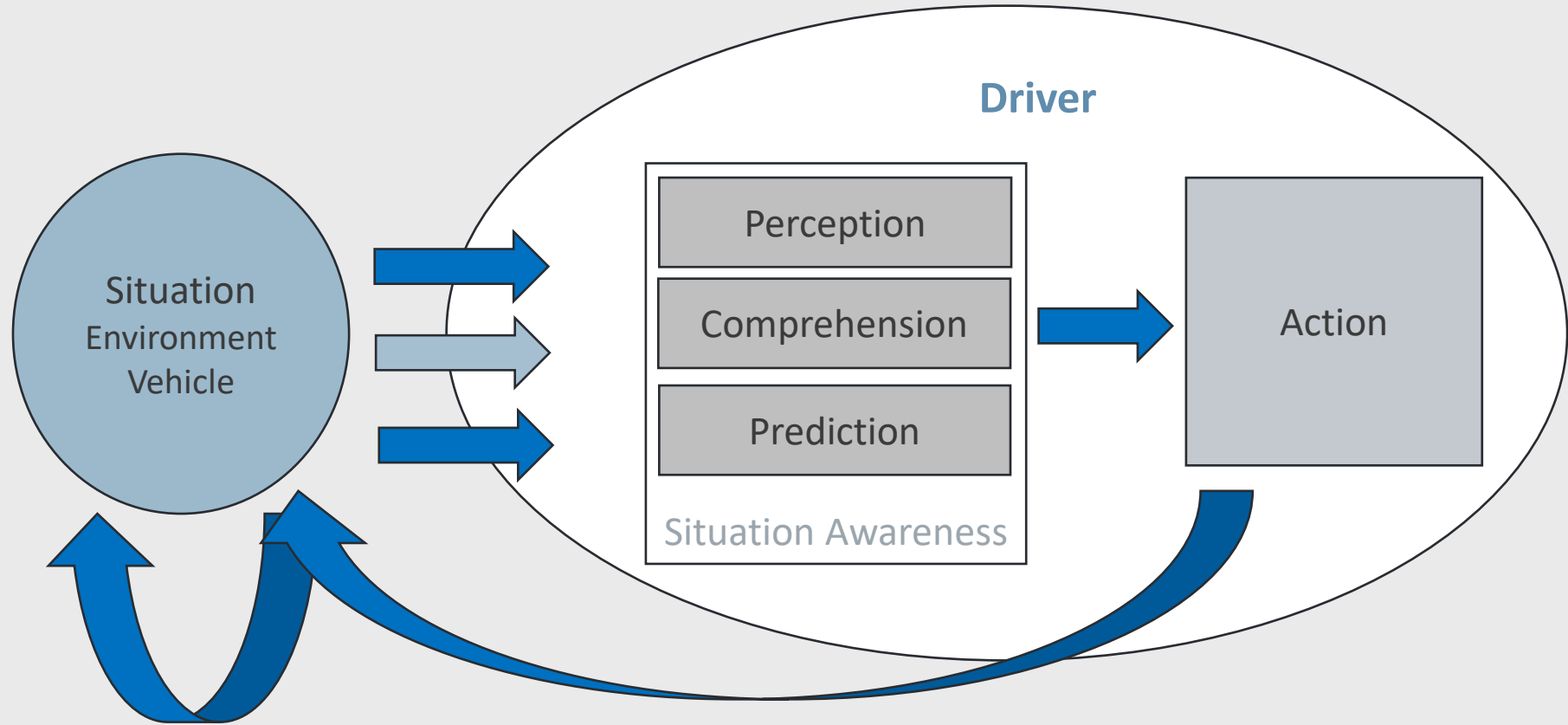**Driver**

| Perception |
| Comprehension |
| Prediction |

Situation Awareness

Situation
Environment
Vehicle

In AD Mode

EXPERIMENTAL APPROACH

RESEARCH QUESTIONS

▶ How can situation awareness in driving with AD be measured?

  ▶ In AD mode only limited set of potential indicators available

    ▪ Driving behaviour can not be evaluated as vehicle is driving

    ▪ In L3 / L4 driving, monitoring of driving scenery is not mandatory

  ▶ SAGAT / Online probes interact with driving and lead to focus on remembering details of the situation

▶ How do the different indicators relate to each other?

APPROACH

▶ Experimental manipulation of level of situation awareness while being in AD mode / at TORs.

▶ Assessment of situation awareness and related concepts with a variety of indicators.

METHODS

VARIATION OF LEVEL OF SITUATION AWARENESS

Manipulation of visual perception in AD mode:

L2	L3+	L3	Black
AD is instructed as L2 system Driver needs to stay attentive during AD mode	AD is instructed as L3 system Driver can watch video during AD mode Additional information is provided on HMI during TORs	AD is instructed as L3 system Driver can watch video during AD mode No additional information	AD is instructed as L3 system Driver can watch video during AD mode Projection of scenery is turned black during AD mode

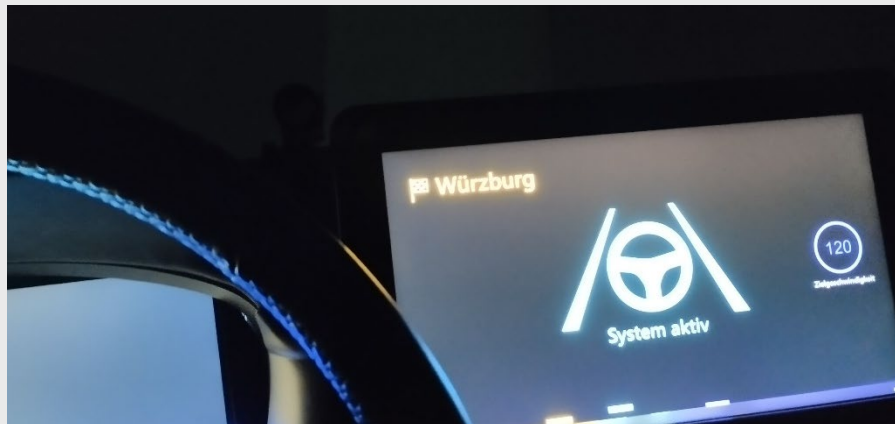→ 4 experimental conditions that are expected to be linked to different levels of situation awareness

METHODS

IMPLEMENTATION OF CONDITIONS

AD MODE

▶ Normal driving environment: L2, L3, L3+

▶ Reduced visual perception: Black

AT TOR

▶ Standard HMI: L2, L3, Black

▶ Extended HMI: L3+

METHODS

EXPERIMENTAL DESIGN

STUDY SETUP

▶ Driving simulator study, in which N=41 participants experience an AD-system in various conditions

▶ Implemented route consists of multiple scenarios with surrounding traffic and diverse demands

▶ Situation awareness in AD mode is experimentally varied by influencing visual perception while driving in AD mode

MEASURING SITUATION AWARENESS

▶ Multiple measures for situation awareness are used. Results for the **bold ones** are presented today.

	Assessment	
	During AD mode	**At TORs**
Subjective SA - post-drive	**Questionnaire items**	**Questionnaire items**
Subjective SA – during drive		**Questionnaire items**
Objective SA – during drive	Online probes	
Behavioural measures	Gaze behaviour	Gaze behaviour
		Quality of takeover reaction
		Takeover reaction time

RESULTS

SUBJECTIVE SITUATION AWARENESS IN AD MODE – POST DRIVE
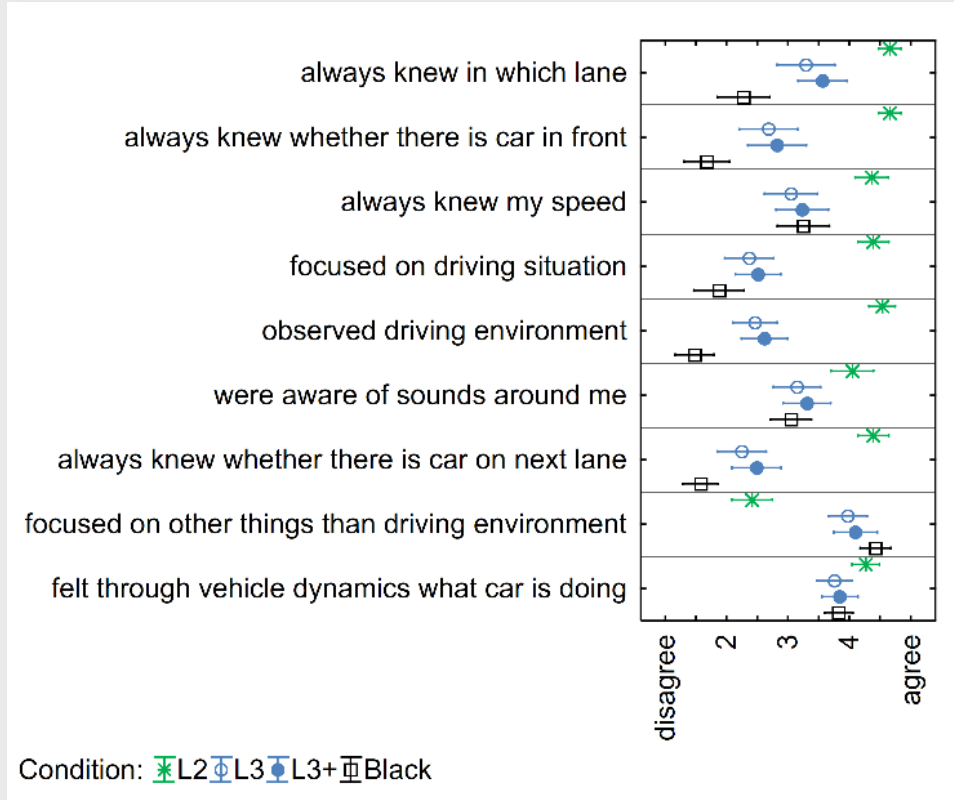
Item	df	F	p
knew in which lane	3,111	32.6	<.001
knew car in front	3,111	52.3	<.001
knew my speed	3,111	18.9	<.001
focused on driving	3,111	47.8	<.001
observed environment	3,111	64.6	<.001
were aware of sounds	3,111	7.9	<.001
knew car on next lane	3,111	68.7	<.001
focused on other things	3,111	35.5	<.001
felt vehicle dynamics	3,111	4.2	<.01

▶ Significant differences between conditions in perceived situation awareness while driving in AD mode.

▶ **Visual perception of driving environment**　　　　　　　　**L2　>　L3 & L3+　>　Black**

▶ **Non-visual perception & perception of in-vehicle information　L2　>　L3 & L3+ & Black**

RESULTS

SUBJECTIVE SITUATION AWARENESS AT TORS – POST DRIVE
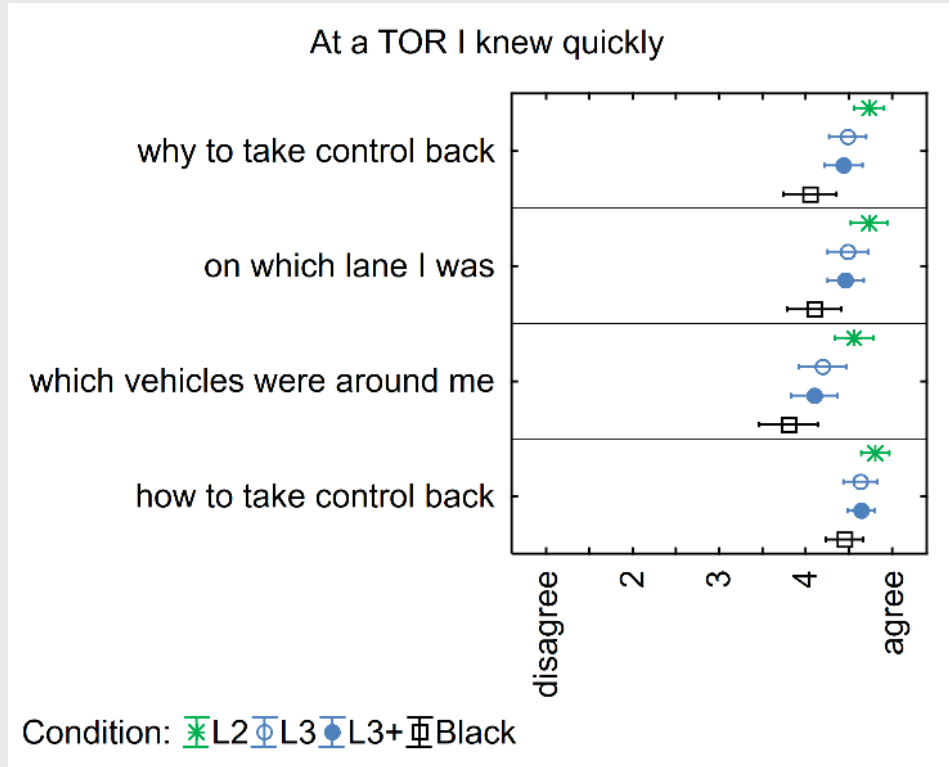
Item	df	F	p
knew why TOR	3,111	8.5	<.001
knew on which lane	3,111	7.4	<.001
knew vehicles around me	3,111	8.4	<.001
knew how to take control back	3,111	3.4	<.05

▶ Significant differences between conditions in perceived situation awareness during TOR.

▶ **Compared to L2, perception & understanding during takeover reactions is significantly reduced in the other conditions:**

L2   >   L3 & L3+   >   Black

RESULTS

SUBJECTIVE SITUATION AWARENESS AT TORS – DURING DRIVE

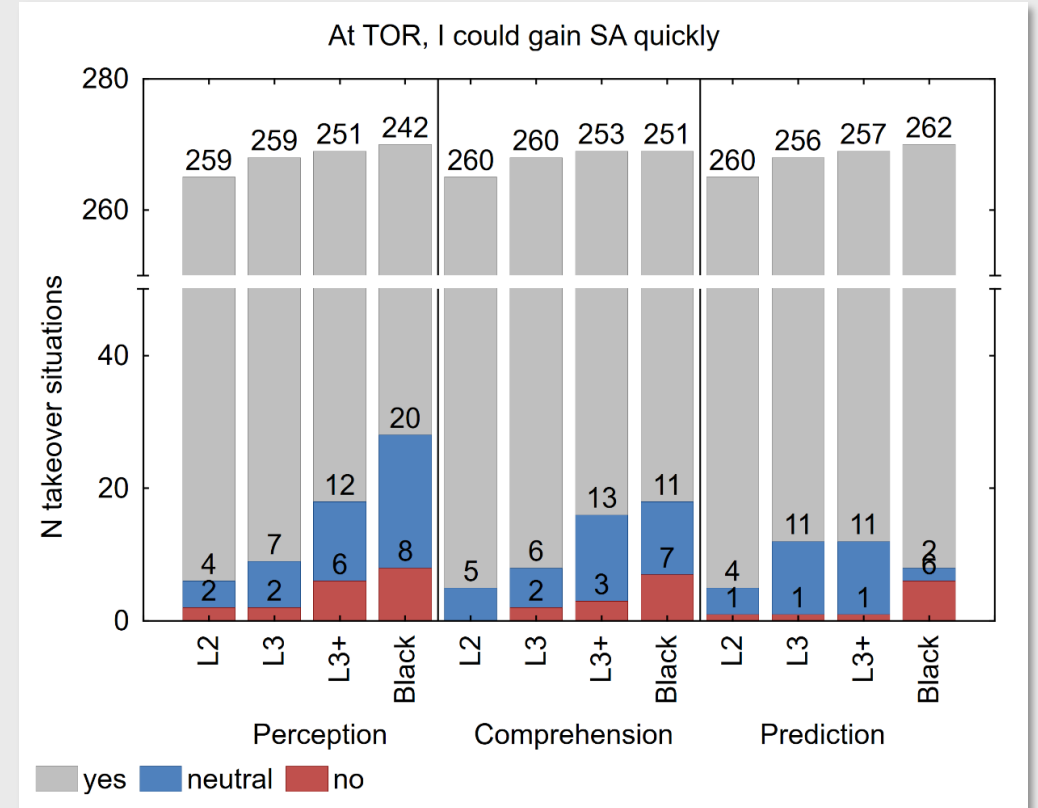Three yes/no questions after each TOR (about 270 TORs per condition).

Ease of gaining situation awareness is assessed separately for the thee components of SA.

Results of Chi-square tests:

ease of perception: X^2=20.4, df=6, p<.01

ease of comprehension: X^2=14.0, df=6, p<.05

ease of prediction X^2=17.7, df=6, p<.01

At TOR, I could gain SA quickly

▶ Overall, no issue with gaining SA at TORs. In all conditions, at least 90% answers stating that SA was gained quickly.

▶ **However, based on the remaining few situations with problems gaining SA, especially in the black condition SA at a TOR is significantly reduced.**
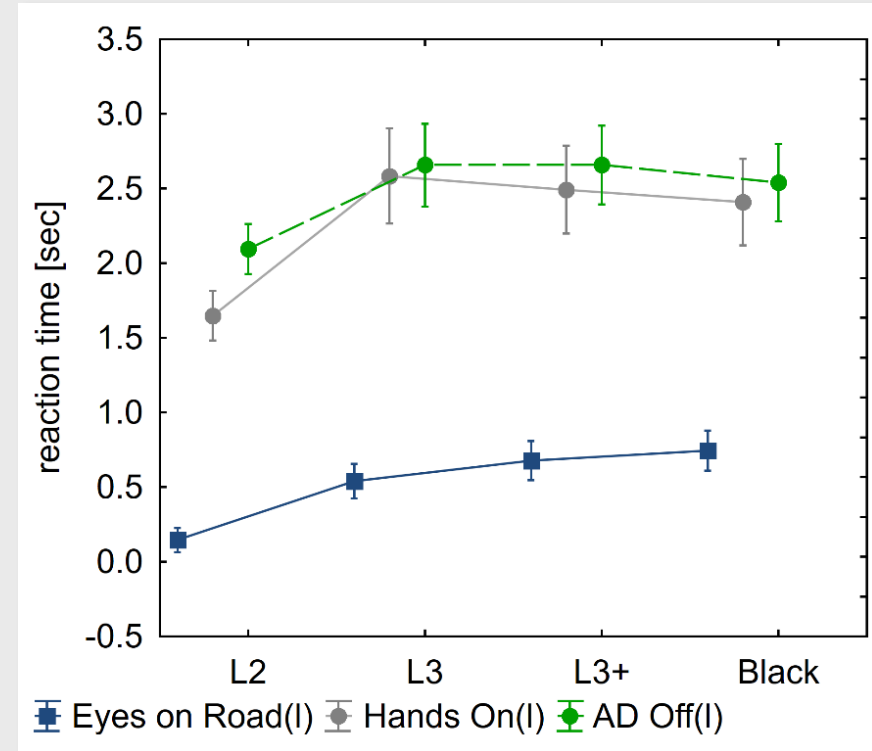
RESULTS

DRIVER REACTIONS AT TORS – DURING DRIVE

The following takeover times are analysed:

▶ Eyes on Road (EoR) time

▶ Hands On time

▶ Time until AD is deactivated

Results of 1-way ANOVAs:

▶ EoR: $F(3, 117)=26.4$, $p<.001$

▶ Hands On: $F(3, 117)=28.7$, $p<.001$

▶ AD Off: ($F(3, 117)=8.8$, $p<.001$

▶ Significant differences between conditions in reaction times to TORs.

▶ Results are similar for all analysed reaction times:

L2   >   L3 & L3+ & Black

SUMMARY & OUTLOOK

MEASURING SITUATION AWARENESS

▶ With all presented measures, a difference between the implemented conditions can be found.

　　▶ Post-drive questionnaire for driving in AD mode and at TORs

　　▶ Questionnaires during drive at TORs

　　▶ Reaction times

▶ Results indicate better situation awareness in the L2 compared to the three other conditions.

▶ Results for the artificial reduction of visual perception are mixed:
subjectively reported differences are not reflected in driver reaction

▶ Overall, the impact of reduced visual perception in AD mode is little compared to the difference L2 vs. L3.

OUTLOOK

▶ In a next step, the remaining indicators will be analysed.

▶ The relation between the all different indicators will be explored in more detail.

THANK YOU

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